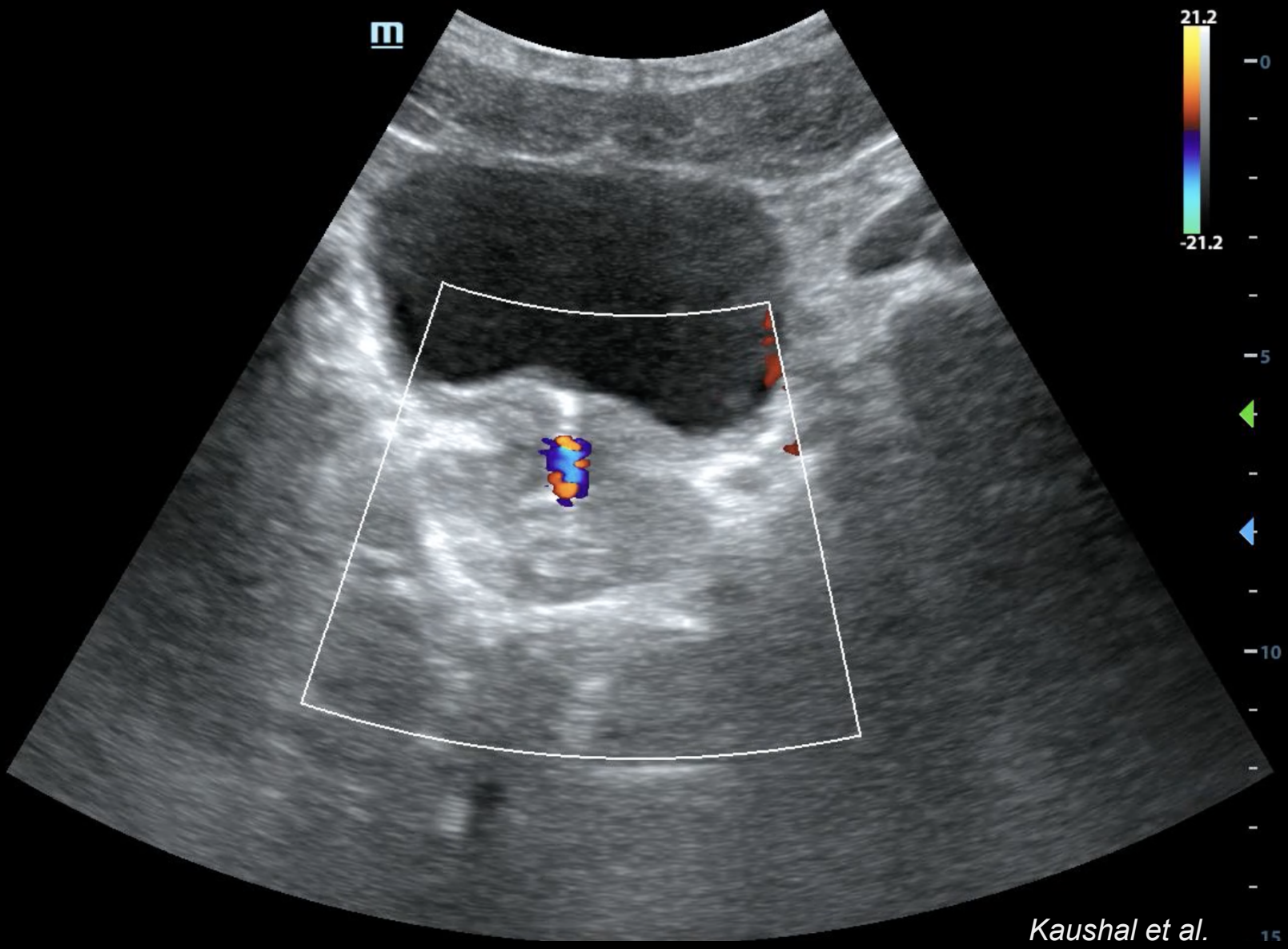
ISSN 2369-8543

POCUS

NOV 2026
Volume 11
Issue 02



Kaushal et al.

The Journal of Point of Care Ultrasound

GE HealthCare

Journal of Point of Care Ultrasound
POCUS Journal

Table of Contents | Volume 11 | Issue 02 | November 2026

Commentary

6 **Inside the November 2026 Issue**
Benjamin T. Galen

Editorials

8-9 **Standardizing POCUS Terminology: The POCUS Journal Style Guide**
Pedro Sartori Manoel; Casey Glass; Amer M. Johri; Benjamin T. Galen

10-13 **Artificial Intelligence-Assisted POCUS: Promises, Pitfalls, and Path Forward**
Sumit Kapoor; Paul M. Wallach; Annie Whitman; Emily Lovallo

14-16 **POCUS and Bayes at the Bedside: Is AI Ready to Help Nurses Diagnose Hydronephrosis?**
Lauren Breslin; Amiran Baduashvili

17-20 **Preserving Clinical Skills in the Era of AI-Enabled POCUS**
Alphonce Oyugi; Titus Kahiga; Kotieno Fredrick

Letters

21-23 **Development of a Dashboard for POCUS Revenue Tracking: Lessons Learned**
Zachary W. Binder; Megan K. McDavitt; Theodore Macnow

Innovations in POCUS Curriculum

Original Research

24-32 **Impact of a Hospital Medicine POCUS Program on Scan Quality, Faculty Satisfaction, and Billing Revenue**
Thomas F. Heyne; Hamid Shokoohi; Andrew S. Liteplo

33-37 **Teaching the Microethics of POCUS: An Everyday Ethics Framework for POCUS Training**
Carter Winberg; Ross Prager; Marat Slessarev

38-44 **Playdough Modelling to Teach Anatomy in a POCUS Course**
Todd S. Cutler; Paula Roy-Burman; Laura Chen; Riya N. Soni; Suean Pascoe; Tanping Wong

Table of Contents (cont.)

Review

45-57 **From Diagnosis to Development: How Point-of-Care Ultrasound Supports the 2030 UN Sustainable Development Goals**

Sachita Shah; Mena Ramos; Heather Harmon Donahoe; Taiba Zahir; Shirish Rao; Sahra Sutaria; Adi Nadimpalli; Nahreen Ahmed; Lori Stolz

POCUS Arts and Humanities

58-59 **Show Me My Heart**

Jessica Y. Chambers

Artificial Intelligence

Original Research

60-70 **Nurse-Validated Handheld POCUS Artificial Intelligence (AI) for Automated Prostate Volume Estimation and Hydronephrosis Detection**

Masaru Matsumoto; Motofumi Suzuki; Mikihiko Karube; Hiroaki Gotoh; Masaya Sato; Tamaki Kobayashi; Minoru Masuda; Sanae Wakita; Atsuo Kawamoto; Yuka Miura; Nao Tamai; Hiromi Sanada

71-79 **Evaluation of AI-Enabled POCUS Versus Standard Echocardiography in Hospitalized Patients**

Evan Baum; John Kugler; Michelle Lo; Caitlin Parmer-Chow; Vishnu Nair; Andre Kumar

Cardiac POCUS

Review

80-86 **POCUS in Undifferentiated Shock: A Narrative Review**

Shiona Maria Fernandes; Anjana Krishna; Yousra Anwar; Anoud Salim Fodkar; Mubassir Shah Awan; Fathima Abdul Kareem; Aishwarya Velineni; Iman Ibrahim Bhaldar; Anon Jo Bracy

Case Report

87-91 **Cardiac Tamponade Secondary to a Giant Pericardial Cyst Diagnosed Using POCUS: A Case Report**

Syed Ghazi; Seth Johnston; Veronica Nguyen; Kristen Downey; Whitney Potomac

92-95 **Respiratory Variation in Coronary Sinus Size**

Jina Bai; Gregory Mints; Todd Cutler; Su Yuan

Table of Contents (cont.)

Vascular POCUS

Original Research

96-105 **Primary Prevention Through Risk Prediction Improvement of Major Cardiovascular Events Using POCUS: PRIME POCUS - A Pilot Study**

Marie-France Hétu; Taylor Barwell; Amrita Pannu; Nilah Ahimsadasan; Tina Zhu; Margaret Cases; Sean C. Haffey; Ian Thomson; Shayna Watson; Taleen Sahakian; Ulf Näslund; Amer M. Johri

Case Report

106-110 **Decades Without Diagnosis: A Case of Aberrant Right Subclavian Artery Diagnosed Using POCUS**

Raghav Gupta; NavYash Gupta; Ilan Kedan

Lung POCUS

Original Research

111-120 **Should the Lung Ultrasound Score Be Used to Evaluate Interstitial Syndrome Severity in Intensive Care Units? A Prospective Observational Study**

Eléonore Vasseur; Florence Dupriez; Caroline Poletti; Zoi Papadoyannaki; Aurélien Ledoux; Romain Courcelle; Marco Vinetti; Jean-Baptiste Mesland; Gauthier Nendumba; Paul Geukens

Case Series

121-131 **Multiparametric POCUS to Differentiate Fluid Overload From Endothelial Complications After Allogeneic Hematopoietic Stem Cell Transplantation: A Case Series**

Bastian Wobbe

Ocular POCUS

Original Research

132-142 **Ophthalmic POCUS to Evaluate the Pupillary Light Reflex in Critically Ill Children**

Vaishnavi Divya Nagarajan; Kurt M. Drury; Katherine Barton; Courtney L. Kraus; Misun Hwang; Becky J. Riggs

Table of Contents (cont.)

Review

143-148 **Technical Pitfalls in Optic Nerve Sheath Diameter POCUS: A Practical Checklist for Image Optimization**

Ricardo Bañuelos-Huerta; Dibanhi S. Ruvalcaba-Trujillo; Jorge A. Lara-Arellano; Gilver Sebastián-Vázquez; Carlos Estrada-Valencia; Wendy J. Ramirez-Salvador; Daniel de J. Vásquez-Hernández; Montserrat Ramírez-Barranco; Eduardo Y. Aguilar-Lazcano; Wendy Sartillo-Guerra

Gastrointestinal POCUS

Case Report

149-153 **Shiitake Mushroom-Induced Small Bowel Obstruction Diagnosed by POCUS**

Yo Ishihara; Nana Obata; Yoshihito Ota; Daichi Sogai; Kota Takahashi; Takaomi Kessoku; Yasushi Shinohara

Genitourinary POCUS

Case Report

154-157 **POCUS with Colour Doppler Used to Diagnose a Prostatic Urethral Stone**

Sanchit Kaushal; Karlina Fiaes; Karan Chawla

Obstetric POCUS

Review

158-166 **Evaluation of Pregnancy and Associated Complications Using POCUS: A Narrative Review**

Zachary Boivin; Christopher L. Moore; Rachel B. Liu

Peri-operative & Surgical POCUS

Case File

167-169 **POCUS Used to Diagnose a Diaphragmatic Rupture Due to a Pyogenic Liver Abscess**

Martine A. Valk; Daan J. Lips; Marleen M. Duivenvoorden; Bart P. X. Grady

Table of Contents (cont.)

Pediatric POCUS

Original Research

170-176 **The Effect of POCUS on Pediatric Acute Scrotum: A Ten-Year Retrospective Analysis**
Eric Scheier; Aviad Nachmany; Layah Alkoby-Meshulam

Inside the November 2026 Issue

Dear Readers,

I would first like to disclose that artificial intelligence (AI) was not used to write this opening intro to the November, 2026 issue of POCUS Journal. However, AI was used in two original research studies contained in this issue. The study by Matsumoto et al. (page 60) evaluated whether nurses can detect prostate volume and hydronephrosis using an AI-enabled POCUS platform. An outstanding accompanying editorial by Breslin and Baduashvili puts this study into perspective; the POCUS community and we at POCUS Journal strive for high-quality evaluations of POCUS as a diagnostic test—with or without AI. The critique and teaching points in this editorial should be read and re-read by POCUS enthusiasts who design their own future studies of POCUS as a diagnostic test.

We are all grappling with how to incorporate AI into our use of POCUS. We are fortunate that thought leaders Oyugi et al. (page 17) and Kappor et al. (page 10) took the time to write editorials for this issue that tackle the tough questions and provide a framework for how to move forward with AI in POCUS. These are must-read pieces that should be saved for reference and use in teaching in the AI enabled POCUS era to come.

As usual we have a variety of novel POCUS cases and high impact research in this packed issue. The November 2026 issue of POCUS Journal is the result of the hard work and dedication of our editorial board, peer reviewers, and publisher. We are grateful that so many authors choose POCUS Journal for their scholarship. We hope you enjoy this issue as much as we enjoyed putting it together.



Benjamin T. Galen, Editor-in-Chief, POCUS Journal

Sincerely,

Benjamin T. Galen, MD
Professor of Medicine
Albert Einstein College of Medicine and Montefiore Medical Center, Bronx, NY, USA
Editor-in-Chief,
POCUS Journal

This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.22296

Editorial Board

Editor-In-Chief
Benjamin Galen, MD
Bronx, NY, USA

Deputy Editor
Casey Glass, MD
Winston-Salem, NC, USA

Associate Editor for Pediatrics
Beryl Greywoode, MD
Philadelphia, PA, USA

Anesthesiology
Wilfredo Puentes, MD
London, ON, Canada
Rob Tanzola, MD
Kingston, ON, Canada
Marta Berrio Valencia, MD
Ottawa, ON, Canada

Cardiology
Nidhish Tiwari, MD
Bronx, NY, USA
Ritu Thamman, MD
Pittsburgh, PA, USA

Emergency Medicine
Wilma Chan, MD
Philadelphia, PA, USA
Robert Allen, MD
Los Angeles, CA, USA

Global Health
Michelle Fleshner, MD
Aurora, CO, USA
Gordon Johnson, MD
Portland, OR, USA

Internal Medicine
Andre Kumar, MD
San Francisco, CA, USA
Manpreet Malik, MBBS
Atlanta, GA, USA
Tanping Wong, MD
New York, NY, USA

Nephrology
Abhilash Koratala, MD
Milwaukee, WI, USA
Nathaniel Reisinger, MD
Philadelphia, PA, USA

Neurology
Jon Rosenberg, MD
New York, NY, USA

Pediatrics
Andrea Matho, MD
Los Angeles, CA, USA
Valeriy Chorny, MD
New York, NY, USA

Pulmonary and Critical Care
Cameron Baston, MD
Philadelphia, PA, USA
Segun Olusanya, MD
London, UK
Marjan Islam, MD
Bronx, NY, USA

Managing Editor
Pedro Sartori Manoel, PhD
Kingston, ON, Canada

Statistical Editor
Nicholas Grubic, MSc
Toronto, ON, Canada

Social Media Team
Riya N. Soni
San Antonio, TX, USA
Vijai Maharajh
Kingston, ON, Canada
Hamza Mirza
Kingston, ON, Canada

Copyeditor
Kathryn Matsushita, MPH
Toronto, ON, Canada

Founding Editor
Amer Johri, MD
Kingston, ON, Canada

Call for Submissions

Physicians, Researchers, and Educators are invited to contribute articles to upcoming issues of POCUS Journal.
For detailed information, visit pocusjournal.com/about/instructions-to-authors.
For inquiries or proposed topics, please contact the editors at submit@pocusjournal.com.

About Us

POCUS Journal is dedicated to the advancement of research and the promotion of education in the field of point of care ultrasound.

It follows a Diamond Open Access model, is listed in the Directory of Open Access Journals (DOAJ), and is part of the Open Journals Collective (OJC).

Access it online at pocusjournal.com.

Subscribe for email updates at pocusjournal.com/subscribe.

To submit a manuscript, visit pocusjournal.com/submit.

For advertising, donations, or announcements, email info@pocusjournal.com.

All online versions of POCUS Journal are available at ojs.library.queensu.ca/index.php/pocus/index as well as all supplementary material.



CARDIOVASCULAR IMAGING NETWORK at Queen's University

Standardizing POCUS Terminology: The POCUS Journal Style Guide

Pedro Sartori Manoel, PhD[1]; Casey Glass, MD[2]; Amer M. Johri, MD MSc[1]; Benjamin T. Galen, MD[3]*

(1) Department of Medicine, Division of Cardiology, CINQ, Queen's University, Kingston, ON, Canada
(2) Department of Emergency Medicine, Wake Forest University School of Medicine, Winston-Salem, NC, USA
(3) Department of Medicine, Albert Einstein College of Medicine and Montefiore Medical Center, Bronx, NY, USA

Point of care ultrasound (POCUS) terminology is critically important to the work that we do. Inconsistent names for POCUS examinations confuse patients, colleagues, and billing/credentialing departments. No field better illustrates this than cardiac POCUS, where over a dozen terms describe essentially the same examination: a clinician evaluates the heart with an ultrasound machine and interprets the findings in real time [1]. Beyond implications for clinical documentation, standardizing POCUS terminology is essential for research purposes as well, including for reproducibility and the interpretation of scientific evidence. Inconsistent terminology can complicate literature searches, hinder comparisons across research studies, and make it difficult to distinguish differences in examination protocols, operator training, and diagnostic scope.

In a 2023 review article published in The American Journal of Medicine, members of POCUS Journal's editorial board and colleagues traced how modern cardiac POCUS emerged from echocardiography and how it is practiced across a variety of medical specialties [2]. A central argument was that 'cardiac POCUS' is the most useful terminology for this practice. It helps to distinguish it from the practice of echocardiography, which is a requisition-based consultative service, often acquired by a credentialed sonographer following a defined protocol, most commonly interpreted by a trained cardiologist, reported in a structured format, and archived. A cardiac POCUS examination has no universally accepted requirement for any of these elements, though jurisdictional regulation may vary.

Aligned with this terminology, our multidisciplinary expert consensus recommended that other anatomic sites examined by a clinician using ultrasound and interpreted in real time follow similar conventions, such as 'lung POCUS' and 'abdominal POCUS', etc., rather than alternative names. Examples of the current terminology used by POCUS Journal are provided in Table 1. Consistent terminology across anatomic applications may also facilitate interdisciplinary communication and support the development of standardized educational resources.

We strive to continuously define the scope of POCUS as its practice evolves, and to reflect upon how it is distinct from other diagnostic imaging tests. An important role of the POCUS Journal is to uphold consistent, consensus-based terminology that allows readers to understand who performed the POCUS examination, with what device, and who interpreted the findings. In our Journal, the term 'ultrasound' is primarily used as an adjective to describe equipment (e.g., ultrasound device, or ultrasound probe), or physical phenomena (e.g., ultrasound artifact).

The term 'POCUS-guided procedure' has not yet achieved full acceptance as common parlance; thus, terms like 'ultrasound-guided thoracentesis' rather than 'POCUS-guided thoracentesis' remain preferred for the time being.

Table 1. Examples of POCUS examination terminology conventions for POCUS Journal.

Examination
Head and Neck POCUS
Ocular POCUS
Cardiac POCUS
Lung POCUS
Abdominal POCUS
Gallbladder POCUS
Gastric POCUS
Kidney POCUS
Bladder POCUS
Vascular POCUS
POCUS for DVT
Skin and Soft Tissue POCUS
Joint POCUS
Knee POCUS
Shoulder POCUS

DVT, deep vein thrombosis; POCUS, point of care ultrasound

*Corresponding Author: Dr. Benjamin T. Galen (email: bgalen@montefiore.org)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.22262

Currently, we do not use the term ‘sonographic’ when the adjective ‘POCUS’ works better. For example, we prefer ‘POCUS findings of an abscess’ rather than ‘sonographic findings of an abscess’. We recognize that many aspects of terminology are still evolving and that the conventions adopted by POCUS Journal might not represent consensus across all fields and all POCUS users. Members of the POCUS community are constantly working on studying evolving terminology. We at POCUS Journal hope that our terminology choices will continue to evolve and reflect the broadest consensus in the field over time.

Artificial Intelligence Statement

The authors used Claude (Opus 5.5; Anthropic, San Francisco, CA) to assist in initially drafting the text and formatting the table of this editorial. The authors reviewed, edited, and verified all content and take full responsibility for the final manuscript.

References

1. Spencer KT, Flachskampf FA. Focused Cardiac Ultrasonography. JACC Cardiovasc Imaging. 2019;12(7 Pt 1):1243-1253. doi: 10.1016/j.jcmg.2018.12.036

2. Johri AM, Glass C, Hill B, Jensen T, Puentes W, Olusanya O, Capizzano JN, Dancel R, Reierson K, Reisinger N, Liblik K, Galen BT. The Evolution of Cardiovascular Ultrasound: A Review of Cardiac Point-of-Care Ultrasound (POCUS) Across Specialties. Am J Med. 2023;136(7):621-628. doi: 10.1016/j.amjmed.2023.02.020

Artificial Intelligence-Assisted POCUS: Promises, Pitfalls, and Path Forward

Sumit Kapoor, MD MS FCCP[1]*; Paul M. Wallach, MD[2]; Annie Whitman, RDMS[3]; Emily Lovallo, MD[4]

(1) Associate Professor, Department of Critical Care Medicine, University of Pittsburgh, Pittsburgh, PA, USA
(2) Professor of Medicine, Executive Vice Dean for Academic Affairs, University of Pittsburgh, Pittsburgh, PA, USA
(3) Sonographer Educator, Center for POCUS Education, University of Pittsburgh, Pittsburgh, PA, USA
(4) Associate Professor, Department of Emergency Medicine, University of Pittsburgh, Pittsburgh, PA, USA

Artificial intelligence (AI) is a transformative technology revolutionizing medical practice across specialties, and medical imaging is no exception [1]. Medical imaging has long been fertile ground for AI. At its core, imaging is a pattern-recognition problem, and machines can detect visual patterns that the human eye cannot reliably perceive [1]. Three major developments have made AI-enabled medical imaging technically feasible and commercially attractive: greater computational power, mature deep learning algorithms, and access to large imaging datasets [2]. Because they produce highly repeatable image series, computed tomography (CT) and magnetic resonance imaging (MRI) integrate seamlessly with AI [3]. However, AI in POCUS is a relatively new medical imaging application that offers unique advantages and challenges. Most contemporary ultrasound systems, from cart-based machines to handheld devices, now include sophisticated AI-enabled algorithms. These automate measurements such as left ventricular ejection fraction (LVEF), left ventricular outflow tract velocity-time integral (LVOT VTI), inferior vena cava (IVC) diameter, B-line quantification, and bladder volume calculation.

In this editorial, we consider three important questions. Why does AI seem a natural fit for POCUS, and what promises does it offer? What challenges and limitations must be addressed before it can be adopted responsibly and at scale? What should be our path forward?

AI in POCUS: Promises

Point of care ultrasound (POCUS) is an indispensable skill with a growing range of applications, capable of answering specific clinical questions in real time at the point of care. The workflow includes image acquisition, interpretation, and medical decision-making, all occurring together at the bedside, often by the treating clinician [4]. This makes POCUS powerful but also highly operator-dependent [4,5]. The quality of decisions after POCUS depends on the operator's skill. This operator dependence is the central reason AI matters in POCUS. Becoming proficient in POCUS requires a deliberate, time-consuming learning path that can span months to years. Limited operator expertise and a shortage of trained POCUS faculty have long constrained POCUS adoption across specialties [5]. POCUS applications continue to expand, and demand for skilled POCUS operators continues to outpace the ability to train and supervise them. AI can bridge the POCUS expertise gap by providing novice users with real-time guidance during image acquisition and coaching on transducer position and movement to obtain optimal views [5]. AI can also improve image quality by auto-adjusting gain, depth, and time-gain compensation. For novice learners, AI can 'upskill' them, shorten the path to proficiency, and reduce cognitive load by shifting attention from knobology and image acquisition to answering the clinical question at hand [5].

POCUS AI can promise to provide faster, more accurate POCUS image interpretation, improving user confidence [3]. For example, novice users can quantify B-lines in pulmonary edema and screen for deep venous thrombosis [4]. POCUS AI can achieve diagnostic accuracy comparable to gold-standard sonographers and clinicians in selected applications [6–8]. Some POCUS measurements, such as LVEF and LVOT VTI, are time-consuming and error-prone, even for experienced POCUS users. AI can perform these calculations in seconds [5]. Automation produces standardized images and measurements, with better intra- and inter-observer reliability [5]. For POCUS educators, AI could transform their workflow. Automated quality assurance through image-quality scoring and competency assessment could give trainees continuous feedback and reduce the burden of manual image review [1,5]. These are among the most time-consuming tasks for faculty who run POCUS programs. Auto-labelling and auto-generating

*Corresponding Author: Dr. Sumit Kapoor (email: kapoors5@upmc.edu)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.22263

standardized reports, along with automated coding and billing support, address a persistent administrative barrier [1,5]. Many POCUS examinations are performed but are never documented or billed, so the clinical work goes unrecognized, and programs lose revenue they need to sustain themselves. When a focused, AI-supported bedside examination answers the clinical question, it can reduce the need for comprehensive ultrasound studies. It can also ease the workload of busy echocardiography and radiology departments and shorten time to diagnosis [5].

Using POCUS AI could improve safety and first-pass success rates [5]. In low- and middle-income countries, POCUS AI-assisted image acquisition and interpretation could extend ultrasound to patients who would otherwise go without imaging [9]. It can 'skill-enable' clinicians who would not otherwise be able to use the modality. Looking further ahead, AI-guided patient self-scanning may support home-based monitoring [1]. One could imagine serial self- lung or IVC assessments by patients with heart failure or kidney disease.

The role of AI in POCUS is therefore evolving in two directions simultaneously. It supports novices by lowering the barrier to entry and upskilling them, and it benefits experts by automating repetitive tasks, adding consistency and reducing strain on them. Table 1 lists important POCUS AI applications.

AI in POCUS: Challenges, Limitations and Pitfalls

Although AI technology is rapidly integrating with POCUS, it remains unclear whether POCUS AI adoption guides patient management, improves patient outcomes, optimizes resource utilization, and provides overall clinical utility [10]. How it impacts workflows for POCUS learners, educators, and administrators remains unanswered [10]. Some inherent challenges of AI are also applicable to POCUS, and others are unique to POCUS. Many POCUS datasets are small, noisy, single-center, homogeneous, and derived mainly from high-quality expert-acquired images [1,3,4]. Models trained on such datasets may perform poorly in real-world patients. Bias may arise from age, sex, ethnicity, body habitus, and image quality [1,3,4]. Over time, domain shift and model drift can erode performance silently as patient populations, ultrasound devices, and practice patterns change [1,3,4]. POCUS images also pose technical interpretation challenges compared to natural images [4]. They differ fundamentally from natural images, contain artifacts, acoustic shadowing, speckle, indistinct tissue boundaries, and change with every adjustment of probe angle, pressure, and machine settings. This makes training and labelling on POCUS datasets challenging. The success of any AI tool depends heavily on the quality of input data; 'garbage in, garbage out' could be a problem with poor-quality POCUS datasets.

AI interpretation could become a problem especially in critically ill patients who are difficult to position, mechanically ventilated, edematous, or obese, and in whom diagnostic-quality windows are hard to obtain [3]. Most AI outputs serve as 'black boxes' without clear explanation of how they were generated [1,3,4]. This lack of transparency undermines clinician trust. The problem is compounded by the proliferation of proprietary, vendor-specific algorithms. There is a risk of automation bias: uncritical acceptance of an algorithm's output [1,4]. For novice users, overreliance and blind trust may lead to de-skilling, mis-skilling, or never-skilling [1,4]. Many AI tools are poorly integrated into clinical workflows and electronic health records, limiting their practical use [10]. Regulatory pathways for AI algorithms are still maturing [3,10]. Protecting patient privacy is essential when models are developed using images. When an AI-guided decision contributes to an undesired outcome, accountability is unclear: the clinician, the institution, or the AI developer [10]. Figure 1 lists major promises and pitfalls of POCUS AI.

Ferre and colleagues identified major barriers to adopting POCUS AI [10]. Most AI tools are technology-driven rather than outcome-driven solutions that focus on solving real-world problems. Data limitations, poor integration into existing clinical workflows, and unresolved regulatory and ethical concerns were additional barriers.

In 2025, an international web-based cross-sectional survey of 1,154 healthcare professionals assessed familiarity with, perceptions of, and adoption of AI in POCUS [2]. Most respondents were experienced emergency medicine and critical care clinicians who use POCUS in their daily work routines. Yet 77% did not use any AI- or machine learning–assisted tool in patient care. Most believed AI could expedite diagnosis, improve accuracy and confidence, and reduce inter-operator variability. However, they cited concerns about inadequate training resources, lack of credentialing pathways, doubts about workflow integration, and limited trust. Many said they would need to verify AI findings themselves before acting on them. The lack of guidelines or endorsement from professional societies, along with cultural resistance to new technology, also slowed adoption. Training and education, followed by clinical validation and evidence, emerged as the leading barriers. The 'black box' nature of AI was a key driver of mistrust, and regulatory approval and clinical validation were seen as solutions to build trust. Notably, enthusiasm for AI in POCUS remained high.

Table 1. Artificial Intelligence (AI) applications for POCUS across five development domains.

POCUS AI Development Domain	How AI can help	Workflow	Examples
Education	• Image Acquisition • Auto gain, auto depth features • Auto-labelling of sonographic anatomy	• Real-time feedback on transducer position and movement for image optimization • Improves image quality and provides immediate feedback	• Help learners obtain quality cardiac views, perform deep venous thrombosis (DVT) scans, and Focused Assessment with Sonography for Trauma (FAST) exams • Help learn sonographic anatomy
Clinical and Workflow	• Image Interpretation • Task Automation • Procedural guidance through heads-up display and labelling of sonographic anatomy	• Detects POCUS-related abnormalities and automated calculations • Automates measurements, auto-labelling, and auto-saving images and cine clips • Heads-up display and labelling of sonographic anatomy	• Cardiac: left ventricular systolic function, diastolic function, valvular pathologies, pericardial effusion, pulse checks during cardiopulmonary resuscitation, right ventricular tricuspid annular plane systolic excursion (TAPSE), right ventricular fractional area change (FAC), automated measurement of left ventricular ejection fraction, velocity time integral for cardiac output calculation • Lung: A-line and B-line detection, pneumothorax, pleural effusion, lung consolidation • Renal/urology: automated bladder volume measurement, obstructive hydronephrosis detection • Vascular: DVT detection, peripheral arterial disease detection, automated calculation of Inferior vena cava (IVC) collapsibility index • Neurologic: automated optic nerve sheath Diameter measurement • Trauma: FAST and eFAST exam • Obstetric and Gynecologic: intrauterine and ectopic pregnancy, fetal age estimation • Breast: suspected breast lesions • Musculoskeletal: wrist fracture detection • Endocrine: thyroid nodule screening • Pediatric: hip dysplasia detection • Identifying safe fluid pockets for drainage procedures such as thoracentesis and paracentesis, and guiding vascular access procedures, including central line, arterial line, and peripheral IV placement
Research and Administrative	• Automated POCUS image classification • Automated report generation • Automated coding and billing	• Quality assurance (QA) • Help with archiving images	• Help with running the POCUS program with QA, classification of POCUS images in the archived database, and creating reports and dashboards for the POCUS program • Help with managing the POCUS database for research, including sorting images

The Path Forward

AI in POCUS is a promising yet still-maturing field. Whether its adoption improves patient outcomes, optimizes resource use, or meaningfully guides management remains to be seen. Realizing its potential will require deliberate effort from all stakeholders. Ferre et al. proposed a framework to identify opportunities for POCUS AI development across five domains: education, clinical, workflow, research, and administration [10]. They also developed an 8-step process to improve POCUS AI adoption across these five domains.

Industry should build POCUS AI tools around end users and real clinical problems [4,10]. Developers and researchers need access to large, diverse, multicenter datasets that include difficult and poor-quality images [4,10]. AI models should be transparent and explainable,

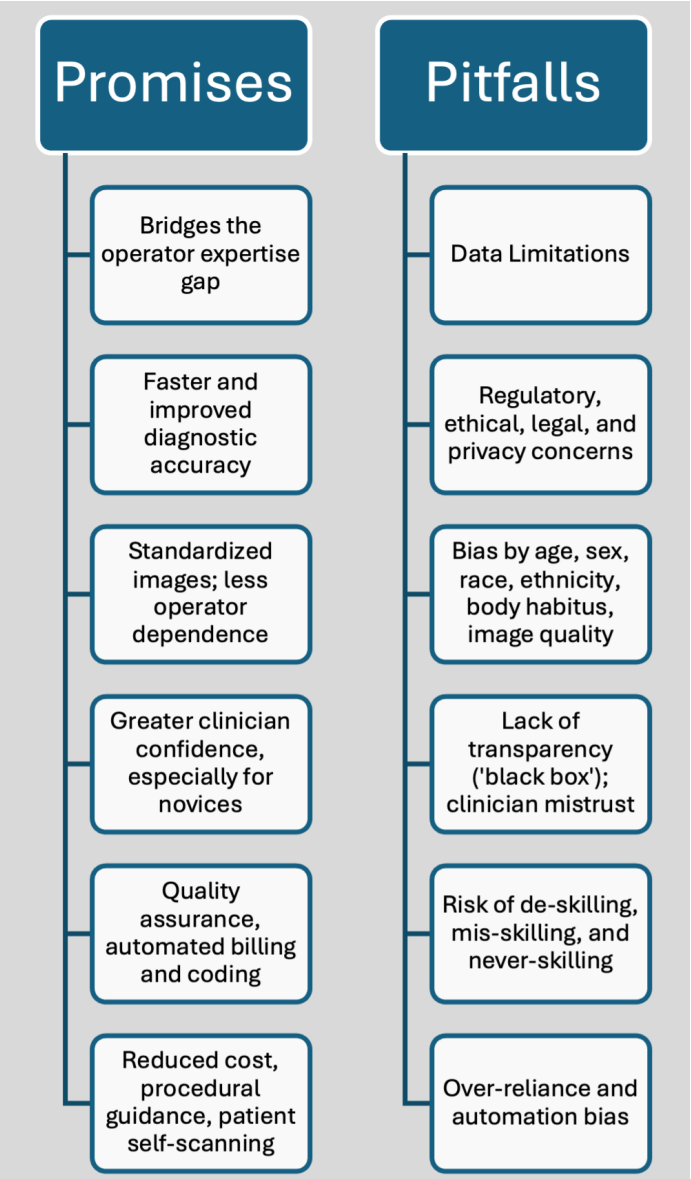


Figure 1. Major promises and pitfalls of Artificial Intelligence (AI) in POCUS.

validated across vendors, and monitored after deployment for drift [4,10]. Educators and professional societies also play an important role. Curricula should teach clinicians how AI tools work, their limitations, when they can fail, and how to verify their outputs [10]. Professional medical societies should develop training and credentialing standards for POCUS AI, and government agencies should issue regulatory approvals [10]. Trainees should develop independent hands-on acquisition and interpretation skills so that AI augments competence and clinical decision-making rather than replacing them.

AI is a powerful tool that can increase POCUS adoption and empower clinicians. It is a path toward precision medicine and, eventually, agentic or autonomous systems that integrate multi-organ findings. No matter how sophisticated AI algorithms become, human oversight, critical thinking, sound education, and, above all, clinical context remain indispensable. AI may change how we hold the probe, but it should not change who makes clinical decisions and who is responsible for the patient.

Disclosure Statement

The authors have no conflicts of interest to disclose.

References

1. Kayarian F, Patel D, O'Brien JR, Schraft EK, Gottlieb M. Artificial intelligence and point-of-care ultrasound: Benefits, limitations, and implications for the future. Am J Emerg Med. 2024;80:119-122. doi:10.1016/j.ajem.2024.03.023

2. Wong A, Roslan NL, McDonald R, Noor J, Hutchings S, D'Costa P, Via G, Corradi F. Clinical obstacles to machine-learning POCUS adoption and system-wide AI implementation (The COMPASS-AI survey). Ultrasound J. 2025;17(1):32. doi: 10.1186/s13089-025-00436-2

3. Kim J, Maranna S, Watson C, Parange N. A scoping review on the integration of artificial intelligence in point-of-care ultrasound: Current clinical applications. Am J Emerg Med. 2025;92:172-181. doi:10.1016/j.ajem.2025.03.029

4. Vega R, Dehghan M, Nagdev A, Buchanan B, Kapur J, Jaremko JL, Zonoobi D. Overcoming barriers in the use of artificial intelligence in point of care ultrasound. NPJ Digit Med. 2025;8(1):213. doi: 10.1038/s41746-025-01633-y

5. Wu D, Arntfield R, Millington SJ. Artificial Intelligence in Point-of-Care Ultrasound. J Intensive Care Med. 2026:8850666261427329. doi: 10.1177/08850666261427329

6. Stringer JSA, Pokaprakarn T, Prieto JC, Vwalika B, Chari SV, Sindano N, Freeman BL, Sikapande B, Davis NM, Sebastião YV, Mandona NM, Stringer EM, Benabdelkader C, Mungole M, Kapilya FM, Almnini N, Diaz AN, Fecteau BA, Kosorok MR, Cole SR, Kasaro MP. Diagnostic Accuracy of an Integrated AI Tool to Estimate Gestational Age From Blind Ultrasound Sweeps. JAMA. 2024;332(8):649-657. doi: 10.1001/jama.2024.10770

7. Asch FM, Mor-Avi V, Rubenson D, Goldstein S, Saric M, Mikati I, Surette S, Chaudhry A, Poilvert N, Hong H, Horowitz R, Park D, Diaz-Gomez JL, Boesch B, Nikravan S, Liu RB, Philips C, Thomas JD, Martin RP, Lang RM. Deep Learning-Based Automated Echocardiographic Quantification of Left Ventricular Ejection Fraction: A Point-of-Care Solution. Circ Cardiovasc Imaging. 2021;14(6):e012293. doi: 10.1161/CIRCIMAGING.120.012293

8. Libon J, Ng C, Bailey A, Hareendranathan A, Joseph R, Dulai S. Remote diagnostic imaging using artificial intelligence for diagnosing hip dysplasia in infants: Results from a mixed-methods feasibility pilot study. Paediatr Child Health. 2023;28(5):285-290. doi:10.1093/pch/pxad013

9. Kim S, Fischetti C, Guy M, Hsu E, Fox J, Young SD. Artificial Intelligence (AI) Applications for Point-of-Care Ultrasound (POCUS) in Low-Resource Settings: A Scoping Review. Diagnostics (Basel). 2024;14(15):1669. doi:10.3390/diagnostics14151669

10. Ferre RM, Liu RB, Lam HS, Blaivas M, Oh L, Sangal RB, Baloescu C, Adhikari S. Artificial Intelligence in Point-of-Care Ultrasound: Domains, Barriers and a Framework for Future Development. J Am Coll Emerg Physicians Open. 2026;7(5):100491. doi: 10.1016/j.acepjo.2026.100491

POCUS and Bayes at the Bedside: Is AI Ready to Help Nurses Diagnose Hydronephrosis?

Lauren Breslin, MD; Amiran Baduashvili, MD*

Division of Hospital Medicine, University of Colorado School of Medicine, Aurora, CO, USA

Point of care ultrasound (POCUS) can expand timely access to diagnostic imaging and reduce reliance on radiation-based studies, but its use is often limited by the availability of clinicians trained to acquire and interpret images. Artificial Intelligence (AI)-assisted interpretation of POCUS images for a focused clinical question could help overcome this bottleneck, extending POCUS to settings where trained sonographers or POCUS-proficient physicians are scarce.

In a single-center study from an academic hospital in Japan, Matsumoto and colleagues developed and validated a machine learning image interpretation algorithm to detect hydronephrosis and assess prostate volume from POCUS images, in two phases [1]. First, they trained the algorithm on images from two sources: a professional sonographer using a console ultrasound machine (traditional high-end radiology equipment), and the same point-of-care device later used for prospective data collection. Second, they tested the tool prospectively on images obtained by nurses, who received just 30 minutes of instruction before scanning renal and prostate views in patients admitted to the hospital's urology floor. One kidney per patient was evaluated. A sonographer, blinded to the AI's output, independently classified each image for the presence or absence of hydronephrosis (without grading severity) and for a prostate volume exceeding 50 mL, a threshold for severe enlargement. The analysis included 32 kidneys (one per patient) and 28 prostates, after 5 non-diagnostic prostate scans were excluded. Most patients were over 60 years old, had a normal body-mass index (20–25 kg/m²), and about half were admitted for a genitourinary diagnosis.

Among the 32 patients evaluated, 15 (47%) had hydronephrosis confirmed by a sonographer. The AI tool correctly identified disease in 14 of 15 cases (sensitivity 93%) and correctly identified its absence in 14 of 17 patients without hydronephrosis (specificity 82%). The positive predictive value (PPV; the probability of true hydronephrosis if the AI tool reported a positive result) was 82%, and the negative predictive value (NPV; the probability of being hydronephrosis-free if the AI tool was negative) was 93%. The corresponding sensitivity, specificity, PPV, and NPV for severe prostate enlargement were 71%, 71%, 45%, and 88%. The authors concluded that their results support using this AI model to triage the presence of hydronephrosis on nurse-acquired POCUS images, with a more cautious endorsement for prostate volume assessment pending further validation.

The authors envisioned deploying this tool in nursing-home and outpatient settings, where nurses could use AI-assisted POCUS to triage patients with lower urinary tract symptoms who need further evaluation. A precedent already exists in automated post-void residual volume calculators, but those devices cannot identify an obstructive cause like prostate enlargement or detect upstream hydronephrosis. This tool could fill those gaps—letting nurses complete a more thorough evaluation and accelerate care. But, is this tool ready for that kind of real-world deployment?

When Predictive Values Predict Confusion

Imagine a co-author of this editorial claims he can see through people's bodies and rule out hydronephrosis by sight alone. If true, the savings on POCUS devices, electricity, AI tokens, and ultrasound gel would be substantial. But first, we have to put his claim to the test. We ask him to look at a lecture hall of 100 medical students and guess who has hydronephrosis and who does not. Afterward, we scan every student with ultrasound, have a radiologist read the images, and compare those reads against his "eye test." Remarkably, our co-author achieves a 99% NPV: 99 out of 100 times he called a student hydronephrosis-free, he was right.

Should we unleash his extraordinary powers at the nearby nursing home? Probably not. It turns out only 1 of the 100 students actually had hydronephrosis, and our co-author simply labeled everyone hydronephrosis-free. His NPV looks impressive only because the prevalence of

*Corresponding Author: Dr. Amiran Baduashvili (email: amiran.baduashvili@cuanschutz.edu)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.22264

hydronephrosis was so low. The same trick works in reverse: asked to diagnose heart failure in a cardiac intensive care unit, where most patients already have it, he could rack up an equally impressive PPV just by labeling everyone positive. The lesson is twofold: predictive values are driven heavily by disease prevalence, and an impressive predictive value can make a test look far more useful than it is.

Unlike our co-author, this AI tool does discriminate between kidneys with and without hydronephrosis. The usefulness of a test is better captured by likelihood ratios, which describe how much a given result shifts the odds of disease [2]. The further away the likelihood ratio is from 1, the more it shifts disease probability, or the more useful it is. For hydronephrosis, this AI tool's positive likelihood ratio (sensitivity ÷ [1 − specificity]) is about 5, and its negative likelihood ratio ([1 − sensitivity] ÷ specificity) is about 0.08. Both likelihood ratios are meaningfully different from 1, unlike our co-author's, whose negative likelihood ratio is exactly 1, despite his impressive NPV. But before interpreting any predictive value, even for a test with genuine discriminating power like this one, we have to ask whether the study's prevalence matches the prevalence of the setting where we plan to deploy it.

In the study by Matsumoto and colleagues, nearly half of the patients scanned had hydronephrosis—far higher than we would expect among community-dwelling adults, even those with lower urinary tract symptoms. Data on the prevalence of hydronephrosis are limited. Estimates range from 3.1% in a large autopsy study spanning all age groups, from neonates to adults [3], to 17% among men undergoing urodynamic testing, with a prevalence of 9.5% among men aged 60 years and older in the same study [4]. Assuming a 10% prevalence among community-dwelling adults with lower urinary tract symptoms, and applying this study's reported sensitivity and specificity, we would expect 100 of 1,000 patients to have hydronephrosis: 93 of those 100 would correctly test positive, and about 740 of the remaining 900 would correctly test negative (with 160 false positives). That leaves 253 patients testing positive: only 93 of whom actually have hydronephrosis, dropping the PPV from an impressive 82% to approximately 36%. We would get the same answer if we converted the pretest probability of 10% to pretest odds of 1/9, multiplied it by the positive likelihood ratio (5), and converted the posttest odds (5/9) to posttest probability (5/14 ~36%).

In sum, predictive values can be misleading. Readers should ask how good the likelihood ratios are at changing the disease odds and whether the disease prevalence in the study is similar to the prevalence in the setting where the tool will be used. Higher-than-expected prevalence can also signal another issue—spectrum bias.

Spectrum Bias and Smoke Detector

Imagine a smoke detector that has only ever been tested in buildings already fully on fire. Unsurprisingly, the alarm will sound every time. Can we conclude this is a very sensitive smoke detector? No, we cannot. A raging fire is easy to detect, but we do not know how well this device will perform with subtler signs of early fire, such as a few wisps of smoke coming from a faulty electric wire. This same idea may apply to the AI tool in this study. It was evaluated on a urology floor, where patients are typically referred because hydronephrosis is advanced—the equivalent of a smoke detector that has only ever seen buildings ablaze. So, the excellent sensitivity reported here may partly reflect how obvious these cases were, rather than how good the tool truly is. In a nursing home or outpatient clinic, where hydronephrosis is often mild and found incidentally, the same tool may struggle far more than these results suggest. In such a population, true sensitivity may be markedly lower than what the authors found. In diagnostic test accuracy literature, the issue of inflated sensitivity due to selection of sicker patients with more obvious disease presentation is known as spectrum bias [5].

Spectrum bias can also affect the test specificity. On a urology floor, the group without hydronephrosis is not made up of patients with healthy kidneys. It is reasonable to assume patients without hydronephrosis have other urologic pathology: renal cysts, masses, and other mimics that can be mistaken for hydronephrosis on ultrasound. The presence of mimics in the group of patients without the disease we are looking for can lead to underestimation of specificity because these mimics may show up as false positives. In a general or broader target population, where the non-disease group mostly has normal kidneys with far fewer confusing mimics, true specificity may actually be higher than this study suggests. Strikingly, both distortions trace back to the same root cause: the referral pattern that pushed hydronephrosis prevalence to 50% simultaneously inflated sensitivity by selecting florid disease and deflated specificity by selecting mimics. We cannot know the degree to which the spectrum bias affects the reported test characteristics, as the authors did not report data on hydronephrosis severity or the composition of the non-disease group. However, it is reasonable to suppose that the study population may represent sicker patients with more severe forms of urologic disease compared to community-dwelling adults experiencing lower urinary tract symptoms.

The broader lesson for readers of diagnostic studies is this: whenever a diagnostic tool is evaluated in a sample of patients with unusually high disease prevalence, ask

who was included in both the disease and non-disease groups. High prevalence is often a signal that the population was pre-selected by referral, severity, or clinical suspicion—and that selection can simultaneously inflate sensitivity by enriching for obvious disease and distort specificity by enriching the non-disease group with look-alike pathology. Reported test characteristics are only as generalizable as the spectrum of disease they were measured against.

Conclusions

The model described in this study raises an intriguing possibility: expanding renal POCUS by letting bedside nurses use handheld ultrasound devices, with AI assistance, to evaluate for hydronephrosis. The authors conclude that the tool is feasible for nurse-led triage. These results are encouraging but should be interpreted with caution. First, the study was small. With only 15 patients with hydronephrosis and 17 without, the estimates are imprecise: the 95% confidence interval for sensitivity spans 70% to 99%, and for specificity 59% to 94%. Second, the prevalence of hydronephrosis in the study population was far higher than even our most generous estimates for community-dwelling adults, so the reported predictive values will not carry over to the settings where the tool is meant to be used. Third, several features of the study may have made the task easier than it will be in practice. Patients were urology inpatients with a clinical indication for ultrasound, likely enriching the sample for more advanced disease. Additionally, only the kidney with the clearest acoustic window was analyzed. Future validation should report the severity of hydronephrosis, even if the tool is not trained to grade it and describe the composition of the non-disease group. It should be conducted in a population whose prevalence and spectrum of disease approximate those of the intended setting, with bilateral scanning, and a sample large enough to estimate test characteristics more precisely. AI evaluation of nurse-obtained images for prostatic enlargement is even less certain. Fifteen percent of prostate scans were non-diagnostic, and with only seven enlarged prostates, sensitivity could plausibly be anywhere from about 36% to 92%. For now, this tool is a promising proof of concept, but it is not ready to replace clinician judgment or formal imaging in real-world triage.

Disclosure Statement

The authors declare that they have no conflict of interest.

Artificial Intelligence Statement

The authors used Claude (Sonnet 5.5) large language model for copy-editing only. The authors take full responsibility for the publication.

References

1. Matsumoto M, Suzuki M, Karube M, Gotoh H, Sato M, Kobayashi T, Masuda M, Wakita S, Kawamoto A, Miura Y, Tamai N, Sanada H. Nurse-validated handheld POCUS artificial intelligence (AI) for automated prostate volume estimation and hydronephrosis detection. POCUS J. 2026;11(2):60-70. doi:10.24908/pocusj.v11i02.20395

2. Newman TB, Kohn MA. Evidence-based diagnosis: an introduction to clinical epidemiology. 2nd ed. Cambridge, UK: Cambridge University Press, 2020.

3. Darrad M, Gupta A, Rukin N. Hydronephrosis. In Blandy's Urology, Aboumarzouk OM (Ed.). 2019. doi:10.1002/9781118863343.ch10

4. Sinha S, Matai L. Is isolated bladder outlet obstruction associated with hydronephrosis? A database analysis. Neurourol Urodyn. 2020;39 (8):2361-2367. doi:10.1002/nau.24495

5. Kohn MA, Carpenter CR, Newman TB. Understanding the direction of bias in studies of diagnostic test accuracy. Acad Emerg Med. 2013;20 (11):1194-1206. doi:10.1111/acem.12255

Preserving Clinical Skills in the Era of AI-Enabled POCUS

Alphonce Oyugi, MD[1]*; Titus Kahiga, PhD[2]; Kotieno Fredrick, MD[2]

(1) Global Health Institute, Duke University, Durham, NC, USA
(2) School of Health Sciences, Kenyatta University, Nairobi, Kenya

Abstract

Artificial intelligence (AI) is rapidly transforming point-of-care ultrasound (POCUS), with applications spanning image acquisition guidance, automated interpretation, and workflow optimization. While these advances promise to democratize bedside imaging and reduce operator dependency, they simultaneously raise urgent concerns about deskilling, misskilling and never-skilling. This opinion article examines how AI-enabled POCUS may alter the clinical skill landscape, outlines the distinct risks of deskilling, misskilling, and never-skilling in ultrasound practice, and proposes a framework of deliberate strategies to safeguard clinical competency. We argue that the choices made now about how AI is integrated into POCUS training and practice will determine whether these tools elevate bedside diagnostic capability or quietly erode the manual and cognitive skills that define it.

Introduction

Point of care ultrasound (POCUS) has transformed bedside medicine, enabling clinicians across emergency medicine, critical care, internal medicine, and primary care to perform rapid, real-time diagnostic assessments. Its power has always resided in the hand-eye-brain loop of the operator: the tactile skill of probe manipulation, the trained eye for image optimization, and the clinical reasoning that is required to integrate POCUS findings with the patient's presentation. These competencies are hard-won, requiring structured training and sustained deliberate practice.

Artificial intelligence (AI) is now entering POCUS use at a higher speed than ever imagined. AI applications in POCUS currently span three domains: acquisition assistance (guiding probe positioning and view quality), automated interpretation (image analysis for pathology detection), and workflow optimization (integrating findings into clinical decision pathways) [1]. The AI medical imaging market is valued at approximately $1.15 billion in 2025 and projected to reach $2.57 billion by 2034, driven by rapid adoption of AI-enabled ultrasound systems across clinical settings [2]. U.S. Food and Drug Administration (FDA) submissions for AI medical devices more than doubled between 2020 and 2024, from 114 to 235 submissions. Manufacturers have also now embedded deep learning directly into handheld POCUS devices, placing algorithmic assistance at the first moment of clinical contact [3].

Yet as AI assumes a growing role in POCUS, a foundational question emerges: what happens to the clinician's own skills? The concern is not hypothetical. On June 1, 2009, Air France Flight 447 crashed into the Atlantic Ocean. All 228 people aboard were killed. The official inquiry highlighted a critical dimension of the automation paradox: when the autopilot was disconnected, pilots with minimal recent manual flying time logged were unable to respond effectively [4]. Heavy reliance on automation had diminished their capacity to intervene when the system failed. Health care is approaching a parallel inflection point.

The literature on colonoscopies offers the earliest clinical signal. A multicenter observational study demonstrated that gastroenterologists and surgeons who used an AI polyp detection system for three months showed measurable declines in adenoma detection rates when AI support was subsequently withdrawn. Their post-AI performance fell below pre-AI baseline, with an estimated 21% decrease in adenoma detection rates, potentially translating to approximately 18% more missed cancer cases [5, 6]. Analogous risks are plausible and arguably amplified in POCUS, where the skill set spans manual dexterity, spatial reasoning, real-time pattern recognition, and integrated clinical judgement. This editorial examines how AI-enabled POCUS may alter the clinical skill landscape, outlines the forms that skill attrition may take, and proposes strategies to ensure AI augments—rather than erodes—the POCUS competencies that define safe bedside practice.

*Corresponding Author: Dr. Alphonce Oyugi (email: alphonce.oyugi@duke.edu)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.21321

The Deskilling Effect

Concerns about AI-related deskilling are no longer theoretical. As Topaz and colleagues articulated in a commentary in Annals of Internal Medicine, there are hundreds of clinical trials that examine whether AI improves detection during use, yet relatively few investigate what happens to clinician skills when AI is removed or unavailable [4]. The mechanism appears to be cognitive offloading: eye-tracking studies show that clinicians using AI exhibit reduced visual scanning. They stop active searching of the visual field and instead wait for the algorithm to highlight abnormalities. When AI is removed, clinicians accustomed to this more passive verification struggle to reengage active searching [4].

This phenomenon extends across specialties. In mammography, radiologists at all experience levels followed incorrect AI suggestions, demonstrating that expertise provides no immunity to automation bias [6]. In 2025, a randomized trial of diagnostic reasoning, clinicians using a large language model deliberately seeded with errors showed a 14-percentage point reduction in diagnostic accuracy compared with those using accurate AI [7]. A mixed-methods review of AI-induced deskilling in medicine identified four distinct types of deskilling. These included technical skill erosion, decision-making heuristic atrophy, moral responsibility diffusion, and interpretive capacity loss. The review further documented a consistent causal chain from automation bias to complacency to disengagement to skill erosion [8].

The risk of deskilling intersects with several distinctive features of the POCUS skill set. Unlike static image interpretation, POCUS is a real-time, operator-dependent procedure in which image quality is itself a product of skill. AI probe placement assistance may prevent novice users from developing the proprioceptive intuition for acoustic windows. Automated view labelling may short-circuit the spatial reasoning that underpins confident, independent scanning. As AI-enabled POCUS devices proliferate, clinicians risk accumulating scan volume without accumulating the perceptual depth that volume is intended to generate.

Three Trajectories of Skill Loss

Three distinct trajectories of skill loss—deskilling, misskilling, and never-skilling—deserve consideration in the context of POCUS, each with different implications for training design and policy.

Deskilling occurs when clinicians have already achieved POCUS competency but experience progressive erosion of foundational skills because of sustained reliance on AI. Automation bias—the well-documented tendency to over-trust automated outputs—accelerates this trajectory [9]. When AI is consistently correct, vigilance erodes, and when AI fails, the clinician may lack the residual skill to catch the error. This can cause both omission and commission errors [4].

Misskilling refers to the adoption of errors or biases encoded within AI systems. POCUS AI tools that are trained predominantly on images from high-resource settings may perform poorly across diverse patient populations, body habitus, or disease prevalences. A clinician who calibrates their gestalt to AI outputs implicitly absorbs these algorithmic biases, potentially developing systematically flawed pattern recognition. This can be harder to detect and correct than simple skill loss.

Never-skilling is perhaps the most consequential risk on a generational timescale. Topaz and colleagues raise this concern directly: if trainees only learn with AI assistance, they may never develop the independent cognitive frameworks required for unassisted practice [4]. If educators themselves become reliant on AI systems, they lose the capacity to model expert reasoning and to teach trainees how to critically evaluate AI outputs, including identifying errors and hallucinations. In POCUS, current guidance recommends 150–300 total scans for baseline competency, with 25–50 per core application area [10]. If AI assistance is present throughout this formative exposure, trainees may complete their requirements without accumulating the independent perceptual experience that volume is intended to generate.

Lessons from Aviation and Other High-Stakes Industries

The Air France 447 disaster provides more than a cautionary metaphor; it illustrates a regulatory response that medicine has yet to replicate. Following that and similar incidents, aviation regulators mandated routine hands-on flight time and simulator programs designed to replicate automation failures, ensuring that the skills required for unexpected events remain intact [4]. For similar reasons, nuclear plant operators rehearse critical emergency scenarios at regular intervals: the consequence of deskilling in high-stakes moments is unacceptable.

These analogies point toward a principle that medicine applies in procedural simulation and cadaveric training but has not yet been systematically applied to POCUS in the context of AI assistance. The question is not whether AI should be integrated into POCUS practice; the evidence for its benefits in improving image quality, accelerating novice learning, and expanding access to bedside diagnostics is compelling [11, 12]. The question is how integration is designed to protect the human competencies that must persist when AI is unavailable, inaccurate, or insufficient.

A Framework for Preserving POCUS Competency

Protecting POCUS competency in an AI-augmented environment will require deliberate intervention at the level of workflow design, educational architecture, and institutional policy. Drawing on the five-point framework proposed by Topaz and colleagues [4] and adapting it to the POCUS context, we propose the following:

First, AI-off intervals should be built into clinical workflows. Analogous to aviation's requirement for manual flight time, POCUS practice should incorporate deliberate periods without AI assistance; for example, one in every five scans performed without algorithmic support. In training settings, AI interpretation could be configured to appear only after the learner has logged independent findings, preserving the formative cognitive engagement that unassisted scanning demands. Institutions should track unaided performance metrics alongside AI-assisted ones to identify emerging skill gaps early.

Second, shadow-mode training should become standard in POCUS education. Learners should form independent assessments before seeing AI output, and simulation should expose trainees to AI failures and erroneous suggestions. This approach preserves active diagnostic reasoning while leveraging AI as a second reader rather than a primary one and ensures trainees can identify when algorithms are wrong.

Third, task boundary design offers a complementary approach for clinical practice. Frameworks should assign AI to high-volume, low-ambiguity sub-tasks confirming image adequacy, rather than applying AI uniformly across the POCUS task spectrum. AI can be used to flag unambiguous pathology while preserving the interpretive challenge of complex and equivocal cases for human clinicians. AI has demonstrated strong performance for detecting regional wall motion abnormalities in straightforward echocardiographic cases [13]. Such cases could be AI-triaged, which would free clinicians to focus on cognitive resources where nuanced human judgement is essential.

Fourth, competency-based assessment must evolve to explicitly account for AI exposure. Credentialing bodies should require demonstration of unaided POCUS competency as a distinct milestone separate from AI-assisted performance to ensure clinicians can function safely when technology fails [10]. As Topaz and colleagues argue, specialty boards should ensure that certification and maintenance assessments evaluate the ability to think critically and exercise independent clinical judgement, including competence in identifying AI errors [4].

Fifth, ongoing independent validation of AI tools must be a condition of clinical deployment. The COMPASS-AI survey of 1,154 healthcare professionals globally found that training and education (27.1%) and clinical validation and evidence (17.5%) were the most frequently cited barriers to adopting AI-use with POCUS [14]. Regulatory and professional bodies must move beyond requiring awareness of automation bias as the current European Union (EU) AI Act does to mandating active skill preservation, including post-market surveillance of unaided clinician performance [4].

Conclusion

AI is remaking the landscape of POCUS in ways that are genuinely promising. Tools that guide probe positioning, automate image quality assessment, and flag pathology in real time have the potential to expand access to bedside diagnostics and improve patient outcomes. Expert consensus has converged on the position that the goal must be augmentation, not replacement, of clinical skills [3].

Achieving that goal requires deliberate action. As Topaz and colleagues conclude, aviation learned through tragedy that automation paradoxically increases the importance of human vigilance rather than reducing it [4]. Health care and POCUS practice specifically is at a similar inflection point. The colonoscopy deskilling experience demonstrates that AI-related skill attrition is observable, measurable, and clinically significant [5]. In POCUS, where the skill set is multidimensional and the consequences of operator error are immediate, the risks of deskilling, misskilling, and never-skilling demand urgent and systematic attention. The choices made now about how AI is introduced to learners, how unaided competency is assessed, and how boundaries between human and algorithmic responsibility are drawn will determine whether AI strengthens POCUS practice or gradually erodes it from within. We can either heed these early warnings and build safeguards now, or risk discovering the costs of convenience only when systems fail and clinicians are no longer prepared to intervene.

Ethics Statement

This opinion editorial does not involve human participants, animal subjects, patient data, or any form of primary data collection. No ethical approval or informed consent was required for this work. All sources cited are publicly available, previously published literature.

Disclosure Statement

The authors declare no conflicts of interest.

Funding

No funding was received for this work.

Author Contributions

AO: conceptualization, methodology, investigation, writing – original draft, writing – review & editing, project administration, visualization. TK: conceptualization, writing – original draft, writing – review & editing, validation. KF: conceptualization, writing – original draft, writing – review & editing, validation.

References

1. Kim J, Maranna S, Watson C, Parange N. A scoping review on the integration of artificial intelligence in point-of-care ultrasound: current clinical applications. Am J Emerg Med. 2025;92:172–181.

2. Towards Healthcare. AI in ultrasound imaging market size, share & growth analysis 2025–2034. 2025. Available from: https://www.towardshealthcare.com/insights/ai-in-ultrasound-imaging-market-size

3. Kumar A. AI in POCUS: expert panel reveals the future of point-of-care ultrasound. Global Ultrasound Institute. 2025. Available from: https://globalultrasoundinstitute.com/ai-pocus-future/

4. Topaz M, Peltonen LM, Zhang Z, Backonja U. The deskilling effect: is artificial intelligence eroding clinical competence? Ann Intern Med. 2026;179:1048–1050. doi: 10.7326/ANNALS-26-00613.

5. Budzyń K, Romańczyk M, Kitala D, Kołodziej P, Bugajski M, Adami HO, Blom J, Buszkiewicz M, Halvorsen N, Hassan C, Romańczyk T, Holme Ø, Jarus K, Fielding S, Kunar M, Pellise M, Pilonis N, Kamiński MF, Kalager M, Bretthauer M, Mori Y. Endoscopist deskilling risk after exposure to artificial intelligence in colonoscopy: a multicentre, observational study. Lancet Gastroenterol Hepatol. 2025;10(10):896–903. doi: 10.1016/S2468-1253(25)00133-5.

6. Dratsch T, Chen X, Rezazade Mehrizi M, Kloeckner R, Mähringer-Kunz A, Püsken M, Baeßler B, Sauer S, Maintz D, Pinto dos Santos D. Automation bias in mammography: the impact of artificial intelligence BI-RADS suggestions on reader performance. Radiology. 2023;307(4):e222176. doi: 10.1148/radiol.222176.

7. Qazi IA, Ali A, Khawaja AU, Akhtar MJ, Sheikh AZ, Alizai MH. Automation bias in large language model assisted diagnostic reasoning among AI-trained physicians: a randomized clinical trial. medRxiv. 2025. doi: 10.1101/2025.08.23.25334280.

8. Natali C, Marconi L, Dias Duran LD, Cabitza F. AI-induced deskilling in medicine: a mixed-method review and research agenda for healthcare and beyond. Artif Intell Rev. 2025;58(11):356. doi: 10.1007/s10462-025-11352-1.

9. Goddard K, Roudsari A, Wyatt JC. Exploring the risks of automation bias in healthcare artificial intelligence applications: a Bowtie analysis. Smart Health. 2024;33:100480.

10. ASRA News. POCUS Spotlight: defining competency in point of care ultrasound. American Society of Regional Anesthesia and Pain Medicine. 2025. Available from: https://asra.com

11. Shokoohi H, LeSaux MA, Roohani YH, Liteplo A, Huang C, Blaivas M. Acquisition of cardiac point-of-care ultrasound images with deep learning. CHEST Pulm. 2023. doi: 10.1016/j.chpulm.2023.100023.

12. Nhat PTH, Van Hao N, Tho PV, Kerdegari H, Pisani L, Thu LNM, Phuong LT, Duong HTH, Thuy DB, McBride A, Xochicale M, Schultz MJ, Razavi R, King AP, Thwaites L, Van Vinh Chau N, Yacoub S, Gomez A; VITAL Consortium. Clinical benefit of AI-assisted lung ultrasound in a resource-limited intensive care unit. Crit Care. 2023;27(1):257. doi: 10.1186/s13054-023-04548-w.

13. Slivnick JA, Gessert NT, Cotella JI, Oliveira L, Pezzotti N, Eslami P, Sadeghi A, Wehle S, Prabhu D, Waechter-Stehle I, Chaudhari AM, Szasz T, Lee L, Altenburg M, Saldana G, Randazzo M, DeCara JM, Addetia K, Mor-Avi V, Lang RM. Echocardiographic detection of regional wall motion abnormalities using artificial intelligence compared to human readers. J Am Soc Echocardiogr. 2024;37(7):655–663. doi: 10.1016/j.echo.2024.03.017.

14. Wong A, Roslan NL, McDonald R, Noor J, Hutchings S, D'Costa P, Via G, Corradi F. Clinical obstacles to machine-learning POCUS adoption and system-wide AI implementation (The COMPASS-AI survey). Ultrasound J. 2025;17(1):32. doi: 10.1186/s13089-025-00436-2.s13089-025-00436-2

Development of a Dashboard for POCUS Revenue Tracking: Lessons Learned

Zachary W. Binder, MD[1,2]*; Megan K. McDavitt, MS RN-BC[1]; Theodore Macnow, MD[1,2]

(1) Department of Pediatrics, UMass Memorial Children's Medical Center, Worcester, MA, USA
(2) Department of Pediatrics, UMass Chan Medical School, Worcester, MA, USA

Dear Editor, we in point of care ultrasound (POCUS) leadership face questions such as:

How do I justify the purchase of a new POCUS machine?

How can I advocate for additional protected time for POCUS?

How can I determine if providers are properly documenting POCUS examinations so that my billing department is able to charge for POCUS studies?

Are third-party payers reimbursing my department for the POCUS studies that are being billed, and what types of studies are more frequently reimbursed?

Which providers are performing the range of POCUS studies for which they are credentialed?

While some of this information can be gleaned from middleware software products or from data extracts provided by administrators, it is often difficult to find the answers to these questions in a real-time, organized, and user-friendly format. POCUS leaders have experience with many administrative responsibilities such as credentialing, quality assurance (QA), educational leadership, and capital investment [1]. However, a nuanced understanding of the impact of our work on revenue is often less understood [2,3]. We partnered with a business intelligence developer (author MM) to build a dashboard that displays our POCUS billing data clearly. Our leadership team was then able to use this data to answer questions like those that are posed above.

Pre-Development Stage

The impetus for the development of a POCUS dashboard was a request made by clinical services leadership at our institution in preparation for the purchase of a new ultrasound device. They asked us to provide the number of POCUS studies our division performs annually, broken down by Current Procedural Terminology (CPT) code. We had no immediate way of responding to this inquiry.

Before a dashboard could be developed, a detailed understanding of the institution's processes for billing POCUS was required. We needed to understand how a POCUS study moved from the ultrasound machine to the middleware software (Synchronicity middleware, R.E. MEDICAL, Austin, TX, USA), and then from the middleware software to PACS (AGFA Healthcare, Mortsel, Belgium), where the images and QA report would be visible in the electronic medical record. At UMass Memorial Medical Center, we use an encounter-based system, rather than an order-based system, for ordering POCUS studies. Therefore, we needed to determine at what point in the workflow the POCUS order was generated and what made a POCUS study visible to our billers. Finally, we needed to determine the point at which completed studies were submitted by the billing department to third-party payers, such as insurers.

Development Stage

The development of this dashboard relied on input and collaboration from internal and external stakeholders. The dashboard was created through a direct partnership with a business intelligence developer at our institution (author MM). Additionally, we met regularly with members of the billing department to ensure congruence between our dashboard and their data. At regular intervals throughout the process, we met with department leadership to present our findings and discuss next steps. We also met with POCUS leaders from around the region to gain insight from their experiences and to obtain feedback on improving our dashboard.

As the dashboard was developed, our questions evolved from "*How many POCUS studies are being performed annually?*" to more nuanced ones, such as "*Are our billers able to generate billed charges for our POCUS studies?*" "*What is our division's collection rate?*" and "*How do our documentation practices affect revenue generation?*"

*Corresponding Author: Dr. Zachary W. Binder (email: zacharybindermd@gmail.com)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.22075

Dashboard Elements:

Data visualization and dynamic filtering were performed using Tableau Desktop, version 2025.1.8 (Tableau Software, LLC, Seattle, WA). Data were obtained via a secure SQL connection to Epic's Clarity database (EPIC Systems Corporation, Verona, WA). We update and publish the dashboard weekly, and it displays current data over time. The data are presented as bar graphs showing month-over-month results and line graphs showing annual trends. In addition, the dashboard tracks "billed charges" and "revenue," and calculates a "collection rate" (Table 1). Data can be filtered by clinical campus, CPT code, study type, performing physician, and QA reviewer (Figure 1). A second display presents tabular data for each POCUS study, including service date, charge date, billed charges, revenue, denials, reasons for denials, and patient demographics such as age.

Table 1. Definitions of key POCUS billing and reimbursement terms.

Billed Charges	The total amount originally invoiced by the provider for a specific service or procedure [6].
Allowed Charges	The amount that an insurance company has contractually agreed to pay a provider for a service.
Revenue	The financial income generated and collected by providers for delivering medical services, treatments and procedures.
Collection Rate	The percentage of billed charges that is collected as revenue.
Capture Rate	The percentage of clinical services provided to patients that are successfully recorded as billed charges
Denial	A decision by an insurance company to refuse payment for a submitted claim after processing and reviewing it.

POCUS Dashboard Successes

1) We were able to quantify the number and types of POCUS studies being performed annually in our department. These data were provided to clinical services leadership, who then incorporated the data into a business plan that ultimately led to the purchase of a new ultrasound machine.

2) We were able to show that our annual POCUS revenue exceeded the cost of the clinical offset time allotted to POCUS. This served as the central argument in favour of providing additional protected time for POCUS.

3) When we reviewed our data, we discovered that billing attribution was being assigned to the QA reviewer, without a record of the performing physician. Following this discovery, we adapted the dashboard to include performing physician data and added the ability to sort data by both performing physician and QA reviewer. As a result, we are now able to provide physicians with individualized POCUS performance metrics. In addition, all physicians within the department have been given real-time access to the POCUS dashboard.

4) We discovered a discrepancy between the number of POCUS studies stored in our middleware software, the software platform that integrates POCUS examination documentation and image management with the electronic health record and billing workflow, and the number of studies generating billed charges. We met with our billing department and discovered they were not billing for POCUS studies done by residents and fellow trainees even when those studies were performed under the direct supervision of a credentialed attending. In response, we changed our POCUS documentation templates to allow indication of when a study was performed by a trainee under the supervision of an attending physician, and to track the subsequent increase in billed charges. Similar work by Ng et al. demonstrated increased POCUS billing after interventions to improve documentation [4].

5) Compared to the year before implementing the new dashboard, our billed charges increased by 25.6%, our revenue increased by 284%, and our collection rate nearly doubled from 10.9% to 20.7%. Prior work by Adhikari et al. has demonstrated the fiscal impact of implementing a POCUS billing program [5].

Next Steps

The development and implementation of our dashboard have increased revenue for our POCUS program. We have only begun to realize the full fiscal and educational impact our dashboard system will have. We plan to explore our "capture rate" (the percentage of clinical services successfully recorded as billed charges) to investigate ongoing documentation requirements for billing and consistency among billers (Table 1). We hope to scrutinize denials to identify interventions that might increase our collection rate.

Disclosure Statement

The authors have no conflicts of interest to disclose.

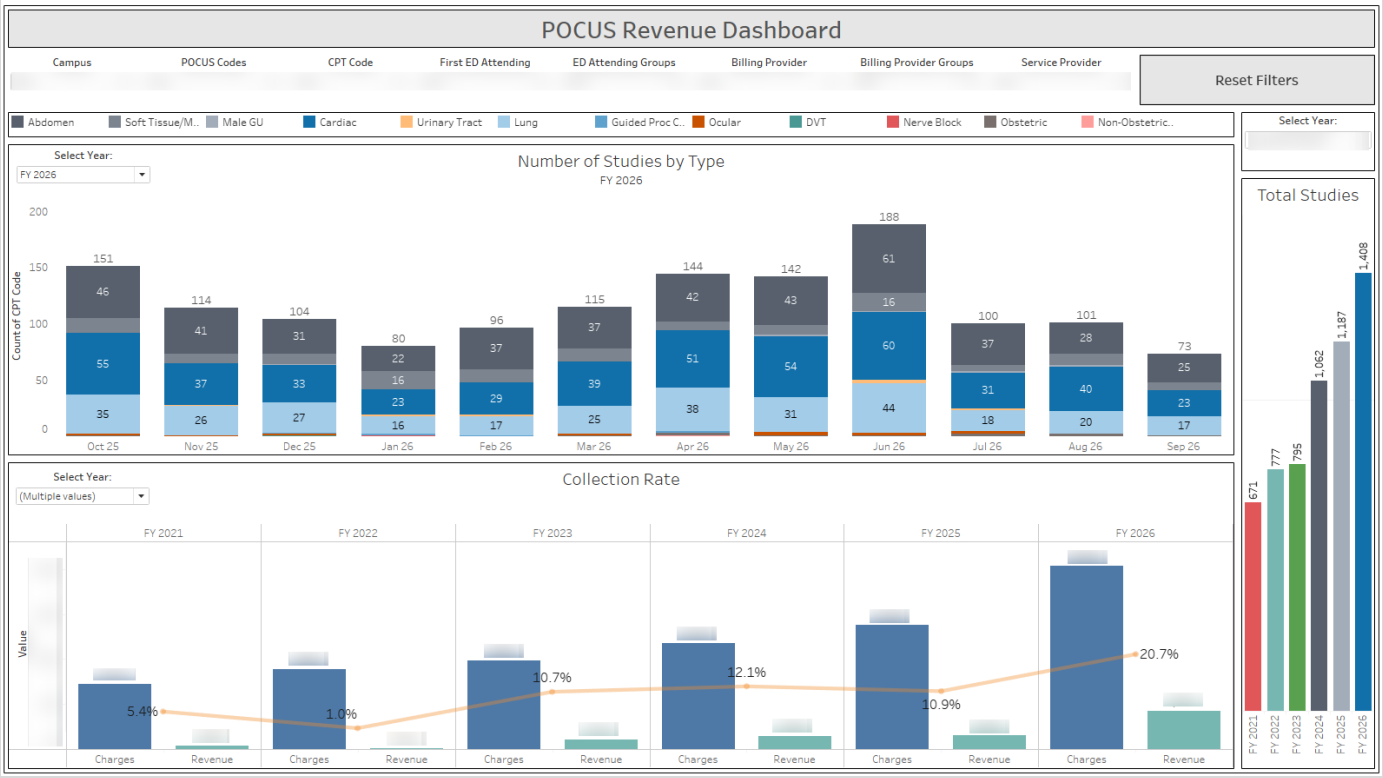


Figure 1. Representative example of the interactive point of care (POCUS) Revenue Dashboard. The top banner contains filters for campus, POCUS code, Current Procedural Terminology (CPT) code, first Emergency Department (ED) attending, ED attending group, billing provider, and service provider. Top: Monthly number of POCUS studies by type for fiscal year (FY) 2026, with the total for each month shown above its bar. Right: Total studies performed per FY. Bottom: Charges and revenue for each FY from FY 2021 to FY 2026, with the line showing the collection rate (revenue as a percentage of charges), which rose from 5.4% in FY 2021 to 20.7% in FY 2026. Dollar values are obscured.

References

1. American College of Emergency Physicians. Ultrasound Guidelines: Emergency, Point-of-Care, and Clinical Ultrasound Guidelines in Medicine. Ann Emerg Med. 2023.

2. Hall MK, Hall J, Gross CP, Harish NJ, Liu R, Maroongroge S, Moore CL, Raio CC, Taylor RA. Use of point-of-care ultrasound in the emergency department: insights from the 2012 Medicare National Payment Data Set. J Ultrasound Med. 2016;35(11):2467-2474.

3. Rosenkrantz AB, Bilal NH, Hughes DR, Duszak R Jr. National specialty trends in billable diagnostic ultrasound in the ED: analysis of Medicare claims data. Am J Emerg Med. 2014;32(12):1470-1475.

4. Ng C, Payne AS, Patel AK, Thomas-Mohtat R, Maxwell A, Abo A. Improving point-of-care ultrasound documentation and billing accuracy in a pediatric emergency department: a quality improvement study. Pediatr Qual Saf. 2020;5(4):e315.

5. Adhikari S, Amini R, Stolz L, O'Brien K, Gross A, Jones T, Fiorello A, Keim SM. Implementation of a novel point-of-care ultrasound billing and reimbursement program: fiscal impact. Am J Emerg Med. 2014;32 (6):592-595.

6. Platt A, Peterson T, Peethumnongsin E, Kuchibhatla M, Theophanous RG. Impact evaluation of a clinical point-of-care ultrasound intervention in an academic emergency department. West J Emerg Med. 2026;27(4):1023-1033.

Impact of a Hospital Medicine POCUS Program on Scan Quality, Faculty Satisfaction, and Billing Revenue

Thomas F. Heyne, MD MSt[1,2,3]*; Hamid Shokoohi, MD MPH[3,4]; Andrew S. Liteplo, MD[3,4]

(1) Department of Medicine, Massachusetts General Hospital, Boston, MA, USA
(2) Department of Pediatrics, Massachusetts General Hospital, Boston, MA, USA
(3) Harvard Medical School, Boston, MA, USA
(4) Department of Emergency Medicine, Massachusetts General Hospital, Boston, MA, USA

Abstract

Background: Given the lack of consensus guidelines for point of care ultrasound (POCUS) for internal medicine (IM) amongst U.S. societies, individual institutions must decide whether to adopt more or less structured approaches to IM-POCUS training, privileging, scan documentation, and quality assurance (QA). Since its inception in 2018, our IM-POCUS program has utilized highly structured guidelines, mirroring protocols suggested in guidelines from the American College of Emergency Physicians (ACEP). We sought to evaluate the impact of such a structured IM-POCUS program on faculty satisfaction, scan quality, and billing revenue. **Methods:** This study used faculty surveys to (1) evaluate faculty trainee satisfaction and (2) identify barriers to training and to POCUS use. We used QA data to assess the diagnostic performance of scanning providers, including positive predictive value (PPV), negative predictive value (NPV), accuracy, and rate of uninterpretable studies, as determined by POCUS experts. Finally, we used billing data to track scan volume and billing revenue. **Results:** A total of 32 hospitalists started the training pathway from 2018 to 2025. To date, 24 hospitalists have completed the training, and 4 are in progress. Of the 24 who completed training, 17 responded to a post-training survey. The majority reported that their training helped make them a better clinician (94%, 16/17), educator (94%, 16/17), proceduralist (77%, 13/17), and physical examiner (77%, 13/17), while 88% (15/17) felt it improved their job satisfaction. The top barriers to POCUS training were busy work and parental schedules. The top barriers to clinical POCUS use were the additional time required to scan and save images, and limited access to ultrasound machines. Clinical scans reviewed for QA showed an overall PPV of 99%, NPV of 97%, and accuracy of 98% (all excluding technically limited studies, TLS), and a TLS rate of 6.9%. Billing data showed a steadily increasing volume of scans and billing revenue, with 1,611 scans and revenue of $37,747 in professional fees in the most recent fiscal year. **Conclusion:** Our IM-POCUS program, which is based on highly structured ACEP guidelines, has shown high faculty trainee satisfaction, good diagnostic POCUS performance, and steady growth in scan volume and revenue. This approach could serve as a useful model for other hospital medicine groups looking to build IM-POCUS training programs.

Introduction

The use of point of care ultrasound (POCUS) continues to expand within internal medicine (IM), with medical students and residents increasingly expecting POCUS training as part of their education [1,2]. However, insufficient numbers of IM faculty trained in POCUS remain a major barrier [3]. Fortunately, the opportunities for IM faculty training have increased, including several hands-on courses (e.g., two-day courses through the American College of Physicians, ACP), new IM-POCUS fellowships, and a relatively new virtual Mentorship Program through the ACP [4]. However, such opportunities may be cost- or time-prohibitive to many faculty. Furthermore, the question remains: “Exactly what kind of training is sufficient for an internist to use POCUS competently for clinical care?” Although impressive efforts have been made towards finding consensus for recommendations for IM residency training [5–7], U.S. professional and residency societies for IM still lack national consensus guidelines for IM-POCUS competency and training, comparable to the well-established, highly structured guidelines from the American College of Emergency Physicians (ACEP) [8]. The Society for Hospital Medicine’s (SHM’s) 2019 position statement cited the lack of POCUS-based competencies within the American Board of Internal

*Corresponding Author: Dr. Thomas F. Heyne (email: theyne@mgb.org)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20346

Medicine's certification, and acknowledged that "practicing hospitalists must work with their local privileging body to determine what credentials are required" [9]. In practice, some hospitalist groups adopt guidelines that are flexible (i.e., treating POCUS as an extension of the physical exam, with minimal requirements for POCUS privileges or scan documentation), while others adopt highly structured guidelines (requiring precise guidelines for POCUS training and hospital privileges, documentation of scans, and scan review/quality assurance, QA) [7]. Arguably, there are benefits and limitations to both loose and strict guidelines [10]. Together with the American College of Chest Physicians (CHEST), the SHM has offered a Certification of Completion for POCUS, which follows a more structured training approach that requires a minimum number of scans as part of a scan portfolio [11]. Prior studies have evaluated training programs aligned with these SHM/CHEST certificate requirements [12–15] or analogous training programs in Europe [16]. These studies have focused on assessing clinicians' POCUS knowledge and skills after completing the training. However, few studies have evaluated the diagnostic accuracy of POCUS scans completed by internists on actual patients after their completion of a structured POCUS training program.

Even smaller single-site studies can contribute helpful data and insights in the absence of multicenter studies evaluating different POCUS training and credentialing pathways. This study, involving one large academic hospital, aimed to evaluate the outcomes of a POCUS program adopted from highly structured ACEP guidelines for a hospital medicine group. It focused on faculty satisfaction, perceived barriers, scan quality, and clinical use. Finally, we sought to draw lessons from challenges encountered.

Program Overview

The IM-POCUS program originated in 2017, founded by a hospitalist who had just completed the emergency department's (ED's) one-year fellowship in Emergency Ultrasound. Highly structured guidelines for an IM-POCUS program were developed (Table 1), mirroring local ED POCUS credentialing guidelines, which are based on ACEP guidelines [8]. Approval for IM-POCUS guidelines was received from both Radiology and Cardiology leadership. Following a "bolus and drip" model [17], IM Faculty trainees were required to undergo a single initial "bolus" of approximately 8 hours of POCUS didactics (initially offered as live lectures and starting in 2020 as online videos). After, trainees completed an image portfolio of 25 ultrasound scans per imaging application—for a total of 150 scans—on actual patients in the hospital. All 150 scans had to meet minimal criteria to be counted: e.g., a minimum of two views were required for each lung exam (see Supplementary Material S1), and image quality needed to be adequate to interpret the images (although image quality per se was not quantitatively recorded for all portfolio scans). To complete their scan portfolio, trainees first met with a POCUS expert (defined as someone who had completed an ultrasound fellowship or similar) for 4 scan sessions, each lasting 2–4 hours. Scans completed during these training sessions counted towards the required 150 scans. Thereafter, trainees completed the rest of their scan portfolio on their own (or together with other trainees) as their schedule permitted, and had their scans reviewed together with the POCUS expert. At the conclusion of training, an Observed Structured Clinical Exam (OSCE) was required. Upon completion of the didactics, scan portfolio, and successful OSCE, physicians received hospital privileges for POCUS. See Supplementary Material S2 for a full description of the training and credentialing guidelines, as well as the OSCE form.

The POCUS training focused on questions related to six applications that were deemed most relevant to our hospitalists. These included: cardiac (is there left ventricle (LV) or right ventricle (RV) dysfunction, or a pericardial effusion?), inferior vena cava (IVC) (is the IVC plethoric with minimal collapse, collapsing >50%, or in between?), lung (is there lung sliding, a pleural effusion, consolidation, or B-lines?), renal/bladder (is there hydronephrosis or urinary retention?), abdominal fluid (is there free fluid; is there enough to tap?), soft tissue/ jugular venous distention (JVD) (is there edema or a fluid

Table 1. Minimum requirements for IM-POCUS training and credentialing in our ACEP-based model.

Component	Details
Didactics	Minimum of 8 hours (initially in-person, later online and asynchronous)
Scan Portfolio	25 scans per imaging application (for a total of 150 scans)
Supervised Scan Sessions	4 sessions with a POCUS expert (2-4 hours each)
Final Assessment	Observed Structured Clinical Exam (OSCE)
Core POCUS Applications	Focused Cardiac, IVC, Lung, Renal/Bladder, Abdomen/FAST, Soft Tissue/JVD.

ACEP, American College of Emergency Physicians; FAST, Focused Assessment with Sonography in Trauma; IM, internal medicine; IVC, inferior vena cave; JVD, jugular venous distention; POCUS, point of care ultrasound.

collection, or what is the height of the internal jugular vein distention?). Trainees were encouraged to scan multiple applications/organ systems within the same patient (particularly given overlap between some applications, e.g., lung, abdominal free fluid, and renal/bladder). Although quite useful to hospitalists, deep vein thrombosis (DVT) scans were excluded as these scans can be readily obtained on our inpatients by either Radiology or the Vascular Lab. Training and QA scan reviews were completed by the initial IM-POCUS expert who started the program (another IM-POCUS expert assisted with QA from 2019 to 2021). Three to six faculty members were trained per year. Our goal was to train faculty who could scan, interpret, and teach POCUS independently, with the assumption that their clinical scans would undergo QA review. Thus, we focused on training hospitalists on the Medicine Procedural Service and the veteran "Core Educator" faculty who have a heavy teaching footprint in the residency. The program generally had two cart-based machines (one for the procedural service, and the other which was shared among hospitalists); hospitalists were also permitted to use ED machines when seeing patients in the ED.

Clinical scans were formally documented in the Electronic Medical Record (EMR) for each scan. Clinical scans were billed in the same manner as IM procedures. Physicians without POCUS privileges could perform educational scans but not make clinical decisions from these scans unless they were overseen by a physician with POCUS privileges (this guideline is widely advertised but admittedly difficult to track, particularly for residents). Clinical scans were reviewed by a POCUS expert for QA, with individualized feedback emailed to providers.

Methods

Study Setting

This study took place in a 1,000-bed quaternary care hospital in the Northeastern U.S. The Division of Hospital Medicine consisted of approximately 140 hospitalist faculty, including approximately 13 on the Medical Procedural Service and 19 on the Core Educator service. The study population included hospitalist faculty who completed training and were credentialed in IM-POCUS between 2018 and 2025.

Study Variables & Measurements

Surveys: To assess program success, IM faculty were requested to complete anonymous pre- and post-training surveys via RedCap. Questions focused on perceived barriers to POCUS training and use, and self-perceived competency and satisfaction from POCUS training.

QA Review: Clinical scans from 2019 to 2025 were reviewed by one of two POCUS experts. Clinicians first started notes in the EMR, uploaded patient data via a Worklist on the POCUS machine and then performed the scan and documented it in the EMR. Thus, all clinical scans were linked to the Picture Archiving and Communication System (PACS). Clinicians would notify the POCUS expert(s) via email when scans were completed, or (starting in 2025), clinicians would list scans in a shared POCUS and Procedure Spreadsheet within the institutional cloud. Scans were reviewed via QPath (Telexy) or (starting in 2021) via Visage Imaging Client by the POCUS expert(s), with a goal of reviewing 100% of clinical scans. A QA system was used, with the QA process answering the question: "Do the images acquired adequately support the interpretation for each POCUS question?" Images that met minimal scan criteria and were interpreted correctly (e.g., as positive or negative for the POCUS question) were scored as True Positive (TP) or True Negative (TN). When images were incorrectly interpreted (i.e., the expert interpretation determined that the opposite interpretation was correct), scans were scored as a False Positive (FP) or a False Negative (FN). When image quality was unacceptable for interpretation and/or did not meet minimal criteria for imaging, the scan was considered a Technically Limited Study (TLS). For each patient, the reviewing expert documented the assessment in a spreadsheet within the institutional cloud. Timely, individualized feedback was emailed to each scanning faculty, focusing on any deficiencies in image quality, minimal scanning criteria, and accurate interpretation. For example, "this cardiac scan was scored as a TLS because it only included one view (minimal criteria not met)" or "scan scored as a TLS because of poor image quality." Characteristics were calculated for each of the scanners whose scans had been QA reviewed: positive predictive value (PPV), negative predictive value (NPV), accuracy, and percent of TLS scans. TLS scans were excluded from calculations of PPV, NPV, and accuracy.

Billing Data: We reviewed the number of scans annually from 2019 to 2025 to assess the volume of scans. We reviewed revenue from professional fees over the same period to assess the financial impact of the program.

Results

A total of 32 hospitalists started the training pathway from 2018 to 2025. One hospitalist from this group had significant prior POCUS training (outside of POCUS-based procedures). Of the 32 who started by completing the required 8-hour bolus of initial didactic lectures, 24 completed the training, 4 are currently working on requirements, and 4 left the institution prior to completion. Of the 24 who completed their training, 9 have left our institution to date. Most faculty trainees completed the training in 9 to 12 months, but 3 of them took more than 2 years. All 24 faculty who completed the training passed

the OSCE on their first attempt.

Results from Faculty Surveys

The initial survey was completed by 66% (21/32) of hospitalists who started the training pathway. The top responses to the question "What barriers did you have (or are you having) to completing your training in a timely manner?" were "busy work schedule" (76%, 16/21) and "parental obligations" (52%, 11/21).

The post-training survey was completed by 71% (17/24) of hospitalists who completed the training. Responses to the Likert scale questions are provided in Figure 1. Among faculty who completed the POCUS training, 88% (15/17) felt "comfortable" or "extremely comfortable" with performing POCUS. Top responses to the question "What barriers do you face to using POCUS on your current clinical shifts (and documenting/billing for it)?" included "additional time required to use the machine or save images" (82%, 14/17) and "inadequate access to machines" (59%, 10/17). Two respondents added free-text comments that expressed gratitude for the POCUS training for their future career choices (one as a pulmonary/critical care fellow, the other as an IM-POCUS program director in another institution).

Results from QA Review

Results are summarized in Figure 2. Clinical scans reviewed for QA showed an overall PPV of 99%, an NPV of 97%, an accuracy of 98%, and a TLS rate of 6.9%. Scanning physicians with both higher and lower volumes of POCUS scans showed comparable diagnostic performance (see Supplementary Material S3 — Figure S1).

Results from Billing Data

Results are summarized in Figure 3 and Table 2. Individual scan volume is given in Supplementary Material S3 — Figure S2, excluding 5 fully trained physicians who completed 30 clinical scans or fewer in the last 4 years.

Discussion

Our IM-POCUS training program, which was modeled after highly structured ACEP guidelines, has been an overall success. Faculty respondents reported overwhelming satisfaction with the program, feeling of POCUS competency, and feeling that their POCUS

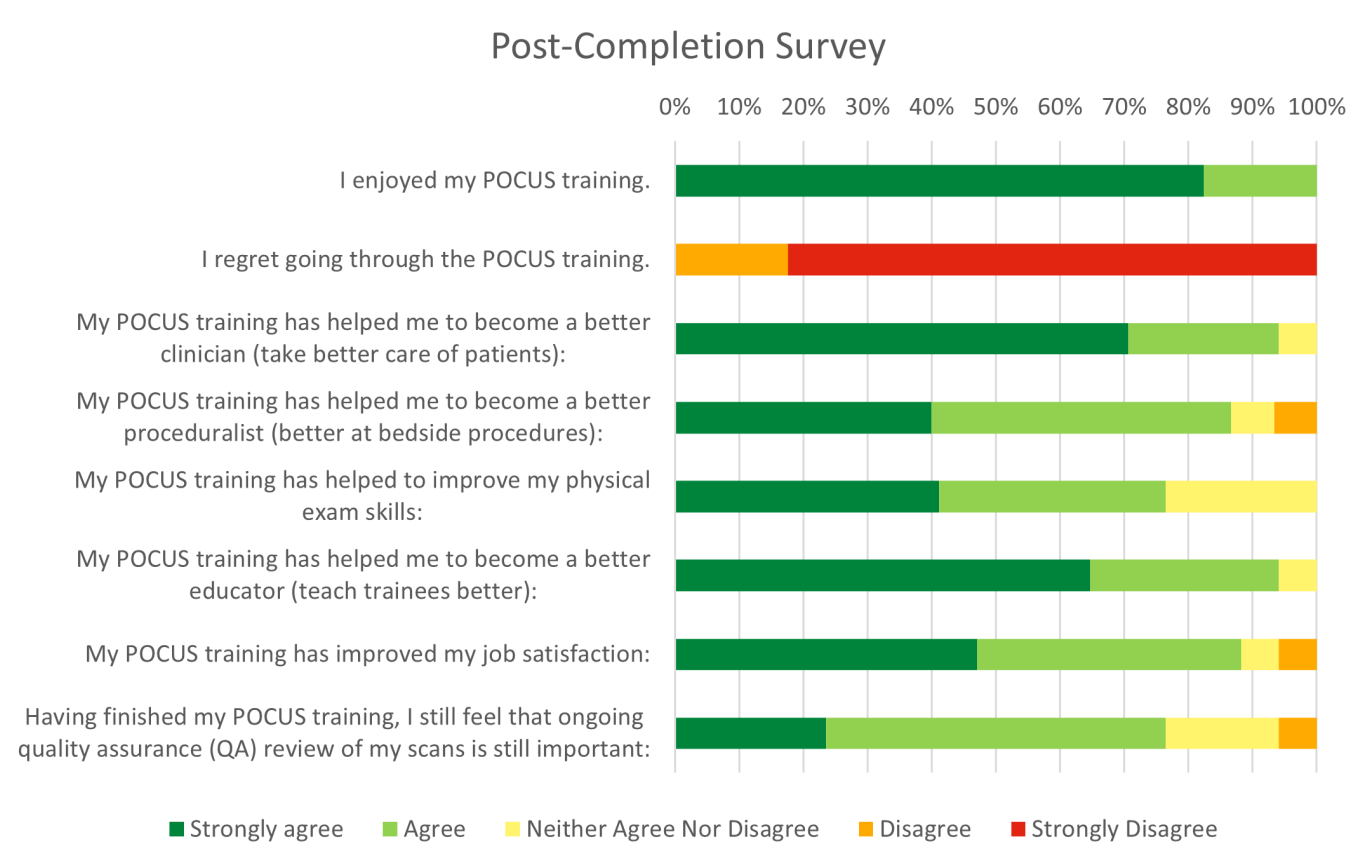


Figure 1. Results from surveys completed by point of care ultrasound (POCUS) trained internal medicine (IM) faculty (n = 17).

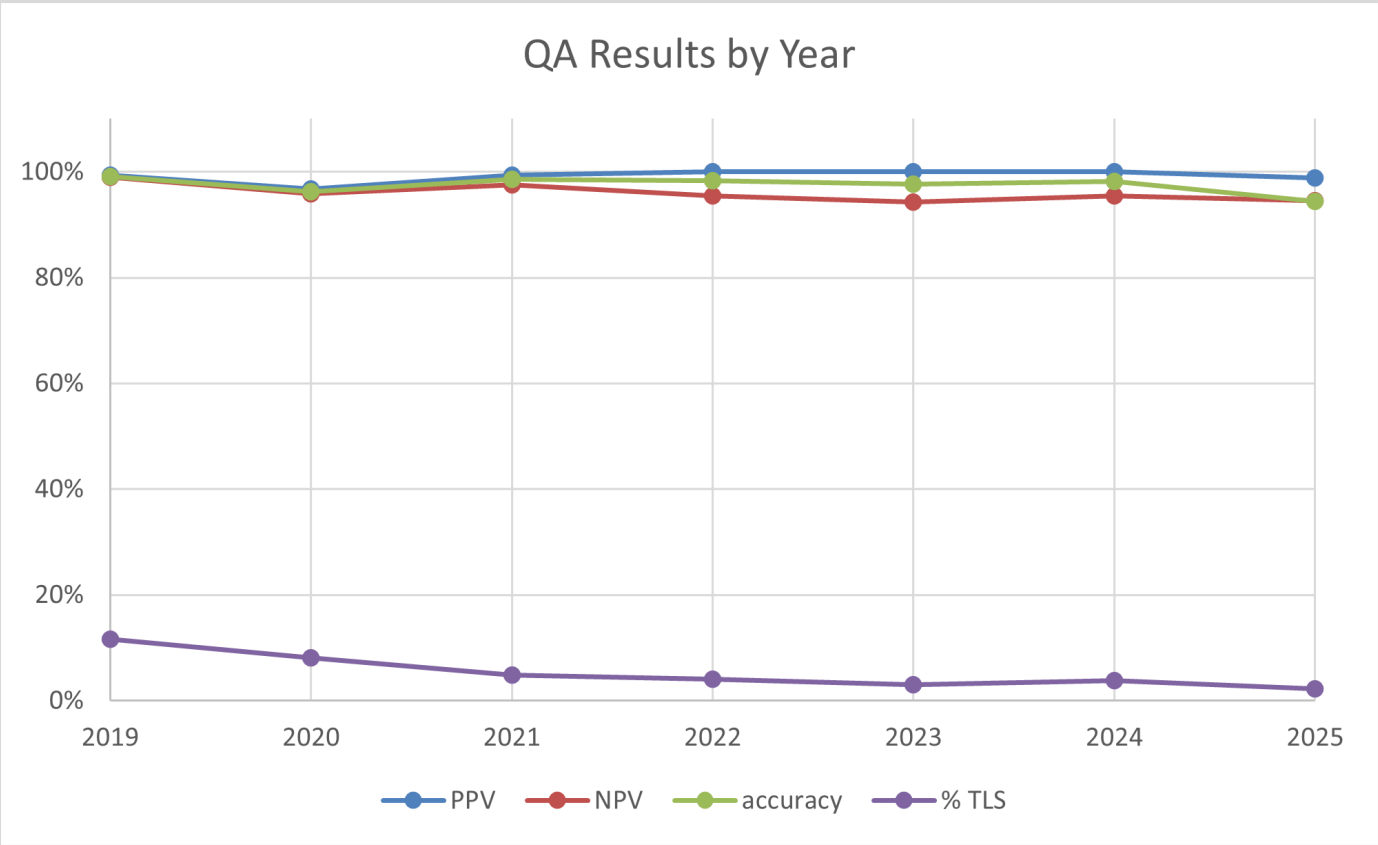


Figure 2. Results of quality assurance (QA) review of clinical scans (performed by the 15 clinicians who completed the training and submitted scans for review). PPV, positive predictive value; NPV, negative predictive value; % TLS, percent of scans determined to be technically limited studies (uninterpretable).

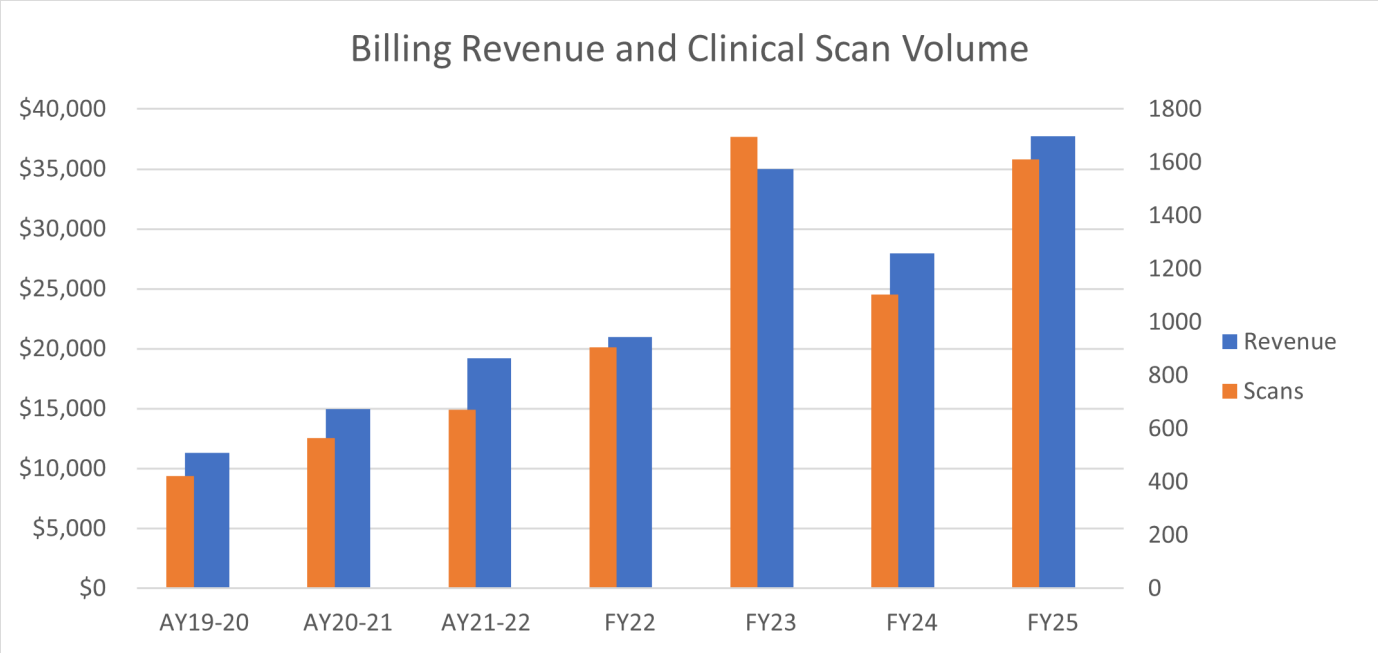


Figure 3. Clinical scan volume and revenue (from professional fees), per year. AY, Academic Year; FY, Fiscal Year.

Table 2. Billing revenue and clinical scan volume for fiscal year 25, by POCUS application.

Billing Code/Indication	Number of scans	Total payments	Average payment per scan
76536 [JVD/neck]	117	$2883.88	$24.65
76604 [lung/thorax]	371	$8519	$22.96
76705 [FAST/abdomen]	480	$12294.99	$25.61
76770 [renal/bladder]	47	$1342.72	$28.57
76775 [IVC/retroperitoneal]	149	$3985.06	$26.75
76857 [bladder/pelvis]	10	$256.31	$25.63
76882 [soft tissue/JVD]	152	$2316.71	$15.24
93308 [limited echo/cardiac]	285	$6148.65	$21.57
TOTAL	1611	$37747.32	$23.43

FAST, Focused Assessment with Sonography in Trauma; IVC, inferior vena cave; JVD, jugular venous distention; POCUS, point of care ultrasound.

training made them better clinicians, educators, and proceduralists, and that it increased their job satisfaction. Two respondents noted how POCUS training helped to further their career aspirations. Overall completion rate for the training pathway has been reasonable, with an expected completion rate of 88% (28/32).

Two recent Delphi-based consensus studies have addressed the longstanding gap in IM-POCUS standardization [5,6]. LoPresti et al. identified 12 core diagnostic indications, 15 diagnostic applications, and 52 specific skill components for IM residency curricula, while Chockalingam et al. established consensus on 53 essential POCUS skills spanning lung, abdominal, procedural, cardiac, musculoskeletal, and vascular domains, along with preferred teaching methods and evaluation strategies. Our program's six core applications align well with the diagnostic applications prioritized in both consensus processes (e.g., focused cardiac, lung, IVC, renal/bladder, and abdominal free fluid), although did not include applications like gallbladder and musculoskeletal, which may be less relevant to a hospitalist. Importantly, both consensus studies were designed for residency training and do not directly address faculty credentialing or QA infrastructure. ACEP-based models like ours may help to fill a persistent gap until similar faculty-level national consensus guidelines are available.

As previously identified [18], a structured approach to POCUS—requiring documentation and billing for each scan—offers several benefits. These include enabling QA review and providing concrete billing revenue information to support administrative decisions (e.g., justifying budget or machine requests). In our structured program, QA review demonstrated that clinical scans completed by trained faculty had a high degree of accuracy (>90%) and a low number of technically limited (uninterpretable) scans, comparable to emergency medicine residents over the course of their four-year residency training [19]. Notably, diagnostic accuracy has been high, starting from the program's first year of QA review, which may reflect the rigor of the training pathway; however, this also limits our ability to demonstrate improvement over time.

The program has also been a financial success. The revenue from professional fees has grown each year, to the point where machines could be purchased or replaced with this revenue. It is possible that revenue would be higher if more machines were available, as faculty listed "inadequate access to machines" as a top barrier to performing and billing for POCUS. Of note, some institutions encourage providers to incorporate POCUS use into their billing codes (e.g., billing for a more complex visit or for critical care time).

Challenges and Responses

Since the program's inception, we have encountered several challenges, some of which we have only partially overcome. These challenges and possible solutions are summarized in Table 3.

Perhaps the greatest challenge has been the length of time required by some faculty to complete the training pathway. The problem is not unique; e.g., a prior study noted a low faculty completion rate of a scanning portfolio modeled after the CHEST/SHM POCUS Certification [12]. Of note, our pathway requires a larger number of scans of several applications compared to this CHEST/SHM Certificate, which requires only 5 normal and 5 abnormal abdominal scans and 3 normal and 3 abnormal soft tissue scans [11]. Most of our trainees finished the training in 9 to 12 months, but 3 physicians took over 2 years to complete their training. To address this challenge, faculty were encouraged to schedule specific times to scan alongside other physicians—either faculty trainees or fully trained faculty. In addition, a helpful

Table 3. Operational challenges in IM-POCUS implementation and practical solutions.

Challenge	Response / Lesson Learned
Limited institutional buy-in for starting POCUS program	Engage key stakeholders (e.g., ED, Cardiology, Radiology) early and often
No national IM-POCUS guidelines	Adopt guidelines acceptable for local stakeholders (e.g., local ED or national ACEP guidelines)
Limited funding for POCUS program / machines	Present current or projected billing revenue to justify investment
Faculty slow to complete training pathway	Set hard deadlines for completion or offer incentives like handheld devices
Low scan documentation and billing among some providers	Streamline process (e.g., scanning patient wristbands), send periodic reminders to faculty, and advocate for additional machines
QA review process is onerous	Focus QA on those newly trained; input review and feedback directly into PACS if possible

ACEP, American College of Emergency Physicians; ED, emergency department; IM, internal medicine; PACS, picture archiving and communication system; POCUS, point of care ultrasound; QA, quality assurance.

impetus for some trainees was the creation of a hard deadline: namely, if faculty do not finish their training in 1.5 years, they can no longer serve on the Medical Procedure Service. In addition to this, we have discussed purchasing a handheld POCUS machine for faculty who complete their training in a timely manner. However, we did not receive funding approval for this incentive. Finally, we have discussed the possibility of emulating other IM programs which train some faculty solely to interpret images, a skill which requires significantly less training than also learning to scan [14]. However, we ultimately have continued with this more intensive model given its overall success.

Another challenge has been a discrepancy in POCUS volume among different providers: namely, some providers have documented and billed for relatively few clinical scans compared to others, with 5 physicians completing 30 scans or fewer in the last 4 years. Completed surveys suggested two major barriers for clinical scanning/billing: 1) the additional time/effort required for the process and 2) inadequate access to machines. Our process is admittedly onerous, requiring providers to first start a note in the EMR, then scan the patient, then complete the note and enter billing information. Some programs have a more streamlined process (including scanning patient wristbands to upload patient information into the machine), but such a solution has not yet seen fruition in our large, complex institution. Instead, providers (particularly those with lower scan volume) are given periodic reminders via email, and de-identified statistics are shared (like in Supplementary Material S3 — Figure S2), whereby providers might be motivated when they compare themselves to other providers. Finally, we continue to advocate for the purchase of additional machines, and recently, our department purchased several handheld ultrasound devices and a new cart-based machine for the residency floors.

The final challenge has been keeping pace with the necessary QA review, which remains labor-intensive. Faculty respondents overwhelmingly felt that QA review of their clinical scans was helpful, but the scan volume has continued to increase. Although our current goal remains to QA review 100% of clinical scans, we are discussing different models. For instance, exploring scenarios whereby recently trained faculty would have 50% of scans reviewed, whereas more veteran faculty would have a relatively small percentage of scans reviewed as long as they met required benchmarks for accuracy. Of note, ACEP guidelines suggest that 10% of clinical scans should undergo QA review [8]. Our QA workflow remains somewhat onerous in that QA review is performed offline, a process requiring the reviewing expert(s) to detail their findings in a separate document and provide feedback via email to individual providers. Programs at other institutions permit QA review entered directly into the PACS system, which obviates the need for additional programs, forms, or emails.

Limitations

This study has several limitations. First, it is possible that our survey data included self-selection bias, since those who benefited from the POCUS program might have been more likely to fill out a voluntary survey. Thus, the high level of satisfaction may not necessarily reflect all participants, particularly those who did not complete training or who were less engaged with the program.

Second, this is a single-site study at a large academic medical center. Our institution had certain resources and structures that may not be available in smaller or community-based settings, including connectivity between machines and PACS/storage clouds, a supportive ED POCUS Division with well-defined POCUS privileges, and funding and access to an IM-POCUS

expert (who was compensated initially with a stipend, and later through a portion of salary, to cover both faculty training and QA review). Thus, our results may not apply directly to hospitals with different resources or structures.

Third, the QA was performed by only two experts, which could introduce bias or variation in how scan accuracy was assessed. Although systematic feedback was provided based on predefined defaults, we did not assess inter-rater reliability or request an external review of the QA cases.

Fourth, we did not systematically collect demographic data on participants' years in practice or prior POCUS exposure beyond noting that only one of 32 trainees had significant prior experience, which limits generalizability.

Conclusion

Modeling after highly structured ACEP guidelines, our POCUS guidelines for training, clinical scans, and QA review have been a feasible and effective model for our hospital medicine faculty. Our experience with this model has shown overall faculty satisfaction, high levels of diagnostic accuracy, and a growing volume of scans and revenue. While not the only model, this pathway offers a replicable approach for other institutions seeking to implement an effective IM-POCUS training program.

Acknowledgements

The authors wish to acknowledge Dr. Melissa Mattison, Chief of the MGH Hospital Medicine Unit, for her timely, visionary support, which allowed the launch of the MGH Hospital Medicine POCUS program. Thanks also to Dr. Roy Heyne, Jr. for assistance with manuscript edits.

Ethics Statement

This work is an analysis of existing quality assurance metrics, aggregated billing data, and an anonymous faculty survey that were administered through routine educational evaluation activities. No identifiable patient data were collected or included, and survey responses were voluntary and anonymous. According to our institutional review board guidelines, this work is considered exempt, and no written informed consent was required.

Disclosure Statement

The authors declare that they have no competing interests.

Funding

The authors did not receive any funding for this research.

Author Contributions

TFH: conceptualization, study design, data acquisition, writing – original draft. HS: conceptualization, writing – review & editing. ASL: conceptualization, writing – review & editing.

References

1. Olgers TJ, Ter Maaten JC. Point-of-care ultrasound curriculum for internal medicine residents: what do you desire? A national survey. BMC Med Educ. 2020;20(1):30. doi:10.1186/s12909-020-1949-4

2. Rosana M, Asmara OD, Pribadi RR, Kalista KF, Harimurti K. Internal Medicine Residents' Perceptions of Point-of-Care Ultrasound in Residency Program: Highlighting the Unmet Needs. Acta Med Indones. 2021;53(3):299–307.

3. Schnobrich DJ, Gladding S, Olson APJ, Duran-Nelson A. Point-of-Care Ultrasound in Internal Medicine: A National Survey of Educational Leadership. J Grad Med Educ. 2013;5(3):498–502. doi:10.4300/JGME-D-12-00215.1

4. Point-of-Care Ultrasound (POCUS) Mentorship Program. American College of Physicians. Available at https://www.acponline.org/meetings-courses/focused-topics/point-of-care-ultrasound-pocus-for-internal-medicine/virtual-pocus-mentorship-program.

5. Chockalingam L, Hammar D, Ortiz-Lopez C, Fleshner M, Keniston A, McBeth L, Baduashvili A. Developing Point-of-Care Ultrasound Curricula for Internal Medicine Residency Programs: Consensus-Based Recommendations on Skills, Teaching Methods, and Evaluation Strategies. Ann Intern Med. 2025;178(11):1624–31. doi:10.7326/ANNALS-25-02271

6. LoPresti CM, Murray KJ, Dancel R, Baston C, Boesch B, Brennan D, Dallas AP, Dversdal R, Flynn T, Sadud RAF, Jensen TP, Mathews BK, Soni NJ, Zhang K, Tierney DM. Internal Medicine Residency Point-of-Care Ultrasound (POCUS) Consensus Recommendations for Core Indications and Applications. Am J Med. 2025;138(12):1705-1715.e23. doi:10.1016/j.amjmed.2025.05.033

7. Mathews BK, Zwank M. Hospital Medicine Point of Care Ultrasound Credentialing: An Example Protocol. J Hosp Med. 2017;12(9):767–72. doi:10.12788/jhm.2809

8. Ultrasound Guidelines: Emergency, Point-of-Care and Clinical Ultrasound Guidelines in Medicine. Ann Emerg Med. 2017;69(5):e27–54. doi:10.1016/j.annemergmed.2016.08.457

9. Soni NJ, Schnobrich D, Mathews BK, Tierney DM, Jensen TP, Dancel R, Cho J, Dversdal RK, Mints G, Bhagra A, Reierson K, Kurian LM, Liu GY, Candotti C, Boesch B, LoPresti CM, Lenchus J, Wong T, Johnson G, Maw AM, Franco-Sadud R, Lucas BP. Point-of-Care Ultrasound for Hospitalists: A Position Statement of the Society of Hospital Medicine. J Hosp Med. 2019;14:E1–6. doi:10.12788/jhm.3079

10. Conner SM, Anstey JE, Thomas MK, Carney PA, Fiore MD, Little CE, Jensen TP, Piro KM. Perspectives on Point-of-Care Ultrasonography Credentialing and Privileging: A Qualitative Study. JAMA Netw Open. 2025;8(10):e2538759. doi:10.1001/jamanetworkopen.2025.38759

11. American College of Chest Physicians. Point-of-Care Ultrasound Certificate of Completion. Available at https://www.hospitalmedicine.org/clinical-topics/ultrasound/pocus-certificate-of-completion/.

12. Janjigian M, Dembitzer A, Srisarajivakul-Klein C, Hardower K, Cooke D, Zabar S, Sauthoff H. Design and evaluation of the I-SCAN faculty POCUS program. BMC Med Educ. 2021;21(1):22. doi:10.1186/s12909-020-02453-2

13. Mathews BK, Reierson K, Vuong K, Mehta A, Miller P, Koenig S, Narasimhan M. The Design and Evaluation of the Comprehensive Hospitalist Assessment and Mentorship with Portfolios (CHAMP) Ultrasound Program. J Hosp Med. 2018;13(8):544–50. doi:10.12788/jhm.2938

14. Anstey J, Jensen T, Lalani F, Conner SM. Teaching the Teachers: A Flexible, Cognitive-Focused Curriculum in Point-of-Care Ultrasound Education for Hospital Medicine Faculty. J Ultrasound Med. 2022;41(12):3103–11. doi:https://doi.org/10.1002/jum.16091

15. Janjigian M, Dembitzer A, Holmes I, Srisarajivakul Klein C, Hardowar K, Sauthoff H. Knowledge and Confidence Among Five Cohorts of Faculty Learners in a Point of Care Ultrasound (POCUS) Program: Factors Defining Learner Success. Pocus J. 2024;9(2):109–16. doi:10.24908/pocus.v9i2.17640

16. Andersen CA, Lundbye-Christensen S, Riis A, Mehnert U, Løkkegaard T, Mengel-Jørgensen T, Rasmussen LD, Soll N, Stork B,

Andersen SK, Pil L, Stjernebjerg C, Graumann O, Jensen MB. General practitioners' scanning competence following tailored ultrasound training: a hybrid effectiveness-implementation study. BMC Med Educ. 2025;25(1):733. doi:10.1186/s12909-025-07356-8

17. Restrepo D, Heyne TF, Schutzer C, Dversdal R. "Teaching old dogs new tricks" - POCUS Education for Senior Faculty. Pocus J. 2023;8(1):9–12. doi:10.24908/pocus.v8i1.16145

18. Koenig SJ, Lou BX, Moskowitz Y, Narasimhan M, Mayo PH. Ultrasound Billing for Intensivists. Chest. 2019;156(4):792–801. doi:10.1016/j.chest.2019.06.006

19. Schleifer J, Haney RM, Shokoohi H, Huang CK, Ratanski D, Kimberly H, Liteplo AS. Longitudinal accuracy analysis of ultrasound performed during a four-year emergency medicine residency. AEM Educ Train. 2021;5(3):e10574. doi:10.1002/aet2.10574



Teaching the Microethics of POCUS: An Everyday Ethics Framework for POCUS Training

Carter Winberg, MD[1,2]*; Ross Prager, MD[2]; Marat Slessarev, MD[2]

(1) Center for Bioethics, Harvard Medical School, Boston, MA, USA
(2) Department of Medicine — Division of Critical Care, Schulich School of Medicine and Dentistry, Western University, London, ON, Canada

Abstract

Point of care ultrasound (POCUS) has changed bedside diagnosis, but POCUS curricula often teach scanning as a technical skill separate from the patient encounter. Traditional bioethical approaches to POCUS appropriately address issues such as consent, privacy, data governance, and professional responsibility, but do not fully capture the ethical significance of how clinicians introduce, perform, interpret, and complete a scan. Microethics, or everyday ethics, offers a complementary lens focused on the ethical work embedded in ordinary clinical practice. Drawing on five everyday ethics skills identified in existing research, we propose a conceptual framework for teaching learners to align the scan with the patient's concerns, preserve dignity and modesty, communicate during image acquisition, share visual information when appropriate, responsibly express uncertainty, and clearly close the encounter. This framework aims to make the relational and ethical dimensions of bedside scanning visible and teachable alongside technical competence.

Introduction

A patient was admitted to the hospital with dyspnea and expressed concern that she had not been "thoroughly examined," despite having a comprehensive point of care ultrasound (POCUS) assessment documented. Diagnostically, the scan provided real-time visualization of cardiac function and pulmonary pathology, superior to traditional physical examination techniques like auscultation or percussion. Despite this, from her perspective, something essential was missing.

This encounter captures a broader tension in contemporary bedside medicine. POCUS has become increasingly integrated into inpatient practice and is supported by contemporary clinical guidelines as an extension of the bedside assessment [1–3]. However, in addition to improving diagnostic accuracy, it also reshapes the physical examination in ways that may not fulfill patient expectations. Historically, bedside examination functioned as both a diagnostic maneuver and a relational ritual, grounded in attention, touch, and presence. When a POCUS examination is performed primarily as a rapid, device-oriented task, diagnostic gains may come at the expense of relational experience. As further integration of bedside technology is both appropriate and inevitable, the ethical task is not to resist POCUS, but to ensure it is practiced in ways that preserve trust, dignity, and human connection in an increasingly technology-rich clinical environment. The field of microethics provides theoretical framing for teaching clinicians how to ethically integrate POCUS into their examinations.

Traditional Bioethics and the Relational Possibility of POCUS

Traditional bioethics provides an important but incomplete lens for understanding the ethical dimensions of POCUS. Clinical bioethics has relied on "principlist concepts" such as respect for autonomy, beneficence, non-maleficence, and claims of justice [4]. When applied to POCUS, this approach appropriately draws attention to issues such as informed consent, bodily privacy, data governance, managing incidental findings, and professional responsibility [5]. This work has been necessary to clarify when POCUS is ethically permissible and assist in regulating its integration into routine bedside care.

However, these traditional bioethical concerns do not address the ethical concern highlighted in the opening vignette. The patient was not raising a question about consent forms, privacy rules, or data governance but was naming a failure in the expected experience of bedside care. The ethical issue lies in how the scan mediates the patient-clinician relationship, alters the ritual of physical

*Corresponding Author: Dr. Carter Winberg (email: carter_winberg@hms.harvard.edu)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.21128

examination, and creates a new information gap between what the clinician sees and what the patient understands.

As POCUS becomes part of the modern physical examination, emerging evidence suggests that bedside scanning may carry socioemotional significance beyond its diagnostic utility. Prior studies have associated POCUS with greater patient satisfaction and confidence in the treating clinician [6,7]. Balmuth and colleagues subsequently proposed the "POCUS positive care effect" (PPCE) to describe potential socioemotional benefits associated with the POCUS encounter [8]. In their mixed-methods study of 30 hospitalized patients, PPCE was characterized using patient perceptions of interactions with providers, care efficiency, and satisfaction with care. Higher PPCE ratings were associated with provider empathy, confidence, and rapport, while qualitative findings emphasized mutual engagement, therapeutic alliance, and reassurance through image interpretation [8].

Despite this potential, in routine practice POCUS is rarely structured to support this potential relational benefit intentionally. It is often performed and taught as a clinician-focused task, with limited attention to how its performance shapes the patient's experience of being examined. The dominant focus on accuracy and efficiency risks obscuring how the performance of POCUS examination can either erode or strengthen relational trust and reflects a failure to recognize the ethical dimensions embedded in routine bedside care. These ethical moments are frequently overlooked and are not well addressed by traditional bioethical frameworks alone, suggesting the need for an alternative ethical lens.

Microethics: The View from the Inside

Microethics, also referred to as everyday ethics, names the ethical work embedded in ordinary clinical practice. Although these terms have been used with slightly different emphases, they were treated as conceptually aligned for this analysis [9]. Instead of identifying ethical tensions only in high-stakes cases requiring formal decisions, microethics directs attention to the ethical significance of routine clinical actions: how clinicians speak, listen, pause, frame information, respond to emotion, and build or erode trust [10,11].

Komesaroff introduced microethics by directing attention to the "finely textured and subtle nature of the interaction between doctor and patient and the social context in which it occurs" [10]. This perspective is particularly relevant to the physical examination, which is not merely a means of acquiring clinical information, but also a relational practice through which trust, authority, and care are negotiated. Subsequent work has argued that ethical analysis confined to rules and principles risks overlooking the moral significance of everyday clinical practice and that microethics is a necessary complement to principlist approaches [11].

Zizzo and colleagues extend this account by grounding microethics in pragmatism and lived moral experience [12]. On this view, microethics does not replace established ethical traditions, but offers an integrative bedside lens through which clinicians may draw on virtue ethics, ethics of care, narrative ethics, clinical ethics, and other traditions as the encounter requires [12]. Its value lies in making ethical attention practical and asking not only what ethical principle applies, but how ethical care is actually performed.

This perspective is well suited to POCUS as it involves close physical proximity, sustained attention, and real-time interpretation of shared visual information. By emphasizing subtle gestures, language, pacing, and positioning, microethics provides a lens for understanding the relational factors that may contribute to a positive POCUS experience. A technically competent scan may still fail relationally and leave the patient feeling ignored, confused, or excluded. In contrast, a patient-centred scan may strengthen trust by directing attention and making the patient feel informed and attended to.

Recent work in everyday ethics offers a flexible framework for making these skills teachable. Five general skills have been identified as broadly relevant to clinical practice: awareness of core values and self-reflective capacity, perspective-taking and empathic presence, communication and relational skills, cultural humility and respect, and organizational understanding and know-how [9]. In this analysis, these five skills provide an accessible framework for teaching POCUS as a relational bedside practice. The framework presented here is a conceptual educational model that applies existing microethics scholarship to POCUS practice. It has not been developed or validated as a formal educational or assessment instrument.

A Microethical Framework for POCUS Training

This microethical framework does not prescribe exact language or rigid behaviours at predefined moments but aims to follow the flow of the bedside encounter and highlight the ethical attention required at each stage. Its application must remain responsive to clinical context. During resuscitation, severe instability, or impaired consciousness, the urgency of care and a patient's ability to participate may appropriately limit the extent and timing of engagement. It is intended for clinicians learning or teaching POCUS in inpatient, emergency, and critical care settings. The goal is not to create a standalone ethics course, but to integrate microethics and make the

moral work that is already present in routine POCUS practice more visible. When embedded alongside existing training in image acquisition and interpretation, the goal is for learners to acquire technical competence and ethical competence in the clinical encounters involved in image generation.

In practice, educators can incorporate these skills into existing POCUS teaching through bedside observation, brief reflection during supervision, simulation or debriefing, and image review that considers relational as well as technical aspects of the encounter. Table 1 maps each microethical skill to an educational focus, examples across the POCUS encounter, and illustrative questions that can be implemented to guide teaching and feedback. These examples are intended as prompts for reflection rather than formal assessment criteria.

Teaching the Five Microethical Skills for POCUS

1. Awareness of core values and self-reflective capacity

A microethical approach begins before the probe touches the patient. POCUS is often framed around efficiency, diagnostic yield, and technical competence, all of which are valuable in the time-limited acute care setting. However, these same priorities risk narrowing the clinician's attention to the screen and away from the person being examined.

Clinicians should be taught to pause before scanning and consider both the clinical question and the patient's likely experience. The opening moments should frame POCUS as part of the bedside assessment and not as an isolated technical maneuver. Clinicians should ask what the patient is most worried about, explain why POCUS is being used, and notice when the patient's concern differs from the clinician's diagnostic priority. These brief, self-reflective moments allow for alignment between the patient experience and the examination to follow.

2. Perspective-taking and empathic presence

Although the clinician may view the POCUS examination as routine, the patient may experience pressure from the ultrasound probe, uncomfortable exposure, unexplained silence, worried facial expressions, or an ultrasound screen that seems to hold important information beyond their reach. Perspective-taking asks learners to view the scan from the patient's vulnerable position.

Teaching this skill can be simple with direct prompts: What can the patient see? What can they hear? What might they infer from your silence or facial expression? Learners should be trained to watch for discomfort, adjust pressure when needed, preserve modesty, and avoid prolonged unexplained silence. Empathic presence does not require constant reassurance but does require enough attention to ensure the patient remains an active

Table 1. Integrating microethical skills across the POCUS encounter.

Microethical Skill	Educational Focus	Examples Across the POCUS Encounter	Illustrative Teaching Question
Awareness of core values and self-reflective capacity	Recognizing the patient's concerns and experience alongside the clinician's diagnostic priorities	Before scanning: identify the clinical question, ask what the patient is most worried about, explain why POCUS is being used, and notice when the patient's concern differs from the clinician's priority.	What was the patient most worried about, and how did this compare with your diagnostic priority?
Perspective-taking and empathic presence	Viewing the scan from the patient's vulnerable position and attending to how ordinary scanning behaviours may be experienced	During scanning: consider pressure, exposure, silence, facial expressions, and what is visible to the patient. Watch for discomfort, preserve modesty, and avoid prolonged unexplained silence.	What can the patient see and hear, and what might they infer from your silence or facial expression?
Communication and relational skills	Keeping the patient oriented and supporting understanding throughout the encounter	Before, during, and after scanning: explain the purpose and limits of POCUS, provide signposting when useful, share visual information when appropriate, communicate uncertainty proportionately, and summarize findings and next steps.	Did the patient understand why you were scanning, what you were doing, what remained uncertain, and what would happen next?
Cultural humility and respect	Eliciting—rather than assuming—how the patient wishes to experience touch, exposure, communication, and participation	Throughout the encounter: seek permission, preserve privacy, use interpreters when needed, and offer choices about narration, screen viewing, or support-person involvement when appropriate.	What preferences did you elicit, rather than assume, about touch, exposure, communication, or participation?
Organizational understanding and know-how	Connecting the bedside encounter to safe, reliable, and ethically accountable POCUS practice	Following the scan: document findings, communicate uncertainty, recognize when comprehensive imaging or escalation is required, archive images appropriately, and remain within one's competence.	What needs to happen with these findings after the scan, and what remains outside the limits of this POCUS assessment?

participant in the encounter.

3. Communication and relational skills

Communication puts the ethical awareness generated by other microethical skills into practice. The POCUS examination should be oriented, narrated, interpreted, and closed in language that supports patient understanding. Before scanning, learners should explain why POCUS is being used, what question it is meant to answer, where the probe will be placed, and what the examination can and cannot determine. Permission should be sought not only at the beginning but also as the examination proceeds, particularly when pain, fatigue, anxiety, exposure, or intimate body regions are involved. During the scan, brief sign-posting statements like “I am looking at your lungs now” or “I am going to be quiet for a moment so I can get the image” can preserve shared reality and prevent silence from being interpreted as abandonment.

Additionally, POCUS offers a unique opportunity for visual communication with live image acquisition. When appropriate, and particularly when desired by the patient, showing the screen can convert POCUS from a private technical act of information gathering to a shared visual encounter. As critical information can be gathered in real-time, learners should be taught how to communicate image interpretation that is staged and proportional. Statements such as “I see signs that may explain your shortness of breath, but I need to put this together with the rest of your assessment” are more ethically accurate than overly certain diagnostic declarations.

Closing the encounter also requires communication and relational skills. At the end of the scan, learners should summarize what was seen, what remains uncertain, and what will happen next. Efforts should be made to restore the patient’s environment by removing gel, restoring gowns and blankets, returning tray tables and patient belongings to appropriate places, and disengaging from the machine.

4. Cultural humility and respect

Patients will not experience the touch, exposure, bodily proximity, technology, and clinical authority involved in POCUS in the same way. Patient preferences may be shaped by culture, religion, gender, trauma history, disability, language, prior medical encounters, and trust in health care institutions. Cultural humility does not require clinicians to memorize traits associated with a group but to recognize that the clinician cannot assume how each patient will experience this examination.

In POCUS education, this skill can be translated into observable behaviours. Learners should be taught to ask permission, explain where and why the probe will be placed, use interpreters when needed, preserve privacy, and offer choices when possible. Before examining a patient with ultrasound, they can ask whether the patient wants to see the screen, hear narration, or have a support person present. Respectful POCUS practice requires eliciting preferences rather than assuming them. This is particularly important in educational scanning, where the learner’s need to practice must not override the patient’s dignity or agency.

5. Organizational understanding and know-how

Although POCUS is performed at the bedside, its consequences move through the clinical system. Findings influence handover, consultation, escalation, documentation, formal imaging, and team confidence. Organizational understanding asks learners to connect the bedside encounter to the systems that make POCUS safe, reliable, and ethically accountable.

This domain includes documenting findings clearly, communicating uncertainty to the team, recognizing when comprehensive imaging remains necessary, archiving images according to institutional policy, and staying within one’s competence.

POCUS supervision and image review should not focus only on technical adequacy. Educators should also query how learners explained the scan, whether the patient was invited to participate, and how uncertainty was communicated. In this way, microethics becomes part of the institutional culture of POCUS rather than an optional bedside courtesy.

Conclusion

The opening vignette highlights a potential disconnect between technically sophisticated bedside assessment and the relational experience of care. Navigating this tension will become increasingly important as advanced technologies become more integrated into bedside medicine. Relying solely on traditional bioethics to guide this integration risks overlooking the ethical tensions embedded in routine clinical encounters. In addition to improving diagnostic accuracy, POCUS reshapes the patient’s experience of being examined and cared for. Microethics offers a lens through which these moment-to-moment ethical decisions can be recognized and deliberately navigated. This microethical framework offers POCUS educators a way to teach learners to integrate technical excellence with self-reflection, perspective-taking, communication, cultural humility, and organizational accountability. As a conceptual framework, further evaluation is required to assess whether its implementation alters clinician behaviour or improves patient trust and relational experience. Its immediate value, however, lies in making the ethical dimensions of POCUS visible and teachable, with the broader aim of advancing bedside technology while preserving

humanism and the relational dimensions of medicine.

Ethics Statement

This article did not involve human participants, patient data, or animal subjects and therefore did not require research ethics board approval or informed consent.

Disclosure Statement

CW and MS have no relevant disclosures. RP is the Chief Medical Officer of Deep Breathe, an AI ultrasound startup.

Funding

This work received no specific financial or material support from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contributions

CW: conceptualization, writing – original draft, writing – review & editing, project administration. MS: conceptualization, writing – review & editing, supervision. RP: conceptualization, writing – review & editing, supervision. All authors reviewed and approved the final manuscript.

References

1. Qaseem A, Etxeandia-Ikobaltzeta I, Mustafa RA, Kansagara D, Fitterman N, Wilt TJ. Appropriate use of point-of-care ultrasonography in patients with acute dyspnea in emergency department or inpatient settings: a clinical guideline from the American College of Physicians. *Ann Intern Med* 2021;174(7):985-993.

2. Diaz-Gomez JL, Sharif S, Ablordeppey E, Lanspa MJ, Basmaji J, Carver T, Taylor JC, Gargani L, Goffi A, Hynes AM, Hernandez A, Kasal J, Koratala A, Kort S, Lindbloom P, Liu R, Livezey P, Lobo V, Malone S, Mayo P, Mitchell C, Niu N, Panebianco N, Parekh M, Price S, Sarwal A, Teran F, Via G, Vieillard-Baron A, Weekes A, Wiley B, Lewis K, Nikravan S. Society of Critical Care Medicine guidelines on adult critical care ultrasonography: focused update 2024. *Crit Care Med* 2025;53 (2):e447-e458.

3. Jones BE, Ramirez JA, Oren E, Soni NJ, Sullivan LR, Restrepo MI, Musher DM, Erstad BL, Pickens C, Vaughn VM, Helgeson SA, Crothers K, Metlay JP, Bissell Turpin BD, Cao B, Chalmers JD, Dela Cruz CS, Gendlina I, Hojat LS, Laguio-Vila M, Liang SY, Waterer GW, Paine M, Hawkins C, Wilson K. Diagnosis and management of community-acquired pneumonia: an official American Thoracic Society clinical practice guideline. *Am J Respir Crit Care Med* 2026;212(1):24-44.

4. Beauchamp TL, Childress JF. Principles of biomedical ethics. 7th ed. New York, NY: Oxford University Press; 2013.

5. Chao SK, Liu YT, Kropf CW, Huang RD, Theyyunni N, Taylor LA, Firn JI, Kessler R, Micheller DR, Battles AJ, Rosculet NP, Ager EE, Valentyne AA, Schellack CJ, Hennessy JP, White C, Tucker RV. Consensus-based ethical best practices for performing educational point-of-care ultrasonography in the emergency department. *AEM Educ Train* 2024;8(2):e10963.

6. Howard ZD, Noble VE, Marill KA, Sajed D, Rodrigues M, Bertuzzi B, Liteplo AS. Bedside ultrasound maximizes patient satisfaction. *J Emerg Med* 2014;46(1):46-53.

7. Claret PG, Bobbia X, Le Roux S, Bodin Y, Roger C, Perrin-Bayard R, Muller L, De La Coussaye JE. Point-of-care ultrasonography at the ED maximizes patient confidence in emergency physicians. *Am J Emerg Med* 2016;34(3):657-659.

8. Balmuth EA, Luan D, Jannat-Khah D, Evans A, Wong T, Scales DA. Point-of-care ultrasound (POCUS): assessing patient satisfaction and socioemotional benefits in the hospital setting. *PLoS One* 2024;19 (2):e0298665.

9. Meyer EC, Lamiani G, Uveges M, McLeod-Sordjan R, Mitchell C, Truog RD, Marron JM, Kennedy KO, Ritholz M, Teti SL, Milliken AB. Everyday clinical ethics: essential skills and educational case scenarios. *HEC Forum* 2025;37(2):179-201.

10. Komesaroff PA. From bioethics to microethics: ethical debate and clinical medicine. In: Komesaroff PA, editor. Troubled bodies: critical perspectives on postmodernism, medical ethics, and the body. Durham, NC: Duke University Press; 1995:62-86.

11. Truog RD, Brown SD, Browning D, Hundert EM, Rider EA, Bell SK, Meyer EC. Microethics: the ethics of everyday clinical practice. *Hastings Cent Rep* 2015;45(1):11-17.

12. Zizzo N, Bell E, Racine E. What is everyday ethics? A review and a proposal for an integrative concept. *J Clin Ethics* 2016;27(2):117-128.

Playdough Modelling to Teach Anatomy in a POCUS Course

Todd S. Cutler, MD[1]*; Paula Roy-Burman, MD MPH DTM&H[1]; Laura Chen, DO[1]; Riya N. Soni[2]; Suean Pascoe, BAppSc(MRT) GradDipMedUS AMS FAIUM[3]; Tanping Wong, MD[1]

(1) Department of Medicine, Weill Cornell Medicine, New York, NY, USA
(2) Department of Medicine, University of Texas Health San Antonio, San Antonio, TX, USA
(3) Zedu Ultrasound Training Solutions, Melbourne, Victoria, Australia

Abstract

Background: Point of care ultrasound (POCUS) requires the integration of multiple cognitive and technical skills. Learners must recall detailed anatomy, manipulate an ultrasound probe, interpret dynamic images, and apply findings to patient care. Managing these tasks simultaneously can overwhelm a novice learner's working memory, a challenge that has been described by cognitive load theory. Playdough modelling, a low-cost activity in which learners construct anatomic structures out of clay, may ease this burden. We integrated playdough modelling into a multi-day introductory POCUS course that also included didactic instruction and hands-on supervised ultrasound scanning. In three sessions, learners built cardiac, abdominal vascular, and lower-extremity vascular models. We designed the sessions to link three-dimensional (3D) anatomy with two-dimensional (2D) sonographic views. **Methods:** Participants were 38 clinicians, including 21 attending physicians, 5 fellows, 5 residents, 5 physician assistants, and 2 nurse practitioners. All completed an anonymous survey assessing their perceived impact on anatomic understanding, ability to translate 3D anatomy into 2D images, reinforcement during scanning, and engagement. Likert responses were analyzed using nonparametric tests. **Results:** Nearly all participants (97%) agreed that modelling improved their ability to visualize 3D anatomy and understand how it could be translated into 2D ultrasound images. The same proportion reported reinforcement of vascular anatomy during scanning (82% strongly agreed), and 92% reported reinforcement of cardiac anatomy (63% strongly agreed). Almost all participants (95%) rated the sessions as more engaging than traditional lectures. Initial skepticism was reported by 9 participants (24%), while 97% endorsed including the activity in future courses. **Conclusions:** Playdough modelling was endorsed across all training levels. Our survey captured perceptions rather than performance, but learners consistently described it as an engaging activity. It is inexpensive, requires no specialized equipment, and can serve as an adjunct in introductory POCUS training.

Introduction

Learning point of care ultrasound (POCUS) requires the integration of complex anatomy, probe manipulation, image interpretation, and clinical reasoning. Clinicians who learn POCUS after their formal training must retrieve anatomic knowledge formed years earlier while simultaneously acquiring new skills. Managing these demands can exceed working memory capacity, a challenge described by cognitive load theory [1].

Instructional methods that clarify POCUS anatomy can ease this cognitive burden. Playdough modelling is a hands-on activity in which learners build anatomic structures out of clay. Though often associated with childhood play, it has demonstrated pedagogical value in health professional education. Educators have applied it across a range of anatomic disciplines and learner levels, from undergraduates to surgical trainees [2–15]. Clay modelling is also practical to deliver. It requires no standardized patients, cadaveric specimens, or specialized equipment, making three-dimensional (3D) anatomic study possible where resources are limited [12].

Constructivist and cognitivist learning theories may explain the educational value of building anatomic models [1,16]. Constructivist theory holds that learners develop understanding by linking new experiences with prior knowledge. Building a model requires learners to retrieve and reorganize anatomy they already know, which may strengthen their understanding more than passive review, serving as a scaffold for more complex material [2]. Cognitive load theory offers a second explanation. Engaging auditory, visual, and tactile channels at once distributes mental effort and reduces reliance on working memory [17]. In POCUS education, this may free learners

*Corresponding Author: Dr. Todd S. Cutler (email: toc9021@med.cornell.edu)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20709

to focus on image acquisition and interpretation during subsequent scanning.

This study describes the integration of playdough modelling activities into an introductory POCUS course. The exercises were designed to reinforce understanding of cardiac and vascular anatomy. Participant feedback on their perceived value is reported.

Methods

Setting and Participants

Playdough activities were integrated into a multi-day POCUS training course for clinicians. The course structure has been described previously [16]. The curriculum included didactic instruction, hands-on supervised ultrasound scanning, and multimodal learning sessions. Participants included attending physicians, residents, fellows, physician assistants, and nurse practitioners. Per course registration records, participants came from 29 institutions in the United States and Canada. They practiced in hospital medicine (n = 21), general internal medicine (n = 5), internal medicine-pediatrics (n = 3), nephrology (n = 2), critical care (n = 2), and one each in infectious diseases, oncology, preventive cardiology, family medicine, and emergency medicine. All completed the playdough modelling activities. The Weill Cornell Medicine Institutional Review Board reviewed this project and determined it to be exempt as an educational research activity.

Curriculum Design and Materials

Playdough modelling sessions were one component of a three-part curriculum on each anatomic region, which also included review of sonographic anatomy and hands-on supervised ultrasound scanning of standardized patients. Each of the three 40-minute playdough sessions, one per anatomic region, was structured around model construction (10–15 min), cutting the model in cross-section to identify structures and interpret corresponding ultrasound images (5–10 min), and group review of projected ultrasound images (10–15 min). Instructors with prior experience teaching POCUS led each session.

Learners worked in pairs to encourage discussion and collaborative problem-solving. Instructions for building the models were provided as printed handouts. Participants used commercially available coloured playdough and basic classroom tools (rulers, plastic cutting tools, and paperclips). Faculty circulated throughout each session to offer guidance, answer questions, and prompt learners to compare their models with corresponding ultrasound images.

Activities

Learners constructed playdough models of three anatomic regions aligned with the POCUS curriculum. Detailed instructions and images for all three models are available in the supplemental materials (Supplementary Materials — S1, S2, S3 and S4).

Cardiac Model: Learners built the heart using colour-coded chambers and great vessels, assembled in sequence to reproduce normal anatomic relationships (Figure 1A). Models were cut in the parasternal and apical planes (Figure 1B) to simulate corresponding cardiac ultrasound views (Figure 1C). Plastic heart models were available for reference.

Abdominal Vascular Model: Learners constructed the abdominal aorta and inferior vena cava with their respective major branches and tributaries. Models were cut in the transverse orientation to demonstrate the sonographic appearance of the vessels.

Lower Extremity Vascular Model: Learners constructed the right common femoral artery and vein with relevant tributaries to illustrate anatomic relationships used in deep vein thrombosis evaluation (Figure 2A). Models were cut in the transverse orientation (Figure 2B), as

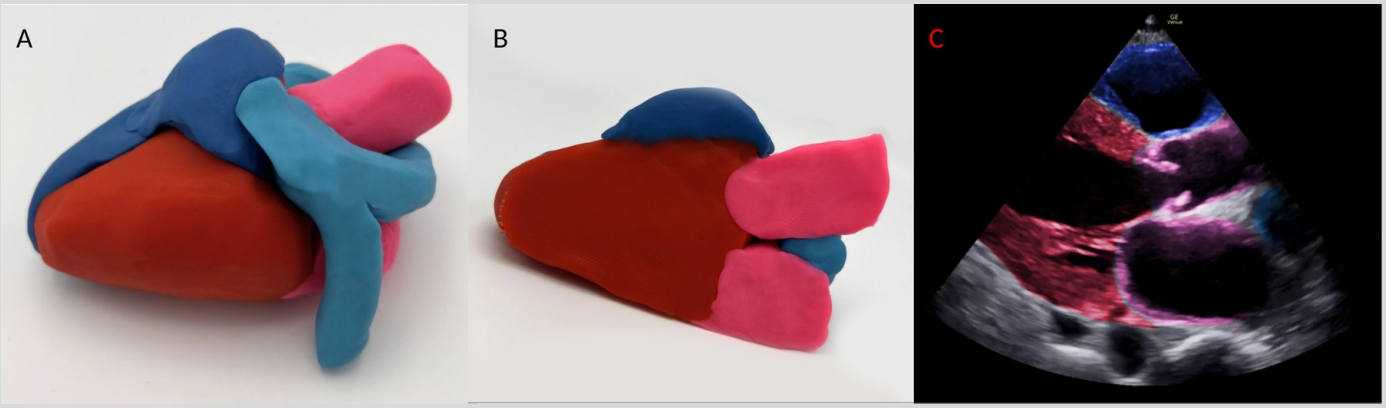


Figure 1. Playdough cardiac model and corresponding echocardiographic view. (A) Assembled three-dimensional cardiac model and (B) sectioned plane corresponding to a parasternal long axis echocardiographic view. (C) Representative echocardiographic image demonstrating the corresponding cardiac anatomy.

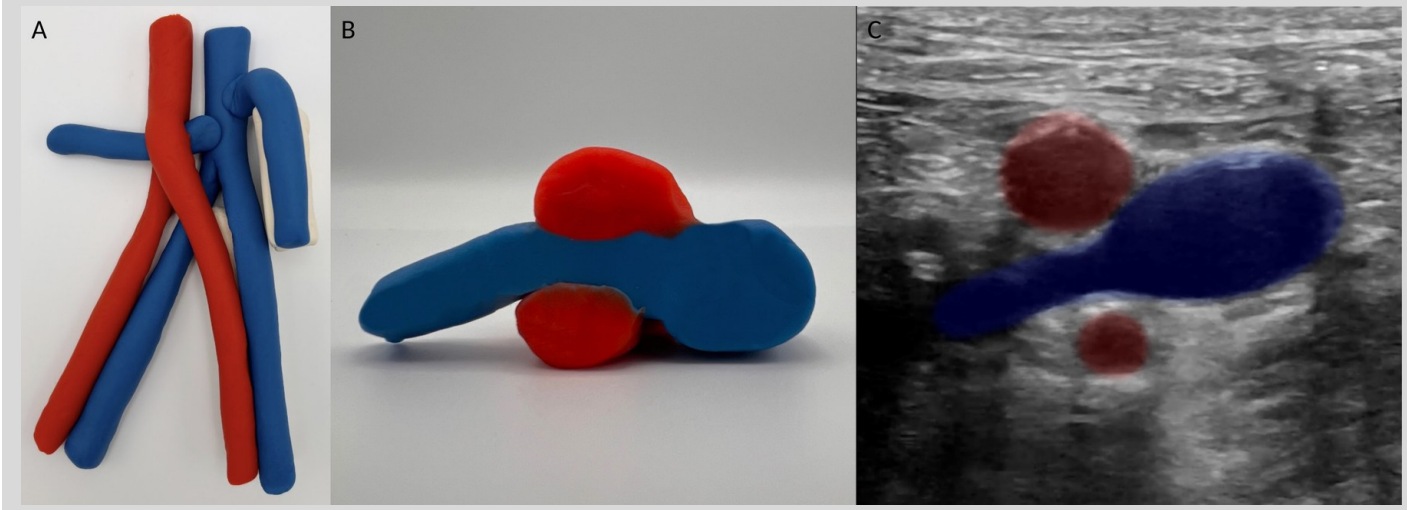


Figure 2. Playdough right lower extremity vessels and corresponding ultrasound view. (A) Assembled model of right lower extremity vessels and (B) sectioned plane at the right common femoral vein and lateral perforator level with (C) representative ultrasound image demonstrating the corresponding anatomy.

used in compression ultrasound (Figure 2C).

Evaluation and Data Collection

After the sessions, participants completed an anonymous electronic survey assessing their perceptions of the playdough activities. The survey included 5-point Likert-scale statements ("Strongly disagree" to "Strongly agree"), as well as categorical questions and optional free-text prompts for qualitative feedback.

Data Analysis

Survey responses were summarized using descriptive statistics. Given the ordinal nature of Likert-scale items, within-subject differences were evaluated using the Wilcoxon signed-rank test. Because individual role categories were small, participants were dichotomized as attending physicians versus all other participants for exploratory subgroup comparisons. Differences between groups were assessed using the Mann-Whitney U test. For categorical survey items, group differences were analyzed using Fisher's exact test. Statistical significance was defined as $p < 0.05$. Open-ended responses were reviewed qualitatively to identify recurring patterns and themes. All statistical analyses were performed using JASP Version 0.95 (University of Amsterdam, The Netherlands).

Results

All 38 course participants completed the survey. Respondents comprised 21 attending physicians, 5 fellows, 5 residents, 5 physician assistants, and 2 nurse practitioners (Table 1). Before the activities, 9 participants (24%) reported skepticism about using playdough to learn ultrasound anatomy (Table 2). Skepticism was similar between attending physicians (5 of 21) and other participants (4 of 17, $p = 1.0$).

Nearly all participants agreed that playdough modelling improved their ability to visualize 3D anatomy (97% agreed, 84% strongly agreed) and understand how that anatomy translates into 2D ultrasound images (97% agreed, 82% strongly agreed).

Table 1. Characteristics of participants.

Training Level	Count (N = 38)	Percentage
Attending	21	55%
Fellow	5	13%
Resident	5	13%
Physician Assistant	5	13%
Nurse Practitioner	2	5%

Table 2. Reported skepticism among participants.

Were you skeptical about using playdough prior to the exercise?	Count (N = 38)	Percentage
No, not skeptical	26	68%
Yes, skeptical	9	24%
Not sure	3	8%

Playdough exercises also helped learners identify gaps in their anatomic knowledge. This was reported for both vascular anatomy (97% agreed, 82% strongly agreed) and cardiac anatomy (92% agreed, 68% strongly agreed) with no significant difference between domains ($p = 0.097$). Table 3 summarizes combined agreement across all survey items.

Participants agreed that the models reinforced their anatomic knowledge while they scanned, for both vascular (97% agreed, 82% strongly agreed) and cardiac

Table 3. Summary of participant survey responses to the playdough activities (N = 38).

Playdough Activities Survey Questions	Strongly Agree N (%)	Agree N (%)	Combined Agreement N (%)
Anatomy understanding			
Helped me better visualize 3D anatomy	32 (84%)	5 (13%)	37 (97%)
Helped me understand how 3D anatomy translates into 2D ultrasound images	31 (82%)	6 (16%)	37 (97%)
Helped me identify gaps in my understanding of vascular anatomy	31 (82%)	6 (16%)	37 (97%)
Helped me identify gaps in my understanding of cardiac anatomy	26 (68%)	9 (24%)	35 (92%)
Building a heart model helped me understand its position and orientation in the chest	27 (71%)	7 (18%)	34 (89%)
Cutting models helped me understand how 2D images represent cross-sections of 3D anatomy	22 (58%)	15 (39%)	37 (97%)
Reinforcement during scanning			
Reinforced my understanding of vascular anatomy during scanning sessions	31 (82%)	6 (16%)	37 (97%)
Reinforced my understanding of cardiac anatomy during scanning sessions	24 (63%)	11 (29%)	35 (92%)
Engagement and endorsement			
Engaged me more than traditional lectures or didactic sessions	31 (82%)	5 (13%)	36 (95%)
Working with a peer during the activity was more engaging	31 (82%)	3 (8%)	34 (89%)
Should be included in future courses	35 (92%)	2 (5%)	37 (97%)

Note: Responses were recorded on a 5-point Likert scale; neutral and disagree responses are not shown. Across all items, a single participant selected strongly disagree for every question. Within-participant comparisons used the Wilcoxon signed-rank test, and between-group comparisons used the Mann-Whitney U test: vascular versus cardiac gaps in understanding, p = 0.097; vascular versus cardiac reinforcement during scanning, p = 0.018; cardiac reinforcement, attending physicians versus all other participants, p = 0.023; vascular reinforcement, attending physicians versus all other participants, p = 0.337.

anatomy (92% agreed, 63% strongly agreed). While participants rated both anatomic domains highly, ratings were higher for vascular than cardiac anatomy (p = 0.018). Non-attending participants rated the cardiac anatomy reinforcement benefit higher than attendings (p = 0.023), whereas vascular reinforcement ratings did not differ by training level (p = 0.337).

Building a heart model improved understanding of cardiac orientation for most participants (89% agreed, 71% strongly agreed). Nearly all participants agreed that cutting the models helped them understand how 2D images represent cross-sections of 3D anatomy (97% agreed, 58% strongly agreed).

Nearly all participants agreed the sessions were more engaging than traditional lectures (95% agreed, 82% strongly agreed) and that working with a peer enhanced the experience (89% agreed, 82% strongly agreed).

Open-ended survey responses were consistent with the quantitative results (Table 4). Participants who were initially skeptical reported that tactile modelling helped their understanding of anatomic orientation and spatial relationships. One respondent found the models more useful for the simple tubular anatomy of the vasculature than for cardiac anatomy. Nearly all respondents endorsed including playdough activities in future POCUS courses (97% agreed, 92% strongly agreed).

Discussion

We describe integrating playdough modelling into an introductory POCUS curriculum as a hands-on strategy to support anatomy education. Participants described tactile modelling as helpful for understanding anatomy and spatial relationships, and nearly all rated the sessions as more engaging than traditional lecture-based formats. These findings echo prior reports that learners find these activities enjoyable and motivating [8,11].

Nearly one quarter of participants (24%) approached the sessions with initial skepticism, consistent with prior descriptions of adult learners resisting play-based tools as insufficiently rigorous [2,8,9]. Several of these participants described a changed impression in their free-text responses, and nearly all ultimately endorsed including playdough in future courses. Working in pairs required learners to articulate their anatomic reasoning to one another, a feature of cooperative learning that has been associated with improved conceptual understanding [17].

Learners reported that playdough modelling reinforced their anatomic understanding during ultrasound scanning practice. Nearly all agreed that cutting the models helped them understand how 2D images represent cross-

Table 4. Representative responses from participants.

Did you feel skeptical about using playdough and did the activities change your impression?
“My anatomy knowledge is much stronger after the playdough exercises, and this translates into knowing what I’m looking at on ultrasound.”
“I didn’t know if it would be worth our time to make it, but I loved reproducing the cuts we did on ultrasound and learning the anatomy.”
“I loved the idea of tactile learning.”
“The playdough activities helped me understand the orientation.”
“I did feel skeptical, but the spatial reasoning that came with the process helped me overcome my initial trepidation.”
Please share any thoughts about the playdough activities, including how they contributed to your learning.
“I think the added tactile feedback allows more active learning of the structures.”
“Playdough helped me understand the anatomy and orientation.”
“The playdough session was great for understanding the 3D position of the abdominal and lower extremity blood vessels. This was a much better teaching tool than 2D images or anatomy textbooks.”
“In a simple tubular structure like the vasculature, it helped. For the heart, the plastic models were more useful and could serve the same purpose if those were focused on instead.”

sections of 3D anatomy. Abu-Zidan and Cevik similarly used cut playdough models to help learners connect probe movements with corresponding changes in ultrasound images [18]. In practice, because playdough can be reassembled and re-sliced, an incorrect cut can be corrected and discussed as a teaching opportunity rather than discarded.

Both anatomic domains were rated highly, though perceived benefit was somewhat greater for the two vascular activities than for the cardiac model. This may reflect the relative simplicity of tubular vascular structures, which are easier to construct and section, compared with the more complex spatial relationships of the heart. Qualitative feedback was consistent with this interpretation, with one participant noting that playdough was particularly helpful for simple tubular vasculature, whereas a pre-existing plastic model was more useful for the heart.

Attending physicians also rated cardiac reinforcement lower than other participants, though overall agreement remained high and vascular ratings did not differ. Pre-activity skepticism was similar between groups, suggesting the difference in cardiac ratings was unlikely to reflect greater resistance among attending learners. One possible explanation to consider is the expertise reversal effect, in which instructional supports that benefit novices provide less benefit as learner expertise increases [19]. We did not measure baseline familiarity with the anatomy, so the reason for this subgroup difference remains uncertain.

Several practical observations emerged from delivering these sessions, whose format has been refined over several years. Learners struggled most when they began building without first reviewing the instructions or when partners divided the work rather than constructing together. In some pairs, for example, one learner built the aorta while the other built the inferior vena cava. These models typically required more faculty correction, suggesting that part of the educational value may lie in working through the anatomic relationships jointly rather than simply producing the model. Pairs also finished at different rates. Supplemental handouts with unlabelled anatomic drawings and additional ultrasound images allowed faster pairs to continue working while others completed their models. A ratio of approximately three instructors to eight learner pairs worked well. Instructors benefited from building the models themselves beforehand, which helped them anticipate common difficulties across session participants.

Controlled studies have shown improved anatomic knowledge after playdough modelling [3,20,21]. Herur et al. reported higher immediate test scores and sustained 30-day retention in neuroanatomy, while Patil found higher immediate and delayed assessment scores in embryology among learners using playdough modelling compared with animated-video instruction [3,21]. A systematic review by Curlewis et al. found objective improvement in assessment outcomes in 11 of 12 studies comparing clay-based modelling with alternative methods of learning anatomy [2].

The educational effects of playdough modelling are likely multifactorial. Haptic feedback and active manipulation may contribute, but they may not fully explain the observed effects. For example, Kooloos et al. found that

live observers outperformed clay modellers in one experiment, whereas clay modellers outperformed video observers in another. This led the authors to emphasize attention and engagement with the learning task rather than manual construction alone [22]. This may be particularly relevant in POCUS training, where competency requires deliberate practice well beyond a single course and sustained learner engagement may support continued practice. As Curlewis et al. noted, even when the mechanisms underlying knowledge gains are uncertain, the ability of clay modelling to meaningfully engage learners is itself educationally valuable [2].

Limitations

This study has several limitations. First, our results are based on post-intervention self-reported perceptions, without baseline or objective assessment. Although prior studies have shown immediate and short-term learning benefits from active anatomic modelling, the durability of these effects remains uncertain [2]. Second, our sample was drawn from a single course, although it included a broad mix of provider types. Third, training level was self-reported, and we did not assess prior POCUS experience, which may have differed across participants and could contribute to the subgroup differences we observed.

Fourth, playdough modelling may not appeal equally to all learners, as reflected by the initial skepticism reported by approximately one quarter of our participants. However, prior work by Estevez et al. found that self-reported learning preferences did not predict perceived value of a clay modelling exercise, suggesting that learners' stated preferences may not reliably identify which instructional approaches are useful [23].

Conclusion

POCUS education presents a complex cognitive challenge, requiring learners to integrate image acquisition, spatial reasoning, and clinical interpretation. Many clinicians, including those in our cohort, begin this process after formal medical training. We found that playdough modelling offers a tactile and engaging approach to building 3D anatomic understanding, with strong endorsement across learner levels. Materials are inexpensive and require no specialized equipment. For learners who must retrieve anatomic knowledge formed years earlier, playdough modelling is a practical and well-received addition to introductory POCUS curricula.

Ethics Statement

This study was reviewed by the Weill Cornell Medicine Institutional Review Board and was determined to be exempt.

Disclosure Statement

Suean Pascoe is Director of Zedu Ultrasound Training Solutions and has a financial interest in the business. She did not receive financial benefit from this publication. The other authors report no conflicts of interest.

Funding

No external funding was received for this study

Author Contributions

TSC: conceptualization, methodology, investigation, formal analysis, writing – original draft, writing – review & editing. PRB: conceptualization, methodology, investigation, formal analysis, writing – original draft, writing – review & editing. RNS: writing – review & editing. LC: writing – review & editing. SP: writing – review & editing. TW: conceptualization, methodology, supervision, writing – review & editing. All authors contributed to manuscript development, critically reviewed the manuscript for important intellectual content, approved the final version, and agree to be accountable for all aspects of the work.

References

1. Van Merriënboer JJG, Sweller J. Cognitive load theory in health professional education: Design principles and strategies. *Med Educ*. 2010;44(1):85-93. doi:10.1111/j.1365-2923.2009.03498.x

2. Curlewis K, Leung B, Perera M, Bazira PJ, Sanders KA. Clay-based modeling in the anatomist's toolkit: A systematic review. *Anat Sci Educ*. 2021;14(2):252-262. doi:10.1002/ase.1996

3. Patil M. Innovative method of teaching embryology using three-dimensional playdough model construction: A constructivist teaching. *Natl J Clin Anat*. 2020;9(4):135-140. doi:10.4103/NJCA.NJCA_67_20

4. Nuchhi AB, Yatagiri SV, Harwalkar VS, Bulagouda RS. Play dough as a teaching tool in the development of cardiovascular system for small group teaching. *European Journal of Molecular & Clinical Medicine*. 2023;10(6):52-57.

5. Hesterman R, Rose S, LeFever W, Stewart R, Krone M, Holihan C, Ackerman K. Utilizing Playdoh in the classroom to construct a 3D model depicting cellular movements and tissue remodeling during human gastrulation, early organogenesis, and embryonic folding. *J Microbiol Biol Educ*. 2021;22(3):e00123-21. doi:10.1128/jmbe.00123-21

6. Steele P, Devlin M, Downie J. The creation of PlayDoh® models as an educational tool for teaching anatomy of the lips and peri-oral musculature. *The PMFA Journal*. 2021;8(3).

7. Manners RM, Jazayeri FR, de Bono Agius M, Webber SM, Macleod ER. PlayDoh® models are a very effective kinaesthetic tool for teaching anatomy of the eye. *Med Sci Educ*. 2017;27(4):585-588. doi:10.1007/s40670-017-0485-2

8. Lace-Costigan G. Perceptions of play: Using Play-Doh to enhance the student experience in bioscience higher education. *Int J Game-Based Learn*. 2017;7(3):26-37. doi:10.4018/IJGBL.2017070103

9. Eftekhar B, Ghodsi M, Ketabchi E, Ghazvini AR. Play dough as an educational tool for visualization of complicated cerebral aneurysm anatomy. *BMC Med Educ*. 2005;5(1):15. doi:10.1186/1472-6920-5-15

10. Irfan MR, Waseem FM, Zahra T, Liaquat A. Using play-dough to enhance neuroanatomy learning and mitigate student stress. *Clin Teach*. 2025;22(2):e70052. doi:10.1111/tct.70052

11. Fall L, Surendran S. Playful learning for anatomy: Using Play-Doh to visualise the heart. *Journal of the Foundation Year Network*. 2023;6:51-64.

12. Gopal V, Bhooshan L. The feasibility of using playdough and household materials as an educational tool for self-learning of

neurosurgical anatomy during COVID-19 lockdown. *Anatomical Sciences Journal*. 2021;18(2):92-99.

13. Chong W, Tran N, Bui A. Effectiveness of a clay pelvic model: A hands-on approach to understanding pelvic floor anatomy. *Obstet Gynecol*. 2022;140(1):94-98. doi:10.1097/AOG.0000000000004820

14. Stead R, Lygo-Baker S, Coppi AA, De Melo MP. Using play-doh to enhance the perceived learning of veterinary medicine. *J Vet Med Educ*. 2021;48(5):549-553. doi:10.3138/jvme-2020-0006

15. Mallashetty N, Itagi V, Angadi AV. Model making exercise: A new tool for teaching and learning anatomy and perception of students towards it. *J Educ Res Med Teach*. 2015;3(1):34-36.

16. Cutler T, Roy-Burman P, Bai J, Chen L, Gee EY, Mints G, Ma I, Wong T. How to design a point-of-care ultrasound training course using educational theories. *J Contin Educ Health Prof*. 2026;46(1):44-49. doi:10.1097/CEH.0000000000000603

17. Michael J. Where's the evidence that active learning works? *Adv Physiol Educ*. 2006;30(4):159-167. doi:10.1152/advan.00053.2006

18. Abu-Zidan FM, Cevik AA. Kunafa knife and play dough is an efficient and cheap simulator to teach diagnostic point-of-care ultrasound (POCUS). *World J Emerg Surg*. 2019;14:1. doi:10.1186/s13017-018-0220-3

19. Kalyuga S. Expertise reversal effect and its implications for learner-tailored instruction. *Educ Psychol Rev*. 2007;19(4):509-539. doi:10.1007/s10648-007-9054-3

20. Haspel C, Motoike HK, Lenchner E. The implementation of clay modeling and rat dissection into the human anatomy and physiology curriculum of a large urban community college. *Anat Sci Educ*. 2014;7(1):38-46. doi:10.1002/ase.1369

21. Herur A, Kolagi S, Chinagudi S, Manjula R, Patil S. Active learning by play dough modeling in the medical profession. *Adv Physiol Educ*. 2011;35(2):241-243. doi:10.1152/advan.00087.2010

22. Kooloos JGM, Schepens-Franke AN, Bergman EM, Donders RART, Vorstenbosch MATM. Anatomical knowledge gain through a clay-modeling exercise compared to live and video observations. *Anat Sci Educ*. 2014;7(6):420-429. doi:10.1002/ase.1443

23. Estevez ME, Lindgren KA, Bergethon PR. A novel three-dimensional tool for teaching human neuroanatomy. *Anat Sci Educ*. 2010;3(6):309-317. doi:10.1002/ase.186



From Diagnosis to Development: How Point-of-Care Ultrasound Supports the 2030 UN Sustainable Development Goals

Sachita Shah, MD DTM&H[1,2]; Mena Ramos, MD[3,4]; Heather Harmon Donahoe, MPH[2]; Taiba Zahir, MPH[2]*; Shirish Rao, MBBS[5]; Sahra Sutaria[2]; Adi Nadimpalli, MD[6]; Nahreen Ahmed, MD MPH[7]; Lori Stolz, MD[8]

(1) Department of Emergency Medicine & Department of Global Health, University of Washington, Seattle, WA, USA
(2) Butterfly Network, Burlington, MA, USA
(3) Global Ultrasound Institute, Walnut Creek, CA, USA
(4) Department of Family and Community Medicine, University of California San Francisco, San Francisco, CA, USA
(5) Association for Socially Applicable Research (ASAR), Pune, Maharashtra, India
(6) Critical Care Medicine, Holy Family Hospital, Methuen, MA, USA
(7) University of Pennsylvania Health System, Philadelphia, PA, USA
(8) Department of Emergency Medicine, University of Cincinnati, Cincinnati, OH, USA

Abstract

Point-of-care ultrasound (POCUS) is a low-cost, portable diagnostic modality that has rapidly evolved to meet diverse clinical needs in both high- and low-resource settings. This paper explores how POCUS aligns with and advances the United Nations Sustainable Development Goals (SDGs), particularly SDG 3, but also others such as SDG 4, 5, 8, 10, 11, 14, 15 and 17. By integrating evidence from multiple specialties, including maternal health, infectious diseases, non-communicable diseases, emergency care, and health workforce training, we position POCUS as a cross-cutting innovation with significant potential to strengthen health systems, improve equity, and enable early diagnosis and treatment in remote and underserved communities. Its ability to empower mid-level providers through task-shifting, and its use in primary care and emergency conditions, further enhances its alignment with the principles of universal health coverage. However, despite growing evidence and technical feasibility, the adoption of POCUS remains limited due to systemic challenges including lack of funding, fragmented implementation, inadequate training, and limited recognition in national diagnostic policies and regulations. We call global health stakeholders, policymakers, funders, regulators, and clinicians, to invest in an enabling ecosystem for POCUS. Aligning national strategies with international frameworks is critical to unleashing the full potential of POCUS as a tool for advancing equitable diagnostic access and accelerating SDG progress.

Introduction

Diagnostic imaging is an essential bridge in the path from patient presentation and illness to treatment and well-being, yet almost half of the global population lacks access to diagnostic imaging in their healthcare delivery [1]. A 2021 Lancet commission report estimates the proportion of individuals without access to diagnostic imaging in low-income countries is more pronounced at 81%, and that over 1 million premature deaths could be avoided annually in low- and middle-income countries (LMICs) by reducing diagnostic gaps for six priority conditions - diabetes, hypertension, HIV, tuberculosis, hepatitis B virus infection for pregnant women, and syphilis for pregnant women [1,2]. As the recent COVID-19 pandemic laid bare and amplified existing disparities, the time is now to equip healthcare professionals in vulnerable communities with powerful diagnostic tools to strengthen health systems and prepare for future health catastrophes in our ever-changing world.

Point of care ultrasound (POCUS) is a bedside clinical decision-making tool with many diagnostic and treatment-supportive uses across a variety of patient types, disease states, and medical specialties. This single tool can be used for diagnosis of conditions affecting maternal, neonatal, and pediatric conditions, as well as non-communicable, traumatic, and infectious diseases. The versatility this allows improves clinicians' diagnostic ability on many fronts. POCUS applications are designed with novice end-users in mind, making them accessible to a wide range of healthcare providers [3]. Recent technological advances have also miniaturized ultrasound machines to be as small as pocket-based, making them

*Corresponding Author: Taiba Zahir (email: tkzahir@gmail.com)

This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.

DOI: https://doi.org/10.24908/pocusj.v11i02.19992

more portable and affordable than traditional machines [4]. This combination of increased clinician capacity and machine usability promotes the provision of high-quality care in any location, regardless of remoteness or resource availability and, when needed, facilitates timely, life-saving referrals.

These benefits are especially important in low resource environments where “task-shifting” of primary and emergency care towards mid-level, non-physician providers has been a strategy employed to address the shortage of medical specialists. By decreasing time and cost associated with making a diagnosis, rapid interventions early in a patient’s course of illness are possible, thereby improving cost effectiveness of care and triage of patients early in care to allow better stewardship of scarce resources.

When adopted at scale in LMICs with limited healthcare resources and large populations, POCUS has the capacity to catalyze major improvements in population health through improved access to quality healthcare and empowerment of healthcare providers. Moreover, POCUS can have significant planetary health benefits by reducing environmental waste through less reliance on other imaging modalities, reduced need for patient/ provider travel through telemedicine applications, and overall improved access to diagnostic imaging in ‘last mile’ contexts [5].

One way progress towards population health is measured and goals are set by global policy makers is through the 2030 United Nations Sustainable Development Goals (SDGs). The SDGs are a collection of 17 interlinked objectives designed by the United Nations (UN) to serve as a shared blueprint for “peace and prosperity for people and the planet” [6]. The SDGs are a comprehensive framework to address global challenges including poverty, inequality, climate change, environmental degradation, peace and justice. Specific targets under each of the goals are expected to be achieved globally and by individual UN member states by 2030, and reaching these targets are highly visible and globally commendable markers of commitment to well-being on Earth [6].

The funding landscape in global population health is often siloed into disease-specific pillars, however, global investment in multi-modal diagnostic tools will strengthen health systems, accelerate progress towards achievement of the SDGs, and benefit all sectors of the population at once. Widespread adoption of POCUS in the public sector at the country level has the capacity to drive progress on many of these goals, which are summarized below.

Sustainable Development Goal 3 - Good Health and Well-being

Target 3.1: By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births

POCUS can be used to identify high-risk conditions of pregnancy including pregnancy of unknown location, ectopic pregnancy, ruptured ectopic pregnancy, multiple pregnancy, placental abnormalities such as previa and abruption, abnormalities in level of amniotic fluid, abnormal fetal lie and presentation, and retained products of conception. It can also be used to accurately date a pregnancy and guide interventions for postpartum hemorrhage [7,8]. The World Health Organization (WHO) recommends one antenatal ultrasound scan before 24 weeks gestation for all pregnant people, and their policy calls out the importance of screening ultrasounds by lower-skilled antenatal providers as complimentary to complete sonography for more advanced uses. These screenings are more easily achieved with POCUS, even in austere environments [9]. Another benefit of routine ultrasound in antenatal care is that fetal imaging may encourage pregnant patients to seek care, improving visit attendance overall [10]. Additionally, educating antenatal care providers in POCUS allows for parallel education on high risk conditions of pregnancy and the peripartum period, improving the quality of care delivered by birth attendants by integrating POCUS training together with overarching clinical training [11].

Target 3.2: By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births

Global progress towards reduction of neonatal mortality rates (NMR; number of live-born infants dying in the first 28 days of life per 1000 live births) has improved in many nations, however much work remains to achieve the SDG NMR targets by 2030 given setbacks in maternal care services in LMICs during the COVID-19 pandemic and disparities in access to healthcare worker attended deliveries in low-income countries [12,13,14,15]. Neonatal mortality in LMICs is caused by three major conditions: asphyxia (e.g., from obstructed labor or placental abruption), infections (e.g., from prolonged time with rupture of membranes prior to delivery), and prematurity (e.g., unrecognized preterm labor due to unknown gestational age) [16,17]. Late-term POCUS helps providers identify risk factors for obstructed labor such as malpresentation or macrosomia, to ensure consideration of birth plans for those conditions such as cesarean section or vacuum assisted delivery. In a 2023 study of a quick bedside scan during labor, malpresentation was identified in a large proportion of patients leading to

actual impact on neonatal mortality and APGAR scores [7]. POCUS to establish gestational age in a patient with potential preterm labor can inform clinicians to administer steroid treatment for lung maturation decreasing risk of neonatal respiratory distress [18,19].

Under-5 mortality is driven by pneumonia and diarrheal illnesses, and POCUS applications are very useful for both conditions [20]. Repeated studies have shown that a pneumonia diagnosis can be made accurately with POCUS for all ages, and with better diagnostic sensitivity than X-ray or clinical diagnosis alone [21]. As for diarrheal diseases, appropriate fluid administration can be lifesaving and ultrasound can optimize this resuscitation in resource-scarce settings [22]. In addition, early identification of pediatric surgical diseases (e.g., intussusception) can be performed by clinicians using POCUS [23,24]. A single hand-held POCUS device can address these preventable causes of death from right before birth, in the newborn period, and into childhood to improve early identification to speed appropriate treatment and avert mortality.

Target 3.3: By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases

POCUS has a strong role to play in the diagnosis and treatment monitoring of patients with AIDS, Tuberculosis (TB), and co-infection. HIV remains a leading cause of death in LMICs, with women of reproductive age disproportionally infected [25]. While HIV may be considered a laboratory diagnosis, POCUS plays an important role in the diagnosis of the leading actual causes of death in AIDS patients including pneumonia, cardiomyopathy, nephropathy, and deep venous thrombosis. TB is one of the leading causes of mortality disease worldwide, registering approximately 1.6 million deaths in 2022 [26]. Yet the diagnosis of TB is still a challenge, especially in patients who have HIV/TB co-infection and are at higher risk of extra-pulmonary TB, which can go undetected by chest radiography. A novel and highly sensitive use of POCUS has been to help identify those patients with evidence of extra-pulmonary TB through the Focused Assessment with Sonography for HIV-associated TB (FASH) exams [27,28].

The role of POCUS with neglected tropical diseases (NTDs) is emerging. Diseases such as malaria, dengue fever, and Leishmaniasis can have dangerous consequences and are often difficult to manage in low-resource settings. POCUS can be used to help evaluate volume status and treat pulmonary edema in patients with malaria and it can be used to diagnose visceral leishmaniasis [29,30,31]. POCUS can be used to aid in the risk stratification of patients with suspected or confirmed Dengue. Mortality in Dengue cases is due to circulatory collapse and is often so severe and rapid that health facilities in low-resource settings cannot refer patients quickly enough. POCUS can identify plasma leakage prior to circulatory collapse, thereby allowing for early recognition and early management and, as in other disease processes, can aid in resource optimization for resuscitation [32,33].

Target 3.4: By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being

POCUS can be used to screen for and detect non-communicable disease. Worldwide, cardiovascular diseases including ischemic heart disease, stroke, and congestive heart failure are leading causes of death and disability affecting over 500 million patients in 2019 [34]. Diagnosis of heart failure is primarily made using echocardiography, and given the dearth of cardiologists and trained sonographers in LMICs, mounting evidence suggests early diagnosis and referral for care can improve outcome. Gross left ventricular (LV) function estimation to identify systolic LV dysfunction and basic valve assessment can be used to screen populations with dyspnea for heart failure or structural valve disease at the primary care level to expedite appropriate referral when cardiac care resources are scarce [35,36,37,38]. Other NCD use cases for POCUS include breast lump assessment (cyst vs solid mass for referral/biopsy), thyroid assessment (thyromegaly vs discrete mass or cyst for referral/biopsy), and pre-chemotherapy echocardiography for cardiovascular risk assessment prior to medication choice (as some chemotherapeutics can be cardiotoxic), which are currently integrated into cancer care programs in resource poor settings. POCUS can also detect emergent non-communicable conditions such as cholecystitis and other biliary disease, deep vein thrombosis, and pyelonephritis, facilitating timely management [39,40].

Target 3.6: By 2020, halve the number of global deaths and injuries from road traffic accidents

According to the WHO, injuries both unintentional and violence-related claim the lives of 4.4 million people each year with three of the top five causes of death in 5–29-year-olds listed as suicide, homicide, and road traffic accidents [41]. With POCUS, the extended Focused Assessment with Sonography in Trauma (eFAST) exam can be performed for evaluation of traumatic injury, speeding time to operative care. In the scenario of undifferentiated shock, POCUS can also play a part in differentiating the etiology, which also allows for informed use of crystalloids and blood products in resuscitation efforts [42].

In settings without easy access to computed tomography (CT) scanning, POCUS can be used to detect cerebral edema and elevated intracranial pressure in patients with traumatic brain injury [43,44,45]. In settings without easy access to radiography or fluoroscopy, POCUS can be used for fracture reduction and ultrasound guided regional anesthesia prior to orthopedic procedures [46]. Additionally, in surgical and trauma critical care units, POCUS guidance for procedures such as central venous catheterization and bladder catheterization, and evaluation of hemodynamic and cardiovascular status necessary for accurate fluid resuscitation are used world-wide [47].

Target 3.7: By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes.

A 2023 systematic review and meta-analysis of randomized controlled trials of ultrasound guidance for intrauterine device (IUD) placement suggests POCUS improves family planning effectiveness through reduced procedural complications, significantly fewer mispositioned IUDs, improved patient comfort and satisfaction, and decreased time for POCUS-guided IUD placement [48,49]. Early diagnosis of ruptured hemorrhagic ovarian cysts through POCUS may speed access to care. Lastly, early confirmation of gestational age dating in intrauterine pregnancy can be valuable in settings with access to gestational age-sensitive abortion.

Target 3.8: Achieve universal health coverage, including financial risk protection, access to quality essential health -care services and access to safe, effective, quality and affordable essential medicines and vaccines for all

A vast number of services benefit from improved safety, efficacy, and quality with POCUS integration (procedural guidance, staged imaging, reducing need for additional diagnostic tests, etc). POCUS has the capacity to reduce healthcare expenditures or end-user fees through decreasing the need for more expensive additional testing if POCUS screening is negative for disease, decreasing unnecessary healthcare visits if referrals do not need to be made, and lower cost-per-use, particularly with the affordability of hand-held ultrasound machines [50]. A recent article, from a high income country, suggests lung POCUS in patients with congestive heart failure can reduce length of hospital stay by guiding more efficient treatment plans, thereby reducing system cost [51].

Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

For many diagnoses, POCUS is an alternative to traditional X-ray, CT, or magnetic resonance imaging (MRI), reducing exposure to radiation and to hazardous chemicals associated with waste from these other imaging modalities. The advent of ultrasound on a microchip has led to the first compliance with the European Union's Restriction of Hazardous Substances (RoHS) directive, whereas other ultrasound devices to date rely on an exemption to RoHS due to containing a level of lead in the piezoelectric crystals that exceeds the level deemed hazardous to humans and the environment [52]. With ever-improving technology, battery based POCUS devices can be more easily charged through renewable energy mechanisms and continue to work without active electricity [53]. This is especially important given increasing recognition of harms of fossil fuel-based energy sources for health care delivery.

While POCUS has emerged as part of the 2023 revised global diagnostic criteria for acute respiratory distress syndrome (ARDS), lung ultrasound as a diagnostic tool for study of inhalation related pneumonitis from contaminated soil or air-borne tropical diseases (eg. histoplasmosis, or pneumoconiosis) requires further study [54]. POCUS can be used to assess blast or chemical injury to the lung in environments contaminated in war, where acute lung injury/ARDS incidence and prevalence in modern conflict range from 3% to 33%, with mortality ranging from 12.8% to 33% [55].

Target 3.c: Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States

One of the main challenges in providing health care in LMICs is the disadvantageous ratio of patients to healthcare providers. This deficit in trained healthcare providers is a major factor in healthcare disparities, with predictions of workforce shortages amplifying in the future leading to an anticipated deficit of 15 million providers worldwide by 2030 [56]. POCUS facilitates the upskilling of healthcare providers, including the development of local, in-country POCUS trainers, and helps to address this deficit [57]. Leveraging tele-guidance and tele-education platforms within app-based POCUS is an innovative training mechanism for care providers in developing countries and further augments this upskilling [58]. The portability of point of care ultrasound equipment allows last mile health workers access to diagnostic imaging even in remote settings, boosting capacity and care delivery. Finally, by increasing training opportunities and improving clinicians' capacity to care for patients, POCUS directly addresses key factors related to 'brain drain' from austere settings [59].

Target 3.d: Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks

POCUS complements improved health systems strengthening through strengthened provision of emergency medicine services and early detection of emerging contagions, especially respiratory contagions. During the recent COVID-19 pandemic, POCUS played a significant role in screening, triage and ongoing management. Due to the portability and ease of disinfection, POCUS stood out as a preferred diagnostic imaging modality [60]. When coupled with digital health applications, hand-held ultrasound platforms could allow remote outbreak of respiratory illnesses to be alerted using national EMR and surveillance apps on the same host device used by the POCUS transducer for real-time monitoring. Lung ultrasound proved to be a valuable diagnostic tool in COVID-19 pneumonia [61, 62].

In summary, multiple POCUS use cases can guide diagnosis, treatment and management to drive progress towards subgoals of SDG 3. These gains are amplified and accelerated across most use cases with the introduction of embedded teleguidance within POCUS devices/software. The added benefit of POCUS are emerging solutions with cloud teleguidance capabilities which can allow for remote patient monitoring for chronic conditions as well as remote training for unique fit-to-purpose POCUS exams. In hard-to-reach areas of the world, where both access to diagnostics and availability of trained personnel is limited, remote capabilities of cloud/guidance-enabled POCUS can connect chronic disease providers worldwide and assist remote clinicians in diagnosis and longitudinal monitoring for patients with non-communicable diseases [63].

Sustainable Development Goal 4 - Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Sustainable POCUS programs are unique in their inclusivity and equitability, with POCUS education programs providing a substantial cache of educational and multilingual educational content. Much of this free open access medical education content is available, allowing educational opportunities despite economic circumstance. A common model for POCUS education is a train-the-trainer program, which provides opportunities for career advancement and continuing education for those involved. While development of a sustainable POCUS training program must be individualized for context, learners, content, need and available resources, several key steps are well documented to lead to success [64].

Ideal programs for POCUS training begin with a partnership with local providers who can guide a needs assessment for identification of high-yield POCUS exam types, given the patient population and burden of disease. Working with a local POCUS champion and adhering to regional policy and guidelines (if any exist around POCUS), can allow true educational partnership in establishing POCUS services. Trainings must focus on basic POCUS technical expertise in image capture, image interpretation, and integrating these skills together with clinical decision-making to promote sustainable use and true adoption [64]. The addition of training on how to use the information from the images acquired to make timely and quality referrals, guide emergent patient care, and center health equity in daily patient interactions is paramount to successful integration of ultrasound services in a care setting. Furthermore, ongoing continuing medical education, professional development coursework, and longitudinal mentorship with feedback/ quality assurance (QA) is important for care providers to harness the rapidly evolving improvements in POCUS technology. Finally, academic partners from the Global North should support research led by partners in the Global South to explore effective POCUS training methods, diagnostic accuracy of POCUS for various diseases, derivation and validation of AI-enabled POCUS in LMICs, and impact of introducing POCUS services on patient outcomes in LMICs.

Sustainable Development Goal 5: Achieve gender equality and empower all women and girls

Healthcare career options for women increase their economic independence and quality of life. Involving women in healthcare delivery not only provides stable long-term careers in communities where employment options for women may be limited but simultaneously increases the capacity for healthcare delivery in their communities. Though women make up 70% of the healthcare workforce in LMICs, they are rarely within the leadership of healthcare organizations [65]. The integration of POCUS into vocational and tertiary healthcare education provides an additional skill set to this cohort, increasing their economic stability, career options and expertise.

Integration of POCUS into routine women's healthcare enables improved patient understanding and decision-making around sexual and reproductive healthcare, perhaps leading to family planning options and ability to participate in the workforce outside the home [49].

Sustainable Development Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

POCUS training builds human resources for health, upskills mid-level providers, and enables task-shifting where appropriate. Relatively, POCUS can be an

economically sustainable intervention for public-sector healthcare delivery settings given its low startup cost and ability to enhance revenue generation in medical practice. Anecdotal evidence suggests empowerment of healthcare workers with an easy-to-use clinical decision-making tool may mitigate healthcare worker burnout, especially following the COVID-19 pandemic, although no rigorous research has yet been published on this idea.

Sustainable Development Goal 10: Reduce inequality within and among countries & Sustainable Development Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

POCUS addresses both SDG 10 and 11 in several ways. Within and between countries, POCUS improves healthcare systems and delivery in austere settings, including humanitarian crisis settings and migrant populations, where poor access to diagnostic tools and time-lags for appropriate referrals can diminish quality of care [66,67]. Among other benefits, this may mitigate health system overload and refugee health crises, which otherwise disproportionately affect poor and marginalized populations. POCUS for bedside diagnosis may also reduce the disparities between urban and rural health outcomes related to trauma, stroke and cardiac emergencies experienced even in high-income countries like the US.

POCUS enables health systems strengthening and improved resilience for disaster risk reduction and is ideally suited for mobile care delivery. This application allows remote and hard-to-reach areas globally to have access to high quality diagnostics, a point which is especially important to address maternal and child health in low resource settings. Within cities and urban human settlements, the portability of POCUS allows care delivery to happen not only in public clinic settings but also further into communities in “street medicine” mobile units to reach urban homeless patients.

Sustainable Development Goals 14 & 15: Conserve and sustainably use the oceans, seas and marine resources for sustainable development & Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

POCUS’ veterinary applications enable protection of the health and well-being of animals, including livestock and marine mammals, and conservation of endangered species, particularly in the face of climate change and environmental degradation [68,69]. Healthy marine and land mammals are a vital part of marine habitats and ecosystems, and POCUS in veterinary medicine applications plays an important role in the reproductive assessment and health of these vital species in rehabilitation and protection facilities.

Sustainable Development Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

POCUS is an ideal candidate for large-scale deployment by way of private-public partnerships and unique, more equitable financing models. SDG 17 includes investing in data and statistics, and the digitization of POCUS including ability of cloud-based technology to share real-time usage statistics to funders and policy makers makes it useful for data point gathering on health outcomes. Target 17.7.1 refers to dissemination and with the miniaturization (multiple vendors) of the physical footprint of POCUS, to the novel use of chip-based ultrasound technology, advancements in POCUS on-chip manufacturing (single vendor isolated) have virtually eliminated the use of lead in the production of the probes [70].

AI-Enabled POCUS

The next phase of large-scale POCUS adoption will likely be driven by Artificial Intelligence (AI). From automating educational tools to enhancing diagnostic speed and accuracy, AI and deep-learning algorithms have become central strategies for expanding POCUS access in underserved regions. Current innovations include AI-labeled image guidance and virtual reality walk-throughs embedded directly into ultrasound devices. Furthermore, cloud-based "smart QA" systems can provide initial AI-led screenings, potentially reducing the administrative burden on expert reviewers. Partnerships between industry and academia have further accelerated this progress by utilizing open software development kits to create interoperable, AI-driven applications for real-time image processing. A landmark University of North Carolina study funded by the Gates Foundation demonstrated this potential; novice midwives using a "blind sweep" method—without a visible ultrasound image—achieved gestational age estimates equivalent to expert sonographers [71]. Emerging research is also expanding POCUS applications to new diagnostic frontiers, such as using deep learning to detect pulmonary tuberculosis [72,73,74]. To ensure the safe and equitable global rollout of these technologies, future efforts must prioritize diverse patient inclusion in algorithm validation, the establishment of regulatory protocols in LMICs, and the maintenance of accessible software pricing.

Conclusions

As more low- and middle-income economies invest in medical technologies and community programming to reach the UN’s sustainable development goals, focus will turn to innovations that can address many goals at once. Many medical landscapes can be described as diagnostic

deserts where clinicians rely heavily on physical exam skills and disease epidemiology/prevalence to make medical diagnoses, limiting their ability to make timely live -saving diagnoses and choose appropriate available treatments. POCUS devices that are compact and simple to use, paired with appropriate training for clinicians, are uniquely suited to address the major gap in diagnostic imaging in LMICs given their vast number of applications, affordability, and portability. Widespread adoption of POCUS as a diagnostic tool in medical care can influence much more than SDG 3 as it relates to health and well-being, as seen in Table 1. Indeed, for the WHO top causes of death in low-income countries, POCUS can be used for either diagnosis or management guidance for nearly every cause of death, as seen in Table 2 [75].

Challenges

Despite technological advancements and the increasing demand for large-scale POCUS integration to address diagnostic imaging gaps, significant implementation barriers persist. These include limited affordability, lack of specialized training, insufficient staffing, and physical infrastructure (including network services) [76]. While point of care ultrasound devices have reduced equipment costs, public healthcare systems in LMICs still struggle to procure necessary consumables like gel and paper towels. Educational barriers also remain substantial due to the high cost of training and the clinical time required for providers to achieve independent proficiency. Furthermore, limited infrastructure—including unreliable electricity, poor internet connectivity, and a lack of downstream specialty services like surgery or intensive care—continues to impede the success of global POCUS programs.

Barriers to Implementation

Over the past decade, the body of high-quality research in support of POCUS use in many of these medical conditions has expanded in quality and quantity. However, national and international policy lags behind the evidence and material need for improved diagnostics. Despite increasing evidence supporting the utility of POCUS, its global implementation is hindered by persistent legal, regulatory, and systemic barriers. In South Asia, for instance, India's Preconception and Prenatal Diagnostic Techniques (PCPNDT) Act, originally aimed at curbing sex-selective practices, has inadvertently constrained clinical POCUS use due to strict restrictive regulations [77]. However, practical policy reforms, such as permitting image-archived scans, establishing clinical-use exemptions in emergency settings, and integrating audit mechanisms, could ensure ethical compliance while enabling access to essential diagnostics in underserved areas [77]. Similar limitations exist globally: in many LMICs, the absence of formal regulatory frameworks means POCUS remains unrecognized in national health strategies, and task-shifting to general physicians, nurses, or midwives remains unsupported [3,78]. However, structured, competency-based training programs have shown that non-physician providers can deliver high-quality POCUS, especially in obstetric and emergency care [79]. In parallel, remote supervision and AI-guided platforms offer scalable, low-cost solutions for quality assurance, particularly in resource-limited settings [80].

We commend the World Health Assembly 2023 resolution on diagnostics that has enabled prioritization of resources specifically to increase access to appropriate diagnostics, and we call for an acceleration of opportunities to allow innovative technologies to reach remote patients [81]. This effort by WHA was further enhanced in WHAs 2025 resolutions to strengthen medical imaging technologies in LMICs, as encouragement to MOH leads in LMICs to consider funding imaging diagnostics more broadly [82]. The United Nations has turned its lens to harness new technologies to accelerate progress towards the 2030 SDGs and we hope this manuscript provides a roadmap to focus all relevant stakeholders on POCUS as one of these technologies [83].

We hope that this review will serve as a call to action for funders, policymakers, market shapers, and Ministries of Health around the world to encourage recognition of POCUS as a diagnostic screening tool with value and acceptable return on investment across multiple provider levels and specialties. To date, siloed funding mechanisms that are geography- and disease-specific have limited adoption of diagnostic innovations in low- and middle-income contexts. We hope that, particularly in a post-COVID-19 context, a substantial shift in funding opportunities and management allows for wide scale uptake of innovations that improve whole-human health and strengthen health systems. Furthermore, we encourage adoption of POCUS into medical curriculums for all health care providers world-wide, such that it becomes as ubiquitous a tool as the stethoscope, and we implore decision-makers to make available equipment, training, and infrastructure to meet these recommendations.

Ethics Statement

This article does not involve human subjects. Therefore, it is exempt from ethics review.

Disclosure Statement

SS, HHD, TZ, & SS are affiliated with Butterfly Network, Inc. MR is affiliated with Global Ultrasound Institute.

Table 1. Summary of selected sustainable development goals and the role of point of care ultrasound.

SDG		Role of Point of Care Ultrasound
3. Good Health and Well-being	3.1	— POCUS can be used to identify high-risk conditions of pregnancy including placental abnormalities/abruption, retained products of conception with subsequent infection, identification of ectopic pregnancy/ruptured ectopic pregnancy, and postpartum complications.
	3.2	— Neonatal mortality is typically related to birth-related complications, which can be averted with early diagnosis in utero. — Under-5 mortality is driven by pneumonia, which is a diagnosis that can be made with ultrasound. Fluid resuscitation in the setting of diarrhea can be facilitated in resource-scarce settings with ultrasound.
	3.3	— Ultrasound can be useful in the diagnosis and management (procedural guidance in relation to complications) in tuberculosis and HIV. — Ultrasound can be diagnostically useful in treating malaria-induced or hepatitis-induced advanced complications. — Ultrasound can be helpful in treating multiple NTDs, including leishmaniasis.
	3.4	— Ultrasound can be useful in the diagnosis of rheumatic heart disease, stroke/cardiovascular disease screening, and has oncology management applications.
	3.6	— The eFAST exam can be conducted with POCUS for evaluation of traumatic injury. — Critical care also benefits from access to ultrasound, especially in the absence of CT Scans.
	3.8	— Benefits many services from improved safety, efficacy, and quality with ultrasound on board (procedural guidance, reducing need for additional diagnostic tests, etc.). — POCUS in general is very affordable compared to standard ultrasound machines on the market - has the capacity to reduce healthcare expenditures or end-user fees.
	3.9	— Portable ultrasound is an alternative to traditional X-ray, reducing exposure to hazardous chemicals associated with X-ray. — POCUS based on microconductor technology reduces lead-waste associated with PZE-crystal based ultrasound.
	3.c	— Upskilling of healthcare providers; development of local, in-country POCUS trainers. — Portability of equipment allows last mile health workers access to diagnostic imaging even in remote settings.
	3.d	— Improved health systems strengthening through strengthened provision of emergency medicine and early detection of emerging contagions (especially respiratory contagions). — Potential to strengthen and promote more resilient primary care systems, resulting in less medical migration.
4. Quality Education		— Advancing vocational and tertiary education programs in the health sciences commonly pursued by women. — Leveraging the trainer model (formal and organic), and open-access education content, to develop sustainable education programs for healthcare providers. — Promoting knowledge and skills needed to promote sustainable development among POCUS learners.
5. Gender Equality		— Enabling improved patient understanding and decision-making around sexual and reproductive healthcare.
8. Decent Work and Economic Growth		— Building human resources for health, upskilling mid-level providers, and enabling task-shifting. — Introducing an economically sustainable intervention into public-sector healthcare delivery settings. — Mitigating healthcare worker burnout, particularly following the COVID-19 pandemic, through introduction of a simple, life-saving tool.
10. Reduced Inequalities		— Improving healthcare in humanitarian crises settings, and among migrant populations, abating health system overload and refugee health crises.
11. Sustainable Cities & Environments		— Health systems strengthening and resilience for disaster risk reduction. — Enabling mobile, point-of-care medical services delivery.
14 & 15. Life Below Water and Life On Land		— Veterinary applications enable protection of the health and well-being of animals, including livestock and marine mammals, and conservation of endangered species.
17. Strengthen Partnerships		— Ideally suited for private/public partnerships for large-scale deployments. — Digitization of health data through cloud-based POCUS can lead to real-time patient outcome information for policy and public health response

Table 2. POCUS exams and AI applications that could influence the top causes of death in low-income countries.

Top Cause of Death in Low-Income	POCUS Exam Type and AI applications	Evidence
1. Lower Respiratory Infection	— Pneumonia screening — Parapneumonic effusion identification and guided drainage — COVID-19 infection identification — AI-guided B-lines	[54,84,85,86,21, 87,88,89,90,91]
2. Stroke	— Carotid and echo screening for cerebrovascular accident risk and prevention	[92]
3. Ischemic Heart Disease	— Echo screening for complications of heart failure with ischemic heart disease — Localized wall-motion abnormality as proxy for myocardial infarction — AI-guided automatic ejection fraction	[38,93,94,95]
4. Malaria	— Splenomegaly or elevated intracranial pressure from cerebral malaria — Volume status and edema in severe malaria	[96,97,98]
5. Diarrheal Diseases	— Volume status and complications of dehydration/management of volume resuscitation — Nematode related bowel obstruction	[99,100,101,102]
6. Preterm birth complications	— Early diagnosis of prenatal conditions — Identification of obstructed labor	[7]
7. Tuberculosis	— Lung ultrasound for diagnosis of pulmonary TB — FASH exam for diagnosis of extrapulmonary TB — Tuberculous meningitis and elevated intracranial pressure	[72,103,104,105, 106,107,108,109]
8. Road Injury	— eFAST exam for diagnosis of pneumothorax, hemothorax, hemoperitoneum, hemopericardium	[110]
9. HIV/AIDS	— Complications of HIV/AIDS including cardiomyopathy, nephropathy, pneumonia/interstitial disease, deep venous thrombosis, Kaposi sarcoma	[111,112,113,114 ,115]
10. Birth Asphyxia and birth trauma	— Malpresentation — Cephalo-pelvic disproportion	[7,116,117,118]

Funding

No associated funding was received for this work.

Author Contributions

SSh: conceptualization, analysis, investigation, methodology, writing-original draft, visualization, writing-editing. MR: conceptualization, analysis, investigation, methodology, writing-original draft. HHD: conceptualization, analysis, investigation, methodology, writing-original draft. TZ: conceptualization, analysis, investigation, methodology, writing-original draft, writing-editing. SR: analysis, writing-editing. SSu: analysis, visualization, writing-editing. AN: analysis, investigation, methodology, writing-editing. NA: analysis, investigation, methodology, writing-editing. LS: analysis, investigation, methodology, writing-original draft.

References

1. Fleming KA, Horton S, Wilson ML, Atun R, DeStigter K, Flanigan J, Sayed S, Adam P, Aguilar B, Andronikou S, Boehme C, Cherniak W, Cheung ANY, Dahn B, Donoso-Bach L, Douglas T, Garcia P, Hussain S, Iyer HS, Kohli M, Labrique AB, Looi LM, Meara JG, Nkengasong J, Pai M, Pool KL, Ramaiya K, Schroeder L, Shah D, Sullivan R, Tan BS, Walia K. The Lancet Commission on diagnostics: Transforming access to diagnostics. Lancet 2021; 398(10315): 1998–2050.

2. Hricak H, Abdel-Wahab M, Atun R, Mikhail Lette M, Paez D, Brink JA, Donoso-Bach L, Frija G, Hierath M, Holmberg O, Khong PL, Lewis JS, McGinty G, Oyen WJG, Shulman LN, Ward ZJ, Scott AM. Medical imaging and nuclear medicine: A Lancet Oncology Commission. Lancet Oncol 2021; 22(4).

3. Abrokwa SK, Ruby LC, Heuvelings CC, Bélard S. Task shifting for point-of-care ultrasound in primary healthcare in low- and middle-income countries—a systematic review. EClinicalMedicine 2022;45:101333.

4. Rykkje A, Carlsen JF, Nielson MB. Hand-held ultrasound devices compared with high-end ultrasound systems: A systematic review.

Diagnostics (Basel) 2019;9(2):61.

5. Tran TT, Hlaing M, Krause M. Point-of-care ultrasound: Applications in low- and middle-income countries. Curr Anesthesiol Rep 2021;11 (1):69–75.

6. United Nations. The 2023 Agenda for Sustainable Development. 2023. Available from: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

7. Knights S, Prasad S, Kalafat E, Dadali A, Sizer P, Harlow F, Khalil A. Impact of point-of-care ultrasound and routine third trimester ultrasound on undiagnosed breech presentation and perinatal outcomes: An observational multicentre cohort study. PLoS Med 2023;20(4).

8. Lozeau AM, Potter B. Diagnosis and management of ectopic pregnancy. American Family Physician 2005;72(9):1707–1714.

9. World Health Organization. Imaging ultrasound before 24 weeks of pregnancy: 2022 update to the WHO antenatal care recommendations for a positive pregnancy experience. World Health Organization; 2022. Available from: https://www.who.int/publications/i/item/9789240051461

10. Ross AB, DeStigter KK, Rielly M, Souza S, Morey GE, Nelson M, Silfen EZ, Garra B, Matovu A, Kawooya MG. A low-cost ultrasound program leads to increased antenatal clinic visits and attended deliveries at a health care clinic in rural Uganda. PLoS One 2023.

11. Shokoohi H, Raymond A, Fleming K, Scott J, Kerry V, Haile-Mariam T, Sayeed S, Boniface KS. Assessment of point-of-care ultrasound training for clinical educators in Malawi, Tanzania, and Uganda. Ultrasound Med Biol 2019;45(6):1351–1357.

12. Waiswa P, Akuze J, Moyer C, Kwesiga D, Arthur S, Sankoh O, Welaga P, Bangha M, Eminas J, Muuo S, Ziraba A, Kerber K; INDEPTH Network MNCH team. Status of birth and pregnancy outcome capture in Health Demographic Surveillance Sites in 13 countries. Int J Public Health 2019;64(6):909–920.

13. United Nations. Levels and trends in child mortality. 2019. Available from: https://www.unicef.org/media/60561/file/UN-IGME-child-mortality-report-2019.pdf.

14. Pattinson R, Fawcus S, Gebhardt S, Soma-Pillay P, Niit R, Moodley J. The impact of COVID-19 on use of maternal and reproductive health services and maternal and perinatal mortality. South African Health Review 2021.

15. World Health Organization. Newborn mortality. 2021. Available from: https://www.who.int/news-room/fact-sheets/detail/levels-and-trends-in-child-mortality-report-2021#:~:text=Preterm%20birth%2C%20intrapartum%2Drelated%20complicationscauses%20of%20most%20neonatal%20deaths.

16. Dhaded SM, Somannavar MS, Vernekar SS, Goudar SS, Mwenche M, Derman R, Moore JL, Patel A, Pasha O, Esamai F, Garces A, Althabe F, Chomba E, Liechty EA, Hambidge KM, Krebs NF, Berrueta M, Ciganda A, Hibberd PL, Goldenberg RL, McClure EM, Koso-Thomas M, Manasyan A, Carlo WA. Neonatal mortality and coverage of essential newborn interventions 2010–2013: A prospective population-based study from low-middle income countries. Reprod Health 2015;12 Suppl 2(Suppl 2).

17. Blencowe H, Cousens S, Chou D, Oestergaard M, Say L, Moller AB, Kinney M, Lawn J; Born Too Soon Preterm Birth Action Group. Born too soon: The global epidemiology of 15 million preterm births. Reprod Health 2013;10 Suppl 1(Suppl 1).

18. Grytten J, Skau I, Sørensen R, Eskild A. Does the use of diagnostic technology reduce fetal mortality? Health Serv Res 2018;53(6):4437–4459.

19. Liu L, Oza S, Hogan D, Chu Y, Perin J, Zhu J, Lawn JE, Cousens S, Mathers C, Black RE. Global, regional, and national causes of under-5 mortality in 2000–15: An updated systematic analysis with implications for the Sustainable Development Goals. Lancet 2016;388(10063):3027–3035.

20. World Health Organization. Child mortality (under 5 years). 2020. Available from: https://www.who.int/news-room/fact-sheets/detail/levels-and-trends-in-child-under-5-mortality-in-2020#:~:text=Globally%2C%20infectious%20diseases%2C%20including%20pneumoniafor%20children%20under%205%20years.

21. Jones BP, Tay ET, Elikashvili I, Sanders JE, Paul AZ, Nelson BP. Feasibility and safety of substituting lung ultrasonography for chest radiography when diagnosing pneumonia in children: A randomized controlled trial. Chest 2016;150(1):131–138.

22. Pourmand A, Pyle M, Yamane D, Sumon K, Frasure SE. The utility of point-of-care ultrasound in the assessment of volume status in acute and critically ill patients. World J Emerg Med 2019;10(4):232–238.

23. Stolz LA, Kizza H, Little K, Kasekende J. Intussusception detected with ultrasound in a resource-limited setting. Lancet 2013;381 (9882):2054.

24. Gingrich AS, Saul T, Lewiss RE. Point-of-care ultrasound in a resource-limited setting: Diagnosing intussusception. J Emerg Med 2013;45(3).

25. UNAIDS. UNAIDS data 2022. 2022. Available from: https://www.unaids.org/sites/default/files/media_asset/data-book-2022_en.pdf.

26. World Health Organization. Tuberculosis. 2021. Available from: https://www.who.int/news-room/fact-sheets/detail/tuberculosis.

27. Heller T, Wallrauch C, Brunetti E, Giordani MT. Changes of FASH ultrasound findings in TB-HIV patients during anti-tuberculosis treatment. Int J Tuberc Lung Dis 2014;18(7):837–839.

28. Kahn D, Pool KL, Phiri L, Chibwana F, Schwab K, Longwe L, Banda BA, Gama K, Chimombo M, Chipungu C, Grotts J, Schooley A, Hoffman RM. Diagnostic ultrasound for high-risk patients and populations in Malawi: 2010–2018. PLoS Negl Trop Dis 2022;16(5).

29. Bélard S, Tamarozzi F, Bustinduy AL, Wallrauch C, Grobusch MP, Kuhn W, Brunetti E, Joekes E, Heller T. Point-of-care ultrasound assessment of tropical infectious diseases—A review of applications and perspectives. Am J Trop Med Hyg 2016;94(1):8–21.

30. Mohammed R, Gebrewold Y, Schuster A, Fikre H, Mekonnen T, Mulaw T, Bogale T, Vogt F, Diro E, van Griensven J. Abdominal ultrasound in the diagnostic work-up of visceral leishmaniasis and for detection of complications of spleen aspiration. PLoS Negl Trop Dis 2021;15(2).

31. Bélard S, Stratta E, Zhao A, Ritmeijer K, Moretó-Planas L, Fentress M, Nadimpalli A, Grobusch MP, Heller T, Heuvelings CC. Sonographic findings in visceral leishmaniasis—A narrative review. Travel Med Infect Dis 2020;39:101924.

32. Michels M, Sumardi U, de Mast Q, Jusuf H, Puspita M, Warma Dewi IM, Sinarta S, Alisjahbana B, van der Ven AJAM. The predictive diagnostic value of serial daily bedside ultrasonography for severe dengue in Indonesian adults. PLoS Negl Trop Dis 2013;7(6).

33. Dewan N, Zuluaga D, Osorio L, Krienke ME, Bakker C, Kirsch J. Ultrasound in dengue: A scoping review. Am J Trop Med Hyg 2021;104 (3):826–835.

34. Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, Barengo NC, Beaton AZ, Benjamin EJ, Benziger CP, Bonny A, Brauer M, Brodmann M, Cahill TJ, Carapetis JR, Catapano AL, Chugh SS, Cooper LT, Coresh J, Criqui M, DeCleene N, Eagle KA, Emmons-Bell S, Feigin VL, Fernández-Solà J, Fowkes G, Gakidou E, Grundy SM, He FJ, Howard G, Hu F, Inker L, Karthikeyan G, Kassebaum N, Koroshetz W, Lavie C, Lloyd-Jones D, Lu HS, Mirijello A, Temesgen AM, Mokdad A, Moran AE, Muntner P, Narula J, Neal B, Ntsekhe M, Moraes de Oliveira G, Otto C, Owolabi M, Pratt M, Rajagopalan S, Reitsma M, Ribeiro ALP, Rigotti N, Rodgers A, Sable C, Shakil S, Sliwa-Hahnle K, Stark B, Sundström J, Timpel P, Tleyjeh IM, Valgimigli M, Vos T, Whelton PK, Yacoub M, Zuhlke L, Murray C, Fuster V; GBD-NHLBI-JACC Global Burden of Cardiovascular Diseases Writing Group. Global burden of cardiovascular diseases and risk factors 1990–2019: Update from the GBD 2019 study. J Am Coll Cardiol 2020;76(25):2982–3021.

35. Inglis J, Boll K, Mohamed AM, Fraden M, Madar A, Merjavy S, Hirsi AA, Haldeman MS, Hategeka C. Assessing the efficacy of POCUS training in the Republic of Somaliland: a retrospective analysis of 500 scans conducted by general practitioners. Australas J Ultrasound Med. 2025;28(3):e70022. doi: 10.1002/ajum.70022

36. Nascimento BR, Sable C, Nunes MCP, Oliveira KKB, Franco J, Barbosa MM, Reese AT, Diamantino AC, Ferreira Filho DSG, Macedo FVB, Raso LAM, Paiva SMW, Ribeiro ALP, Beaton AZ; PROVAR+ (Programa de RastreamentO da VAlvopatia Reumática e outras Doenças Cardiovasculares) investigators. Echocardiographic screening of pregnant women by non-physicians with remote interpretation in primary care. Fam Pract. 2021;38(3):225-230. doi: 10.1093/fampra/cmaa115

37. Muhame RM, Dragulescu A, Nadimpalli A, Martinez D, Bottineau MC, Venugopal R, Runeckles K, Manlhiot C, Nield LE. Cardiac point of care ultrasound in resource limited settings to manage children with congenital and acquired heart disease. Cardiol Young. 2021;31 (10):1651-1657. doi: 10.1017/S1047951121000834

38. Huson MAM, Kaminstein D, Kahn D, Belard S, Ganesh P, Kandoole -Kabwere V, Wallrauch C, Phiri S, Kreuels B, Heller T. Cardiac ultrasound in resource-limited settings (CURLS): towards a wider use of basic echo applications in Africa. Ultrasound J. 2019;11(1):34. doi: 10.1186/s13089-019-0149-0

39. Hamill C, Ellis PK, Johnston PC. Point of care thyroid ultrasound (POCUS) in endocrine outpatients: A pilot study. Ulster Med J 2020;89 (1):21–24.

40. Kidder Bukhman A, Nsengimana VJP, Lipsitz MC, Henwood PC, Tefera E, Rouhani SA, Dukundane D, Bukhman GY. Diagnosis and management of acute heart failure in sub-Saharan Africa. Curr Cardiol Rep 2019;21(10):120.

41. World Health Organization. Injuries and violence. 2021. Available from: https://www.who.int/news-room/fact-sheets/detail/injuries-and-violence#:~:text=Injuries%E2%80%
93bothunintentionalandviolencetrafficinjuries,homicideandsuicide.

42. Humbal H, Parikh R, Patel RB, Pancholi SH, Saxena K, Chawada A. Utility of point-of-care ultrasound in differentiating causes of shock in resource-limited setup. J Emerg Trauma Shock 2019;12(1):10–17.

43. Wang LJ, Chen LM, Chen Y, Bao LY, Zheng NN, Wang YZ, Xing YQ. Ultrasonography assessments of optic nerve sheath diameter as a noninvasive and dynamic method of detecting changes in intracranial pressure. JAMA Ophthalmol 2018;136(3):250–256.

44. Harbison H, Shah S, Marill K, Noble V. Correlation of optic nerve sheath diameter with direct measurement of intracranial pressure. Acad Emerg Med 2008;15(2):201–204.

45. Maissan I, Dirven PJAC, Haitsma IK, Hoeks SE, Gommers D, Stolker RJ. Ultrasonographically measured optic nerve sheath diameter as an accurate and quick monitor for changes in intracranial pressure. J Neurosurg 2015;123(3):743–747.

46. Ang SH, Lee SW, Lam KY. Ultrasound-guided reduction of distal radius fractures. J Med Ultrasound 2009;17(3):73–76.

47. Ramsingh D, Mangunta VR. The use of point-of-care ultrasonography in trauma anesthesia. Anesthesiol Clin 2019;37(1):93–106.

48. Nowitzki KM, Hoimes ML, Chen B, Zheng LZ, Kim YH. Ultrasonography of intrauterine devices. Ultrasonography 2015;34 (3):183–194.

49. Baradwan S, Alshahrani MS, Alnoury A, Khadawardi K, Khan MA, Abdelkader RAA, Saleh OI, Galal HM, Mohamed SMA, Abdelhakim AM, Elgedawy AM, Elbahie AM, Gaber MA, Magdy AA, Shaheen K. Does ultrasound guidance provide pain relief during intrauterine contraceptive device insertion? A systematic review and meta-analysis of randomized controlled trials. J Ultrasound Med 2023;42(7):1401–1411.

50. Lentz B, Fong T, Rhyne R, Risko N. A systematic review of the cost-effectiveness of ultrasound in emergency care settings. Ultrasound J 2021;13(1):16.

51. Maganti K, Chen C, Jamthikar AD, Parikh P, Yanamala N, Sengupta PP. Cardiopulmonary point-of-care ultrasonography for hospitalist management of undifferentiated dyspnea. JAMA Netw Open. 2025;8 (9):e2530677. doi:10.1001/jamanetworkopen.2025.30677.

52. European Commission. Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS). 2023. Available from: https://environment.ec.europa.eu/topics/waste-and-recycling/rohs-directive_en.

53. Nolting L, Baker D, Hardy Z, Kushinka M, Brown HA. Solar-powered point-of-care sonography: Our Himalayan experience. J Ultrasound Med 2019;38(9):2477–2484.

54. Matthay MA, Arabi Y, Arroliga AC, Bernard G, Bersten AD, Brochard L. A new global definition of acute respiratory distress syndrome. Am J Respir Crit Care Med 2023.

55. Broderick JC, Mancha F, Long BJ, Maddry JK, Chung KK, Schauer SG. Combat trauma-related acute respiratory distress syndrome: A scoping review. Crit Care Explor 2022;4(9).

56. Liu JX, Goryakin Y, Maeda A, Bruckner T, Scheffler R. Global health workforce labor market projections for 2030. Hum Resour Health 2017;15(1):11.

57. Stolz LA, Muruganandan KM, Bisanzo MC, Sebikali MJ, Dreifuss BA, Hammerstedt HS, Nelson SW, Nayabale I, Adhikari S, Shah SP. Point-of-care ultrasound education for non-physician clinicians in a resource-limited emergency department. Trop Med Int Health 2015;20 (8):1067–1072.

58. Lipsitz M, Levin L, Sharma V, Herrala J, Rimawi A, Bernier D, Kimberly H, Thomson A, Soucy Z, Henwood P. The state of point-of-care teleultrasound use for educational purposes: A scoping review. J Ultrasound Med 2022;41(8):1889–1906.

59. Dohlman L, DiMeglio M, Hajj J, Laudanski K. Global brain drain: How can the Maslow theory of motivation improve our understanding of physician migration? Int J Environ Res Public Health 2019;16(7):1182.

60. Hussain A, Via G, Melniker L, Goffi A, Tavazzi G, Neri L, Villen T, Hoppmann R, Mojoli F, Noble V, Zieleskiewicz L, Blanco P, Ma IWY, Wahab MA, Alsaawi A, Al Salamah M, Balik M, Barca D, Bendjelid K, Bouhemad B, Bravo-Figueroa P, Breitkreutz R, Calderon J, Connolly J, Copetti R, Corradi F, Dean AJ, Denault A, Govil D, Graci C, Ha YR, Hurtado L, Kameda T, Lanspa M, Laursen CB, Lee F, Liu R, Meineri M, Montorfano M, Nazerian P, Nelson BP, Neskovic AN, Nogue R, Osman A, Pazeli J, Pereira-Junior E, Petrovic T, Pivetta E, Poelaert J, Price S, Prosen G, Rodriguez S, Rola P, Royse C, Chen YT, Wells M, Wong A, Xiaoting W, Zhen W, Arabi Y. Multi-organ point-of-care ultrasound for COVID-19 (PoCUS4COVID): International expert consensus. Crit Care 2020;24(1):702.

61. Pivetta E, Goffi A, Tizzani M, Locatelli SM, Porrino G, Losano I, Leone D, Calzolari G, Vesan M, Steri F, Ardito A, Capuano M, Gelardi M, Silvestri G, Dutto S, Avolio M, Cavallo R, Bartalucci A, Paglieri C, Morello F, Richiardi L, Maule MM, Lupia E. Lung ultrasonography for the diagnosis of SARS-CoV-2 pneumonia in the emergency department. Ann Emerg Med 2021;77(4):385–394.

62. Shumbusho JP, Duanmu Y, Kim SH, Bassett IV, Boyer EW, Ruutiainen AT, Riviello R, Ntirenganya F, Henwood PC. Accuracy of resident-performed point-of-care lung ultrasound examinations versus chest radiography in pneumothorax follow-up after tube thoracostomy in Rwanda. J Ultrasound Med 2020;39(3):499–506.

63. Lam J, Wong S, Grubic N, Nihal S, Herr JE, Belliveau DJ, Gauthier S, Montague SJ, Johri AM. Accelerated remote consultation tele-POCUS in cardiopulmonary assessment (ARCTICA). POCUS J 2020;5 (2):55–58.

64. Shah S. Implementing ultrasound in developing countries. In: Cosby K, Kendall J, editors. Practical guide to emergency ultrasound. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2014.

65. World Health Organization. Delivered by women, led by men. 2023. Available from: https://iris.who.int/bitstream/handle/10665/311322/9789241515467-eng.pdf?ua=1.

66. Rijken MJ, Gilder ME, Thwin MM, Ladda Kajeechewa HM, Wiladphaingern J, Lwin KM, Jones C, Nosten F, McGready R. Refugee and migrant women's views of antenatal ultrasound on the Thai Burmese border: A mixed methods study. PLoS One 2012;7(4).

67. Jordan K, Lewis T, Roberts B. Quality in crisis: A systematic review of the quality of health systems in humanitarian settings. Confl Health 2021;15(1):7.

68. Borriello G, Guccione J, Di Loria A, Bosco A, Pepe P, Prisco F, Cringoli G, Paciello O, Rinaldi L, Ciaramella P. Fast focus ultrasound liver technique for the assessment of cystic echinococcosis in sheep. MDPI 2021;11(2):452.

69. Macpherson C, Bartholomot B, Frider B. Application of ultrasound in diagnosis, treatment, epidemiology, public health, and control of Echinococcus granulosus and E. multilocularis. Parasitology 2003;127 Suppl.

70. Rothberg JM, Ralston TS, Rothberg AG, Martin J, Zahorian JS, Alie SA, Sanchez NJ, Chen K, Chen C, Thiele K, Grosjean D, Yang J, Bao L, Schneider R, Schaetz S, Meyer C, Neben A, Ryan B, Petrus JR, Lutsky J, McMahill D, Corteville G, Hageman MR, Miller L, Fife KG. Ultrasound-on-chip platform for medical imaging, analysis, and collective intelligence. Proc Natl Acad Sci U S A. 2021;118 (27):e2019339118. doi: 10.1073/pnas.2019339118.

71. Stringer JSA, Pokaprakarn T, Prieto JC, Vwalika B, Chari SV, Sindano N, Freeman BL, Sikapande B, Davis NM, Sebastião YV, Mandona NM, Stringer EM, Benabdelkader C, Mungole M, Kapilya FM, Almnini N, Diaz AN, Fecteau BA, Kosorok MR, Cole SR, Kasaro MP. Diagnostic accuracy of an integrated AI tool to estimate gestational age from blind ultrasound sweeps. JAMA. 2024;332(8):649-657. doi: 10.1001/jama.2024.10770

72. Suttels V, Du Toit JD, Fiogbé AA, Wachinou AP, Guendehou B, Alovokpinhou F, Toukoui P, Hada AR, Sefou F, Vinasse P, Makpemikpa G, Capo-Chichi D, Garcia E, Brahier T, Keitel K, Ouattara K, Cissoko Y, Beye SA, Mans PA, Agodokpessi G, Boillat-Blanco N, Hartley MA. Point-of-care ultrasound for tuberculosis management in Sub-Saharan Africa

-a balanced SWOT analysis. Int J Infect Dis. 2022;123:46-51. doi: 10.1016/j.ijid.2022.07.009. PMID: 35811083.

73. Ghent University. Comparative efficacy of CUS, CXR and CAD in TB diagnosis in LMIC [Internet]. 2024 May 14. Available from: https://clinicaltrials.gov/study/NCT06409780. ClinicalTrials.gov identifier: NCT06409780.

74. Suttels V, Wachinou P, Toit JD, Boillat-Blanco N, Hartley MA. Ultrasound for point-of-care sputum-free tuberculosis detection: building collaborative standardized image-banks. EBioMedicine. 2022;81:104078. doi: 10.1016/j.ebiom.2022.104078

75. World Health Organization. The top 10 causes of death. 2023. Available from: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death.

76. Githemo G, Wanyoro A, Masika J, Onsongo L, Bett S, Githuku S, Gachuiri G, Walker D, Santos N, Ghosh R, Otieno G. Evaluation of large-scale implementation of obstetric point of care ultrasound in eight counties in Kenya using RE-AIM framework. BMC Health Serv Res. 2025;25:1016. doi: 10.1186/s12913-025-13212-8

77. Smith M, Krishnan SV, Leamon A, Galwankar S, Sinha TP, Kumar VA, Laere JV, Gallien J, Bhoi S. Removing barriers to emergency medicine point-of-care ultrasound: Illustrated by a roadmap for emergency medicine point-of-care ultrasound expansion in India. J Emerg Trauma Shock 2023;16(3):116–126.

78. Suttels V, Guedes Da Costa S, Garcia E, Brahier T, Hartley MA, Agodokpessi G, Wachinou P, Fasseur F, Boillat-Blanco N. Barriers and facilitators to implementation of point-of-care lung ultrasonography in a tertiary centre in Benin: A qualitative study among general physicians and pneumologists. BMJ Open 2023;13(6):e070765.

79. Wanjiku GW, Bell G, Wachira B. Assessing a novel point-of-care ultrasound training program for rural healthcare providers in Kenya. BMC Health Serv Res 2018;18:607.

80. Dougherty A, Kasten M, DeSarno M, Badger G, Streeter M, Jones DC, Sussman B, DeStigter K. Validation of a telemedicine quality assurance method for point-of-care obstetric ultrasound used in low-resource settings. J Ultrasound Med 2021;40(3):529–540.

81. World Health Organization. Strengthening diagnostics capacity. 2023. Available from: https://apps.who.int/gb/ebwha/pdf_files/EB152/B152(6)-en.pdf.

82. Lancet Oncology Commission on Medical Imaging and Nuclear Medicine. WHA Resolution [Internet]. Vienna: Imaging Commission; 2025. Available from: https://imagingcommission.org/wha-resolution-2/

83. United Nations. The Secretary-General's strategy on new technologies. 2023. Available from: https://www.un.org/en/un-chronicle/secretary-general%E2%80%99s-strategy-new-technologies-0.

84. Chavez MA, Shams N, Ellington LE, Naithani N, Gilman RH, Steinhoff MC, Santosham M, Black RE, Price C, Gross M, Checkley W. Lung ultrasound for the diagnosis of pneumonia in adults: A systematic review and meta-analysis. Respir Res 2014;15(1):50.

85. Ye X, Xiao H, Chen B, Zhang S. Accuracy of lung ultrasonography versus chest radiography for the diagnosis of adult community-acquired pneumonia: Review of the literature and meta-analysis. PLoS One 2015;10(6).

86. Yan JH, Yu N, Wang YH, Gao YB, Pan L. Lung ultrasound vs chest radiography in the diagnosis of children pneumonia. Medicine (Baltimore) 2020;99(50).

87. Schaad S, Brahier T, Hartley MA, Cordonnier JB, Bosso L, Espejo T, Pantet O, Hugli O, Carron PN, Meuwly JY, Boillat-Blanco N. Point-of-care lung ultrasonography for early identification of mild COVID-19: A prospective cohort of outpatients in a Swiss screening center. BMJ Open 2022;12(6).

88. Peixoto AO, Costa RM, Uzun R, Fraga AMA, Ribeiro JD, Marson FAL. Applicability of lung ultrasound in COVID-19 diagnosis and evaluation of the disease progression: A systematic review. Pulmonology 2021;27(6):529–562.

89. Fang HY, Chang KW, Chao YK. Ultrasound-guided pleural effusion drainage: Effect on oxygenation, respiratory mechanics, and liberation from mechanical ventilation in surgical intensive care unit patients. Diagnostics (Basel) 2021;11(11):2000.

90. Demi L, Wolfram F, Klersy C, De Silvestri A, Ferretti VV, Muller M, Miller D, Feletti F, Wełnicki M, Buda N, Skoczylas A, Pomiecko A, Damjanovic D, Olszewski R, Kirkpatrick AW, Breitkreutz R, Mathis G, Soldati G, Smargiassi A, Inchingolo R, Perrone T. New international guidelines and consensus on the use of lung ultrasound. J Ultrasound Med 2023;42(2):309–344.

91. Volpicelli G, Caramello V, Cardinale L, Mussa A, Bar F, Frascisco MF. Bedside ultrasound of the lung for the monitoring of acute decompensated heart failure. Am J Emerg Med 2008;26(5):585–591.

92. Kent A, Patil P, Davila V, Bailey JK, Jones C, Evans DC, Boulger CT, Adkins E, Balakrishnan JM, Valiyaveedan S, Galwankar SC, Bahner DP, Stawicki SP. Sonographic evaluation of intravascular volume status: Can internal jugular or femoral vein collapsibility be used in the absence of IVC visualization? Ann Thorac Med. 2015;10(1):44-9. doi:10.4103/1817-1737.146872

93. Shah SP, Shah SP, Fils-Aime R, Desir W, Joasil J, Venesy DM, Muruganandan KM. Focused cardiopulmonary ultrasound for assessment of dyspnea in a resource-limited setting. Crit Ultrasound J 2016;8(1):7.

94. Vafaie M. State-of-the-art diagnosis of myocardial infarction. Diagnosis (Berl) 2016;3(4):137–142.

95. Yu AR, Hasjim B, Yu LE, Gabriel C, Anshus A, Lee JB, Louthan MJ, Kim EC, Lee K, Tse C, Keown T, Lahham S, Alvarado M, Bunch S, Gari A, Fox JC. Comparison of ultrasound-measured properties of the common carotid artery to tobacco smoke. exposure in a cohort of Indonesian patients. World J Emerg Med 2017;8(3):177–183.

96. Pugliese CM, Adegbite BR, Edoa JR, Mombo-Ngoma G, Obone-Atome FA, Heuvelings CC, Bélard S, Kalkman LC, Leopold SJ, Hänscheid T, Adegnika AA, Huson MA, Grobusch MP. Point-of-care ultrasound to assess volume status and pulmonary oedema in malaria patients. Infection 2022;50(1):65–82.

97. Beare NA, Glover SJ, Lewallen S, Taylor TE, Harding SP, Molyneux ME. Prevalence of raised intracranial pressure in cerebral malaria detected by optic nerve sheath ultrasound. Am J Trop Med Hyg 2012;87(6):985–988.

98. Murphy S, Cserti-Gazdewich C, Dhabangi A, Musoke C, Nabukeera-Barungi N, Price D, King ME, Romero J, Noviski N, Dzik W. Ultrasound findings in Plasmodium falciparum malaria: A pilot study. Pediatr Crit Care Med 2011;12(2).

99. Levine AC, Shah SP, Umulisa I, Munyaneza RB, Dushimiyimana JM, Stegmann K, Musavuli J, Ngabitsinze P, Stulac S, Epino HM, Noble VE. Ultrasound assessment of severe dehydration in children with diarrhea and vomiting. Acad Emerg Med 2010;17(10):1035–1041.

100. Modi P, Glavis-Bloom J, Nasrin S, Guy A, Chowa EP, Dvor N, Dworkis DA, Oh M, Silvestri DM, Strasberg S, Rege S, Noble VE, Alam NH, Levine AC. Accuracy of inferior vena cava ultrasound for predicting dehydration in children with acute diarrhea in resource-limited settings. PLoS One 2016;11(1).

101. Kołodziej M, Jalali A, Łukasik J. Point-of-care ultrasound to assess the degree of dehydration in children: A systematic review with meta-analysis. Arch Dis Child 2024;109(4):275–281.

102. Gottlieb M, Peksa GD, Pandurangadu AV, Nakitende D, Takhar S, Seethala RR. Utilization of ultrasound for the evaluation of small bowel obstruction: A systematic review and meta-analysis. Am J Emerg Med 2018;36(2):234–242.

103. Giannelli F, Cozzi D, Cavigli E, Campolmi I, Rinaldi F, Giachè S, Rogasi PG, Miele V, Bartolucci M. Lung ultrasound (LUS) in pulmonary tuberculosis: Correlation with chest CT and X-ray findings. J Ultrasound 2022;25(3):625–634.

104. Fentress M, Ugarte-Gil C, Cervantes M, Rivas D, Moore D, Caliguiri P, Bergman K, Noazin S, Padovani A, Gilman RH. Lung ultrasound findings compared with chest X-ray findings in known pulmonary tuberculosis patients: A cross-sectional study in Lima, Peru. Am J Trop Med Hyg 2020;103(5):1827–1833.

105. Donovan J, Oanh PKN, Dobbs N, Phu NH, Nghia HDT, Summers D, Thuong NTT, Thwaites GE; Vietnam ICU Translational Applications Laboratory (VITAL) Investigators. Optic nerve sheath ultrasound for the detection and monitoring of raised intracranial pressure in tuberculous meningitis. Clin Infect Dis 2021;73(9).

106. Bobbio F, Di Gennaro F, Marotta C, Kok J, Akec G, Norbis L, Saracino A, Mazzucco W, Lunardi M. Focused ultrasound to diagnose HIV-associated tuberculosis (FASH) in the extremely resource-limited setting of South Sudan: A cross-sectional study. BMJ Open 2019;9(4).

107. Heller T, Wallrauch C, Goblirsch S, Brunetti E. Focused assessment with sonography for HIV-associated tuberculosis (FASH): A short protocol and a pictorial review. Crit Ultrasound J 2012;4(1):21.

108. Luntsi G, Ugwu AC, Ahmadu MS, Ohagwu CC, Sidi M, Ochie K, Mshelia EP, Erim AE, Abubakar U, Nkubli FB, Nwobi CI, Ayogu E. Routine ultrasonography for intensified tuberculosis case finding in high HIV and TB burdened countries: A proposed framework. J Med Ultrasound 2022;30(4):245–250.

109. Huson MAM, Kumwenda T, Gumulira J, Rambiki E, Wallrauch C, Heller T. Ultrasound findings in Kaposi sarcoma patients: Overlapping sonographic features with disseminated tuberculosis. Ultrasound J 2023;15(1):27.

110. Netherton S, Milenkovic V, Taylor M, Davis PJ. Diagnostic accuracy of eFAST in the trauma patient: A systematic review and meta -analysis. CJEM 2019;21(6):727–738.

111. Huson M, Rokx C. Exploring the role of point-of-care ultrasound for people with HIV in a resource-affluent setting: A prospective observational study. Int J STD AIDS 2023;34(13):984–989.

112. Waheed S, Atta MG. Predictors of HIV-associated nephropathy. Expert Rev Anti Infect Ther 2014;12(5):555–563.

113. Sud K, Argulian E. Echocardiography in patients with HIV infection. Curr Cardiol Rep 2020;22(9):100.

114. Vululi ST, Bugeza S, Zeridah M, Ddungu H, Openy AB, Frank M, Parkes-Ratanshi R. Prevalence of lower limb deep venous thrombosis among adult HIV-positive patients attending an outpatient clinic at Mulago Hospital. AIDS Res Ther 2018;15(1):3.

115. Marggrander DT, Koç-Günel S, Tekeli-Camcı N, Martin S, Golbach R, Wolf T. Lung ultrasound effectively detects HIV-associated interstitial pulmonary disease. Int J Infect Dis 2021;111:204–210.

116. Salim I, Staines-Urias E, Mathewlynn S, Drukker L, Vatish M, Impey L. The impact of a routine late third trimester growth scan on the incidence, diagnosis, and management of breech presentation in Oxfordshire, UK: A cohort study. PLoS Med. 2021 Jan 15;18 (1):e1003503. doi: 10.1371/journal.pmed.1003503

117. Ekéus C, Norman M, Åberg K, Winberg S, Stolt K, Aronsson A. Vaginal breech delivery at term and neonatal morbidity and mortality—a population-based cohort study in Sweden. J Matern Fetal Neonatal Med. 2019;32(2):265-270. doi: 10.1080/14767058.2017.1378328. PMID: 28889774.

118. Luterkort M, Polberger S, Persson PH, Bjerre I. Role of asphyxia and slow intrauterine growth in morbidity among breech delivered infants. Early Hum Dev. 1986 Jul;14(1):19-31. doi: 10.1016/0378-3782 (86)90166-0

NOV 2026 vol. 11 iss. 02 | POCUS J | 58

Show Me My Heart

Jessica Y. Chambers, MD MPH FHM FACP

Dell Medical School, University of Texas at Austin, Austin, TX, USA

Despite being an internist who primarily cares for adults, I find myself in the pediatric ward at Moi Teaching and Referral Hospital in Eldoret, Kenya. It's late afternoon, and the hottest part of the day is contributing to an increasing burden of sweat under my N95 mask. The windows are propped open for what little airflow can make its way into the humid halls. Rhythmic voices are communicating in Kiswahili and English around us. A row of metal-framed beds line the open bay, and on each one a child rests in some shade of stillness—a toddler with a saline drip taped to a tiny hand, a school-aged boy curled toward his mother under a black and white cow print blanket, a girl colouring in an octopus while her grandmother fans them both with a magazine.

Moi recently received a grant for portable ultrasound devices. The faculty has started using them, and a formal point of care ultrasound (POCUS) curriculum for the medical students and registrars (the Kenyan counterpart of North American residents) is being built but has not yet launched. I have brought my own personal probe. So, when word reaches the pediatric registrars and medical students that a visiting internist is around with both a handheld probe and a few weeks of unhurried time, we find each other on the ward. We don't necessarily find each other as instructors and trainees, but as colleagues in different parts of our POCUS learning journeys. I have spent more hours, thus far, with a probe in my hand. But they know the patients, the language, the families, and the wards I am a guest in. We started scanning together.

I pull out my handheld probe, set up my tablet screen, and uncap the bottle of gel. The mother of a young boy nods through our interpreter—yes, please, please show him his heart.

I kneel on the bed beside him. Through the interpreter, I tell him I am going to put a little jelly on his chest, that it will not hurt, and that we will all see his own heart on the screen. I hold the probe between two fingers up against his ribcage, gently angling towards the apex of his heart. A four-chambered view blooms readily onto the display—the steady hush of his ventricles, the leaflets opening and closing like butterfly wings. His eyes grow enormous. His mother's hand, which had been resting on his ankle, drifts up to her own collarbone.

I do not speak Kiswahili. I know jambo and asante sana and almost nothing else. But the boy looks at me and grins a mile-wide smile, and I cannot help but sink into that simple joy. I smile too, communicating back in a way that transcends the boundaries of language. I spent time earlier that day trying to nail down common medical terms, diseases, and organs in Kiswahili. The word for "heart" was proving difficult to recall back up to the front of my mind. "Ah-ha! I got it," I say as I stand. I point to the currently beating heart and say, with full confidence, "MOJO!" Most of the kids laugh, automatically recognizing my mistake. The word I was looking for is "moyo," the Kiswahili word for "heart."

While the registrars take turns obtaining different views of the boy's heart, the child in the next bed begins to shift and shuffle, craning her neck to see the screen. A girl, no more than five or six years old, with her hair styled in mini ponytails, is very intrigued by what we are doing to her friend. The girl has a shy smile emerging across her face. She looks up to her mom and says something in Kiswahili, and then her eyes, also now smiling, return down to the screen. I know that look well, the look of wonderment. She is grinning because she recognizes the unmistakable rhythm of a beating heart.

She crawls to the edge of her bed and points at the screen, drawing our attention. She points with gusto, with decisiveness. And then, she points at her own chest. Me too.

The boy beside her sees her, and his hand shoots up. Then the boy in the next bed. Then the girl across the aisle. One by one, small hands rise into the warm air, and small fingers point insistently at small chests. Me. Me. Me. The mothers are laughing and looking between one another, then at us, eyebrows up in question. The registrars look at me. I look at the interpreter. The interpreter speaks to all of the mothers. One by one, the mothers nod.

So we go down the line.

*Corresponding Author: Dr. Jessica Y. Chambers (email: jessica.chambers@austin.utexas.edu)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20984

One of the medical students, Kezia, takes her turn with the probe, naming the structures aloud as she finds them. She points out the chambers, vessels, and valves in English, and pauses expectantly with a grin as we await the echoing responses from the children repeating the structures back out loud with us in a sing-song way. We warm gel in our hands and press the probe to one chest after another, always with a parent's nod first. Each child watches their own heart move across the screen with the same expression: the held breath, the slow widening of the eyes, the small involuntary smile that is the same in every language I have ever encountered. One boy cannot stop giggling, secondary to either the gentle rocking of the probe or the situation or both. At the end he quietly notes, "I am really ticklish." But Kezia assures him his bravery against said tickle monster is of the finest quality she has ever seen.

One of the older girls asks if she can join the next teaching session because she wants to be a nurse one day, just like her mom—so we bring her in on the one we're doing right now. Another imaginative young boy queries me, with great seriousness in his eyes, and leans over to my ear to whisper his crucial question: can the probe see his deepest, darkest secrets? He is quite relieved as we disclose that our probe lacks that particular feature. One enthusiastic tween girl says she can bedazzle my probe for me with glitter and gemstones because "girls all over the world deserve pretty things!" (I still regret not taking her up on her offer). Each of these detours is delightfully unexpected given my usual experience providing ultrasound on adults—and adults, so often, have forgotten how to delight in the ordinary the way children can.

Looking back, we were not changing management. We were not, in most cases, finding pathology. The registrars and I had come to practice cardiac windows, lung sliding, and hepatorenal recesses—the diagnostic grammar of POCUS we were each still learning. But what those children taught us in the space of ninety minutes was something the didactics had not prepared us for; curiosity is universal, and so is wonder. When we hand a child the chance to see themselves, they reach for it with both hands.

I carried that afternoon home with me. When I teach now, back home in Austin and in the messages I still trade with the registrars in Eldoret, I tell trainees that the ultrasound probe is not only a diagnostic tool. It is also an invitation. It says to a patient, in any language: "Come closer. Let us look together. This is your heart."

So, I think back to the pale-yellow walls of Moi. The roomful of souls in various stages of life and healing. The girl colouring in an octopus with a range of colours not found in nature, but vivid in the imagination. Protective, loving mothers who, one by one, said yes. Small hands raised, pointing at small chests. And I cannot help but smile when I think, "Mine, too!"

Acknowledgements

The author would like to acknowledge Clarissa Johnston, MD, Joseph Oti-Nimoh, MD, Lauren Contreras, MD and Paige Bowman, MD for their collaboration in reciprocal POCUS learning in the Kenyan teaching hospital setting.

Ethics Statement

No confidential or personal patient information is included in this piece. There is no human subject research requiring IRB or ethical approval.

Disclosure Statement

The author has no conflicts of interest.

Funding

The author has no financial disclosures.

NOV 2026 vol. 11 iss. 02 | POCUS J | 60

Nurse-Validated Handheld POCUS Artificial Intelligence (AI) for Automated Prostate Volume Estimation and Hydronephrosis Detection

Masaru Matsumoto, PhD RN[1,2]*; Motofumi Suzuki, PhD MD[3]; Mikihiko Karube, M.Eng[2]; Hiroaki Gotoh, MPharm MT RMS[4]; Masaya Sato, PhD MD[5]; Tamaki Kobayashi, PhD MT RMS[4]; Minoru Masuda, MHS RN[6,7]; Sanae Wakita, RN[6]; Atsuo Kawamoto, PhD RT RMS[8]; Yuka Miura, PhD RN[2,9]; Nao Tamai, PhD RN[2,10,11]; Hiromi Sanada, PhD RN CWOCN[7,11,12]

(1) Department of Well-being Nursing, Graduate School of Nursing, Ishikawa Prefectural Nursing University, Kahoku, Ishikawa, Japan
(2) Former Department of Imaging Nursing Science, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan
(3) Department of Urology, Mishima General Hospital, Mishima, Shizuoka, Japan
(4) Department of Clinical Laboratory Medicine, The University of Tokyo Hospital, Tokyo, Japan
(5) Department of Clinical Laboratory Medicine, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan
(6) Former Department of Nursing, The University of Tokyo Hospital, Tokyo, Japan
(7) Department of Gerontological Nursing/Wound Care Management, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan
(8) Division of Ultrasound and Department of Diagnostic Imaging, Tokyo Medical University Hospital, Tokyo, Japan
(9) Research Center for Implementation Nursing Science Initiative, Fujita Health University, Toyoake, Aichi, Japan
(10) Department of Nursing, Graduate School of Medicine, Yokohama City University, Yokohama, Kanagawa, Japan
(11) Former Global Nursing Research Center, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan
(12) Ishikawa Prefectural Nursing University, Kahoku, Ishikawa, Japan

Abstract

Background: Artificial intelligence (AI) can detect hydronephrosis and estimate prostate volume on ultrasound, but most systems rely on expert-acquired images from conventional console ultrasound systems. We developed an on-device AI model for handheld point-of-care ultrasound (POCUS) and prospectively evaluated it on nurse-acquired scans for bedside triage/decision support. **Methods**: The model was trained using retrospective console images (101 renal and 100 prostate cases) and prospective POCUS development clips (44 renal and 88 prostate patients), then evaluated prospectively on ward nurse-acquired renal and suprapubic POCUS videos after brief instruction. Reference standards were blinded expert adjudication of hydronephrosis and expert planimetry for prostate volume. Primary outcomes were sensitivity/specificity for hydronephrosis detection and screening performance for severe prostate enlargement (≥50 mL). **Results**: For hydronephrosis detection, 32 evaluable patients were analyzed (one kidney per patient; prevalence 46.9%). The AI achieved a sensitivity of 93.3% (95% CI 70.2–98.8) and a specificity of 82.4% (59.0–93.8). For severe prostate enlargement (≥50 mL; n = 28), sensitivity and specificity were both 71.4%. Agreement for continuous prostate volume was moderate: ICC(A,1) = 0.789; Bland–Altman bias +5.1 mL, with 95% limits −25.0 to +35.1 mL. **Conclusions**: On nurse-acquired handheld POCUS, AI showed high sensitivity for hydronephrosis and moderate agreement for prostate-volume estimation, supporting its feasibility for triage support while requiring further validation.

Introduction

Lower urinary tract symptoms (LUTS) are common urological problems in older adults receiving home care and occur more frequently than in the general population [1]. In Japan, the need for urinary care in home settings is growing as healthcare increasingly shifts outside of hospitals. The proportion of older adults is projected to exceed 30% by 2025 and approach 40% by 2065 [2]. LUTS, encompassing storage, voiding, and post-void symptoms, can substantially impair quality of life [3,4]. Because management depends on symptom type and cause, accurate characterization is essential [5]. When bladder emptying fails and urine remains undrained for prolonged periods, complications such as acute retention, upper urinary tract dilatation and urinary tract infection may ensue [6,7]. In home care, early recognition by visiting nurses is critical for preventing disease progression.

*Corresponding Author: Dr. Masaru Matsumoto (email: matumoto@ishikawa-nu.ac.jp)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20395

POCUS has expanded nurses' ability to assess LUTS at the bedside, especially with the development of handheld systems that are portable, inexpensive, and readily available. Current guidelines recommend measuring postvoid residual urine volume to screen for voiding dysfunction, typically using a threshold of approximately 100 mL [8,9]. Handheld devices can quantify small bladder volumes, including with automated measurement functions. Nursing education programs for handheld POCUS are being developed [10,11].

However, bladder-only imaging cannot determine the etiology or severity. It does not establish whether outlet obstruction from prostate enlargement is present, nor whether stasis has propagated upstream to the kidneys, causing hydronephrosis. Patients benefit from a multiorgan view that includes the bladder, prostate, and kidneys for clinical decision-making, triage, catheter management, and referral. An algorithmic approach using POCUS to measure bladder volume while also assessing prostatic hypertrophy and hydronephrosis has been proposed to support timely selection of voiding care in home care settings [10]. However, consistent image interpretation requires training and time.

Artificial intelligence (AI) has shown promise for refining and streamlining interpretation of urological health metrics, including hydronephrosis detection and automatic prostate-volume (PV) estimation. However, most prior studies used console ultrasound systems with expert-acquired images, focused on single-organ tasks, and provided limited evidence for generalizability to nurse-acquired handheld scans in real-world settings [11–13]. Although AI-based hydronephrosis detection and deep-learning frameworks for prostate-volume estimation have been reported, integrated prostate-kidney assessment on handheld platforms evaluated using nurse-acquired images remains largely unreported [13–17].

To address this gap, we developed an AI system purpose-built for handheld POCUS and prospectively evaluated it using nurse-acquired scans after brief instruction. Our objectives were to (i) determine diagnostic performance for kidney-level hydronephrosis detection and (ii) assess agreement with an expert reference for patient-level PV estimation, including a prespecified ≥50 mL triage flag, in routine bedside practice.

Methods

Study design and setting

We conducted a diagnostic accuracy study using a development–validation sequence at a national university hospital in Japan. Phase 1 consisted of image collection, annotation, and algorithm development, while Phase 2 was a prospective clinical evaluation of nurse-acquired handheld scans. Reporting follows key STARD items where applicable [18].

Participants and sampling (evaluation cohort)

During the evaluation phase, consecutive adult inpatients in the urology ward were prospectively enrolled between April and September 2021. Eligible patients had a clinical indication for bedside renal and/or prostate ultrasound and were able to undergo POCUS scanning. Patients who could not provide consent or whose scans were non-diagnostic because of inadequate acoustic windows were excluded. Ward nurses with limited prior ultrasound experience performed all scans after a 30-minute device-use lecture. A STARD-style flow diagram is shown in Figure 1.

Intended use and clinical role of the index test

The index test is an automated algorithm intended for handheld POCUS to support nurse-led bedside assessment. It provides two functions: hydronephrosis detection (present/absent), and prostate volume estimation with severity classification, labelling severe enlargement when volume is ≥50 mL. The ≥50 mL threshold was selected *a priori* to identify more pronounced prostate enlargement relevant to triage and referral decisions in nurse-led bedside assessment, rather than to define any prostate enlargement. We acknowledge that lower thresholds, such as 30 mL, are commonly used to define prostate enlargement in other clinical contexts; evaluation of lower thresholds was beyond the scope of this pilot study. The intended clinical roles are triage, decision support for catheter management, and referral in home and ward settings.

Image acquisition (evaluation cohort; index test data)

Nurses acquired handheld scans using a wireless POCUS device with a convex probe (iViz air, FUW-1; Fujifilm, Tokyo, Japan; 2–5 MHz) using the abdomen preset according to a standardized protocol. This device allows adjustment of gain and depth only; these settings were optimized by each operator at the bedside. The longitudinal and transverse sweeps of both kidneys were recorded as 800 × 600-pixel videos, sampled every 12 frames (approximately 0.5 s), and resized to 512 × 384 pixels for analysis. For this pilot patient-level analysis, one kidney per patient was evaluated to avoid within-patient correlation in a small cohort; the side with the clearest acoustic window was selected. We acknowledge below that this selection may introduce bias compared with bilateral screening. Kidneys with indeterminate views were excluded, as specified. For the prostate, suprapubic transverse and sagittal views were obtained with the bladder filled when feasible; however, bladder volume was not standardized or systematically recorded. Videos were captured at 800 × 600 pixels, frames were sampled every 24 frames (approximately 1.0 s) and resized to 512

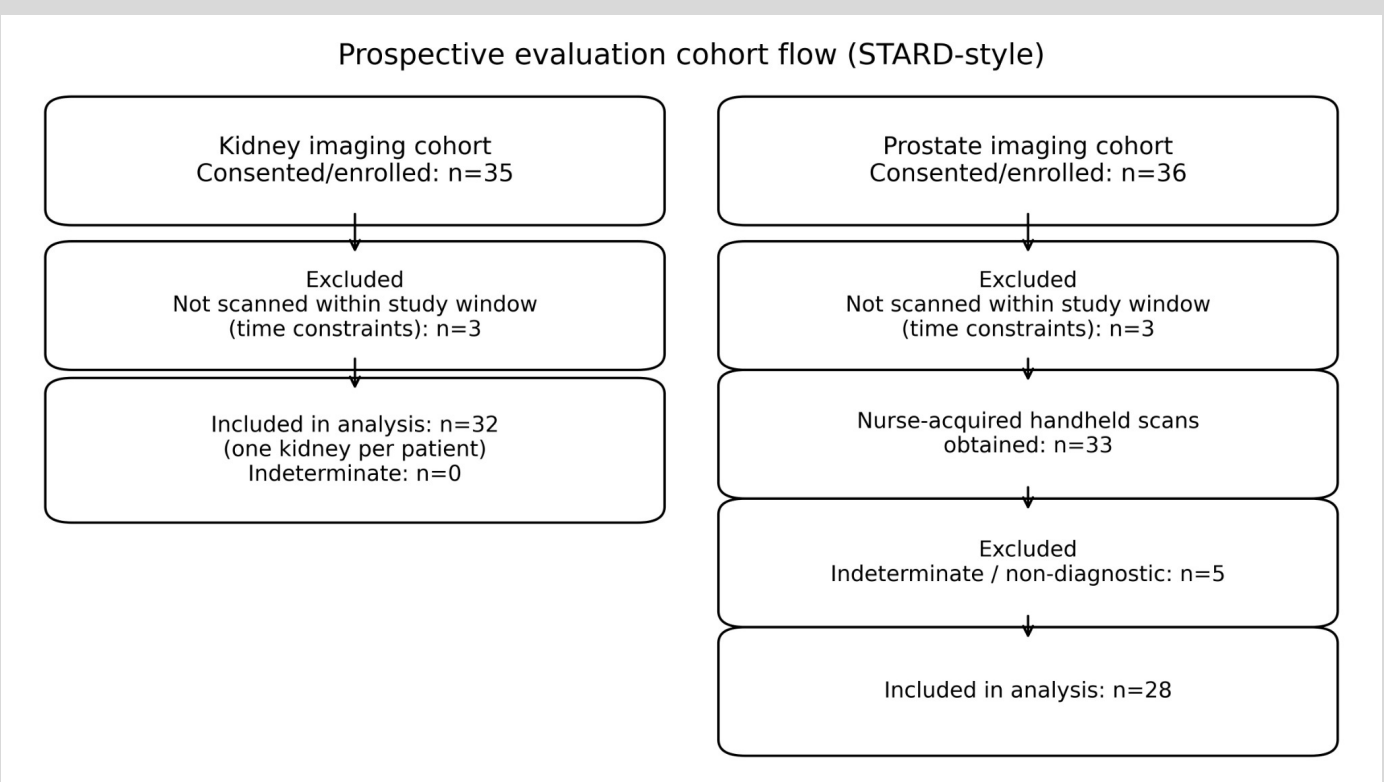


Figure 1. STARD-style flow diagram for the prospective evaluation cohort. Kidney imaging: 35 patients consented; 3 were not scanned within the study window (time constraints), and 32 were included in analysis (indeterminate = 0). Prostate imaging: 36 patients consented; 3 were not scanned within the study window, 33 were scanned, 5 were excluded as indeterminate/non-diagnostic, and 28 were included in analysis.

× 384 pixels for analysis. Operator identity and prior experience were not recorded in this analysis.

Reference standards and blinding

For hydronephrosis, a certified sonographer who was blinded to all index test outputs and metadata reviewed the nurse-acquired clips. They determined the presence or absence per patient based on dilatation of the renal pelvis and calyces visualized on the handheld videos. Borderline renal pelvic fullness or mild pelviectasis was adjudicated according to the binary expert reference standard and was not modelled as a separate category. For prostate volume, the same blinded expert performed manual segmentation and planimetry on selected transverse and sagittal frames. The prostate volume was calculated using the ellipsoid formula (0.52 × width × height × length). Severe prostate enlargement was defined as ≥50 mL *a priori*. The time interval between the index and reference was zero because both were derived from off-line readings of the same acquisition. Rules for non-evaluable cases were prespecified as follows: kidneys for which hydronephrosis could not be adjudicated because of inadequate acoustic windows were classified as indeterminate and excluded from accuracy estimates. The number of indeterminate kidneys is reported in the results section. For prostate volume, frames with inadequate anatomical delineation were discarded. If no valid orthogonal frame pair could be identified, the case was considered indeterminate and excluded from accuracy analyses. The counts of such cases are reported in the results section.

Development datasets (training only; not used for accuracy estimates)

Separate datasets were assembled at the same institution for algorithm development. Retrospective high-end conventional console ultrasound still images acquired by certified technologists included 101 hydronephrosis-positive renal still-image cases and 100 prostate still-image cases (paired transverse and sagittal views). In addition, prospective handheld development clips were collected using the same handheld device as the evaluation cohort (iViz air) from consenting patients. The kidney handheld dataset comprised 44 patients with both kidneys scanned (88 clips, 10 s each; 20 hydronephrosis-positive and 68 negative). Thus, the retrospective console renal data and handheld renal data were different data units (still-image cases versus video clips sampled into frames) and should not be interpreted as 121 hydronephrosis-positive clips. The prostate handheld dataset comprised 88 patients (10 s suprapubic clips). For handheld development clips, still frames were

extracted at 12 frames/s for annotation and training; the training sets used 3,341 kidney frames and 7,420 prostate frames. Development data were split at the case/patient level into training and validation sets (kidney: 128/17; prostate: 167/21). The prospective nurse-acquired evaluation cohort served as an independent test set (kidney: 32 patients; prostate: 28 patients). Details of dataset sources and case/patient-level splits are summarized in Table 1. These developmental data were used solely for training and tuning. All accuracy estimates in this study were derived from prospectively collected nurse-acquired handheld scans in the ward.

Annotation for development

A single certified sonographer blinded to the clinical information and index test outputs annotated the training data using LabelMe (open-source Python/Qt implementation by Kentaro Wada; exact software version was not retained in the study records). For handheld videos, frames were extracted at 12 frames per second to generate still images and representative frames were selected for polygon annotation. For kidneys, polygonal regions of interest delineated the entire kidney and the anechoic intrapelvicalyceal urine. Frames were sampled every 0.5 s. For the prostate, polygons outlined the prostate and bladder on both transverse and sagittal frames. Frames were sampled every 1.0 s. Annotations were exported as JSON and converted to pixel-wise binary masks at the native resolution for model training. Figure 2 shows representative examples of training data.

Algorithm and implementation

We implemented a frame-level semantic segmentation network comprising a U-Net decoder and a ResNeXt-50 encoder pretrained on natural image data [19]. Data augmentation consisted of random brightness, contrast, sharpness changes, horizontal flips, and random erasing. The inputs were resized to 512 × 384 pixels, while preserving the aspect ratio. Training used the Adam optimizer with an initial learning rate of 1×10^{-5} for 100 epochs, was implemented in Keras, and ran on a single NVIDIA GTX 1080 Ti GPU.

Table 1. Composition of development and evaluation datasets (Phase 1 and Phase 2). Phase 1 development sources: kidney—101 hydronephrosis-positive high-end conventional console still-image cases (retrospective) and 44 handheld cases with both kidneys scanned (88 video clips, 10 s each; 20 hydronephrosis-positive and 68 negative). These retrospective console data and handheld video data represent different data units (still-image cases versus video clips sampled into frames) and were not pooled as clips. Prostate—100 high-end conventional console still-image cases with paired transverse and sagittal views (retrospective) and 88 handheld cases (10-s suprapubic clips). Handheld clips were acquired with the same handheld device as the prospective evaluation cohort. Case/patient-level split (train/validation/independent prospective test): kidney 128/17/32; prostate 167/21/28. Approximate number of frames used for training: kidney 3,341; prostate 7,420. Phase 2 prospective evaluation: kidney cohort—35 consented/enrolled, 3 not scanned within the study window, 32 included in analysis (indeterminate/non-diagnostic, 0); prostate cohort—36 consented/enrolled, 3 not scanned within the study window, 5 indeterminate/non-diagnostic, and 28 included in analysis.

Task	Split	Cases/ patients (n)	Dataset/acquisition	Notes
Hydronephrosis (kidney)	Training	128	Phase 1 development (console still images + handheld clips)	3,341 labelled frames used for training; handheld clips were converted to still frames at 12 frames/s.
Hydronephrosis (kidney)	Validation	17	Phase 1 development (console still images + handheld clips)	Used for tuning and pre-specification of operating points.
Hydronephrosis (kidney)	Prospective evaluation (test)	32	Phase 2 nurse-acquired handheld clips	One kidney per patient; indeterminate=0.
Prostate volume estimation	Training	167	Phase 1 development (console still images + handheld clips)	7,420 labelled frames used for training; handheld clips were converted to still frames at 12 frames/s.
Prostate volume estimation	Validation	21	Phase 1 development (console still images + handheld clips)	Used for tuning and pre-specification of operating points.
Prostate volume estimation	Prospective evaluation (test)	28	Phase 2 nurse-acquired handheld clips	Excluded indeterminate = 5 (non-diagnostic).

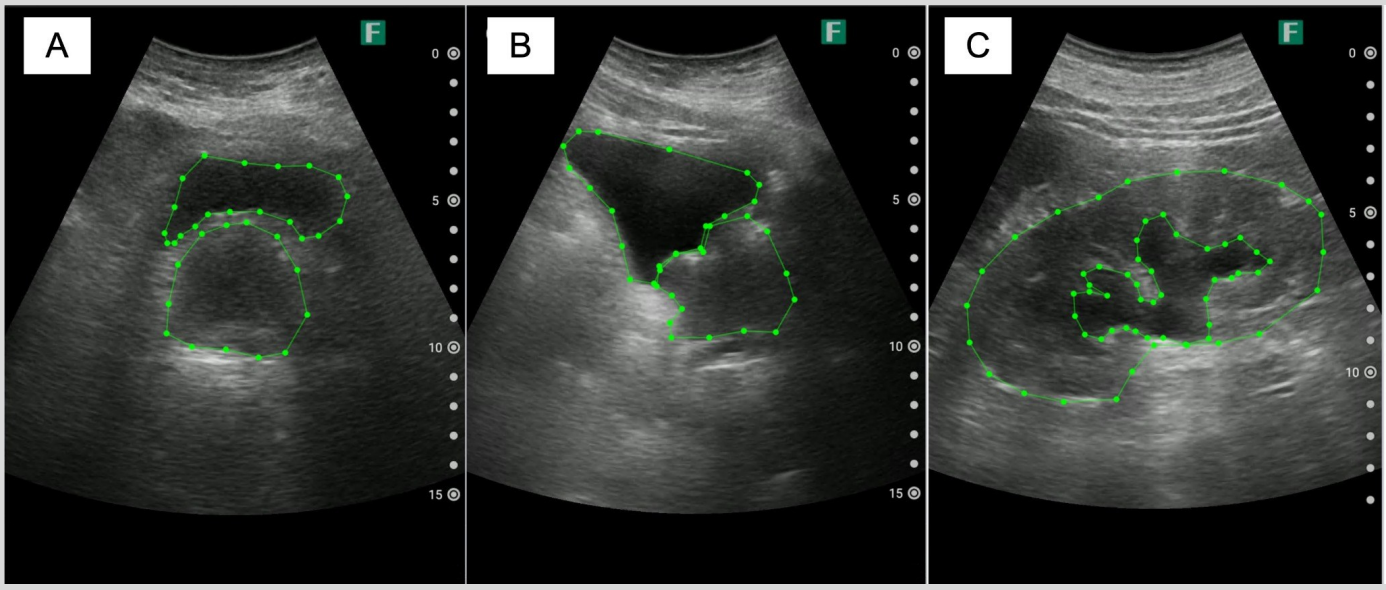


Figure 2. Training annotations for prostate and kidney on handheld ultrasound. (A) Transverse suprapubic view of the prostate. Polygonal overlays drawn in LabelMe delineate the prostate gland. The bladder lumen is additionally contoured to clarify the prostate–bladder interface during labelling. (B) Sagittal suprapubic view of the prostate using the same scheme, with separate polygons for prostate and bladder to maintain anatomical separation across planes. (C) Renal section. Polygons outline the entire kidney and the anechoic renal pelvic urine collection corresponding to hydronephrosis. All annotations were created as polygon regions of interest in LabelMe and exported as binary masks for supervised training of the segmentation model. Images are representative frames sampled from nurse-acquired handheld video clips according to the study protocol. Colored overlays are illustrative only. Model training used the underlying pixel-wise masks.

Post-processing and case-level aggregation

For hydronephrosis, the model produced a probability mask for intrarenal urine within each frame. A kidney was classified as positive if any frame within its clip exceeded a prespecified probability or area threshold determined on a held-out development set. Otherwise, it was classified as negative. The current implementation was designed for binary hydronephrosis detection and did not separately classify mild pelviectasis/renal pelvic fullness from clinically significant hydronephrosis. Prostate volume, width, anteroposterior height, and length were extracted from the segmented transverse and sagittal frames. The per-patient volume was computed using the ellipsoid formula. The per-patient volume was defined as the median value across valid frame pairs within a study. The ≥50 mL threshold for severe enlargement of the prostate and the frame-selection rule were fixed before clinical evaluation.

Outcomes

Primary outcomes at the prespecified operating points were sensitivity and specificity for hydronephrosis detection on a per-patient basis and sensitivity, specificity, and overall accuracy for severe prostate enlargement (≥50 mL) on a per-patient basis. The secondary outcome was agreement for continuous prostate volume (ICC(A,1), Bland–Altman, Pearson's r).

Statistical analysis

Participant characteristics were summarized at the patient level. Diagnostic accuracy was calculated for each patient with hydronephrosis and each patient with prostate outcomes. Sensitivity, specificity, positive predictive value, negative predictive value, and 95% confidence intervals (CIs) were reported using the Wilson method. For continuous prostate volume, agreement between the index test and the reference was quantified using the intraclass correlation coefficient (ICC(A,1)), a two-way mixed-effects, absolute-agreement, single-measure model in which subjects were treated as random and the two raters (AI and the reference reader) as fixed. This reflected how closely a single AI measurement reproduced the reference on the same subject and penalized both constant bias and scale differences. The 95% CI for the ICC was obtained via percentile bootstrapping with 1,000 resamples. Correlations were summarized using Pearson's r with 95% CIs derived from Fisher's z transformation, and Bland–Altman analysis reported bias and 95% limits of agreement. Missing or indeterminate results were handled according to the prespecified rules described in the methods section. No formal *a priori* sample size calculation was performed. The evaluation was

conceived as a pilot technical and implementation study to assess prespecified operating points chosen in the held-out development data. Therefore, the primary analysis reports fixed-threshold diagnostic accuracy rather than ROC-optimized thresholds; ROC analyses were not undertaken in this pilot report and should be incorporated into larger validation studies.

Results

Thirty-five patients were enrolled for kidney imaging. After consent was obtained, three patients could not be scanned within the study window due to time constraints and were excluded. Of the remaining 32 patients with complete baseline data, the mean age was 71.8 ± 10.7 years (median, 74.0; interquartile range (IQR), 69.8–79.0) and the mean body mass index (BMI) was 23.0 ± 3.3 kg/m² (median, 23.4; IQR, 21.1–24.7). In the primary diagnosis category, genitourinary conditions accounted for 18/32 (56.3%) cases, and neoplasms accounted for 14/32 (43.7%) cases. No kidneys were classified as indeterminate (non-diagnostic) in the evaluable cohort.

The reference prevalence of hydronephrosis was 46.9% (15/32 patients). At the prespecified operating point, the index test achieved sensitivity 93.3% (95% CI, 70.2–98.8), specificity 82.4% (95% CI, 59.0–93.8), PPV 82.4% (95% CI, 59.0–93.8), negative predictive value (NPV) 93.3% (95% CI, 70.2–98.8), and overall accuracy 87.5% (95% CI, 71.9–95.0). Representative qualitative examples are shown in Figure 3. The corresponding 2 × 2 contingency table is shown in Table 2.

A total of 36 patients were enrolled for prostate imaging. After providing consent, three patients could not be scanned within the study window because of time constraints and were excluded. Nurse-acquired POCUS was obtained in 33 patients, of whom five (15.2% of scanned patients) were excluded due to complete or partial absence of the AI-estimated prostate area, non-detection of the bladder region, or frames unsuitable for reference planimetry.

Twenty-eight men were included in the prostate analysis. Mean age was 71.9 ± 8.2 years (median, 72.5; IQR, 67.2–78.0). Mean BMI was 22.8 ± 3.0 kg/m² (median, 22.4; IQR, 21.0–24.0). In the primary diagnosis category, neoplasms accounted for 16/28 (57.1%) patients, genitourinary conditions for 9/28 (32.1%), and other conditions for 3/28 (10.7%). Within the neoplasm category, eight patients were evaluated for suspected malignancy, and one had a testicular tumour.

In the per-patient prostate analysis, 28 paired measurements of the reference and AI-estimated volumes were available. Using the prespecified threshold of ≥50 mL to define severe prostate enlargement, the prevalence by reference was 25.0% (7/28). At this operating point, the AI achieved sensitivity 71.4% (95% CI, 35.9–91.8), specificity 71.4% (95% CI, 50.0–86.2), positive predictive value 45.5% (95% CI, 21.3–72.0), negative predictive value 88.2% (95% CI, 65.7–96.7), and overall accuracy 71.4% (95% CI, 52.9–84.7). The corresponding 2 × 2 table is shown in Table 3.

The agreement with the reference was ICC(A,1) = 0.789, indicating moderate absolute agreement between a single AI measurement and the expert reference. The correlation coefficient was Pearson's r = 0.821 (95% CI: 0.647–0.914) (Figure 4). Bland–Altman analysis showed a mean bias of +5.1 mL (AI minus reference) and relatively wide 95% limits of agreement from −25.0 to

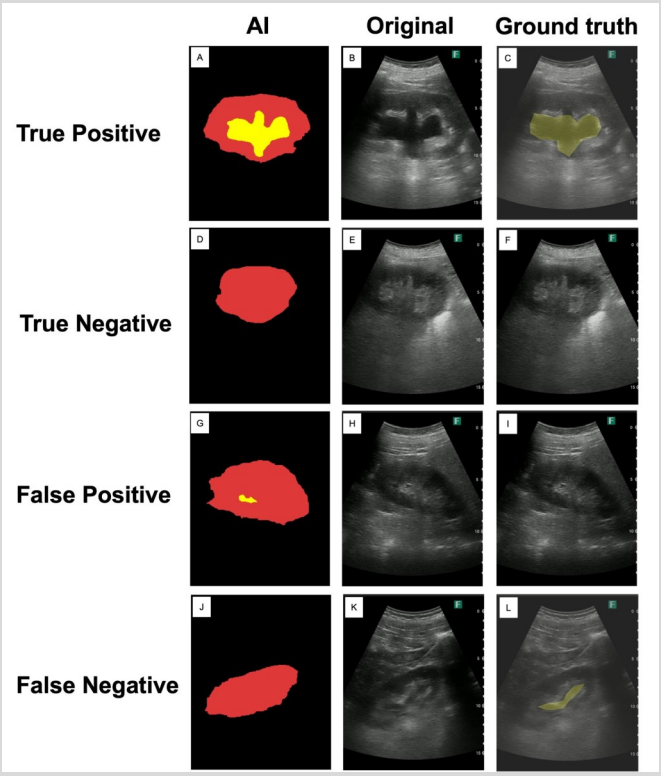


Figure 3. Qualitative outcomes of AI hydronephrosis detection on handheld ultrasound. Panels are arranged by rows (case outcome) and columns (from left to right: AI mask, original ultrasound, ground truth). Row 1 (A–C) shows a True Positive kidney; Row 2 (D–F) a True Negative; Row 3 (G–I) a False Positive; Row 4 (J–L) a False Negative. In the AI panels (A, D, G, J), red indicates the segmented kidney and yellow indicates anechoic renal pelvic urine collection (dilatation). In the ground truth panels (C, F, I, L), the yellow polygon is the expert annotation used to derive reference labels. All examples are nurse-acquired handheld scans selected to illustrate typical success and failure modes, such as subtle dilation or poor acoustic windows. Colours are for visualization only. Classifications were computed from the underlying binary masks according to prespecified rules. AI, artificial intelligence.

+35.1 mL (Figure 5), indicating substantial individual-level variability despite acceptable group-level correlation. Representative examples of AI underestimation and overestimation of prostate volume are shown in Figure 6.

Table 2. Hydronephrosis (per patient): 2 × 2 contingency table for the index test vs reference. Evaluable patients (one kidney per patient): N = 32 (TP = 14, FP = 3, FN = 1, TN = 14). The sensitivity, specificity, PPV, and NPV were reported with 95% confidence intervals (Wilson method).

		Reference	
		+ (present)	− (absent)
AI	+ (present)	14	3
	− (absent)	1	14

Table 3. Severe prostate enlargement (≥50 mL): per patient contingency table for the index test vs reference. AI positive was defined as AI-estimated prostate volume ≥50 mL; reference positive was defined as manual planimetry (ellipsoid formula) ≥50 mL. Sensitivity, specificity, positive predictive value, and negative predictive value were reported with 95% CIs calculated using the Wilson method. AI, artificial intelligence; CI, confidence interval.

		Reference	
		≥50 mL	<50 mL
AI	≥50 mL	5	6
	<50 mL	2	15

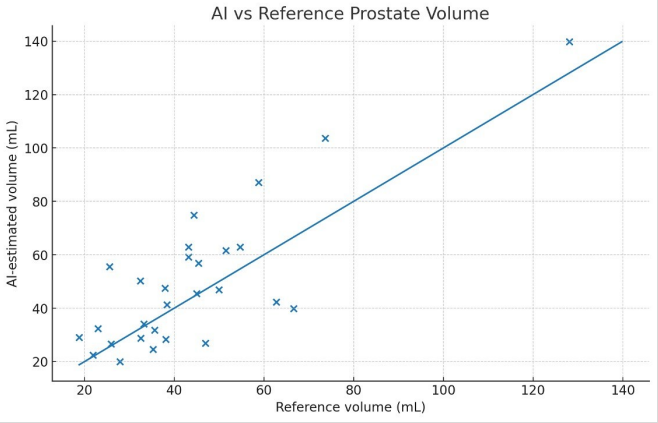


Figure 4. AI-estimated vs reference prostate volume (per patient). Scatterplot of AI-estimated versus reference prostate volume; the diagonal line represents y = x (perfect agreement). Pearson's r = 0.821 (95% CI, 0.65–0.91). CI, confidence interval; AI, artificial intelligence.

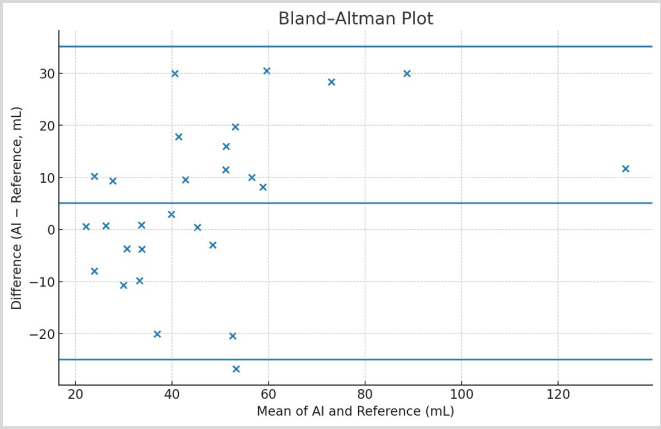


Figure 5. Bland–Altman plot for prostate volume (per patient). Differences (AI − reference, mL) are plotted against the mean volume (mL). The middle horizontal line indicates the mean bias (+5.1 mL), and the upper and lower horizontal lines indicate the 95% limits of agreement (−25.0 to +35.1 mL; bias ± 1.96 SD). ICC (A,1) = 0.789 (two-way mixed-effects, absolute-agreement, single-measure). ICC, intraclass correlation coefficient; SD, standard deviation; AI, artificial intelligence.

Discussion

In this pilot diagnostic accuracy study, we developed an AI system tailored to handheld POCUS and evaluated it using nurse-acquired scans. The model showed high sensitivity with acceptable specificity for hydronephrosis detection. For prostate volume, the model showed moderate agreement with the expert reference and may have potential as a triage-support tool, but individual-level errors were substantial, as reflected by the wide Bland–Altman limits of agreement.

Our focus on nurse acquisition aligns with prior work showing that nurses can be trained to obtain urological ultrasound and integrate the results into care pathways in home and ward settings [10]. Integrative reviews indicate that registered nurses and nurse practitioners can reliably perform POCUS with appropriate training, supporting an expanded imaging role at the bedside [20]. Quality improvement and implementation reports of nurse-performed bladder ultrasound demonstrate its feasibility and perceived efficiency gains in routine care [21]. Nurse-led LUTS clinics have reduced specialist workloads without compromising safety [22]. Beyond feasibility, bladder scanners have been associated with fewer unnecessary catheterizations and reduced catheter-associated urinary tract infection (UTI), highlighting the tangible patient benefits of nurse-integrated ultrasound workflows [23].

The novelty of our contribution lies in the prospective evaluation of AI on handheld (pocket) POCUS using

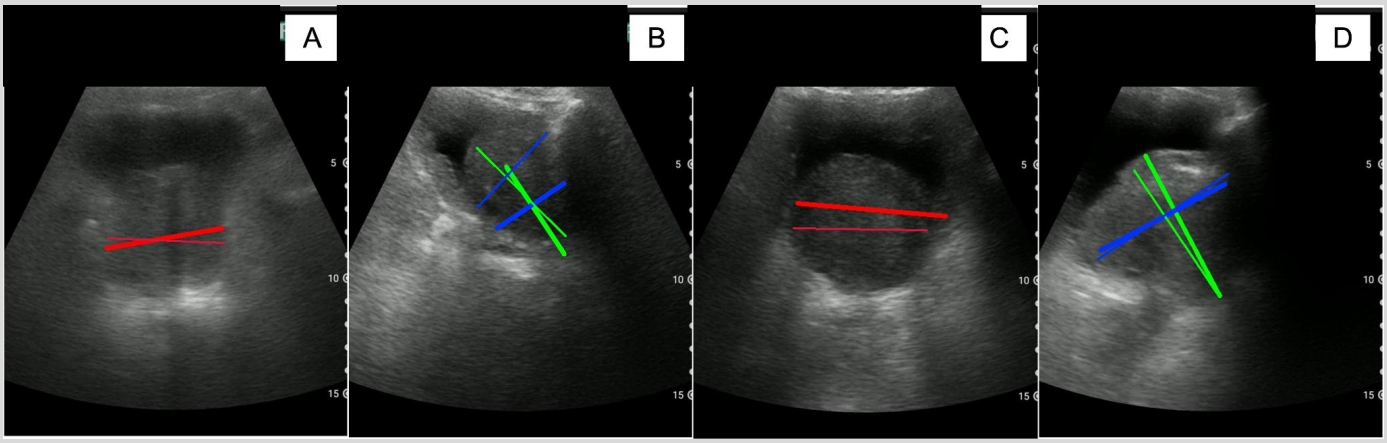


Figure 6. Examples of AI under- and overestimation of prostate volume on handheld ultrasound. Four nurse-acquired suprapubic ultrasound images illustrate discrepancies between AI-estimated and reference prostate volume. (A–B) Underestimation by AI relative to the expert reference; (C–D) overestimation. (A, C) Transverse views with red lines indicating left–right width; (B, D) sagittal views with blue lines indicating anteroposterior depth and green lines indicating cranio-caudal length. Thick colored lines indicate AI-estimated diameters, whereas thin colored lines indicate expert reference measurements. AI, artificial intelligence.

nurse-acquired clips after brief instruction, thereby testing the system under the image-quality and operator-variability constraints inherent to point-of-care nursing workflows. By prespecifying operating points aligned to triage/decision support, our approach emphasizes practical deployment. Overall, this extends prior AI efforts—largely console-based or expert-acquired—and provides nurse-validated evidence.

This clinical context supports our choice of the operating point for hydronephrosis. In non-expert hands, POCUS typically yields moderate sensitivity and specificity compared to computed tomography (CT) (often approximately 70–80% each) [24–26]. A randomized trial showed that ultrasound-first imaging can reduce radiation exposure for suspected nephrolithiasis without worsening safety outcomes. However, the performance varies with operator experience and case severity [26]. Against this backdrop, our high sensitivity and correspondingly high NPV at a fixed threshold support a rule-out role in nurse-led workflows. When the AI output is negative, clinically important dilatation is unlikely, permitting de-escalation or alternative diagnoses while reserving confirmatory imaging for positive or equivocal cases [24–26].

For the prostate, conventional ellipsoid formulas are convenient yet can systematically misestimate true gland size. Contemporary series against surgical or advanced imaging references report underestimation with the standard 0.52 coefficient and improved accuracy with revised coefficients or “bullet”-shape assumptions [27]. Recent comparative data indicate strong correlations between imaging-based volume and specimen volume, with magnetic resonance imaging (MRI) generally outperforming transabdominal ultrasonography (TAUS) for large glands. This highlights the challenges of ultrasound-based volumetry [28]. In this context, modern deep learning approaches to ultrasound autosegmentation have shown promising reproducibility and accuracy for prostate boundary delineation and derived volumes, offering a pathway to reduce operator dependence [29]. Consistent with these trends, our nurse-validated system showed moderate agreement with expert planimetry and modest screening performance at the prespecified ≥50 mL threshold. The wide limits of agreement and the observed under- and overestimation cases indicate that the system should be considered a triage-support aid rather than a definitive volumetric measurement method.

This study had several limitations. First, this was a single-center evaluation with a modest sample size, wide confidence intervals, and limited precision. Second, only one kidney per patient was included in the primary hydronephrosis analysis. Although this approach avoided within-patient correlation in a small pilot cohort, selecting the kidney with the clearest acoustic window may have introduced selection bias. This may overestimate performance compared with bilateral screening. Future studies should evaluate both kidneys and account for clustering within patients. Third, the model was designed for binary hydronephrosis detection and did not explicitly distinguish mild pelviectasis/renal pelvic fullness from clinically significant hydronephrosis or grade hydronephrosis severity. Future studies should evaluate severity categories such as mild, moderate, and severe hydronephrosis. Fourth, the reference for prostate volume was single-reader planimetry on the same acquisition rather than an independent modality, such as TAUS/MRI/specimen, or a multi-reader consensus. This

limits the assessment of inter-reader variability and absolute volumetric accuracy. This underscores how reference choice affects apparent bias for ellipsoid-based estimates [28,29]. Fifth, five nurse-acquired prostate studies were non-diagnostic and excluded from accuracy analyses. Although this was prespecified because a reliable reference measurement could not be obtained, excluding non-diagnostic cases may overestimate operational performance among all attempted scans. The non-diagnostic rate should therefore be considered an implementation outcome. Sixth, bladder volume was not standardized or systematically recorded. Small bladder volumes may have limited the suprapubic acoustic window and contributed to prostate volume errors. Future protocols should standardize bladder filling or incorporate minimum bladder-volume and image-quality criteria. Seventh, participants had a relatively low BMI (prostate cohort median, 22.4 kg/m²; IQR, 21.0–24.0), and generalizability to patients with obesity or more difficult acoustic windows remains uncertain. Eighth, operator factors and image quality affect usability. Although scans were acquired by ward nurses after brief instructions, operator-level metadata—such as years of experience and prior POCUS use—were not collected, and we did not stratify the diagnostic performance of individual nurses. Therefore, potential interoperator differences and learning effects could not be assessed. Finally, the development of the model mixed conventional console and handheld data from one institution. Prospective validation on nurse scans improved the ecological validity, but generalizability to other devices, settings, and nurse cohorts remains to be confirmed.

Clinically, the hydronephrosis results support bedside rule-out aids operated by nurses, complementing ultrasound-first pathways that aim to reduce radiation exposure without compromising safety [24–26]. For prostate enlargement, the results should be interpreted as feasibility evidence for triage support rather than as definitive volumetry. Shape-prior or contour-completion approaches may help estimate prostate boundaries when anatomical delineation is incomplete and may reduce non-diagnostic rates in future models. Future work should pursue multicenter, multi-device external validation in diverse nurse cohorts, bilateral kidney evaluation with clustered analyses, multi-reader references, and, where feasible, independent comparators (TAUS/MRI/specimen), evaluation of impact outcomes (time-to-decision, catheterization rates, avoidable transfers), standardized bladder filling for prostate scans, real-time acquisition coaching, and case-mix-specific threshold calibration. The broader literature suggests that nurse–AI collaboration can improve consistency and timeliness of urinary tract assessments at the point of care [16,20,30–31].

Conclusions

Our nurse-validated evidence showed that AI models can be used to detect hydronephrosis and estimate prostate volume on handheld POCUS at prespecified operating points for triage/decision-support. This advances AI ultrasound from expert, console-based contexts to nurse-operated bedside care. However, the prostate volume results should be interpreted as feasibility evidence requiring further validation because non-diagnostic scans, wide limits of agreement, and individual-level errors remain important limitations.

Acknowledgements

We sincerely thank the patients who participated in this study. We are deeply grateful to the faculty and staff of the Department of Urology, the urology ward nurses, and the Clinical Laboratory at The University of Tokyo Hospital for their invaluable support. We also thank the many colleagues and related personnel across the hospital and the Graduate School of Medicine, including former affiliates and collaborators, who contributed to patient coordination and scheduling, image acquisition, data handling, and regulatory procedures; this study would not have been possible without their collaboration.

Ethics Statement

This study was approved by the Ethics Committee of the Graduate School of Medicine, The University of Tokyo (approval nos. 2019051NI-(3) and 2020301NI-(1)). All imaging data were de-identified at acquisition and used exclusively for research purposes. The study adhered to the Declaration of Helsinki and relevant institutional guidelines. For the prospective evaluation cohort, all participants received written information and provided written informed consent prior to imaging. For the retrospective development dataset, an IRB-approved opt-out procedure was implemented. Additionally, a detailed overview of the study was posted on the institutional website, and patients were allowed to decline participation at any point in the study.

Disclosure Statement

Masaru Matsumoto, Mikihiko Karube, Nao Tamai, and Yuka Miura were affiliated with a social collaboration department that received funding from Fujifilm Corporation through the end of fiscal year 2022 (FY2022). The other authors have disclosed no competing interests.

Funding

This work was supported in part by the joint research fund from the Department of Imaging Nursing Science, Graduate School of Medicine, The University of Tokyo. This study was also partly supported by JSPS KAKENHI

Grant Number 21H03262 (Grant-in-Aid for Scientific Research (B) for M. Matsumoto). The funders had no role in the study design, data collection, analysis, decision to publish, or manuscript preparation.

Author Contributions

MaM: conceptualization; methodology; validation; formal analysis; data curation; writing – original draft; writing – review & editing; visualization; project administration. MoS: conceptualization; methodology; resources; writing – review & editing; visualization. MK: methodology; software; validation; formal analysis; data curation; writing – review & editing; visualization. HG: methodology; investigation; resources; writing – review & editing. MaS: resources; writing – review & editing. TK: investigation; writing – review & editing. MiM: investigation; writing – review & editing. SW: investigation; writing – review & editing. AK: validation; formal analysis; writing – review & editing. YM: conceptualization; writing – review & editing. NT: conceptualization; supervision; project administration; funding acquisition; writing – review & editing. HS: conceptualization; resources; supervision; funding acquisition; writing – review & editing. All authors read and approved the final manuscript.

Artificial Intelligence Statement

Generative AI tools were used for limited language editing and proofreading of sections of the abstract and main text. All authors reviewed and edited the output, take full responsibility for the content, and confirm that no generative AI tool was used to generate scientific results, analyze data, or draw conclusions.

Data Availability Statement

Availability of data and material: The clinical imaging datasets generated and/or analyzed during the current study are not publicly available and cannot be shared outside the institution due to ethics approvals and institutional policies governing patient data. Summary results are reported in the manuscript; no individual-level imaging data will be provided. The study code and trained model are not publicly available at this time because of institutional and ongoing development considerations; selected analysis details may be made available from the corresponding author upon reasonable request, subject to institutional approval.

References

1. Osuga Y, Okamura K, Ando F, Shimokata H. Prevalence of lower urinary tract symptoms in middle-aged and elderly Japanese. Geriatr Gerontol Int. 2013;13(4):1010-1017. doi:10.1111/ggi.12048.

2. Cabinet Office, Government of Japan. Annual Report on the Ageing Society: Summary 2021. 2021. Available from: https://www8.cao.go.jp/kourei/english/annualreport/index-wh.html. Accessed September 1, 2026.

3. Grzybowska ME, Wydra D. 24/7 usage of continence pads and quality of life impairment in women with urinary incontinence. Int J Clin Pract. 2019;73(8):e13267. doi:10.1111/ijcp.13267.

4. Kelleher C. Quality of life and urinary incontinence. Baillieres Best Pract Res Clin Obstet Gynaecol. 2000;14(2):363-379. doi:10.1053/beog.1999.0079.

5. Abdelmoteleb H, Jefferies ER, Drake MJ. Assessment and management of male lower urinary tract symptoms (LUTS). Int J Surg. 2016;25:164-171. doi:10.1016/j.ijsu.2015.11.043.

6. Ross SS, Forster CS, Borawski K. Urinary tract infection and neuropathic bladder. Urol Clin North Am. 2024;51(4):551-559. doi:10.1016/j.ucl.2024.06.009.

7. Zambon JP, Koslov DS, Mihai B, Badlani GH. Bladder and ureteral dysfunction leading to hydronephrosis and hydroureteronephrosis in adults. Urology. 2018;117:1-8. doi:10.1016/j.urology.2017.11.049.

8. Homma Y, Gotoh M, Kawauchi A, Kojima Y, Masumori N, Nagai A, Saitoh T, Sakai H, Takahashi S, Ukimura O, Yamanishi T, Yokoyama O, Yoshida M, Maeda K. Clinical guidelines for male lower urinary tract symptoms and benign prostatic hyperplasia. Int J Urol. 2017;24(10):716-729. doi:10.1111/iju.13401.

9. Takahashi S, Takei M, Asakura H, Gotoh M, Ishizuka O, Kato K, Koyama M, Takeyama M, Tomoe H, Yamanishi T, Yokoyama O, Yoshida M, Yoshimura Y, Yoshizawa T. Clinical Guidelines for Female Lower Urinary Tract Symptoms (second edition). Int J Urol. 2021;28(5):474-492. doi:10.1111/iju.14492.

10. Matsumoto M, Tamai N, Miura Y, Okawa Y, Yoshida M, Igawa Y, Nakagami G, Sanada H. Evaluation of a point-of-care ultrasound educational program for nurse educators. J Contin Educ Nurs. 2021;52(8):375-381. doi:10.3928/00220124-20210714-07.

11. Matsumoto M, Tsutaoka T, Yabunaka K, Handa M, Yoshida M, Nakagami G, Sanada H. Development and evaluation of automated ultrasonographic detection of bladder diameter for estimation of bladder urine volume. PLoS One. 2019;14(9):e0219916. doi:10.1371/journal.pone.0219916.

12. Matsumoto M, Tsutaoka T, Nakagami G, Tanaka S, Yoshida M, Miura Y, Sugama J, Okada S, Ohta H, Sanada H. Deep learning-based classification of rectal fecal retention and analysis of fecal properties using ultrasound images in older adult patients. Jpn J Nurs Sci. 2020;17(4):e12340. doi:10.1111/jjns.12340.

13. Natali T, Kurucz LM, Fusaglia M, Mertens LS, Ruers TJM, van Leeuwen PJ, Dashtbozorg B. Automatic prostate volume estimation in transabdominal ultrasound images. Eur J Radiol. 2025;191:112274. doi:10.1016/j.ejrad.2025.112274.

14. Albayrak NB, Akgul YS. Estimation of the prostate volume from abdominal ultrasound images by image-patch voting. Appl Sci. 2022;12(3):1390. doi:10.3390/app12031390.

15. Lien WC, Chang YC, Chou HH, Lin LC, Liu YP, Liu L, Chan YT, Kuan FS. Detecting hydronephrosis through ultrasound images using state-of-the-art deep learning models. Ultrasound Med Biol. 2023;49(3):723-733. doi:10.1016/j.ultrasmedbio.2022.10.001.

16. Alexa R, Kranz J, Kramann R, Kuppe C, Sanyal R, Hayat S, Casas Murillo LF, Hajili T, Hoffmann M, Saar M. Harnessing artificial intelligence for enhanced renal analysis: automated detection of hydronephrosis and precise kidney segmentation. Eur Urol Open Sci. 2024;62:19-25. doi:10.1016/j.euros.2024.01.017.

17. van den Kroonenberg DL, Delberghe FT, Jager A, Postema AW, Beerlage HP, Zwart W, Mischi M, Oddens JR. Development and validation of an algorithm for segmentation of the prostate and its zones from three-dimensional transrectal multiparametric ultrasound images. Eur Urol Open Sci. 2025;75:48-54. doi:10.1016/j.euros.2025.03.005.

18. Bossuyt PM, Reitsma JB, Bruns DE, Gatsonis CA, Glasziou PP, Irwig L, Lijmer JG, Moher D, Rennie D, de Vet HCW, Kressel HY, Rifai N, Golub RM, Altman DG, Hooft L, Korevaar DA, Cohen JF; STARD Group. STARD 2015: an updated list of essential items for reporting diagnostic accuracy studies. BMJ. 2015;351:h5527. doi:10.1136/bmj.h5527.

19. Xie S, Girshick R, Dollar P, Tu Z, He K. Aggregated residual transformations for deep neural networks. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR); 2017. p. 1492-1500. doi:10.1109/CVPR.2017.634.

20. Totenhofer R, Luck L, Wilkes L. Point of care ultrasound use by registered nurses and nurse practitioners in clinical practice: an integrative review. Collegian. 2021;28(4):456-463. doi:10.1016/j.colegn.2020.10.002.

21. Liptrott SJ, Saliquni A, Giau L, Pecora R, Cimino C, Lo Piccolo A, Palermo A, Vidovic B, Cheda E, Imhof S, Tolotti A, Guastamacchia I, Cavatorti S. Nurse performed bladder ultrasound: a clinical quality improvement initiative. Contemp Nurse. 2025;61(3):270-286. doi:10.1080/10376178.2024.2406350.

22. Keane KG, Inder MS, McIntyre C, Omer S, McEvoy E, Smyth LG, Casey RG, Thomas AZ, Manecksha RP, Flynn RJ. Implementation of a nurse-led lower urinary tract symptoms (LUTS) clinic reduces general urology clinic workload in a Model 4 Hospital: a pilot study in Tallaght University Hospital. Ir J Med Sci. 2021;190(3):1123-1128. doi:10.1007/s11845-020-02428-8.

23. Palese A, Buchini S, Deroma L, Barbone F. The effectiveness of the ultrasound bladder scanner in reducing urinary tract infections: a meta-analysis. J Clin Nurs. 2010;19(21-22):2970-2979. doi:10.1111/j.1365-2702.2010.03281.x.

24. Herbst MK, Rosenberg G, Daniels B, Gross CP, Singh D, Molinaro AM, Luty S, Moore CL. Effect of provider experience on clinician-performed ultrasonography for hydronephrosis in patients with suspected renal colic. Ann Emerg Med. 2014;64(3):269-276. doi:10.1016/j.annemergmed.2014.01.012.

25. Sibley S, Roth N, Scott C, Rang L, White H, Sivilotti MLA, Bruder E. Point-of-care ultrasound for the detection of hydronephrosis in emergency department patients with suspected renal colic. Ultrasound J. 2020;12(1):31. doi:10.1186/s13089-020-00178-3.

26. Smith-Bindman R, Aubin C, Bailitz J, Bengiamin RN, Camargo CA Jr, Corbo J, Dean AJ, Goldstein RB, Griffey RT, Jay GD, Kang TL, Kriesel DR, Ma OJ, Mallin M, Manson W, Melnikow J, Miglioretti DL, Miller SK, Mills LD, Miner JR, Moghadassi M, Noble VE, Press GM, Stoller ML, Valencia VE, Wang J, Wang RC, Cummings SR. Ultrasonography versus computed tomography for suspected nephrolithiasis. N Engl J Med. 2014;371(12):1100-1110. doi:10.1056/NEJMoa1404446.

27. Aprikian S, Luz M, Brimo F, Scarlata E, Hamel L, Cury FL, Tanguay S, Aprikian AG, Kassouf W, Chevalier S. Improving ultrasound-based prostate volume estimation. BMC Urol. 2019;19(1):68. doi:10.1186/s12894-019-0492-2.

28. Guo S, Zhang J, Jiao J, Li Z, Wu P, Jing Y, Qin W, Wang F, Ma S. Comparison of prostate volume measured by transabdominal ultrasound and MRI with the radical prostatectomy specimen volume: a retrospective observational study. BMC Urol. 2023;23(1):62. doi:10.1186/s12894-023-01234-5.

29. Kurucz LM, Natali T, Fusaglia M, Dashtbozorg B. Advances in deep learning methods for prostate segmentation and volume estimation in ultrasound imaging. Appl Sci. 2024;14(15):6550. doi:10.3390/app14156550.

30. Gao Y, Zeng S, Xu X, Li H, Yao S, Song K, Li X, Chen L, Tang J, Xing H, Yu Z, Zhang Q, Zeng S, Yi C, Xie H, Xiong X, Cai G, Wang Z, Wu Y, Chi J, Jiao X, Qin Y, Mao X, Chen Y, Jin X, Mo Q, Chen P, Huang Y, Shi Y, Wang J, Zhou Y, Ding S, Zhu S, Liu X, Dong X, Cheng L, Zhu L, Cheng H, Cha L, Hao Y, Jin C, Zhang L, Zhou P, Sun M, Xu Q, Chen K, Gao Z, Zhang X, Ma Y, Liu Y, Xiao L, Xu L, Peng L, Hao Z, Yang M, Wang Y, Ou H, Jia Y, Tian L, Zhang W, Jin P, Tian X, Huang L, Wang Z, Liu J, Fang T, Yan D, Cao H, Ma J, Li X, Zheng X, Lou H, Song C, Li R, Wang S, Li W, Zheng X, Chen J, Li G, Chen R, Xu C, Yu R, Wang J, Xu S, Kong B, Xie X, Ma D, Gao Q. Deep learning-enabled pelvic ultrasound images for accurate diagnosis of ovarian cancer in China: a retrospective, multicentre, diagnostic study. Lancet Digit Health. 2022;4(3):e179-e187. doi:10.1016/S2589-7500(21)00278-8.

31. Xu T, Zhang XY, Yang N, Jiang F, Chen GQ, Pan XF, Peng YX, Cui XW. A narrative review on the application of artificial intelligence in renal ultrasound. Front Oncol. 2024;13:1252630. doi:10.3389/fonc.2023.1252630.

Evaluation of AI-Enabled POCUS Versus Standard Echocardiography in Hospitalized Patients

Evan Baum, MD*; John Kugler, MD; Michelle Lo, MD; Caitlin Parmer-Chow, MD; Vishnu Nair, MD; Andre Kumar, MD MEd

Department of Medicine, Stanford University School of Medicine, Stanford, CA, USA

Background: Artificial intelligence (AI) may improve ultrasound image acquisition and interpretation, but there have been few validation studies comparing AI-enabled machines to traditional measurement workflows. In this diagnostic comparison study, we evaluated AI-enabled point of care ultrasound (POCUS) compared to standard transthoracic echocardiography (TTE) measurements. **Methods:** Hospitalized adults at a single academic center who underwent both AI POCUS and standard TTE scans within 7 days of one another were eligible for inclusion. The AI POCUS software used convolutional neural network models to estimate left ventricular ejection fraction (LVEF), right ventricular fractional area change (RVFAC), valvular regurgitation, valvular stenosis, and inferior vena cava (IVC) diameter based on standard cardiac views. Agreement between AI POCUS and TTE was assessed using weighted Cohen's κ and exploratory Bland-Altman analyses. **Results:** Seventy patients were included, with a median of 1 day (IQR 1–2 days, range 0–6 days) between AI POCUS and TTE examinations. AI POCUS demonstrated substantial agreement with TTE for LVEF (κ = 0.75, 95% CI 0.42–0.92). Agreement was lower for RVFAC (κ = -0.003), IVC diameter (κ = 0.382), aortic regurgitation (κ = 0.541), mitral regurgitation (κ = 0.438), tricuspid regurgitation (κ = 0.400), and aortic stenosis (κ = 0.086). Using a dichotomized threshold of LVEF <50% versus ≥50%, AI POCUS demonstrated 80.0% sensitivity and 88.6% specificity for detecting reduced LVEF. **Conclusions:** AI POCUS demonstrated substantial agreement with TTE for the estimation of LVEF. Agreement was lower for other echocardiographic parameters. These findings support the potential of AI POCUS for assessing left ventricular function.

Introduction

Approximately 56 million people are affected by heart failure worldwide [1,2]. Echocardiography, the gold-standard test for evaluating heart failure [3], is available in less than 7% of healthcare facilities in lower- and middle-income countries [4], contributing to delayed diagnosis and treatment for heart failure for millions worldwide [2].

Point of care ultrasound (POCUS) can help address shortages and barriers to accessing formal echocardiography [5]. POCUS differs from traditional echocardiography because the clinician obtains and interprets images in real time at the bedside, rather than a sonographer acquiring images that a cardiologist later interprets [5]. Previous randomized trials have demonstrated that POCUS can improve time to diagnosis among patients presenting with symptoms concerning for decompensated heart failure [6], while others have demonstrated improved quality of care among hospitalized patients with heart failure who received POCUS [7].

Recently, artificial intelligence (AI) algorithms have been integrated into POCUS systems, aiding in image acquisition and image quality [8–10]. AI can also aid in interpretation of both formal echocardiograms and POCUS examinations with a high degree of accuracy [11], including for measurements of left ventricular ejection fraction (LVEF) [12,13].

While there has been demonstrated utility of AI-enabled POCUS to assist with diagnosing heart failure [8–10,13], there is a critical need to further validate the accuracy of emerging AI systems in a clinical context, including their utility in categorizing disease severity compared to reference standards [14]. Notably, among all Food and Drug Administration (FDA) approvals for AI-enabled devices, fewer than 10% of the applications reported data from prospective clinical studies [15]. Validation studies are vital to improve provider and patient trust in AI and to facilitate larger systemic adoption to address current delivery limitations for heart failure [14].

The objective of this study was to assess the agreement of measurements between standard transthoracic

*Corresponding Author: Dr. Evan Baum (email: evanbaum@stanford.edu)

This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.

DOI: https://doi.org/10.24908/pocusj.v11i02.21227

echocardiography (TTE) and an AI POCUS software product that is FDA-approved and commercially available for clinical environments. We hypothesized that AI POCUS would show substantial agreement with TTE for assessments of systolic function and at least moderate agreement for assessments of valvular function.

Methods

Setting and Participants

This single-arm, prospective diagnostic comparison study included 70 adult inpatients at a single tertiary medical center in California, USA, between April and October 2025. Consecutive adult patients ≥18 years were identified from a convenience sample of individuals who were admitted to medical-surgical or step-down units and received a TTE for routine clinical care. Patients were eligible for the study if they received an AI POCUS examination within 7 days of their TTE. Patients were excluded if they had history of congenital heart disease, mechanical valve replacement, or did not receive an AI POCUS scan within 7 days of TTE. The Stanford University Institutional Review Board approved the study (IRB Protocol #77758) and waived the requirement for informed consent.

Scanning Protocol and AI Software

Comprehensive TTEs were performed by cardiac sonographers in accordance with American Society of Echocardiography (ASE) guidelines [16]. All TTEs were interpreted by a board-certified cardiologist credentialed at the medical center for echocardiography, as part of the patient's standard care. POCUS exams were performed by three expert users (EB, JK, AK) using a Philips Lumify S4-1 Phased Array probe on a Samsung tablet. For the POCUS examination, four standard views were obtained: parasternal long (PLAX), parasternal short (PSAX), apical four-chamber (A4C), and subcostal inferior vena cava (IVC). Views were obtained in both B-mode and with colour Doppler and archived.

All POCUS images were then analyzed on an AI platform, AISAP, which is an FDA-approved software application for POCUS and AI. As part of its regulatory approval, AISAP was validated on a large patient database and demonstrated high diagnostic performance in retrospective studies for classifying LVEF, right ventricular fractional area change (RVFAC), and valvular disease [17,18].

The AISAP model was internally validated using over 140,000 TTE studies acquired between 2007 and 2021 [17]. All studies adhered to ASE standards and were labelled using final clinical interpretations by board-certified cardiologists. The model was trained via supervised learning to assess severity classifications assigned by clinicians and validated on POCUS cardiac images [18].

The diagnostic model computes LVEF, RVFAC, mitral regurgitation (MR), tricuspid regurgitation (TR), aortic regurgitation (AR), aortic stenosis (AS), and IVC diameter. It does so from the following views: PLAX with and without colour Doppler over the aortic valve, PSAX at the level of the aortic valve, A4C with and without colour Doppler over the tricuspid and mitral valves, and standard subcostal IVC views. The software provides real-time feedback on acceptability of image quality. During processing, if the model determines that the views obtained do not meet sufficient diagnostic quality for interpretation, it will not provide an estimate. The model does not rely on guideline-based measurements such as proximal isovelocity surface area (PISA), vena contracta width, or effective regurgitant orifice area (EROA) for valvular assessments. Instead, it infers severity based on learned visual patterns and assigns a probability to each severity class (none, mild, moderate, severe) and selects the most likely category [18]. A full description of the model is available in the Supplementary Materials.

Statistical Analysis

Results from AISAP and TTE reports were classified using predefined categories. LVEF was classified into four categories based on the American Heart Association (AHA) guidelines for heart failure: ≥50%, 41–49%, 26–40%, and ≤25% [3,19]. Notably, the ≤25% cutoff for LVEF is based on the 2024 AHA imaging guidelines [19]. RVFAC was categorized based on the 2025 ASE guidelines: >35%, 30–35%, 23–29%, and ≤22% [20]. Valvular abnormalities, including MR, TR, AR, and AS were assigned based on AHA classifications of valvular disease: none to trace, mild to moderate, moderate to severe, and severe [21]. IVC diameter was categorized as ≤2.1 cm or >2.1 cm based on ASE guidelines [16,20]. Measurements not available or not reported by either the AISAP software or the TTE report were noted and excluded from statistical analyses.

Weighted Cohen's kappa (κ) coefficients were calculated for each of the ordinal categories to determine the level of agreement between AI POCUS and TTE. Weighted κ was chosen as it allows for partial agreement between adjacent severity categories, with penalties assigned to larger discrepancies. Bias-corrected and accelerated (BCa) bootstrap confidence intervals were calculated to account for non-normal data distribution and potential bias in κ estimates [22].

Agreement between LVEF and RVFAC measurements was further assessed using exploratory Bland-Altman analyses of representative numeric values mapped from the ordinal categories. Exact continuous LVEF and RVFAC values were not consistently available in formal

TTE reports, which were frequently reported as ranges or categorical assessments. Therefore, LVEF categories in the study were mapped to 50%, 45%, 33%, and 25%, and RVFAC categories to 35%, 32.5%, 26%, and 22%, which represent the midpoint or boundary of each category. To assess the effect of assumptions for the open-ended categories, sensitivity analyses used alternative mappings of 55% and 20% for the highest (≥50%) and lowest (≤25%) LVEF categories, respectively, and 40% and 18% for the highest (>35%) and lowest (≤22%) RVFAC categories, respectively. Mean bias and limits of agreement (LoA) were calculated for both the primary and sensitivity mappings [23]. As an additional secondary analysis, percent agreement of AI POCUS with normal TTE findings was calculated and sensitivity and specificity at dichotomized thresholds for normal versus abnormal findings were calculated. Normal TTE findings were defined as LVEF ≥50%, RVFAC >35%, IVC ≤2.1 cm, or valvular regurgitation or stenosis of none to trace.

Statistical analysis scripts were generated using ChatGPT Enterprise (OpenAI GPT-5.5; accessed May 2026) in a configuration with model training disabled. All AI-generated code was reviewed, tested, and revised by the authors, who confirmed the accuracy and reproducibility of the results. Statistical analyses were performed using Python (version 3.13.5; Python Software Foundation). Data processing and statistical analyses were conducted using pandas (version 3.0.2), NumPy (version 2.4.4), SciPy (version 1.17.1), and scikit-learn (version 1.8.0).

Results

Patient Characteristics

We included a convenience sample of 70 participants in the analysis. Patient characteristics are shown in Table 1. There was no significant difference in patient characteristics between interpretable and non-interpretable scans when accounting for multiple comparisons (Supplementary Material S1 — Table S1). The median time between AI POCUS and TTE being performed was 1 day (IQR 1–2 days, total range 0–6 days).

LVEF and RVFAC

The AI POCUS model provided an interpretation of LVEF in 45 patients (64%), while 25 patients had an indeterminate output from the model. Among these 45 individuals, there was 82% categorical agreement between AI POCUS and TTE, with an overall Cohen's κ = 0.749 (95% CI 0.415–0.924; Figure 1 and Table 2). Exploratory Bland-Altman plots of LVEF with locked boundaries showed a mean bias of -0.67 (LoA -9.36–8.03) without marked change in mean bias but with slightly wider LoA under sensitivity analysis conditions, likely driven by a small number of outliers (Supplementary Material S1 — Figures S1A and S1B). For TTEs with normal LVEF, the AI POCUS model provided an interpretation in 60% of scans with 89% agreement (Figure 2; Supplementary Material S1 — Table S2). Using a dichotomized threshold of LVEF <50% versus ≥50%, AI POCUS demonstrated a sensitivity of 80.0% (95% CI 44.4–97.5%; Supplementary Material S1 — Table S3) and specificity of 88.6% (95% CI 73.3–96.8%; Supplementary Material S1 — Table S3) for detecting reduced LVEF.

Table 1. Baseline characteristics of study population.

Characteristic	Value
Patients, N	70
Age, yr — mean ± SD	68.5 ± 18.5
Age, yr — median (IQR)	70.5 (61.3–82.8)
Male sex — N (%)	42 (60)
Body-mass index, kg/m² — mean ± SD	25.9 ± 5.0
Body-mass index, kg/m² — median (IQR)	25.9 (22.6–28.6)

IQR, interquartile range; SD, standard deviation.

For RVFAC, the AI POCUS model provided an interpretation in 43 patients (61%), while 27 had an indeterminate output. Among those 43 individuals, there was 61% categorical agreement between AI POCUS and TTE, with an overall Cohen's κ = -0.003 (95% CI -0.110–0.189; Figure 1 and Table 2). Exploratory Bland-Altman analysis with locked boundaries showed a mean bias of -1.67 and a LoA -9.79–6.45, with a larger mean bias of -3.02 and substantially wider LoA (-16.89–10.85) under sensitivity analysis conditions (Supplementary Material S1 — Figures S1C and S1D). For TTEs with normal RVFAC, the AI POCUS model provided an interpretation in 63% of scans with 65% agreement (Figure 2). Using a dichotomized threshold of RVFAC ≤35% versus >35%, AI POCUS demonstrated a sensitivity of 50.0% (95% CI 11.8–88.2%; Supplementary Material S1 — Table S3) and specificity of 64.9% (95% CI 47.5–79.8%; Supplementary Material S1 — Table S3) for detecting reduced RVFAC.

IVC Diameter

For subcostal IVC evaluation, the AI POCUS model provided an interpretation in 54 patients (77%), while 16 had an indeterminate output. Among those 54 individuals, there was 74% categorical agreement between AI POCUS and TTE, with an overall Cohen's κ = 0.382 (95% CI 0.114–0.631; Figure 1 and Table 2). For TTEs with normal IVC diameter, the AI POCUS model provided an interpretation in 77% of scans with 78% agreement (Figure 2). Using a dichotomized threshold of IVC >2.1

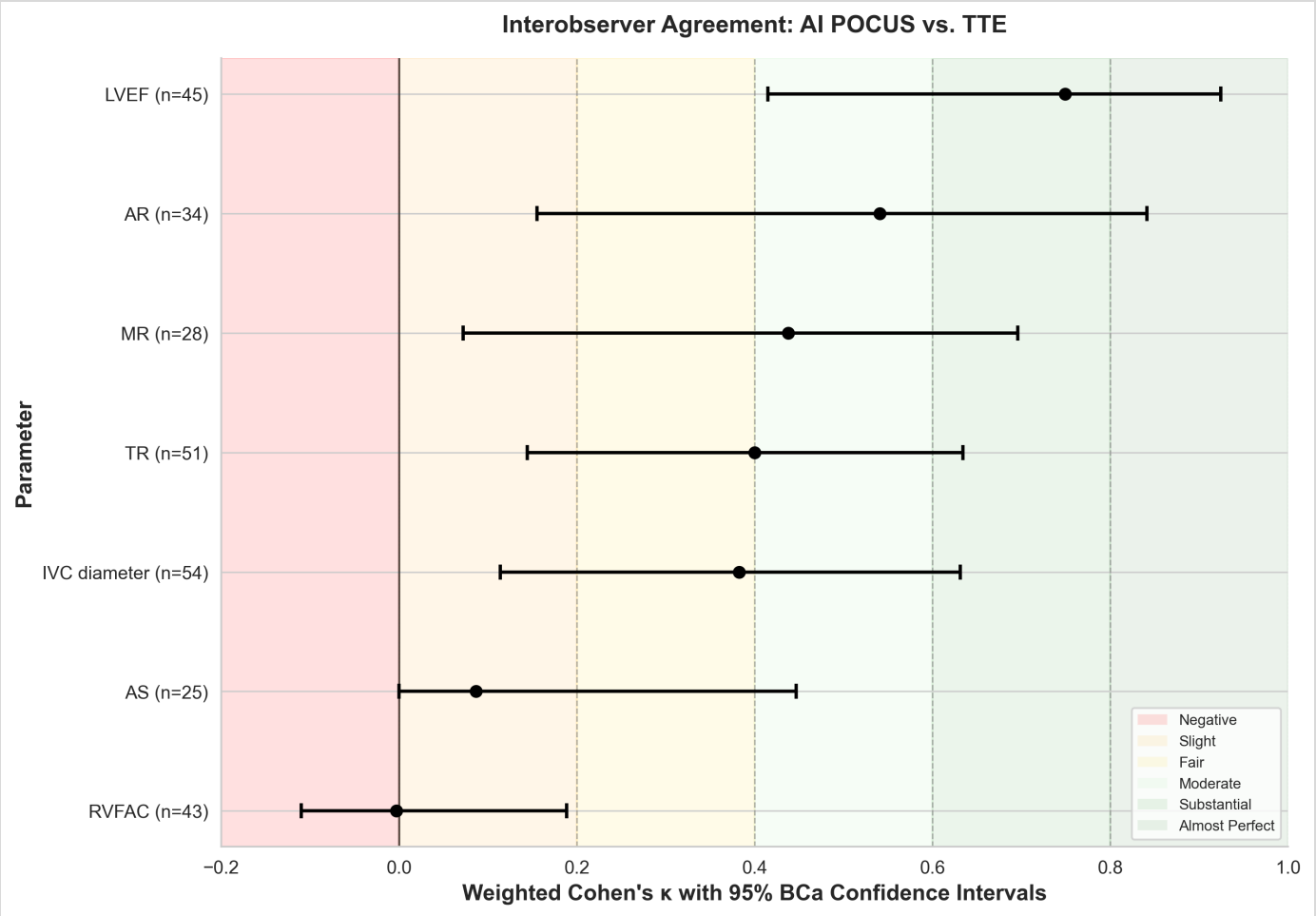


Figure 1. Forest plot of weighted κ values for artificial intelligence (AI) point of care ultrasound (POCUS) versus transthoracic echocardiography (TTE) with 95% bias-corrected and accelerated (BCa) bootstrap confidence intervals. AR, aortic regurgitation; AS, aortic stenosis; IVC, inferior vena cava; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; RVFAC, right ventricular fractional area change; TR, tricuspid regurgitation.

Table 2. Cohen's κ agreement between artificial intelligence (AI) point of care ultrasound (POCUS) and transthoracic echocardiography (TTE).

Parameter	Patients, N	Weighted κ (95% BCa CI)	Exact Agreement (%)
LVEF	45	0.749 (0.415–0.924)	82
MR	28	0.438 (0.072–0.696)	68
AR	34	0.541 (0.155–0.841)	85
AS	25	0.086 (0.000–0.447)	56
TR	51	0.400 (0.144–0.634)	71
IVC diameter	54	0.382 (0.114–0.631)	74
RVFAC	43	-0.003 (-0.110–0.189)	61

Agreement was assessed using weighted Cohen's κ, with 95% bias-corrected and accelerated (BCa) bootstrap confidence intervals. Weighted κ accounts for partial agreement between ordered categories. Exact agreement represents the percentage of observations classified identically by AI POCUS and TTE. AR, aortic regurgitation; AS, aortic stenosis; IVC, inferior vena cava; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; RVFAC, right ventricular fractional area change; TR, tricuspid regurgitation.

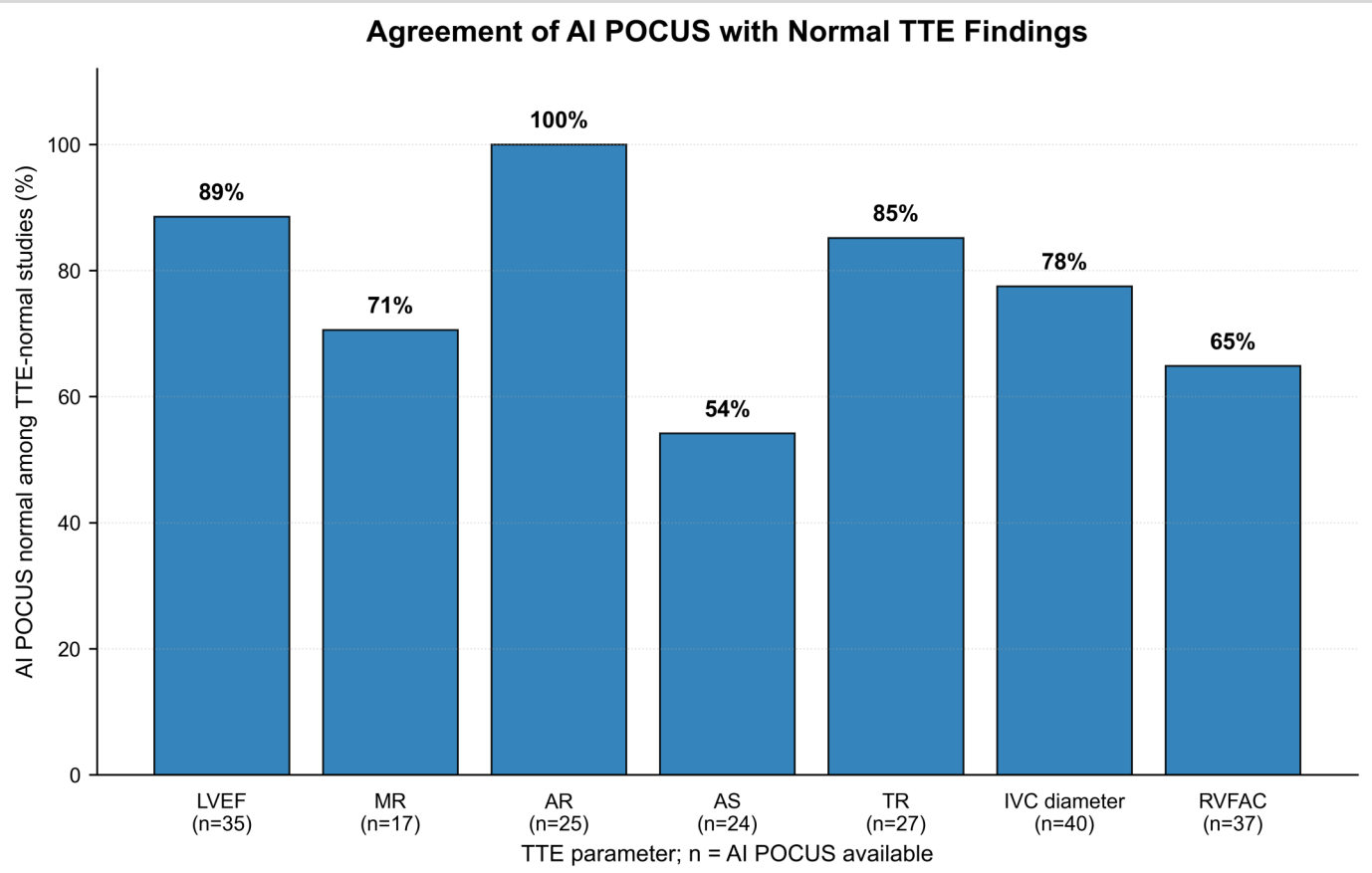


Figure 2. Percent agreement of artificial intelligence (AI) point of care ultrasound (POCUS) with normal transthoracic echocardiography (TTE) findings by parameter. AR, aortic regurgitation; AS, aortic stenosis; IVC, inferior vena cava; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; RVFAC, right ventricular fractional area change; TR, tricuspid regurgitation.

cm versus ≤2.1 cm, AI POCUS demonstrated a sensitivity of 64.3% (95% CI 35.1–87.2%; Supplementary Material S1 — Table S3) and specificity of 77.5% (95% CI 61.5–89.2%; Supplementary Material — Table S3) for detecting an IVC >2.1 cm.

Valvular Evaluation

For AR, the AI POCUS model provided interpretation in 34 patients (49%), while 36 had indeterminate output. Among those 34 individuals, there was 85% categorical agreement between AI POCUS and TTE, with an overall Cohen's κ = 0.541 (95% CI 0.155–0.841; Figure 1 and Table 2). For TTEs with AR of none to trace, the AI POCUS model provided an interpretation in 47% of scans with 100% agreement (Figure 2). AI POCUS demonstrated a sensitivity of 44.4% (95% CI 13.7–78.8%; Supplementary Material S1 — Table S3) and specificity of 100% (95% CI 86.3–100%; Supplementary Material S1 — Table S3) for detecting greater than trace AR.

For MR, the AI POCUS model provided interpretation in 28 patients (40%), while 42 had indeterminate output. Among those 28 individuals, there was 68% categorical agreement between AI POCUS and TTE, with an overall Cohen's κ = 0.438 (95% CI 0.072–0.696; Figure 1 and Table 2). For TTEs with MR of none to trace, the AI POCUS model provided an interpretation in 36% of scans with 71% agreement (Figure 2). AI POCUS demonstrated a sensitivity of 72.7% (95% CI 39.0–94.0%; Supplementary Material S1 — Table S3) and specificity of 70.6% (95% CI 44.0–89.7%; Supplementary Material S1 — Table S3) for detecting greater than trace MR.

For TR, the AI POCUS model provided interpretation in 51 patients (73%), while 19 had indeterminate output. Among those 51 individuals, there was 71% categorical agreement between AI POCUS and TTE, with an overall Cohen's κ = 0.400 (95% CI 0.144–0.634; Figure 1 and Table 2). For TTEs with TR of none to trace, the AI POCUS model provided an interpretation in 68% of scans with 85% agreement (Figure 2). AI POCUS demonstrated a sensitivity of 54.2% (95% CI 32.8–74.4%; Supplementary Material S1 — Table S3) and specificity of 85.2% (95% CI 66.3–95.8%; Supplementary Material S1 — Table S3) for detecting greater than trace TR.

For AS, the AI POCUS model provided interpretation in

25 patients (36%), while 45 had indeterminate output. Among those 25 individuals, there was 56% categorical agreement between AI POCUS and TTE, with an overall Cohen's κ = 0.086 (95% CI 0.000–0.447; Figure 1 and Table 2). For TTEs with AS of none to trace, the AI POCUS model provided an interpretation in 41% of scans with 54% agreement (Figure 2). AI POCUS demonstrated a sensitivity of 100% (95% CI 2.5–100%; Supplementary Material S1 — Table S3) and specificity of 54.2% (95% CI 32.8–74.4%; Supplementary Material S1 — Table S3) for detecting greater than trace AS.

Discussion

In this single-arm, prospective diagnostic comparison study, we compared a commercially available AI POCUS model with standard TTE performed within a median of one day among hospitalized patients. We observed strong agreement for LVEF between AI POCUS and TTE, while there was lower agreement for IVC diameter, valvular assessments, and RVFAC. When the TTE reported normal parameters, the AI POCUS model had high levels of agreement for LVEF, AR, TR, and IVC diameter. AI POCUS demonstrated moderate-to-high sensitivity for detecting reduced LVEF and greater than trace MR. At the dichotomized thresholds used in this study, specificity generally exceeded sensitivity, which suggests more consistent classification of normal findings than mild or greater abnormalities. However, sensitivity estimates were imprecise because of the small number of abnormal cases for several parameters and should not be interpreted as evidence that AI POCUS is uniformly unable to detect clinically significant disease. These findings highlight both the strengths and current limitations of AI POCUS compared with standard TTE and support its potential role as an adjunctive screening tool rather than a replacement for definitive echocardiographic diagnosis and management. Our study builds on existing literature by evaluating AI POCUS prospectively and in a clinical context, providing a pragmatic assessment of agreement between imaging modalities.

The differences in agreement between LVEF and other parameters likely reflect both image acquisition and physiologic factors. LVEF can be rapidly and reliably estimated with POCUS using PLAX and PSAX views, which are easier and faster to obtain compared to the A4C view required to calculate RVFAC [24–26]. In contrast, the RV has a complex, crescentic shape and sits behind the sternum, making it more challenging to assess in the A4C acoustic window [27]. RVFAC is particularly affected by image foreshortening [20], which is common among POCUS users and contributes to reduced reproducibility even in standard echocardiography [28–30]. For IVC, the measured diameter may vary based on volume status, respiratory status, and patient positioning, which may lead to moderate interrater reliability [31]. This observed variability in IVC may have impacted our study with the additional factor of the time difference between when POCUS and the TTE scans were obtained. Lastly, valvular quantifications are some of the most challenging tasks in echocardiography, requiring multiple technical inputs with particular difficulty in differentiating mild from moderate severity. Given that the AI tool uses colour Doppler to make measurements without other standard assessments, this could have led to lower agreement with TTE [32].

Our study builds on prior work evaluating AI POCUS applications, many of which focus on model development and classification performance based on retrospective datasets [17,18]. Fisher et al. applied the AI deep learning model from this study retrospectively to over 120,000 TTE exams, demonstrating that a single A4C view could accurately identify valvular disease and RV dysfunction while reliably estimating LVEF [18]. In another retrospective study, Cohen et al. demonstrated high diagnostic accuracy of the AI model in identifying clinically significant MR (AUC 0.98) and TR (AUC 0.96) in formal TTE images [17]. Notably, in the Cohen et al. study, predictions were generated in approximately 38% of studies, suggesting the sensitivity of the model to input image quality [17].

Interpretability in our study likewise varied substantially by parameter, ranging from 36% for AS to 77% for IVC diameter, and was in several instances (LVEF, RVFAC, AS, AR, and MR) lower than the rates recently reported by Fisher et al. in a separate prospective study using the same AI platform and ultrasound probe [33]. Several factors may help explain this difference. Novice operators in the Fisher et al. study completed a structured 6-hour training program with cardiologist supervision of each operator's first 20 examinations and ongoing access to real-time expert support, an infrastructure not available to the more experienced POCUS operators in our study. The AISAP software also provides a real-time image-quality indicator that requires a consistent internet connection; this feature was used in the Fisher et al. study but was not consistently available on the devices used in our study, which may have favoured acquisition of higher-quality images in their cohort. Fisher et al. was also conducted in a different country (Israel), and differences in patient population or disease prevalence could have further contributed to the observed differences in interpretability. Because the studies were not designed to directly compare acquisition workflows, we cannot quantify the individual contribution of these factors.

Another prospective investigation by Fisher et al. using the AI POCUS software utilized in our study demonstrated strong performance of AI POCUS for detecting reduced LVEF (AUC 0.97) and reduced RV function (AUC 0.95), with more modest performance for detecting at least moderate MR (AUC 0.72) and TR (AUC 0.86) based on a single A4C view, compared to standard TTE [18]. These findings underscore an important distinction between diagnostic discrimination and clinical interchangeability. Although the AI system may reliably categorize normal versus abnormal findings, this does not necessarily imply agreement with comprehensive echocardiography across a full range of measurements. In our study, we build on this work by directly evaluating agreement between AI POCUS and formal TTE across multiple measurements and severity categories, demonstrating strong concordance for LVEF, with lesser agreement for RVFAC, IVC diameter, and valvular assessments. Our study adds to the literature supporting AI POCUS as a powerful tool for identifying and categorizing LVEF, while highlighting its current limitations in replacing comprehensive TTE.

Diagnostic thresholds also differed across studies, which complicates direct comparison of sensitivity and specificity. Our prespecified analysis was consistent with ASE guidelines and classified any abnormality as positive (LVEF <50%, RVFAC ≤35%, IVC diameter >2.1 cm, and valvular disease greater than none-to-trace). Fisher et al. defined clinically significant disease as LVEF <40% and moderate-or-greater valvular or RV dysfunction [33]. We therefore repeated our LVEF analysis at the closest comparable threshold supported by our categorical data (LVEF ≤40%); sensitivity was 80.0% (95% CI, 28.4% to 99.5%) and specificity was 95.0% (95% CI, 83.1% to 99.4%), compared with 80.0% and 88.6%, respectively, at the <50% threshold (Supplementary Material S1 — Table S4). Specificity at this threshold approximated that reported by Fisher et al., although sensitivity remained lower and was based on only five TTE-positive cases. An equivalent ≥moderate valvular reanalysis was not feasible, as our mild-to-moderate and moderate-to-severe categories cross the ≥moderate cutoff and cannot be retrospectively separated without introducing classification assumptions. These comparisons are further limited by differences in study design: the noninterventional AI POCUS validation study drew on 5,203 formal echocardiographic examinations rather than bedside POCUS, and the Fisher et al. and Cohen et al. estimates were calculated only among patients selected for confirmatory echocardiography rather than a systematically sampled cohort, introducing potential verification bias of indeterminate direction and magnitude. Prior studies also reported point estimates without confidence intervals. Given our smaller sample, several of our confidence intervals are wide, and cross-study differences in point estimates for sensitivity and specificity should be interpreted in this context rather than as direct measures of relative model performance [17,18,33].

There are several implications of this study in clinical practice. Given the strong agreement in LVEF in this study between AI POCUS and TTE, it could be used as a screening tool for LVEF in patients presenting with symptoms of heart failure, which is supported by prior investigations that found that AI systems perform well in identifying reduced LVEF [18,25,33,34]. Similarly, AI POCUS could be used to screen for clinically significant valvular disease [11]. Employing a point-of-care tool such as AI POCUS that can reliably detect normal versus low LVEF or screen for the presence of more severe valvular dysfunction on a population level could help determine which patients should undergo formal TTE or hospitalization for further testing, particularly in low-resource settings. It is worth emphasizing that AI POCUS has not demonstrated the capability to replace TTE as a standard assessment.

There are several limitations to this study. This was a single-institution study derived from a convenience sample of inpatient participants. Each participant underwent a single scan by a member of the research team, and interrater reliability was not calculated among POCUS scanners. Although the median time from POCUS scan to TTE was one day, variations in echocardiographic findings, especially in dynamic inpatient settings where patients are acutely ill, may have contributed to differences between the two studies. This is especially true for IVC diameter and valvular function, which may vary with changes in volume status [35]. The overall sample size was modest, with only fifteen AI POCUS scans resulting in complete imaging reports. The remaining scans had missing measurements due to inability to obtain the required view or the view classification feature deeming the inputs unsuitable for the diagnostic model. This may have led to limited precision for less prevalent findings, particularly AS, MR, and AR, but is also reflective of POCUS in clinical practice, where adequate views may be difficult to obtain in some patients. Successful AI interpretation depends on acquisition of adequate quality images and the required echocardiographic views, and inadequate image quality may prevent the platform from generating a diagnostic interpretation. In particular, the apparent 100% sensitivity for detecting AS (Supplementary Material S1 — Table S3) was derived from a small number of interpretable and TTE-positive cases, yielding a correspondingly wide confidence interval, and should not be interpreted as evidence of reliable AS detection by AI POCUS. Rather,

the small number of cases limits conclusions regarding AS performance and underscores the need for caution when integrating AI POCUS findings into clinical decision -making. Lastly, all scans were obtained using a single device (Philips Lumify S4-1 Phased Array Probe) and analyzed by a single commercial AI product, limiting generalizability to other devices and AI systems.

Conclusions

In this single-arm, prospective diagnostic comparison study, AI POCUS demonstrated close agreement with standard TTE for the estimation of LVEF. Agreement was lower for RVFAC, valvular assessments, and IVC diameter. These findings support the potential role of AI POCUS for assessing left ventricular function, particularly where access to comprehensive echocardiography is limited. Further integration and validation studies are needed to assess the role of AI POCUS in clinical practice and its impact on management decisions.

Ethics Statement

This study received human subjects approval by the Stanford University Institutional Review Board (IRB Protocol #77758). The requirement for informed consent was waived by the IRB.

Disclosure Statement

AK serves as a consultant for GE Healthcare and Exo Inc. EB is a co-investigator for a study sponsored by GE Healthcare.

Funding

No associated funding was received for this study

Author Contributions

EB: conceptualization, data curation, methodology, formal analysis, writing – original draft, writing – review & editing. JK: data curation, project administration, writing – original draft, writing – review & editing. ML: data curation, writing – original draft, writing – review & editing. CPC: data curation, writing – original draft, writing – review & editing. VN: data curation, writing – original draft, writing – review & editing. AK: conceptualization, data curation, methodology, supervision, writing – original draft, writing – review & editing.

References

1. Savarese G, Becher PM, Lund LH, Seferovic P, Rosano GMC, Coats AJS. Global burden of heart failure: a comprehensive and updated review of epidemiology. Cardiovasc Res 2023; 118(17):3272-3287.

2. Global Burden of Cardiovascular Diseases and Risks 2023 Collaborators. Global, regional, and national burden of cardiovascular diseases and risk factors in 204 countries and territories, 1990-2023. J Am Coll Cardiol 2025; 86(22):2167-2243.

3. Heidenreich PA, Bozkurt B, Aguilar D, Allen LA, Byun JJ, Colvin MM, Deswal A, Drazner MH, Dunlay SM, Evers LR, Fang JC, Fedson SE, Fonarow GC, Hayek SS, Hernandez AF, Khazanie P, Kittleson MM, Lee CS, Link MS, Milano CA, Nnacheta LC, Sandhu AT, Stevenson LW, Vardeny O, Vest AR, Yancy CW. 2022 AHA/ACC/HFSA guideline for the management of heart failure: Executive summary: A report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. J Am Coll Cardiol 2022; 79 (17):1757-1780.

4. Yadav H, Shah D, Sayed S, Horton S, Schroeder LF. Availability of essential diagnostics in ten low-income and middle-income countries: results from national health facility surveys. Lancet Glob Health 2021; 9 (11):e1553-e1560.

5. Díaz-Gómez JL, Mayo PH, Koenig SJ. Point-of-care ultrasonography. N Engl J Med 2021; 385(17):1593-1602.

6. Qaseem A, Etxeandia-Ikobaltzeta I, Mustafa RA, Kansagara D, Fitterman N, Wilt TJ, Clinical Guidelines Committee of the American College of Physicians, Batur P, Cooney TG, Crandall CJ, Hicks LA, Lin JS, Maroto M, Tice J, Tufte JE, Vijan S, Williams JW Jr. Appropriate use of point-of-care ultrasonography in patients with acute dyspnea in emergency department or inpatient settings: A clinical guideline from the American College of Physicians. Ann Intern Med 2021; 174(7):985-993.

7. Maganti K, Chen C, Jamthikar AD, Parikh P, Yanamala N, Sengupta PP. Cardiopulmonary point-of-care ultrasonography for hospitalist management of undifferentiated dyspnea. JAMA Netw Open 2025; 8 (9):e2530677.

8. Baum E, Tandel MD, Ren C, Weng Y, Pascucci M, Kugler J, Cardoza K, Kumar A. Acquisition of cardiac point-of-care ultrasound images with deep learning: A randomized trial for educational outcomes with novices. CHEST Pulm 2023; 1(3):100023.

9. Trost B, Rodrigues L, Ong C, Dezellus A, Goldberg YH, Bouchat M, Roger E, Moal O, Singh V, Moal B, Lafitte S. Artificial intelligence empowers novice users to acquire diagnostic-quality echocardiography. JACC Adv 2025; 4(8):102005.

10. Kumar A, Baum E, Parmer-Chow C, Kugler J. Limited echocardiogram acquisition by novice clinicians aided with deep learning: A randomized controlled trial. Biol Methods Protoc 2025; 10 (1):bpaf083.

11. Holste G, Oikonomou EK, Tokodi M, Kovács A, Wang Z, Khera R. Complete AI-enabled echocardiography interpretation with multitask deep learning. JAMA 2025; 334(4):306-318.

12. Kagiyama N, Abe Y, Kusunose K, Kato N, Kaneko T, Murata A, Ota M, Shibayama K, Izumo M, Watanabe H. Multicenter validation study for automated left ventricular ejection fraction assessment using a handheld ultrasound with artificial intelligence. Sci Rep 2024; 14 (1):15359.

13. Motazedian P, Marbach JA, Prosperi-Porta G, Parlow S, Di Santo P, Abdel-Razek O, Jung R, Bradford WB, Tsang M, Hyon M, Pacifici S, Mohanty S, Ramirez FD, Huggins GS, Simard T, Hon S, Hibbert B. Diagnostic accuracy of point-of-care ultrasound with artificial intelligence -assisted assessment of left ventricular ejection fraction. NPJ Digit Med 2023; 6(1):201.

14. Vega R, Dehghan M, Nagdev A, Buchanan B, Kapur J, Jaremko JL, Zonoobi D. Overcoming barriers in the use of artificial intelligence in point of care ultrasound. NPJ Digit Med 2025; 8(1):213.

15. Lin JC, Jain B, Iyer JM, Rola I, Srinivasan AR, Kang C, Patel H, Parikh RB. Benefit-risk reporting for FDA-cleared artificial intelligence-enabled medical devices. JAMA Health Forum 2025; 6(9):e253351.

16. Mitchell C, Rahko PS, Blauwet LA, Canaday B, Finstuen JA, Foster MC, Horton K, Ogunyankin KO, Palma RA, Velazquez EJ. Guidelines for performing a comprehensive transthoracic echocardiographic examination in adults: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr 2019; 32(1):1-64.

17. Cohen I, Malins JG, Cohen-Shelly M, Asaf Y, Fiman M, Faierstein K, Fisher L, Sudri K, Raanani E, Schwammenthal E, Klempfner R, Maor E. Deep learning for atrioventricular regurgitation diagnosis: an external validation study. Eur Heart J Digit Health 2025; 6(5):949-958.

18. Fisher L, Fiman M, Segal E, Lidar S, Rubin N, Am-Shalom A, Cohen I, Faierstein K, Tsur AM, Schwammenthal E, Klempfner R, Zimlichman E, Raanani E, Maor E. Artificial intelligence assessment of valvular disease and ventricular function by a single echocardiography view. Front Digit Health 2025; 7:1684933.

19. Doherty JU, Daugherty SL, Kort S, London MJ, Mehran R, Merli GJ,

Schoenhagen P, Soman P, Starling RC, Johnson DM, Dehmer GJ, Bhave NM, Biederman RW, Bittencourt MS, Burroughs MS, Doukky R, Hays AG, Indik JH, Kim KM, Lotfi AS, Macchiavelli AJ, Neuburger P, Patel H, Pellikka PA, Reece TB, Rong LQ. ACC/AHA/ASE/ASNC/HFSA/HRS/SCAI/SCCT/SCMR/STS 2024 appropriate use criteria for multimodality imaging in cardiovascular evaluation of patients undergoing nonemergent, noncardiac surgery. J Am Coll Cardiol 2024; 84(15):1455-1491.

20. Mukherjee M, Rudski LG, Addetia K, Afilalo J, D'Alto M, Freed BH, Friend LB, Gargani L, Grapsa J, Hassoun PM, Hua L, Kim J, Mercurio V, Saggar R, Vonk-Noordegraaf A. Guidelines for the echocardiographic assessment of the right heart in adults and special considerations in pulmonary hypertension: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr 2025; 38(3):141-186.

21. Otto CM, Nishimura RA, Bonow RO, Carabello BA, Erwin JP 3rd, Gentile F, Jneid H, Krieger EV, Mack M, McLeod C, O'Gara PT, Rigolin VH, Sundt TM 3rd, Thompson A, Toly C. 2020 ACC/AHA guideline for the management of patients with valvular heart disease: A report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation 2021; 143(5):e72-e227.

22. Efron B. Better bootstrap confidence intervals. J Am Stat Assoc 1987; 82(397):171-185.

23. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; 1 (8476):307-310.

24. Lebeau R, Robert-Halabi M, Pichette M, Vinet A, Sauvé C, Dilorenzo M, Le V, Piette E, Brunet M, Bédard W, Serri K, Poulin F. Left ventricular ejection fraction using a simplified wall motion score based on mid-parasternal short axis and apical four-chamber views for non-cardiologists. BMC Cardiovasc Disord 2023; 23(1):115.

25. Gallant C, Bernard L, Kwok C, Wichuk S, Noga M, Punithakumar K, Hareendranathan A, Becher H, Buchanan B, Jaremko JL. AI-augmented point of care ultrasound in intensive care unit patients: Can novices perform a “basic echo” to estimate left ventricular ejection fraction in this acute-care setting? J Clin Med 2025; 14(9):2899.

26. Bahl A, Johnson S, Altwail M, Brackney A, Xiao J, Price J, Shotkin P, Chen NW. Left ventricular ejection fraction assessment by emergency physician-performed bedside echocardiography: A prospective comparative evaluation of multiple modalities. J Emerg Med 2021; 61(6):711-719.

27. Hahn RT, Lerakis S, Delgado V, Addetia K, Burkhoff D, Muraru D, Pinney S, Friedberg MK. Multimodality imaging of right heart function: JACC scientific statement. J Am Coll Cardiol 2023; 81(19):1954-1973.

28. Spencer KT, Flachskampf FA. Focused cardiac ultrasonography. JACC Cardiovasc Imaging 2019; 12(7 Pt 1):1243-1253.

29. Mor-Avi V, Khandheria B, Klempfner R, Cotella JI, Moreno M, Ignatowski D, Guile B, Hayes HJ, Hipke K, Kaminski A, Spiegelstein D, Avisar N, Kezurer I, Mazursky A, Handel R, Peleg Y, Avraham S, Ludomirsky A, Lang RM. Real-time artificial intelligence-based guidance of echocardiographic imaging by novices: Image quality and suitability for diagnostic interpretation and quantitative analysis. Circ Cardiovasc Imaging 2023; 16(11):e015569.

30. Marwick TH. Ejection fraction pros and cons: JACC state-of-the-art review. J Am Coll Cardiol 2018; 72(19):2360-2379.

31. Policastro P, Ermini L, Civera S, Albani S, Musumeci G, Roatta S, Mesin L. Effect of respirophasic displacement of the inferior vena cava on size measurement in 2-D ultrasound imaging. Ultrasound Med Biol 2024; 50(12):1785-1792.

32. Zoghbi WA, Adams D, Bonow RO, Enriquez-Sarano M, Foster E, Grayburn PA, Hahn RT, Han Y, Hung J, Lang RM, Little SH, Shah DJ, Shernan S, Thavendiranathan P, Thomas JD, Weissman NJ. Recommendations for noninvasive evaluation of native valvular regurgitation: A report from the American Society of Echocardiography developed in collaboration with the Society for Cardiovascular Magnetic Resonance. J Am Soc Echocardiogr 2017; 30(4):303-371.

33. Fisher L, Fiman M, Yarkoni Y, Segal E, Fishman B, Faierstein K, Rubin N, Am-Shalom A, Amital H, Zhao Q, Kort S, Mehrotra P, Schwammenthal E, Klempfner R, Zimlichman E, Raanani E, Maor E. Artificial intelligence-enhanced cardiac point-of-care ultrasound: A prospective single-arm study. Mayo Clin Proc Digit Health 2026; 4 (2):100355.

34. Campbell RT, Petrie MC, Docherty KF, Brooksbank KJM, McKinley G, Haig C, McConnachie A, Lam CSP, Adamson C, Butler E, Curtain JP, Hartshorne-Evans N, Graham FJ, Hainey H, Jarvie J, Lee MMY, Macklin L, Mangion K, McCoubrey A, McDowell K, McIntyre A, Nordin S, Osmanska J, Pellicori P, Simpson J, Sonecki P, Taylor K, Taylor-Sweet D, Turnbull P, Welsh P, McMurray JJV, Murphy CL, Lowe DJ. Artificial intelligence fully automated analysis of handheld echocardiography in real-world patients with suspected heart failure. Eur J Heart Fail 2025; 27(12):3401-3410.

35. Kawata T, Daimon M, Nakanishi K, Kimura K, Sawada N, Nakao T, Hirokawa M, Ishiwata J, Takeda N, Yatomi Y, Komuro I. Factors influencing inferior vena cava diameter and its respiratory variation: Simultaneous comparison with hemodynamic data. J Cardiol 2022; 79 (5):642-647.

POCUS in Undifferentiated Shock: A Narrative Review

Shiona Maria Fernandes, MD[1]*; Anjana Krishna[2]; Yousra Anwar[2]; Anoud Salim Fodkar[3]; Mubassir Shah Awan[3]; Fathima Abdul Kareem, MD[4]; Aishwarya Velineni, MD[5]; Iman Ibrahim Bhaldar, MD[1]; Anon Jo Bracy[1]

(1) Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia
(2) David Tvildiani Medical University, Tbilisi, Georgia
(3) The University of Georgia, Tbilisi, Georgia
(4) Caucasus International University, Tbilisi, Georgia
(5) Tbilisi State Medical University, Tbilisi, Georgia

Abstract

Background: Undifferentiated shock is a common emergency presentation. Clinical signs alone are not sufficient to identify its cause, which can delay treatment and worsen outcomes. **Methods**: A narrative review of the literature was completed from 2010–2025 on point of care ultrasound (POCUS) protocols, diagnostic accuracy, and outcomes in undifferentiated shock. **Results**: POCUS improved diagnostic accuracy (45–60% to 80–89%) and hemodynamic endpoints in septic shock. However, large randomized controlled trials (FATE-ICU, SHoC-ED) showed no mortality benefit from routine use in unselected populations. Newer tools (VExUS, artificial intelligence-assisted analysis) require further validation. Cost-effectiveness data remain limited. **Conclusions**: POCUS improves diagnostic accuracy and guides targeted treatment, but mortality benefit is context-dependent. It should be applied strategically by trained operators and integrated with clinical assessment rather than as universal screening.

Introduction

Undifferentiated shock is defined by inadequate tissue perfusion relative to metabolic demand. Patients typically present with hypotension, tachycardia, altered mental status, and reduced urine output. These features are common across all shock subtypes, which makes early identification of the cause difficult [1]. Delays in diagnosis are associated with increased morbidity and mortality [1].

Standard investigations such as computed tomography (CT) and laboratory tests take time and require a degree of patient stability. Point of care ultrasound (POCUS) avoids these limitations by providing real-time bedside imaging without interrupting resuscitation [2]. A 2022 systematic review found that adding POCUS to clinical assessment improved diagnostic accuracy from 45–60% to 80–89% in emergency department patients with undifferentiated shock [3]. A 2026 systematic review of 14 studies further confirmed that POCUS-guided resuscitation in septic shock improved hemodynamic outcomes, including mean arterial pressure and lactate clearance [4].

This review summarizes the current evidence on POCUS in undifferentiated shock, covering protocols, organ-specific findings, diagnostic accuracy, limitations, and emerging advances.

Methods

A narrative review of English-language literature on POCUS in undifferentiated shock was completed. PubMed, Embase, and Scopus were searched from January 2010 to March 2026 using terms including “point-of-care ultrasound,” “POCUS,” “shock,” “undifferentiated hypotension,” “RUSH protocol,” and “VExUS.” Systematic reviews, meta-analyses, and randomized controlled trials were prioritized. Selected articles were reviewed for diagnostic accuracy, hemodynamic outcomes, and mortality data. Emerging technologies, including artificial intelligence (AI)-assisted image analysis, were evaluated based on 2023–2026 validation studies.

Pathophysiology of Shock

Shock is divided into four main types: hypovolemic, distributive, cardiogenic, and obstructive. All result in inadequate tissue perfusion, but have different causes [1].

Hypovolemic shock results from loss of intravascular volume through hemorrhage or dehydration, reducing preload and cardiac output. Distributive shock occurs when peripheral vasodilation redistributes blood flow, most commonly in sepsis or anaphylaxis. Cardiogenic shock results from impaired myocardial contractility or

*Corresponding Author: Dr. Shiona Maria Fernandes (email: fernandesshiona18@gmail.com)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20704

mechanical failure. Obstructive shock occurs when something physically blocks cardiac filling or outflow, such as pulmonary embolism or tension pneumothorax [1,5].

Because these subtypes present similarly on examination, POCUS is particularly valuable for rapid bedside differentiation.

Principles of POCUS in Shock

POCUS provides real-time bedside imaging that allows cardiac function, volume status, lung pathology, and vascular abnormalities to be assessed without moving the patient or pausing resuscitation [2]. It can be repeated serially to track changes over time and guide treatment adjustments.

Its main limitation is operator-dependent study quality. Image quality and interpretation vary with training and experience [5,6]. Standardized protocols and structured teaching are therefore important for reliable use. A 2024 systematic review of 81 studies confirmed that POCUS accurately diagnoses a broad range of emergency conditions and guides procedural interventions when performed by trained clinicians [7].

POCUS Protocols for Shock

RUSH Protocol

The Rapid Ultrasound in Shock (RUSH) protocol uses a pump, tank, and pipes framework. It assesses cardiac function, volume status, and vascular integrity in a structured sequence [8]. It is the most widely used and validated bedside shock protocol. A 2023 systematic review found that multi-organ POCUS protocols had high sensitivity and positive likelihood ratios for identifying each shock subtype, with the strongest results for obstructive shock [9] (Figure 1).

ACES and SHoC Protocols

The Abdominal and Cardiac Evaluation with Sonography (ACES) protocol focuses on cardiac dysfunction, pericardial effusion, and abdominal pathology [10]. The Sonography in Hypotension and Cardiac Arrest (SHoC) protocol uses a tiered approach that starts with core views and adds targeted assessments based on clinical context [11]. Both are used internationally and are incorporated into emergency medicine training curricula.

Organ-Based Ultrasound Findings

Cardiac POCUS

Assessment of the heart is central to shock evaluation. Reduced left ventricular contractility with wall motion abnormalities points to cardiogenic shock. A small, hyperdynamic left ventricle (LV) is typically seen in hypovolemia or distributive shock [5]. Right ventricular dilation with septal flattening (D-sign) suggests pulmonary embolism. Pericardial effusion with diastolic chamber collapse is diagnostic of tamponade.

Inferior Vena Cava

Inferior vena cava (IVC) diameter and collapsibility give indirect information on volume status. A collapsible IVC (less than 2.1 cm with more than 50% respiratory variation) suggests low filling pressures [5]. However, IVC -based fluid responsiveness prediction has real limitations. A 2024 systematic review of 29 studies found pooled sensitivity of 0.82 for IVC indices but highlighted significant heterogeneity and cautioned against its use in mechanically ventilated patients [13]. The IVC does not reliably predict fluid responsiveness in ventilated patients, and isolated reliance on IVC findings may contribute to inappropriate fluid administration.

Lung Ultrasound

Lung POCUS identifies B-lines (indicating pulmonary edema), pleural effusions, and pneumothorax. Absent lung sliding with A-lines is highly specific for pneumothorax. B-lines alongside reduced LV function support cardiogenic shock. A 2024 systematic review found POCUS sensitivity of 94.5% for pleural effusion compared to 67.7% for chest radiograph [12].

Abdominal POCUS and eFAST

The extended Focused Assessment with Sonography in Trauma (eFAST) identifies free fluid and pneumothorax in trauma patients and guides decisions on urgent surgery. In non-trauma shock, abdominal POCUS helps assess the aorta for aneurysm and evaluate hepatic vein flow [5].

VExUS

Venous Excess Ultrasound (VExUS) is a multi-vessel Doppler protocol that grades systemic venous congestion using flow patterns in the IVC, hepatic vein, portal vein, and intrarenal veins [14]. It is particularly relevant when fluid overload may be contributing to organ dysfunction. A 2025 meta-analysis found that VExUS grade 2 or higher was associated with a significantly higher rate of acute kidney injury in critically ill patients (OR 2.63; 95% CI 1.06 –6.54) [15]. A prospective cohort study found VExUS grade 2 or higher was strongly associated with major adverse kidney events within 30 days of intensive care unit (ICU) admission (OR 4.3; 95% CI 1.2–20.7) [16]. VExUS requires Doppler-capable equipment and works best as a complement to other POCUS findings, not as a standalone tool.

POCUS-Based Differentiation of Shock Subtypes

POCUS allows rapid bedside differentiation of shock subtypes. Cardiogenic shock shows reduced LV function, dilated chambers, B-lines, and a plethoric IVC. Hypovolemic shock presents with a small, hyperdynamic



Figure 1. RUSH protocol algorithm — sequential assessment of cardiac function (pump), volume status (tank), and vascular integrity (pipes), with corresponding shock subtypes for specific findings. LV, left ventricle; RV, right ventricle; IVC, inferior vena cava; EF, ejection fraction; PE, pulmonary embolism; PTX, pneumothorax; ALI, acute lung injury; FAST, focused assessment with sonography in trauma; RUSH, rapid ultrasound in shock.

LV, collapsible IVC, and clear lungs. Obstructive shock from pulmonary embolism shows right ventricular dilation and septal bowing; tension pneumothorax presents with absent lung sliding and A-lines. Distributive shock typically shows preserved or hyperdynamic LV function with a collapsible IVC [5,8] (Table 1).

A 2023 systematic review and meta-analysis confirmed that POCUS achieves high sensitivity and positive likelihood ratios for identifying each shock type, with the strongest diagnostic performance seen for obstructive shock [9]. A 2022 systematic review found overall diagnostic accuracy improved from 45–60% with clinical assessment alone to 80–89% with POCUS added [3].

Clinical Integration in Emergency Medicine

POCUS is now a standard part of emergency medicine curricula worldwide and is routinely used during the primary survey in most high-income settings. The 2023 American College of Emergency Physicians ultrasound guidelines support its use across a wide range of emergency presentations [17].

Serial POCUS is particularly useful because it allows real-time assessment of treatment response. Clinicians can adjust fluids, vasopressors, and other interventions based on changes seen at the bedside. A 2023 meta-analysis of 14 randomized controlled trials and cohort studies found that POCUS-guided resuscitation was associated with lower 28-day mortality (RR 0.88; 95% CI 0.78–0.99) and shorter vasopressor duration (mean difference −0.73 days; 95% CI −1.16 to −0.30), with low to moderate certainty of evidence [4].

In 2024, the Accreditation Council for Graduate Medical Education (ACGME) mandated POCUS competency requirements for critical care fellowships in the United States, reflecting its shift from an optional adjunct to a core clinical skill [18].

Evidence Supporting POCUS in Shock

The evidence base for POCUS in shock has grown considerably since 2020, though results are heterogeneous and context-dependent. A 2022 systematic review of six studies showed consistent improvement in diagnostic accuracy when POCUS was added to clinical assessment in emergency department patients with undifferentiated shock [3]. A 2023 meta-analysis confirmed high sensitivity and positive likelihood ratios across shock subtypes, with robust data for obstructive shock [9].

For septic shock specifically, a 2026 systematic review of 14 studies confirmed measurable improvements in hemodynamic outcomes with POCUS-guided resuscitation compared to standard care [4]. However, mortality benefits are less consistent. The 2023 meta-analysis by Yoshida et al. found POCUS-guided resuscitation associated with lower 28-day mortality (RR 0.88), but certainty of evidence was low to moderate due to risk of bias and imprecision [9].

Limitations and Pitfalls

POCUS has several well-recognized limitations that must be understood for safe clinical use.

Operator dependency is the most significant. Image quality and interpretation accuracy vary with training level [5,6]. IVC assessment is unreliable in mechanically ventilated patients, those with raised intra-abdominal pressure, and patients with significant tricuspid regurgitation [12]. Obesity can significantly reduce image quality, and equipment may not be available in all settings.

There is also a risk of anchoring bias when POCUS findings are interpreted in isolation. A hyperdynamic LV with a collapsible IVC may suggest hypovolemia but could also reflect early distributive shock. Distinguishing between the two requires clinical context and laboratory data. Over-reliance on IVC measurement alone has been linked to inappropriate fluid administration.

Most current evidence comes from heterogeneous study designs with varying operator experience and inconsistent outcome definitions. Larger prospective multicenter trials with standardized POCUS protocols are needed.

Large randomized controlled trials including FATE-ICU and SHoC-ED showed no mortality benefit from routine

Table 1. Summary of point of care ultrasound (POCUS) findings characteristic of each shock subtype. Findings require clinical correlation as overlap exists, particularly in early or mixed presentations.

Shock Type	Cardiac	IVC	Lung
Hypovolemic	Small hyperdynamic LV	Collapsible (<2.1cm, >50% variation)	Clear lungs
Cardiogenic	Reduced LV function, dilated chambers	Plethoric	B-lines, pleural effusions
Obstructive (PE)	RV dilation, septal flattening (D-sign)	Plethoric or normal	Clear or A-lines
Obstructive (PTX)	Normal or hyperdynamic	Variable	Absent lung sliding, A-lines
Distributive	Preserved or hyperdynamic LV	Collapsible	Clear lungs

IVC, inferior vena cava; LV, left ventricle; PE, pulmonary embolism; PTX, pneumothorax; RV, right ventricle.

POCUS in unselected populations [25,26].

Training and Implementation

Effective POCUS use requires structured training that combines teaching, simulation, and supervised practice [6]. Simulation-based programs have shown improvements in competency and clinical confidence across trainee levels [6]. The ACGME formally mandated POCUS competency for critical care fellows in 2024, and emergency medicine residencies in many countries now include it in core training [18].

Portable and handheld devices have helped expand access in resource-limited and prehospital settings. A 2025 systematic review of prehospital POCUS found lung POCUS was feasible and diagnostically useful across more than 20 studies, with a median examination time under five minutes [19]. Tele-guided training has also shown promise in settings where on-site experts are not available.

Despite expanding use, formal cost-effectiveness analyses of POCUS in shock remain limited. Handheld devices reduce capital costs ($2,000–$10,000 vs. $25,000–$50,000 for cart-based systems) and enable prehospital deployment [19]. However, hidden costs include training time (estimated 20–40 hours for basic competency), maintenance, quality assurance programs, and potential downstream expenses from false-positive findings prompting unnecessary interventions [27]. A 2024 health technology assessment from NICE found insufficient economic evidence to recommend routine POCUS for undifferentiated shock outside specialist centres, noting that cost savings from reduced CT utilization were offset by increased ultrasound device expenditure and operator training costs [28]. Formal cost-utility analyses incorporating long-term outcomes are needed to define optimal deployment strategies.

Emerging Technologies and Current Advances

Handheld POCUS devices have improved portability and reduced cost, enabling use outside the hospital. Paramedics and emergency physicians now apply abbreviated protocols such as RUSH in prehospital settings to assess for tamponade and aortic pathology [19].

AI-assisted tools have been developed to support image acquisition and measurement. These include automated ejection fraction calculation, automated left ventricular outflow tract velocity-time integral (LVOT-VTI) measurement, and automated IVC assessment. A 2023 validation study found that AI-assisted VTI measurement in critical care trainees produced narrower measurement ranges and lower variability compared to manual tracing, with feasibility of 100% [21]. A 2025 review found that AI tools can reduce operator dependency and support novice clinicians in acquiring diagnostically useful images [22].

Most AI tools are still in validation stages and are not yet widely available. Challenges related to algorithm generalizability and data privacy remain, and clinical deployment requires careful evaluation before widespread adoption.

VExUS extends volume assessment beyond IVC diameter by incorporating multi-vessel Doppler grading of venous congestion. Current evidence suggests it may identify patients at risk of fluid overload-related organ injury, though randomized data are lacking and further validation is needed [15,16].

Integration with electronic health records and remote training platforms is ongoing, with early evidence supporting improvements in workflow and teaching in distributed settings [18].

Conclusion

POCUS is a practical and effective tool in the evaluation of undifferentiated shock. It allows rapid, repeatable, bedside assessment of cardiac function, volume status, lung pathology, and venous congestion without moving the patient or delaying treatment. Structured protocols including RUSH, ACES, and SHoC support systematic use and reduce variability. Recent meta-analyses show improved diagnostic accuracy and hemodynamic endpoints when POCUS guides resuscitation, particularly in septic shock and obstructive shock.

However, mortality benefits are not universal. Large randomized controlled trials including FATE-ICU and SHoC-ED found no survival advantage from routine POCUS application in undifferentiated ICU or emergency department populations. This suggests that benefit may be context-dependent: maximized when POCUS is applied early, by experienced operators, integrated with specific treatment protocols, and targeted to particular shock subtypes rather than used as a universal screening tool.

Advances in handheld devices, AI-assisted measurement, and VExUS assessment are expanding access beyond tertiary centres. Formal POCUS competency requirements in postgraduate training reflect its growing role as a core clinical skill. Economic considerations remain unresolved; while device costs have fallen, formal cost-effectiveness analyses are lacking, and hidden costs of training and quality assurance may offset savings from reduced imaging.

Operator dependency, image quality variability, and the risk of diagnostic anchoring remain important limitations. POCUS should be used alongside clinical judgment and laboratory data, not as a standalone assessment, with

recognition that diagnostic enhancement does not automatically translate to improved survival. As the evidence base continues to evolve, incorporating both positive and negative trial results, POCUS represents an essential but targeted component of shock assessment and resuscitation.

Ethics Statement

This article is a narrative review of published literature. No patient data, images, or identifiable information were used. Ethics approval and patient consent were not required.

Disclosure Statement

The authors declare no conflicts of interest.

Funding

No funding was received for this work.

Author Contributions

SMF: conceptualization, methodology, formal analysis, investigation, writing - original draft. AK, YA, ASF, MSA, FAK, AV, and IIB: investigation, data curation, writing - review & editing. AV: data visualization. AJB: supervision, validation, writing - review & editing. All authors reviewed and approved the final manuscript.

References

1. Vincent JL, De Backer D. Shock. N Engl J Med. 2013;369(18):1726-1734.

2. Moore CL, Copel JA. Point-of-care ultrasonography. N Engl J Med. 2011;364(8):749-757.

3. Berg I, Walpot K, Lamprecht H, Valois M, Lanctôt JF, Srour N, van den Brand C. A Systemic Review on the Diagnostic Accuracy of Point-of-Care Ultrasound in Patients With Undifferentiated Shock in the Emergency Department. Cureus. 2022;14(3):e23188. doi: 10.7759/cureus.23188

4. Dunay Silva AAA Sr, Tovar SM, Usma Gutierrez JS, Fiallos Baldeón RD, Arias Merino ER, Ceja M, Gutiérrez Hoyos PA. Impact of Point-of-Care Ultrasound-Guided Resuscitation Protocols in the Treatment of Septic Shock: A Systematic Review of Hemodynamic Outcomes and Mortality. Cureus. 2026;18(1):e100850. doi: 10.7759/cureus.100850

5. Labovitz AJ, Noble VE, Bierig M, Goldstein SA, Jones R, Kort S, Porter TR, Spencer KT, Tayal VS, Wei K. Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. J Am Soc Echocardiogr. 2010;23(12):1225-30. doi: 10.1016/j.echo.2010.10.005

6. Amini R, Stolz LA, Gross A, O'Brien K, Panchal AR, Reilly K, Chan L, Drummond BS, Sanders A, Adhikari S. Theme-based teaching of point-of-care ultrasound in undergraduate medical education. Intern Emerg Med. 2015;10(5):613-8. doi: 10.1007/s11739-015-1222-8

7. Popat A, Harikrishnan S, Seby N, Sen U, Patel SK, Mittal L, Patel M, Vundi C, Patel Y, Babita, Kumar A, Nakrani AA, Patel M, Yadav S. Utilization of Point-of-Care Ultrasound as an Imaging Modality in the Emergency Department: A Systematic Review and Meta-Analysis. Cureus. 2024;16(1):e52371. doi: 10.7759/cureus.52371

8. Perera P, Mailhot T, Riley D, Mandavia D. The RUSH exam: Rapid Ultrasound in Shock in the evaluation of the critically ill. Crit Care Med. 2010;38(1):176-181.

9. Yoshida T, Yoshida T, Noma H, Nomura T, Suzuki A, Mihara T. Diagnostic accuracy of point-of-care ultrasound for shock: a systematic review and meta-analysis. Crit Care. 2023;27(1):200. doi: 10.1186/s13054-023-04495-6

10. Atkinson P, Bowra J, Lambert M, Lamprecht H, Noble V, Jarman B. International Federation for Emergency Medicine point of care ultrasound curriculum. CJEM. 2015;17(2):161-70. doi: 10.1017/cem.2015.8

11. International Federation for Emergency Medicine. Sonography in Hypotension and Cardiac Arrest (SHoC) guidelines. 2017.

12. Zaki HA, Albaroudi B, Shaban EE, Shaban A, Elgassim M, Almarri ND, Basharat K, Azad AM. Advancement in pleura effusion diagnosis: a systematic review and meta-analysis of point-of-care ultrasound versus radiographic thoracic imaging. Ultrasound J. 2024;16(1):3. doi: 10.1186/s13089-023-00356-z

13. Juhl-Olsen P, Vistisen ST, Christiansen LK, Rasmussen LA, Frederiksen CA, Sloth E. Ultrasound of the inferior vena cava does not predict fluid responsiveness in mechanically ventilated patients. Crit Care. 2011;15(4):R145.

14. Assavapokee T, Rola P, Assavapokee N, Koratala A. Decoding VExUS: a practical guide for excelling in point-of-care ultrasound assessment of venous congestion. Ultrasound J. 2024;16(1):48. doi: 10.1186/s13089-024-00396-z

15. Melo RH, Gioli-Pereira L, Melo E, Rola P. Venous excess ultrasound score association with acute kidney injury in critically ill patients: a systematic review and meta-analysis of observational studies. Ultrasound J. 2025;17(1):16. doi: 10.1186/s13089-025-00413-9

16. Klompmaker P, Mousa A, Allard DJ, Hagen BSH, Bánki T, Vermeulen W, de Waal M, van Wolfswinkel S, De Grooth HJS, Veelo DP, Vlaar APJ, Tuinman PR. The association between venous excess ultrasound grading system (VExUS) and major adverse kidney events after 30 days in critically ill patients: A prospective cohort study. J Crit Care. 2025;88:155097. doi: 10.1016/j.jcrc.2025.155097

17. American College of Emergency Physicians. Ultrasound guidelines: emergency, point-of-care and clinical ultrasound guidelines in medicine. Ann Emerg Med. 2023;82:e115-e155.

18. Guevarra KG, Greenstein Y. Point-of-care ultrasonography in the critical care unit: an update. CHEST. 2025.

19. Taheri O, Samain J, Mauny F, Puyraveau M, Desmettre T, Marx T. Contribution of point-of-care ultrasound in the prehospital management of patients with non-trauma acute dyspnea: a systematic review and meta-analysis. Eur J Emerg Med. 2025;32(2):87-99. doi: 10.1097/MEJ.0000000000001205

20. Hirata Y, Kusunose K. AI in Echocardiography: State-of-the-art Automated Measurement Techniques and Clinical Applications. JMA J. 2025 Jan;8(1):141-150. doi: 10.31662/jmaj.2024-0180

21. Gohar E, Herling A, Mazuz M, Tsaban G, Gat T, Kobal S, Fuchs L. Artificial Intelligence (AI) versus POCUS Expert: A Validation Study of Three Automatic AI-Based, Real-Time, Hemodynamic Echocardiographic Assessment Tools. J Clin Med. 2023;12(4):1352. doi: 10.3390/jcm12041352

22. East SA, Wang Y, Yanamala N, Maganti K, Sengupta PP. Artificial Intelligence-Enabled Point-of-Care Echocardiography: Bringing Precision Imaging to the Bedside. Curr Atheroscler Rep. 2025;27(1):70. doi: 10.1007/s11883-025-01316-9

23. Lichtenstein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. Intensive Care Med. 2008;34(3):577-584.

24. Kirkpatrick, A., Sirois, M., Laupland, K., Liu, D., Rowan, K., Ball, C., Hameed, S., Brown, R., Simons, R., Dulchavsky, S., Hamiilton, D., & Nicolaou, S. (2004). Hand-Held Thoracic Sonography for Detecting Post-Traumatic Pneumothoraces: The Extended Focused Assessment With Sonography For Trauma (EFAST). Journal of Trauma: Injury, Infection & Critical Care, 57(2), 288–295. doi: 10.1097/01.TA.0000133565.88871.E4

25. Pontet J, Yic C, Díaz-Gómez JL, Rodriguez P, Sviridenko I, Méndez D, Noveri S, Soca A, Cancela M. Impact of an ultrasound-driven diagnostic protocol at early intensive-care stay: a randomized-controlled trial. Ultrasound J. 2019;11(1):24. doi: 10.1186/s13089-019-0139-2

26. Atkinson PR, Milne J, Diegelmann L, Lamprecht H, Stander M, Lussier D, Pham C, Henneberry R, Fraser JM, Howlett MK, Mekwan J, Ramrattan B, Middleton J, van Hoving DJ, Peach M, Taylor L, Dahn T, Hurley S, MacSween K, Richardson LR, Stoica G, Hunter S, Olszynski PA, Lewis DA. Does Point-of-Care Ultrasonography Improve Clinical Outcomes in Emergency Department Patients With Undifferentiated

Hypotension? An International Randomized Controlled Trial From the SHoC-ED Investigators. Ann Emerg Med. 2018;72(4):478-489. doi: 10.1016/j.annemergmed.2018.04.002

27. Kory PD, Pellecchia CM, Shiloh AL, Mayo PH, DiBello C, Koenig SCost analysis of point-of-care ultrasound in the critical care unit. Chest. 2022;161(4):1051-1058

28. National Institute for Health and Care Excellence. Point-of-care ultrasound for undifferentiated shock: diagnostic accuracy and cost-effectiveness. NICE Diagnostic Guidance. 2024;DG55.



Cardiac Tamponade Secondary to a Giant Pericardial Cyst Diagnosed Using POCUS: A Case Report

Syed Ghazi[1]; Seth Johnston[1]*; Veronica Nguyen, MD[1]; Kristen Downey, MD[1];

Whitney Potomac, DO MS FACEP FPD-AEMUS[2]

(1) Texas A&M Naresh K. Vashisht College of Medicine, Bryan, TX, USA
(2) Department of Emergency Medicine, Baylor University Medical Center, Dallas, TX, USA

Abstract

Background: Pericardial cysts are uncommon and usually asymptomatic, but very large cysts can become problematic when they compress adjacent intrathoracic structures. Reported cases of cardiac tamponade caused by a pericardial cyst are exceptionally rare in the literature. **Case Summary:** A 56-year-old man with morbid obesity (BMI of 40.3) presented with worsening dyspnea. Cardiac point of care ultrasound (POCUS) revealed a large, encapsulated pericardial fluid collection causing right atrial systolic and ventricular chamber diastolic collapse. Chest computed tomography (CT) imaging demonstrated a 20 cm pericardial cyst that compressed the right heart. Soon after, the patient was taken by cardiothoracic surgery to the operating room for a pericardial window. His postoperative course was complicated by transient hypercapnic respiratory failure, volume overload, and an acute kidney injury. Ultimately, he was discharged in stable condition. **Conclusion:** Although typically benign, giant pericardial cysts can rarely produce life-threatening cardiac tamponade physiology. Cardiac POCUS can be used for early diagnosis of pericardial cyst and facilitate timely surgical intervention.

Introduction

Pericardial cysts are rare mediastinal lesions with an estimated incidence of approximately 1 in 100,000 individuals, accounting for about 7% of mediastinal masses and up to one-third of mediastinal cysts [1–3]. They are usually congenital, arising from incomplete fusion of mesothelial lacunae during embryologic development, although acquired cysts have been reported after pericarditis, thoracic surgery, or trauma [1–3]. Most pericardial cysts measure a few centimetres in diameter, with pooled series describing an average diameter of around 5–6 cm, and roughly 60–75% are detected incidentally and remain asymptomatic [1–4]. However, when they grow, they can compress adjacent cardiac chambers, great vessels, or lung tissue, resulting in dyspnea, chest discomfort, arrhythmias, or signs of heart failure [1,3,5]. Cysts that are larger than 10 cm, often termed giant pericardial cysts, are more likely to be symptomatic and have been associated with serious complications, including arrhythmias and hemodynamic compromise [4–6].

Cardiac tamponade caused by a pericardial cyst is exceedingly uncommon; only isolated cases have been described, usually involving giant, hemorrhagic, or rapidly enlarging cysts that compress low-pressure right-sided cardiac chambers [5–9]. These cases highlight the fact that even benign lesions can become acutely life-threatening. We report a case of a giant pericardial cyst producing right-sided chamber collapse and ultrasonographic evidence of cardiac tamponade, which was diagnosed rapidly with cardiac POCUS.

On cardiac POCUS, cardiac tamponade is characterized by impaired diastolic filling that results from elevated intrapericardial pressure exceeding intracardiac pressures. The earliest and most sensitive sonographic finding is right atrial systolic collapse, which occurs because the right atrium is a low-pressure chamber during systole and is therefore particularly susceptible to external compression [10,11]. With further increases in intrapericardial pressure, right ventricular diastolic collapse may be observed, signifying compromised right ventricular filling. A plethoric inferior vena cava with minimal respiratory variation reflects elevated right atrial pressure and impaired venous return [10]. Doppler interrogation commonly demonstrates exaggerated respiratory variation in transvalvular flow velocities, with reduced mitral inflow and increased tricuspid inflow

*Corresponding Author: Seth Johnston (email: scjohnston48@tamu.edu)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20402

during inspiration, reflecting ventricular interdependence and impaired left-sided cardiac filling [11,12].

It is important to distinguish sonographic cardiac tamponade from clinical cardiac tamponade, as these entities do not always occur simultaneously. Sonographic tamponade refers to echocardiographic evidence of impaired cardiac filling (right atrial systolic collapse, right ventricular diastolic collapse, inferior vena cava plethora, and exaggerated respiratory variation in transvalvular flow) identified in the absence of overt hemodynamic instability. In contrast, clinical tamponade is defined by the presence of these echocardiographic findings together with signs of circulatory compromise, including hypotension, tachycardia, elevated jugular venous pressure, and evidence of end-organ hypoperfusion [10,13]. Patients may therefore demonstrate tamponade physiology on cardiac POCUS or echocardiogram while remaining normotensive, particularly in subacute or slowly progressive processes, until compensatory mechanisms are exhausted. Recognizing sonographic tamponade is critical, as it identifies patients at high risk for impending hemodynamic decompensation and enables timely intervention before progression to clinical shock [10,14]. In the high-acuity environment of the emergency department (ED), the hemodynamic significance of pericardial fluid is determined less by absolute volume and more by the rate of accumulation relative to pericardial compliance. With gradual or chronic accumulation, the pericardium adapts along a nonlinear pressure–volume curve, permitting larger volumes to accumulate before a critical rise in intrapericardial pressure occurs. In contrast, acute or acute-on-chronic increases in pericardial (or pericardial-adjacent) fluid can rapidly traverse the steep portion of this curve, producing a tipping point at which intrapericardial pressure exceeds low right-sided intracardiac diastolic pressures. This impairs ventricular filling, reduces stroke volume, and manifests echocardiographically as progressive chamber collapse—often beginning with right atrial systolic collapse and advancing to right ventricular diastolic collapse, a hallmark finding of tamponade physiology [10,13]. In this patient, progressive dyspnea in the setting of a massive pericardial cyst suggested subacute worsening superimposed on chronic right-heart compression. This culminated in ED cardiac POCUS evidence of tamponade physiology before overt hypotension.

Case Presentation

A 56-year-old man living with morbid obesity (BMI of 40.3), moderate persistent asthma, rheumatoid arthritis (RA) controlled with methotrexate, and chronic kidney disease (stage 3) presented to the ED with progressively worsening shortness of breath for one week, refractory to daily albuterol, shortly after discharge from an outside hospital. On arrival, the patient had diminished breath sounds in the bilateral lower lung fields and an oxygen saturation of 92% on pulse oximetry. He remained normotensive (blood pressure 134/107 mm Hg) and was alert and appropriately mentating. Other vital signs were within normal limits, including a heart rate of 93 beats per minute (bpm), temperature of 98.1°F, and respiratory rate of 18 breaths per minute. Repeat heart rate per electrocardiogram demonstrated tachycardia at 103 bpm.

POCUS was performed within minutes of presentation and demonstrated a large, well-circumscribed, predominantly anechoic pericardial fluid collection encasing the right side of the heart. The cardiac POCUS exam demonstrated right atrial systolic collapse and right ventricular diastolic collapse, consistent with early tamponade physiology. Based on these findings, cardiology and cardiothoracic surgery were urgently consulted (Supplementary Materials - Video S1, Video S2 and Video S3).

Lung POCUS displayed bilateral pleural thickening, left pleural effusion, and right pleural effusion with lower lobe atelectasis (Figure 1, Supplementary Materials - Video S4 and Video S5).

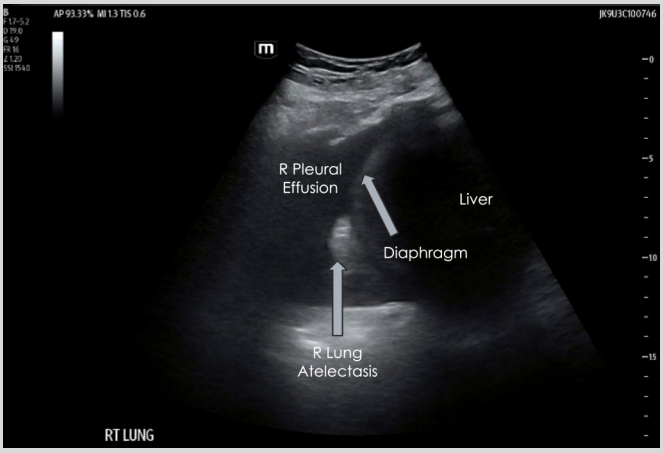


Figure 1. Point of care ultrasound (POCUS) of right lung demonstrating pleural effusion causing atelectasis. R, right.

Subsequent contrast-enhanced CT of the chest revealed a massive, nearly circumferential pericardial cyst measuring approximately 20 cm in craniocaudal dimension, extending from the superior cardiac border to the apex and encasing the right atrium and ventricle. The cyst was causing near-complete compression of the right ventricle and approximately 50% compression of the right atrium. Additional findings included a right-sided pleural effusion with associated right lower-lobe atelectasis, a smaller left pleural effusion, and mild perihepatic and perisplenic ascites. The CT appearance was consistent

with a large, encapsulated pericardial cyst rather than a free pericardial effusion (Figure 2, Supplementary Material - Video S6).

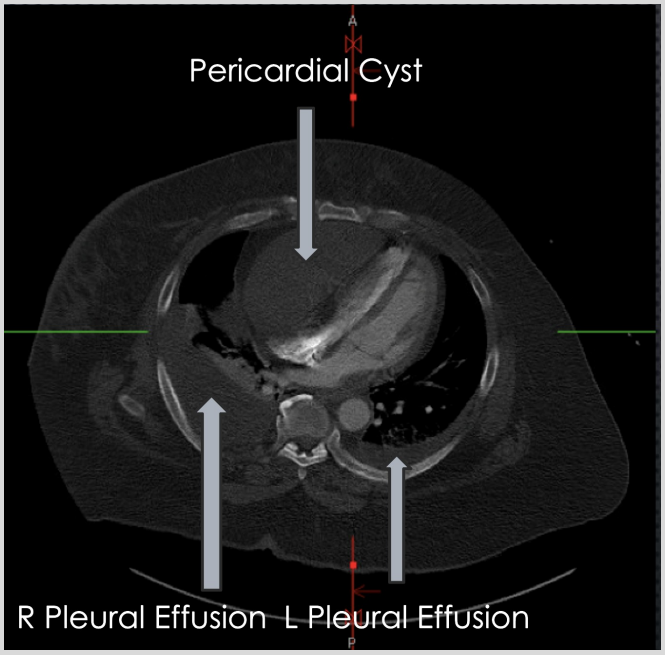


Figure 2. CTAChest showing bilateral pleural effusion. A large 20 cm pericardial cyst causing major right ventricular collapse. R = right; L = left.

On admission to the intensive care unit, there was concern for community-acquired pneumonia superimposed on pleural effusion, plus elevated lactate and tachycardia. Empiric vancomycin and cefepime were started, and cultures were drawn.

On day 0, the patient underwent a surgical pericardial window and 500 mL of bloody fluid was evacuated. In the immediate postoperative period, he developed multifactorial hypercapnic respiratory failure, likely secondary to asthma exacerbation, atelectasis, and bilateral pleural effusions, and required Bilevel Positive Airway Pressure (BiPAP), scheduled bronchodilators, inhaled budesonide, and a five-day course of prednisone. Antibiotics were discontinued after five days of negative cultures and inflammatory markers.

Over the ensuing days, with all of the interventions, the patient became volume overloaded. This was managed with intravenous furosemide followed by an oral diuretic regimen. Transient volume overload following pericardial decompression has been described in the literature and is thought to result from abrupt changes in venous return, ventricular interdependence, and myocardial compliance after relief of chronic pericardial constraint [15]. He also experienced an acute kidney injury, with his serum creatinine rising transiently but improving to his baseline of 1.4–1.5 mg/dL with cautious volume management. During the postoperative course, POCUS was not used for further differential evaluation. Instead, a transthoracic echocardiogram was performed on postoperative day 1, which demonstrated grossly normal chamber sizes, mildly increased left ventricular wall thickness, and mildly reduced systolic function with a left ventricular ejection fraction of 40–45% and global hypokinesis. Grade 1 diastolic dysfunction was noted with normal left atrial pressure. There was no significant valvular stenosis or regurgitation; the inferior vena cava was normal in calibre, with greater than 50% respiratory collapse consistent with normal right atrial pressure, and no residual pericardial effusion was identified. By postoperative day 2, his respiratory status and hemodynamics had stabilized sufficiently for transfer to a step-down unit. The chest tube was removed on day 5, and he was discharged home on day 6 with instructions to resume methotrexate and to hold tofacitinib until outpatient follow-up for RA. The patient had two follow-up encounters with cardiothoracic surgery. His first postoperative follow-up occurred on postoperative day 13, and his second follow-up occurred on postoperative day 41. At the first follow-up appointment, the patient was asymptomatic but was found to have a right-sided pleural effusion on imaging. He was advised to continue furosemide for an additional seven days and to obtain a repeat chest radiograph in one month. At the subsequent follow-up visit, repeat chest radiography demonstrated a small residual right pleural effusion, and the patient was advised to follow up as needed.

Discussion

Giant pericardial cysts, while rare, can exert substantial mass effect on adjacent cardiac chambers [1,4–6]. In contrast to classic effusive cardiac tamponade, in which circumferential pericardial fluid uniformly elevates intrapericardial pressure, cyst-related tamponade results from localized extrinsic compression of low-pressure chambers, usually the right atrium and right ventricle. Prior reports have described giant or hemorrhagic cysts compressing the right heart, sometimes presenting with syncope, right-sided heart failure, or acute cardiac tamponade requiring emergent surgical intervention [5–9]. In this case, the 20 cm circumferential cyst—which nearly obliterated the right ventricle and narrowed the right atrium by 50%—represented an extreme example of this mechanism. The case adds to accumulating evidence that giant pericardial cysts can behave unpredictably and should be managed with heightened vigilance when they demonstrate rapid growth or produce symptoms.

The etiology of the bilateral pleural effusions may be multifactorial. Pleural thickening and effusions are likely an extra-articular manifestation of RA treated with methotrexate. Of patients with RA, 30–40% experience

involvement of the respiratory system, and pleural effusion is a common manifestation in middle-aged men [16–18]. Additionally, right-sided heart failure and increased right atrial filling pressure might contribute to pleural effusion, especially on the right side. Increased filling pressure of the right atria (demonstrated by the bounding interventricular septum on the apical four-chamber view) requires an increase in systemic venous pressure to continue forward flow of return blood. This causes a backup in fluid in the venous system, resulting in fluid overload symptoms, such as ascites seen in this patient. Thus, the lymphatic system of the lungs draining into the venous system would also be congested, contributing to a transudative pleural effusion. However, this phenomenon was not seen in a smaller study of isolated elevated right atrial pressure [19].

POCUS played a central role in this case by rapidly identifying tamponade physiology prior to hemodynamic collapse and prompting immediate surgical consultation. Echocardiography is the primary diagnostic tool for tamponade, and multiple observational studies have shown that POCUS is associated with earlier diagnosis and shorter time to pericardial intervention compared with traditional imaging pathways [10–12]. In one ED cohort, the use of POCUS was linked to a significantly reduced time from arrival to pericardial drainage in patients undergoing pericardiocentesis or surgical evacuation of an effusion [10]. Similar findings have been reported in inpatient and academic-center settings, where POCUS facilitated recognition of pericardial effusions, cardiac tamponade and shortened time to diagnosis and intervention [11,12]. This case aligns with the literature: tamponade physiology was recognized at the bedside within minutes of presentation, leading to rapid CT confirmation and urgent pericardial window rather than a delayed or stepwise imaging approach. CT and medical resonance imaging (MRI) remain important complementary modalities for defining the size, location, and relationship of pericardial cysts to adjacent structures, which is crucial for surgical planning [1,3,7,13].

Most asymptomatic or small pericardial cysts can be managed conservatively and followed by cardiologists with periodic imaging [1–3,7]. Although no universal follow-up interval exists, for incidental, asymptomatic pericardial cysts with benign imaging characteristics, conservative management with interval surveillance is generally recommended [1,2]. Serial transthoracic echocardiography is commonly used for longitudinal surveillance to minimize radiation exposure, with CT or cardiac MRI reserved for cases that require improved anatomic delineation or when echocardiographic windows are inadequate [1,2]. Observational data describing the natural history of pericardial cysts demonstrate that many remain stable or decrease in size over approximately two years of follow-up, supporting a nonoperative strategy in asymptomatic patients without evidence of compression [20]. Although no evidence-based size threshold mandates surgical intervention, cysts larger than 10 cm (often termed giant pericardial cysts) are more likely to become symptomatic and are frequently managed surgically because of increased risk of compression and hemodynamic compromise [4–6,9]. Surgical resection or pericardial window is therefore generally recommended for symptomatic patients who demonstrate interval growth or exhibit imaging evidence of compression of cardiac chambers, great vessels, or adjacent lung parenchyma [1,3–6]. Intervention is generally reserved for symptomatic patients who have large or enlarging cysts or exhibit evidence of compression of cardiac chambers, great vessels, or airways [1,3–6]. In such cases, surgical resection or pericardial window is usually preferred over percutaneous drainage because of the risk of recurrence and the frequent presence of thick cyst walls [1,4–6]. In this patient, the combination of giant cyst size, right-sided chamber collapse, and echocardiographic signs of tamponade clearly warranted definitive surgical decompression. His subsequent respiratory failure, transient kidney injury, and volume overload mirror postoperative challenges previously reported in patients undergoing intervention for giant pericardial cysts and other large pericardial lesions [6,8,9].

Conclusion

Giant pericardial cysts are uncommon lesions that can produce life-threatening tamponade physiology through severe extrinsic compression of right-sided cardiac chambers. This case illustrates how rapid assessment with cardiac POCUS can identify tamponade physiology within minutes of presentation, expedite definitive imaging, and facilitate timely surgical intervention. Despite their rarity, pericardial cysts should be considered in the differential diagnosis of patients presenting with unexplained tamponade physiology, particularly when imaging reveals a localized, encapsulated fluid collection.

Acknowledgements

Images captured by Drs. Brandon Chin and Whitney Potomac.

Ethics Statement

This case was carried out in full compliance with ethical research guidelines. Measures were taken to ensure the privacy and confidentiality of the presented data.

Disclosure Statement

The authors declare no conflicts of interest related to this work.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contributions

SG: writing - original draft, data curation, writing – review & editing, Investigation. SJ: writing – review & editing, data curation, visualization, investigation. VN: data curation, project management. KD: data curation, project management. WP: conceptualization, writing – review & editing, visualization, investigation, methodology, project management, supervision

References

1. Kar SK, Ganguly T. Current concepts of diagnosis and management of pericardial cysts. *Indian Heart J.*2017;69(3):364–370.

2. Meredith A, Zazai IK, Kyriakopoulos C. *StatPearls [Internet]*. Pericardial Cyst. Updated January 4, 2023. https://www.ncbi.nlm.nih.gov/books/NBK562287/, accessed December 12, 2026.

3. Noori MAM, Mohammadian M, Saeed H, Abboud R, Polyak A, Jawed Q, Shah D, Singh P, Ibrahim M, Joshi M. Pericardial cyst, a rare incidental finding in an uncommon location: a case report. Cureus. 2022;14(6):e26037. doi:10.7759/cureus.26037

4. Hekmat M, Ghaderi H, Mirjafari SA, Jodati A. Giant pericardial cyst: a case report and review of the literature. *Iran J Radiol.* 2016;13 (1):e21921.

5. Cho JS, Huh U, Lee J, Ahn HY. Giant pericardial cyst with cardiac tamponade: a case report. *Asian J Surg.*2021;44(5):794–795.

6. Elhakim A, Boguschewski A, Zamzow P, Saad M. A haemorrhagic pericardial cyst compressing the right side of the heart: a case report. *Eur Heart J Case Rep.* 2023;7(10):ytad497.

7. Labi J, Ibrahim EU, Anim DA, Sereboe LA, Mensah YB. Giant pericardial cyst, an unusual cause of right heart failure in an elderly patient with tuberculosis and HIV: a case report. Radiol Case Rep. 2023;18(4):1466-1470. doi:10.1016/j.radcr.2023.01.048

8. Amr BS, Dalia T, Simmons A. Acute cardiac tamponade secondary to ruptured pericardial cyst: case report and literature review. J Cardiol Cases. 2018;18(2):43-46. doi:10.1016/j.jccase.2018.04.003

9. Vicentin JM, Tibaldi M, Moreyra C, Cafaro M, Figueroa M, Moreyra E. Symptomatic giant pericardial cyst. CASE (Phila). 2025;10(1):33-37. doi:10.1016/j.case.2025.09.008

10. Spodick DH. Acute cardiac tamponade. N Engl J Med. 2003;349 (7):684–690.

11. Appleton CP, Hatle LK, Popp RL. Cardiac tamponade and pericardial effusion: respiratory variation in Doppler echocardiographic velocities. J Am Coll Cardiol. 1988;11(5):1020–1030.

12. Hanson MG, Chan B. The role of point-of-care ultrasound in the diagnosis of pericardial effusion: a single academic center retrospective study. *Ultrasound J.* 2021;13(1):2.

13. Adler Y, Charron P, Imazio M, Badano L, Barón-Esquivias G, Bogaert J, Brucato A, Gueret P, Klingel K, Lionis C, Maisch B, Mayosi B, Pavie A, Ristić AD, Tenas MS, Seferovic P, Swedberg K, Tomkowski W, ESC Scientific Document Group. 2015 ESC Guidelines for the diagnosis and management of pericardial diseases. Eur Heart J. 2015;36(42):2921–2964.

14. Hoch VC, Abdel-Hamid M, Liu J, Hall AE, Theyyunni N, Fung CM. ED point-of-care ultrasonography is associated with earlier drainage of pericardial effusion: a retrospective cohort study. *Am J Emerg Med.* 2022;60:156–163.

15. Chamoun A, Cenz R, Mager A, Rahman A, Champion C, Ahmad M, Birnbaum Y. Acute left ventricular failure after large volume pericardiocentesis. Clin Cardiol. 2003;26(12):588-590. doi:10.1002/clc.4960261209

16. Alunno A, Gerli R, Giacomelli R, Carubbi F. Clinical, Epidemiological, and Histopathological Features of Respiratory Involvement in Rheumatoid Arthritis. *Biomed Res Int*. 2017;2017:7915340.

17. Balbir-Gurman A, Yigla M, Nahir AM, Braun-Moscovici Y. Rheumatoid pleural effusion. *Semin Arthritis Rheum*. 2006;35(6):368-378.

18. Abu-Shakra M, Nicol P, Urowitz MB. Accelerated nodulosis, pleural effusion, and pericardial tamponade during methotrexate therapy. *J Rheumatol*. 1994;21(5):934-937.

19. Wiener-Kronish JP, Goldstein R, Matthay RA, Biondi JW, Broaddus VC, Chatterjee K, Matthay MA. Lack of association of pleural effusion with chronic pulmonary arterial and right atrial hypertension. Chest. 1987;92(6):967-970.

20. Patel J, Park C, Michaels J, Rosen S, Kort S. Clinical features, natural history, and management of pericardial cysts. Am J Cardiol. 2018;122(9):1590 to 1593.

NOV 2026 vol. 11 iss. 02 | POCUS J | 92

Respiratory Variation in Coronary Sinus Size

Jina Bai, PA[1]*; Gregory Mints, MD[2]; Todd Cutler, MD[1]; Su Yuan, MD[3]

(1) Weill Cornell Medical Center, Department of General Internal Medicine, Section of Hospital Medicine, New York, NY, USA
(2) Department of Medicine, Division of Hospital Medicine, Kings County Hospital and SUNY Downstate Medical University, Brooklyn, NY, USA
(3) Weill Cornell Medical Center, Division of Cardiology, New York, NY, USA

Abstract

The coronary sinus (CS), when distended and its muscular wall pathologically weakened, may undergo cyclical respirophasic changes in diameter analogous to those known to occur in the inferior (IVC) and superior (SVC) venae cavae. Here, we report a case of a markedly dilated CS due to a persistent left superior vena cava (PLSVC) and describe its volume-dependent respiratory size variation. As expected based on known physiology, respirophasic variations were prominent under conditions of hypovolemia and respiratory distress, became less pronounced with euvolemia, and disappeared entirely in overt right ventricular failure. To our knowledge, this is the first report to illustrate changes in CS size with variation in intrathoracic pressure.

Case presentation

A 64-year-old man with mild systolic heart failure and pancreatic adenocarcinoma metastatic to the lungs and the liver presented to the hospital with 3 days of progressive shortness of breath and left-sided chest pain. On presentation, he was hypoxemic to 80% on room air, and a chest radiograph revealed large bilateral pleural effusions. He underwent bilateral thoracentesis and left-sided chest tube placement, which improved his oxygenation. Two weeks into his hospitalization, the patient had another episode of respiratory distress. He was tachypneic (26 breaths per minute) and hypoxemic, requiring 6 litres per minute of supplemental oxygen via nasal cannula to maintain an oxygen saturation of 95%. His heart rate was 118 beats per min with stable blood pressure. Cardiac point of care ultrasound (POCUS) in the parasternal long axis (PLAX) view (Supplementary Material - Video S1) revealed a hyperdynamic left ventricle. A markedly dilated coronary sinus (CS) was found incidentally. This was confirmed in the CS view, a modified apical 4-chamber view with dorsal transducer tilt (Supplementary Material - Video S2). Notably, the CS diameter showed respirophasic variation, while the inferior vena cava (IVC) was small with complete inspiratory collapse, which suggested a low right atrial pressure. A prior computed tomography (CT) of the chest with intravenous contrast (Figure 1) showed a persistent left SVC, explaining the patient's dilated CS. The patient's hypoxemia was attributed to the combined effects of pulmonary metastatic tumour burden and persistent bilateral malignant pleural effusions.

Three weeks into hospitalization, the patient's condition deteriorated again. He had worsening respiratory failure and hypotension, which eventually required intubation and initiation of vasopressors. While intubated and sedated, a mobile, non-occlusive thrombus was identified in the patient's left common femoral vein. A transthoracic echocardiogram showed new severe right ventricular (RV) failure, further increase in size of the dilated CS, and loss of the prominent respirophasic variation of CS size previously seen (Supplementary Material - Video S3). A pulmonary embolism (PE) was suspected as the cause of this new RV failure. The patient's condition continued to worsen. He transitioned to comfort-focused care and subsequently passed away.

Discussion

Lying in the posterior atrioventricular groove between the left atrium and left ventricle, the CS is the largest epicardial vein. The normal CS is approximately 2–3 cm long. It collects blood from the cardiac veins and drains into the right atrium (RA) [1,2]. During fetal development, the left anterior cardiac vein typically atrophies, leaving a fibrous cord (Marshall's ligament) [2]. If the left common and anterior cardinal veins fail to regress, they form a persistent left superior vena cava (PLSVC) that carries blood from the left upper body to the RA via the CS (Figure 2). The CS is normally a rather small vein.

*Corresponding Author: Jina Bai (email: jib9010@nyp.org)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20271

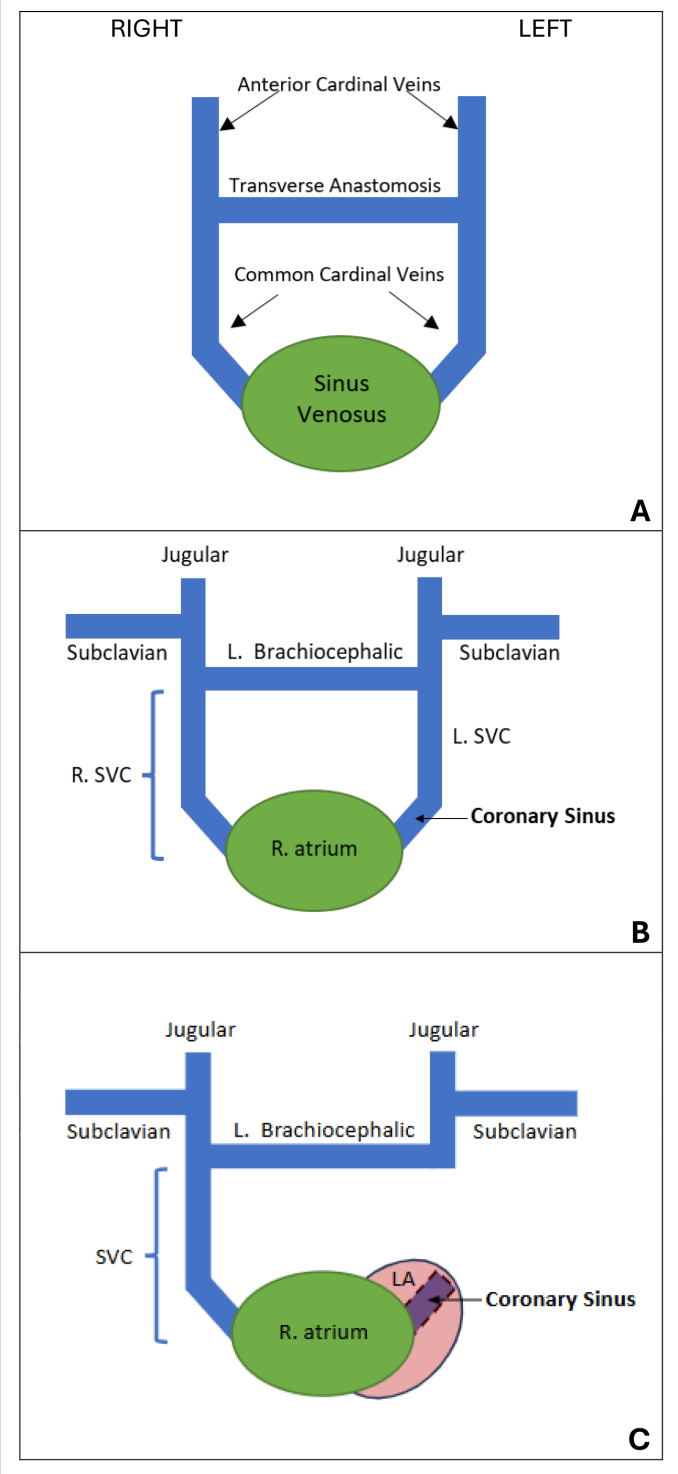


Figure 1. Embryological development of the cephalad venous system and the most common persistent left superior vena cava (PLSVC) anatomy. A) In the embryo, paired anterior and posterior cardinal veins (posterior not shown) join to form the common cardinal veins, which empty into the sinus venosus. The left and right systems are initially separate, but a transverse anastomosis later forms between the left and right anterior cardinal veins. B) This transverse anastomosis matures into the left brachiocephalic vein. At this stage, both the right and left superior vena cava (SVC) are present: the right SVC forms from the right anterior and common cardinal veins, and the left SVC from the left anterior cardinal vein. The left common cardinal vein forms most of the CS. In typical development, the left SVC regresses, leaving the CS as the only remnant of the embryonal left cephalad circulation. Failure of regression results in a persistent left SVC draining into the right atrium (RA) via the CS. C) In typical development, the left SVC atrophies, leaving behind only a fibrous cord (Marshall's ligament, not shown), and all upper-body venous return drains through the right-sided SVC.

However, like other vessels and the heart's chambers, the CS can dilate due to two factors: volume or pressure overload. Volume overload usually arises from anomalous systemic or pulmonary venous return into the CS, of which the most common is a PLSVC [1,3]. Pressure overload results from chronic elevation of RA pressure, as seen in RV failure and pulmonary hypertension [1,4,5]. Whereas pressure overload tends to cause only a modest increase in CS size, volume overload states can cause much more substantial CS dilation, which sometimes becomes massive [4]. In most cases, a PLSVC and a dilated CS are benign. However, a PLSVC can complicate left-sided central venous access, cardiac catheterization, or device implantation [6–8]. In pediatric patients, a markedly dilated CS has been reported to exert a mass effect on the nearby left atrium, causing left ventricular inflow obstruction, particularly when associated with other congenital cardiac abnormalities [9,10].



Figure 2. Computed tomography (CT) of the chest with intravenous contrast showed a persistent left superior vena cava (PLSVC), confirming the etiology of the patient's severely dilated coronary sinus (CS).

Both the SVC and the IVC exhibit cyclical changes in diameter and blood flow with respiration. The magnitude of these changes is known to be predictive of right atrial pressure (RAP) and has been suggested for use as a predictor of volume responsiveness in shock states [11]. In a spontaneously breathing person, the IVC collapses on inspiration as the intrathoracic pressure falls, intra-abdominal pressure rises, and venous return to the heart increases [11]. In contrast, during positive pressure ventilation (PPV), the IVC collapses during expiration [12] (Table 1). The SVC, located entirely within the thoracic cavity, demonstrates the opposite respiratory variation pattern: The SVC collapses on expiration in spontaneously breathing patients, and collapses on inspiration in patients on PPV [13,14] (Table 1). The diameter of the venae cavae is also influenced by the magnitude of intrathoracic pressure change during inspiration. Spontaneously breathing patients in respiratory distress can generate substantial negative intrathoracic pressures, producing marked respiratory fluctuations in vessel calibre—even in patients who are adequately fluid-resuscitated.

The tunica media of a normal CS is formed by a thicker layer of striated cardiac muscle continuous with the RA myocardium, rather than smooth muscle as seen in other veins [1]. The presence of this thicker wall and the relatively small CS size likely dampen the respiratory size changes in the normal CS. However, in cases of marked CS dilation, as seen with PLSVC, the vessel wall becomes thinned and distended. This diminishes its ability to resist intrathoracic pressure fluctuations and allows for visible respirophasic size variation. We were unable to find any published reports documenting respirophasic size changes in the PLSVC or the CS. We speculate that blood flow dynamics in the CS and PLSVC should be similar to those in the SVC, given their shared drainage into the RA [15].

In our patient, the CS diameter demonstrated marked respirophasic variation during spontaneous breathing, which was likely caused by hypovolemia and respiratory distress (Supplementary Material - Video S1). A baseline echocardiogram was obtained when the patient was euvolemic and not in distress. This showed much less pronounced CS size variation (Supplementary Material - Video S4). Following a suspected PE, an echocardiogram revealed (Supplementary Material - Video S3) severe RV failure and further CS dilation with loss of respiratory size variability. This was likely due to the persistent elevation of RAP throughout the respiratory cycle. This case provides valuable insight into the dynamic physiological relationship between the venae cavae and intrathoracic pressure during the respiratory cycle. Although respiratory variation in CS diameter may correlate with RV filling pressure similarly to the changes in IVC and SVC measurements, its clinical applicability is limited by the CS's small size and inconsistent visualization on POCUS. To the best of our knowledge, this physiology of CS diameter change with the respiratory cycle has not been previously reported.

Table 1. Respiratory variation in venae cavae size during the respiratory cycle. The inferior vena cava (IVC) collapses on inspiration in spontaneously breathing patients, and on expiration in patients on positive pressure ventilation (PPV). The superior vena cava (SVC) demonstrates the opposite pattern, collapsing during expiration in spontaneously breathing patients and during inspiration while on PPV.

	IVC collapse	SVC collapse
Spontaneous breathing	Inspiration	Expiration
PPV	Expiration	Inspiration

Ethics Statement

This study was conducted in accordance with the amended Declaration of Helsinki. Institutional review board not applicable for case reports.

Disclosure Statement

The authors report no known competing financial interests or personal relationships that could have influenced the work.

Funding

The authors received no financial support for the research, authorship, and/or publication of this case report.

Author Contributions

JB: investigation (literature review); writing – original draft. GM: investigation (literature review); writing – review & editing; visualization. TC: writing – review & editing. SY: supervision; writing – review & editing.

References

1. D'Cruz IA, Shala MB, Johns C. Echocardiography of the coronary sinus in adults. Clin Cardiol. 2000;23(3):149-154. doi:10.1002/clc.4960230304

2. Sirajuddin A, Chen MY, White CS, Arai AE. Coronary venous anatomy and anomalies. J Cardiovasc Comput Tomogr. 2020;14(1):80-86. doi:10.1016/j.jcct.2019.08.006

3. Bolognesi M. Dilated coronary sinus due to persistent left superior vena cava in a healthy athlete: A case report with brief review. J Integr Cardiol. 2015;1: doi:10.15761/JIC.1000131

4. Kolski BC, Khadivi B, Anawati M, Daniels LB, Demaria AN, Blanchard DG. The dilated coronary sinus: utility of coronary sinus cross-sectional area and eccentricity index in differentiating right atrial pressure overload from persistent left superior vena cava. Echocardiography. 2011;28(8):829-832. doi:10.1111/j.1540-8175.2011.01445.x

5. Młynarski R, Młynarska A. Coronary Sinus Diameter as a Potential Marker of Right Ventricle Impairment. Int J Environ Res Public Health. 2022;19(4):2217.

6. Lopez JA. Transvenous biventricular pacing for cardiac resynchronization therapy in patients with persistent left superior vena cava and right superior vena cava atresia. Tex Heart Inst J. 2008;35(1):54-57.

7. Chen X, Yu Z, Bai J, Wang W, Qin S, Wang J, Sun Z, Han F, Su Y, Ge J. Transvenous cardiac implantable electronic device implantation in patients with persistent left superior vena cava in a tertiary center. J Interv Card Electrophysiol. 2018;53(2):255-262. doi:10.1007/s10840-018-0377-4

8. Kim T, Kim KR, Jung WH, Choi HJ, Park J, Hong SH, Park CS, Chae MS. Clinical Implications of a Persistent Left Superior Vena Cava in a Patient With Right Superior Vena Cava Thrombosis Undergoing Emergency Deceased Donor Liver Transplantation: A Case Report. Transplant Proc. 2022;54(6):1648-1653. doi:10.1016/j.transproceed.2022.03.052

9. Bryant R. No longer novel: The association of a dilated coronary sinus with left ventricular inflow obstruction. The Journal of Thoracic and Cardiovascular Surgery. 2016;153(2):e31-e32.

10. Dibardino DJ, Fraser CD Jr, Dickerson HA, Heinle JS, McKenzie ED, Kung G. Left ventricular inflow obstruction associated with persistent left superior vena cava and dilated coronary sinus. J Thorac Cardiovasc Surg. 2004;127(4):959-962. doi:10.1016/j.jtcvs.2003.07.010

11. Elsaeed, A.M.R., Nor El-Din, B.M.E., El Taher, W.A.M. et al. Internal jugular vein distensibility variation and inferior vena cava collapsibility variation with fluid resuscitation as an indicator for fluid management in spontaneously breathing septic patients. Ain-Shams J Anesthesiol. 2022. 14(26). doi:10.1186/s42077-022-00226-1

12. Barbier C, Loubières Y, Schmit C, Hayon J, Ricôme JL, Jardin F, Vieillard-Baron A. Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. Intensive Care Med. 2004;30(9):1740-1746. doi:10.1007/s00134-004-2259-8

13. Fadel BM, Kazzi B, Mohty D. Ultrasound Imaging of the Superior Vena Cava: A State-of-the-Art Review. J Am Soc Echocardiogr. 2023;36(5):447-463. doi:10.1016/j.echo.2023.01.017

14. Li Y, Jiang L, Wang L, Dou D, Feng Y. Evaluation of fluid responsiveness with dynamic superior vena cava collapsibility index in mechanically ventilated patients. Perioper Med (Lond). 2023 Apr 10;12(1):10. doi:10.1186/s13741-023-00298-z

15. Reynolds T, Appleton CP. Doppler flow velocity patterns of the superior vena cava, inferior vena cava, hepatic vein, coronary sinus, and atrial septal defect: a guide for the echocardiographer. J Am Soc Echocardiogr. 1991;4(5):503-512. doi:10.1016/s0894-7317(14)80386-6

Primary Prevention Through Risk Prediction Improvement of Major Cardiovascular Events Using POCUS: PRIME POCUS - A Pilot Study

Marie-France Hétu, PhD MSc[1]; Taylor Barwell, PhD MSc[1]; Amrita Pannu, MHPE MBBS[1]; Nilah Ahimsadasan, BMSc[1]; Tina Zhu, MD FRCPC[2,3]; Margaret Cases, MD FRCPC[3]; Sean C. Haffey, MD MSc CCFP(AM)[4]; Ian Thomson, MSc MD CCFP (SEM)[4]; Shayna Watson, MEd MD CCFP FCFP[4]; Taleen Sahakian[1]; Ulf Näslund, MD PhD[5]; Amer M. Johri, MD MSc FRCPC FASE[1]*

(1) Department of Medicine, Division of Cardiology, CINQ, Queen's University, Kingston, ON, Canada
(2) Department of Medicine, Queen's University, Kingston, ON, Canada
(3) APEX Heart Centre, Kingston, ON, Canada
(4) Department of Family Medicine, Queen's Family Health Team, Queen's University, Kingston, ON, Canada
(5) Department of Public Health and Clinical Medicine, Umeå University, Umeå, Sweden

Abstract

Background: Early screening and treatment of subclinical atherosclerosis is key to preventing myocardial infarction, stroke, and cardiovascular (CV) morbidity and mortality. Carotid point of care ultrasound (POCUS) can be quickly learned by non-conventional ultrasound users and has the potential to be a rapid, safe, inexpensive, and powerful CV risk prediction tool in primary care settings. The goal of this study was to determine the feasibility of training primary healthcare providers (HCPs) in carotid POCUS for CV risk stratification. **Methods**: This was a prospective two-site study. HCPs completed a 45-minute online training module and a 1-hour expert-led workshop on carotid POCUS and the Rotterdam plaque score. HCPs performed POCUS on their patients who were statin naïve, ≥40 years, with ≥1 cardiac risk factor. Scans were reviewed by an expert to determine the intraclass correlation coefficient (ICC). Treating physicians were surveyed on CV risk reclassification following POCUS results. **Results**: Five HCPs were enrolled and performed a minimum of 15 carotid POCUS assessments each. The average ICC for the five HCPs was 0.764 (good agreement). Of the 77 patients scanned, plaque score ≥2 (higher risk) was observed in 26 (34%). Changes in treating physician behaviour occurred for 27 patients (35%), where 20 (26%) were reclassified as higher risk, prompting statin initiation. **Conclusions**: Training community clinic HCPs in carotid POCUS for plaque detection was successful. POCUS influenced patient risk assessment and early statin therapy initiation. Establishing vascular POCUS guidelines and training strategies for non-traditional users is crucial for developing CV screening programs and advancing personalized care.

Introduction

Atherosclerotic cardiovascular disease (ASCVD) imposes an immense burden on both health outcomes and economic resources worldwide [1,2]. A catastrophic but common presentation of ASCVD is a first-time myocardial infarction or stroke in a patient with no previous documentation of ASCVD. In the United States of America (USA), it is estimated that 50% of men and 64% of women who died of sudden cardiac death did not have a previous manifestation of atherosclerosis, and most were not considered high risk by the Framingham score [3]. These catastrophic outcomes occur despite atherosclerosis being a highly chronic, progressive disease that begins early in life and includes a prolonged subclinical phase, offering ample opportunity for detection and prevention [4,5]. Thus, the first episode of unstable angina, infarction, or stroke may represent an advanced stage of missed disease due to a lack of accessible screening tools and investments in primary prevention.

It is established that subclinical atherosclerosis can be detected using imaging biomarkers like carotid ultrasound. A focused, carotid ultrasound protocol that detects plaque presence is well-suited for screening ASCVD, as it can be performed in-office, is easy to learn, and is accompanied by an extensive body of evidence showing that carotid plaque correlates with outcomes [6–16]. Yet, screening for carotid plaque is not currently included in Canadian guidelines, in part due to a lack of evidence demonstrating the reliability and translation of

*Corresponding Author: Dr. Amer Johri (email: amerschedule@gmail.com)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20477

such technology into primary prevention [17]. European guidelines support selective screening in high-risk subgroups where there is a higher prevalence of >70% asymptomatic carotid stenosis. However, these have not yet recommended population-wide screening for asymptomatic carotid stenosis due to its low prevalence and lack of evidence towards reducing CV risk [18]. Similarly, the US Preventive Services Task Force does not currently recommend screening for asymptomatic carotid stenosis in the general adult population [19].

Treatment with statins is equivocal in asymptomatic patients for primary prevention if low-density lipoprotein cholesterol (LDL-C) is ≥2 mmol/L but <3.5 mmol/L, as per the Canadian Cardiovascular Society (CCS) lipid guidelines [17]. Within this grey area, the guidelines suggest that if carotid atherosclerosis is detected, then this places the patient at higher risk and statins are recommended. The inherent contradiction is that such a simple, inexpensive test, which robustly predicts disease and could identify potentially missed higher-risk patients, is not yet incorporated on a routine basis.

Carotid ultrasound directly visualizes an individual's atherosclerotic burden, transforming an abstract estimate into a tangible finding that can change both prescribing and patient adherence behaviour, as shown by the "Visualization of asymptomatic atherosclerotic disease for optimum CV prevention" (VIPVIZA) trial [20–22]. The problem for the VIPVIZA trial and other visualization trials has been the need for centralized imaging infrastructure, which limits atherosclerosis evaluation as a scalable screening strategy.

Technological advancements have led to the miniaturization of ultrasound devices into compact, even handheld sizes, as well as lower device costs. Together, these developments have made it feasible for physicians to perform real-time, bedside assessments using ultrasound—a practice known as point of care ultrasound (POCUS) [23]. We have demonstrated good correlation between POCUS and conventional ultrasound for detecting plaque, even with complex measurements like plaque height and total plaque area [12]. We have also taught emergency department physicians to perform carotid POCUS in patients presenting with chest pain and showed a correlation with outcomes [6]. This tool could thus complement current risk stratification tools such as the Framingham risk score (FRS) [24] and the Primary Care Through Evidence and Education (PEER) score [25], which estimates a 10-year cardiovascular (CV) disease risk. We have recently demonstrated that a simple carotid plaque score can predict 10-year risk for major adverse CV events (MACE) in intermediate-risk patients [15].

POCUS is an emergent technology set to become the next stethoscope in primary care, with several family medicine programs across Canada calling for further training and uptake [26,27]. The development of continuing medical education (CME) training modules for POCUS provides clinicians with essential skills for real-time diagnostic bedside imaging. In the USA, POCUS has increased in family medicine residencies, with 53% of program directors reporting an established core curriculum [29]. The American Academy of Family Physicians (AAFP) has also published guidelines for residents, while organizations like the American College of Physicians (ACP) provide tailored POCUS pathways for internal medicine. Carotid POCUS training empowers primary care physicians to initiate the first stages of specialized care to facilitate referrals to cardiology. The widespread applications of POCUS hold promise not only for informing CV risk assessment procedures but also for offering tangible support to issues plaguing our primary healthcare system.

The purpose of this study was to determine the feasibility of implementing a focused carotid POCUS protocol into primary care practice to assess the presence of ASCVD in low-intermediate risk, asymptomatic patients.

Methods

Study Design

This study was a prospective two-site clinical study, testing the feasibility of integrating carotid POCUS in primary care by non-traditional POCUS users. Carotid POCUS represented a novel imaging biomarker not traditionally used in primary care in community clinics. A rapid, simple and easy-to-learn POCUS protocol was developed to detect carotid atherosclerosis in asymptomatic patients.

Participating Health Care Providers

Primary HCPs (physicians or nurses) from two local community clinics were approached using a pre-approved poster/email to participate in the study. Once enrolled and consent was gained, they were trained in carotid POCUS and plaque scoring via a web-based learning module (www.arcticapocus.com) and through a 1-hour expert-led hands-on workshop. ARCTICA Module 4: Carotid POCUS is now certified for up to two MAINPRO+ credits for Family Medicine Specialists and accredited for up to two hours of MOC Section Three Self -Assessment credits for Royal College Specialists. Following training, HCPs scanned and scored eligible patients from their respective clinics. Physician competency was assessed by comparing their plaque scoring to that of a vascular imaging expert. The selected expert was a vascular researcher with >10 years of experience in carotid ultrasound image analysis. Feedback on images and scores was provided for the

first few patients. The ensuing change in physician behaviour (pre- and post-carotid POCUS) regarding the level of CV risk (low, moderate, high) of their patient and treatment strategy was evaluated in response to carotid POCUS by questionnaire. Questions (Supplementary Material – Appendix S1) included: Risk Perception – What was your baseline risk assessment for the patient? (Low, Intermediate, High); Does the use of carotid POCUS change your risk assessment of this patient? (Yes, No; If yes, Increased or Decreased).

Sample Patient Population

Consecutive outpatients attending their primary care clinic visit meeting the inclusion criteria received a carotid POCUS using a focused vascular ultrasound protocol to image the three carotid segments. The inclusion criteria included: 1) Males and females ≥40 years; 2) Referred to a primary care community clinic for risk assessment and having one or more cardiac risk factors: BMI ≥30 kg/m^2, diabetes or elevated fasting glucose (5.6 mmol/L (100 mg/dL), HbA1c ≥6.2%), hypertension (elevated blood pressure: systolic >130 and/or diastolic >85 mmHg or treated), current smoker (tobacco), elevated triglycerides: 1.7 mmol/L (150 mg/dL), reduced high-density lipoprotein cholesterol (HDL-C): 1.0 mmol/L (40 mg/dL) in males, 1.3 mmol/L 50 mg/dL in females, or LDL-C ≥2 mmol/L; 3) Able and willing to give informed consent. The exclusion criteria were statin usage within the last 12 months, history of stroke, history of myocardial infarction (MI), history of significant coronary artery disease (percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), or coronary angioplasty), contradiction to statins (known or documented hypersensitivity or allergy), and any condition expected to limit survival <3 years, a condition expected to limit adherence (alcoholism, addiction, or known poor adherence), or previous enrolment in the study.

Each HCP required a minimum of 15 patients. Baseline clinical variables such as patient demographics and comorbidities were collected by patient interviews and medical chart reviews. Study data were collected and managed using REDCap electronic data capture tools hosted at Queen's University [30,31].

Follow-up for Cardiovascular Outcomes and Medication Adherence

Patient participants were followed for up to 1-year by telephone and medical chart review. Information collected included: changes in medications, lifestyle changes (smoking cessation, diet, and exercise), CV testing (stress test, computed tomography-angio, coronary angiogram), ASCVD-related hospitalization, cardiology referrals, and MACE (all-cause mortality, myocardial infarction, unstable angina, stroke, transient ischemic attack, and coronary revascularization – PCI and CABG). If the participant was prescribed a statin medication, the Morisky Medication Adherence Scale (MMAS-8) scoring questionnaire was given to determine medication adherence (permission obtained) [32]. The MMAS-8 total score ranges from 0 to 8. The general interpretation was for High Adherence: Score of 8, Medium Adherence: Score of 6 to <8, and Low Adherence: Score <6 [32].

Carotid POCUS

For each patient participant, a focused carotid ultrasound of the common carotid artery (CCA), bulb, and internal carotid artery (ICA) was performed by the primary care provider. Images were taken using a Vscan Extend™ Handheld Ultrasound (GE Healthcare Canada, Mississauga, ON, Canada) with a linear array transducer (3.3–8.0 MHz).

Plaque scores were determined using the Rotterdam method (demonstrated in Figure 1) and noted on a worksheet (Supplementary Material – Appendix S1) [7,15,16,33]. In brief, the minimal score was 0, and the maximal score is 6. If plaque was present in 2 or more of the 6 carotid segments (left or right CCA, bulb, ICA), this represented a plaque score ≥2, which correlated to an increased risk for 10-year MACE [15]. Clinically significant carotid plaque was defined as having a minimum plaque height of ≥1.5mm (Grade II) [11].

General Protocol

Start with the left side. Perform a short-axis sweep of the carotid artery, starting at the CCA, moving towards the bulb/bifurcation, and following the ICA to assess for the presence of plaque. Save/store the video clip with the transducer indicator pointed toward the patient's right side. Next, rotate the transducer (indicator pointed to the patient's head) to obtain long-axis views. Assess the three segments (CCA, ICA, and bulb; excluding the ECA) for plaque, and pause to store the images. Assign one point to each segment containing plaque, regardless of wall location or the number of plaques. Sum the points to calculate the plaque score for the left side.

Repeat the procedure on the right side. The total plaque score is the sum of the left and right-sided scores (range 0 to 6).

If there is uncertainty in distinguishing plaque or Carotid Intima-Media Thickness (CIMT), use callipers to measure the height from the adventitia to the top of the protrusion into the lumen. Plaque is defined as a thickness that is ≥1.5 mm.

Statistical Analyses

All statistical analyses were performed using JMP version 18.0 (JMP Statistical Discovery LLC, Cary, NC, USA). The Fisher's exact test (two-tailed) was used to compare

nominal variables, and two-sample t tests (two-tailed, unequal variances) were used for continuous variables. To assess the competence of HCPs in determining plaque score using carotid POCUS, scans were reviewed by an imaging expert. The Shrout-Fleiss correlation was used to assess the reliability of agreement (intraclass correlation coefficient, ICC) between HCPs and the expert in plaque score. To evaluate whether POCUS application changed physician behaviour in the treatment plan, a change in risk assessment of their patient was quantified (no change, increased, or decreased). Statistical significance was accepted at $\alpha < 0.05$.

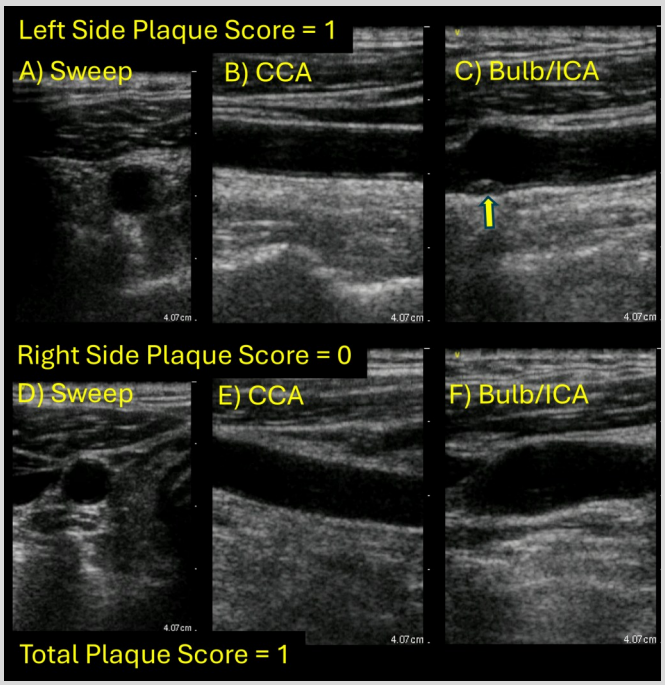


Figure 1. Carotid POCUS Plaque Score Protocol. Starting on the left side, (A) perform a short-axis sweep of the carotid artery starting at the common carotid artery (CCA), moving towards the bulb/bifurcation and following the internal carotid artery (ICA) to identify any presence of plaque; capture the cine loop video (last 4 seconds of acquisition). (B) Changing the orientation of the transducer to the long-axis, acquire a still image of the CCA and (C) the bulb/ICA. If plaque is identified in any of the three segments (CCA, ICA, bulb), one point is assigned per segment (the external carotid artery, ECA, is not taken into consideration in the score). Repeat on the right side (D) short axis sweep video, (E) CCA still image, and (F) bulb/ICA still image. Assign one point per segment if plaque is present. The sum of the plaque scores for the two sides gives the patient the total plaque score (a minimum of zero, if there is no plaque, to a maximum of 6, if plaque is present in all segments). The patient in this figure has a total plaque score of 1. The yellow arrow points to a plaque present in the bulb.

Results

Patient Participant Baseline Characteristics

A total of 77 patient participants were enrolled and received a carotid POCUS between November 17, 2023, and February 12, 2026. The mean age of the study cohort was 59.6 ± 10.2 years old and there were 55 females and 22 males (Table 1). The main cardiac risk factors included hypertension (35.1%), hyperlipidemia (15.6%), and smoking (16.7%).

Some sex differences were observed in the sample population (Table 1). Compared to females, males were more likely to have hypertension (59.1% vs 25.6%; p = 0.008) and be current smokers (31.8% vs 10.9%; p = 0.04). Among participants with complete data for FRS calculation (n = 50), the mean FRS was lower in females (8.26 ± 5.08) compared to males (21.3 ± 8.17; p = 0.0001) [24]. A similar pattern was observed for the PEER score [25].

Carotid POCUS Intraclass Correlation Coefficient of Health Care Providers compared to Expert

Five HCPs, two nurses, and three family physicians were enrolled from two community clinics. HCPs completed a 45-minute web-based learning module and quiz assessment, with a requirement of an 85% grade to pass the module. A 1-hour hands-on workshop was also held, where each HCP was able to learn how to operate the POCUS device and given the opportunity to perform a carotid ultrasound on a volunteer under the guidance of an expert.

After training, HCPs performed 15–17 carotid scans and scored the plaque. POCUS was performed within the workflow of the clinic. The average scan time was 7.00 ± 3.51 minutes. Images were reviewed and scored separately by a vascular imaging expert. To assess the HCP accuracy in performing the POCUS exam and assigning a plaque score, the HCP plaque score and the expert plaque score were compared. The average ICC was 0.764 (Table 2), which corresponded to good agreement (good reliability).

Among the 77 patient participants imaged, 26 (35%) had a plaque score ≥2, deemed higher risk for 10-year MACE (Table 3). Males were more likely to have a plaque score ≥2 compared to females (54.6% vs 25.5%; p = 0.02). Females were more likely to have a plaque score = 0, compared to males (47.3% vs 18.2%; p = 0.02). The FRS and PEER scores were plotted against plaque score to determine correlations. Plaque score increased with FRS (p = 0.001) and PEER scores (P<0.0001) (Figure 2).

Change in Treating Physician Behaviour Following Carotid POCUS

After performing patient scans, treating physicians were

Table 1. Study sample baseline characteristics.

Variable	All (N = 77)	Female (N = 55)	Male (N = 22)	P-Value
Age (years), mean ± SD	59.6 ± 10.2	59.7 ± 10.1	59.1 ± 10.5	0.82
BMI (kg/m^2), mean ± SD	31.5 ± 11.3	32.6 ± 12.8	28.7 ± 4.35	0.07
LDL (mmol/L), mean ± SD	3.08 ± 0.76	3.06 ± 0.80	3.15 ± 0.63	0.66
HDL (mmol/L), mean ± SD	1.53 ± 0.46	1.59 ± 0.48	1.36 ± 0.36	0.06
Total Cholesterol (mmol/L), mean ± SD	5.19 ± 1.01	5.20 ± 0.99	5.15 ± 1.11	0.89
Glucose (mmol/L), mean ± SD	5.32 ± 0.43	5.31 ± 0.54	5.33 ± 0.24	0.92
eGFR (mL/min/1.73), mean ± SD	84.0 ± 18.1	83.6 ± 18.4	85.0 ± 17.9	0.79
FRS (%), mean ± SD	11.4 ± 8.12	8.26 ± 5.08	21.3 ± 8.17	0.0001
PEER (%), mean ± SD	11.5 ± 9.49	7.96 ± 4.90	22.8 ± 11.7	0.0001
Diabetes, n (%)	3 (3.90)	2 (3.64)	1 (4.55)	1.00
Hypertension, n (%)	27 (35.1)	14 (25.6)	13 (59.1)	0.008
Hyperlipidemia, n (%)	12 (15.6)	10 (18.2)	2 (9.09)	0.49
Current Smoker, n (%)	13 (16.9)	6 (10.9)	7 (31.8)	0.04
Cardiac Medications				
ACE Inhibitors, n (%)	11 (14.3)	5 (9.09)	6 (27.3)	0.07
ARBs Angiotensin, n (%)	9 (11.7)	7 (12.7)	2 (9.09)	1.00
Alpha-Blockers, n (%)	2 (2.60)	0	2 (9.09)	0.08
Beta-Blockers, n (%)	15 (19.5)	9 (16.4)	6 (27.3)	0.34
Calcium Channel Blockers, n (%)	15 (19.5)	8 (14.6)	7 (31.8)	0.11
Anti-Platelet/Anti-Coagulation, n (%)	12 (15.6)	8 (14.6)	4 (18.2)	0.73
NSAIDS, n (%)	4(2.19)	2 (3.64)	2 (9.09)	0.57
Anti-Anginal, n (%)	2 (2.60)	1 (1.82)	1 (4.55)	0.49
Diuretics, n (%)	12 (15.6)	9 (16.4)	3 (13.6)	1.00
Non-Insulin Diabetes Medication, n (%)	7 (9.09)	6 (10.9)	1 (4.55)	0.67

ARB, angiotensin II receptor blockers; ACE, angiotensin-converting enzyme inhibitors; BMI, body mass index; eGFR, estimated glomerular filtration rate; FRS, Framingham risk score; NSAIDS, non-steroidal anti-inflammatory drugs; PEER, primary care through evidence and education.

Table 2. Intraclass correlation coefficient of health care providers compared to an expert.

Healthcare Provider	N (POCUS scans)	ICC	Interpretation	Bias and Interactions Impact	Lower 95% CI
1	17	0.786	Good agreement	0.21	0.57
2	15	0.709	Moderate agreement	0.29	0.42
3	15	0.714	Moderate agreement	0.28	0.43
4	15	0.841	Good agreement	0.16	0.68
5	15	0.772	Good agreement	0.23	0.54
All	77	0.764	Good agreement	0.23	0.53

HCP, health care provider; CI, confidence interval; ICC, intraclass correlation coefficient.

Table 3. Plaque scores of the study population.

Plaque Score	All (N = 77)	Female (N = 55)	Male (N = 22)	P-Value
Plaque score = 0, n (%)	30 (39.0)	26 (47.3)	4 (18.2)	0.02
Plaque score = 1, n (%)	21 (27.3)	15 (27.3)	6 (27.3)	1.00
Plaque score = 2, n (%)	18 (23.4)	(10 (18.2)	8 (36.4)	0.13
Plaque score = 3, n (%)	5 (6.49)	3 (5.45)	2 (9.09)	0.62
Plaque score = 4, n (%)	0	0	0	N/A
Plaque score = 5, n (%)	3 (3.90)	1 (1.82)	2 (9.09)	0.19
Plaque score = 6, n (%)	0	0	0	N/A
Plaque score <2, n (%)	51 (66.2)	41 (74.6)	10 (45.5)	0.02
Plaque score ≥2, n (%)	26 (33.8)	14 (25.5)	12 (54.6)	0.02

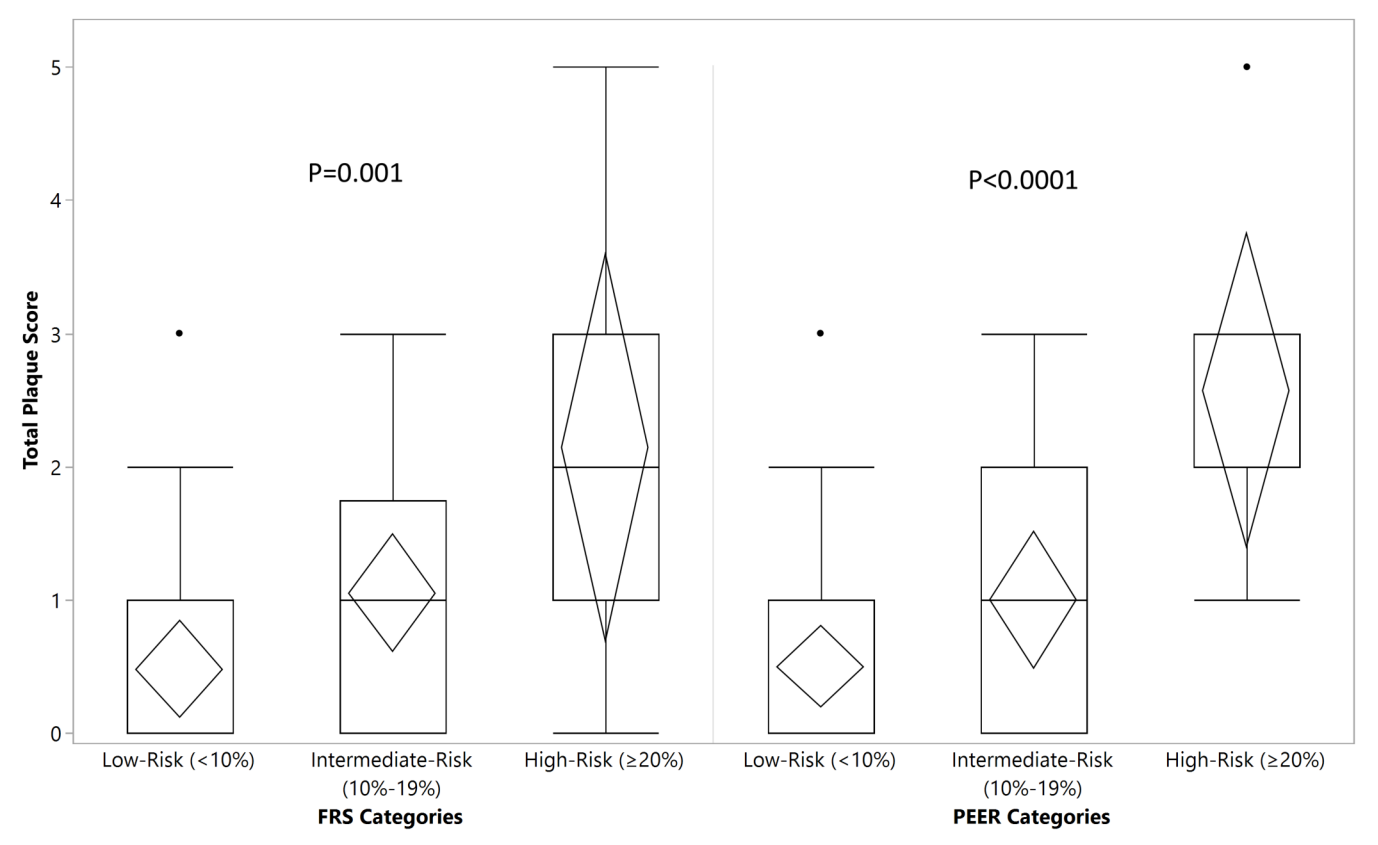


Figure 2. Box plot of plaque score in relation to traditional cardiovascular risk stratification tools. (A) Framingham Risk Score and (B) Primary Care Through Evidence and Education (PEER) score. Plaque score increased with traditional cardiovascular risk scores. Means were compared using one-way ANOVA.

asked to complete a questionnaire to determine whether the carotid POCUS results changed their CV risk assessment of their patient. For the HCPs who were nurses, the PCUS plaque score was sent to the treating physician. For the HCP family physicians, these were their own patients. Changes in physician behaviour were noted for 27 patients (35%), triggering statin treatment initiation. From these, the addition of POCUS resulted in an increase in baseline CV event risk assessment in 20 patients and a decrease in baseline CV event risk assessment in 7 patients. Statin treatment was initiated by 16 patients (Table 4); 7 with a plaque score <2 (likely due to the presence of CV risk factors, cholesterol levels, or plaque score = 1) and 9 with a plaque score ≥2.

Table 4. Patient risk reclassification.

Baseline CV risk	N (All)	Plaque Score <2						
		Risk Change?						N Statin (Initiated)
		No Change	Statin (Initiated)	Decreased	Statin (Initiated)	Increased	Statin (Initiated)	
Unknown	10	7	1	3	0	0	0	1
Low	30	23	1	0	0	7	1	2
Intermediate	9	6	1	2	0	1	1	2
High	2	2	2	0	0	0	0	2
Sum	51	38	5	5	0	8	2	7
Baseline CV risk	**N (All)**	**Plaque Score ≥2**						
		Risk Change?						N Statin (Initiated)
		No Change	Statin (Initiated)	Decreased	Statin (Initiated)	Increased	Statin (Initiated)	
Unknown	8	6	2	0	0	2	2	4
Low	5	0	0	0	0	5	3	3
Intermediate	10	4	2	2	0	4	0	2
High	3	2	0	0	0	1	0	0
Sum	26	12	4	2	0	12	5	9
All	77	50	9	7	0	20	7	16

CV, cardiovascular.

Fourteen participants answered the MMAS-8 questionnaire [32]. The average score was 7.35, indicating medium to high adherence. Eight participants had a score of 8 (high adherence, 62%), 4 participants had a score of 6 to <8 (medium adherence, 29%), and only 1 had a score <6 (low adherence, 8%).

Follow-up for MACE

Patient participants were followed up to 1-year for MACE (Death, MI, Unstable Angina, PCI, CABG, Stroke, TIA). No MACE occurred during follow-up. Three participants received an angiogram but were found to have no or mild coronary artery disease. Thirteen participants were diagnosed with hyperlipidemia, and two with hypertension. One participant was referred to a formal carotid ultrasound; carotid plaques were identified bilaterally.

HCP Feedback:

Following our pilot study, we conducted a stakeholder group feedback session to assess the impact on clinical burden. The feedback was overwhelmingly positive: POCUS added minimal additional time to the physical exam vascular check, as there was no archiving or formal reporting beyond brief documentation in physical exam notes. HCPs were strongly in favour of continuing to use the tool, as the absence of having this information for risk assessment was a glaring clinical gap. The tool helped reduce decision time and simplified practice by reducing the need to bring borderline patients back for repeated clinic visits and counselling to decide whether statins should begin. In certain cases, when plaque was present, the physician and patient were motivated to follow guidelines (start treatment when previously undecided).

Discussion

In this prospective pilot study, we demonstrated that primary HCPs can be successfully trained to perform focused carotid POCUS to detect subclinical atherosclerosis, with good agreement compared to an expert reader. Following a brief training program, HCPs achieved good reliability in plaque scoring using the Rotterdam method. The incorporation of carotid POCUS into routine primary care visits further influenced physician risk assessment and management decisions in a significant proportion of patients. Together, these findings support the feasibility of implementing carotid POCUS as a vascular risk stratification tool in primary care settings.

A key finding of this study was the strong agreement between HCP–assigned plaque scores and expert interpretation, reflected by an average ICC of 0.764, consistent with good reliability. This level of agreement is notable given the short duration of training and the fact that participants included non-traditional ultrasound

users. These findings align with prior work that demonstrated focused vascular ultrasound protocols can be learned rapidly and applied reliably by non-experts, particularly when the protocol emphasizes binary plaque detection rather than more complex measurements such as total plaque area [6,15,16]. Our results extend this literature by demonstrating that carotid POCUS can be implemented successfully in community primary care clinics, rather than academic or emergency department environments.

The detection of carotid plaque score ≥2 in 34% of this asymptomatic (61% with the presence of some plaque, plaque score ≥1), low-to-intermediate risk population highlight the limitations of traditional CV risk scoring tools. Numerous studies have shown that carotid plaque is a strong and independent predictor of MI and stroke, often outperforming conventional risk scores [7–9,14,16]. Visualization of carotid POCUS at the bedside affects both patient and physician adherence to guideline-directed therapy [34,35]. The presence of plaque represents silent disease and may provide a more intuitive and actionable signal for both clinicians and patients. In this study, visualization of plaque directly influenced physician behaviour, with reclassification of CV risk and the initiation of statin therapy in a subset of patients. Importantly, management changes not only resulted in detecting increased risk; in some cases, POCUS findings lowered baseline risk assessment of the patient, suggesting that carotid POCUS may also help avoid unnecessary treatment. High adherence to statin therapy was observed in 62% of patients prescribed statins, indicating a need for improved education. It is important to note that a negative POCUS does not replace CV risk factor assessment and cholesterol findings but may help provide additional information on the vascular health of the patient. Additional work to assess MACE in a larger population is needed to establish test characteristics.

These findings are particularly relevant in the context of current CV prevention guidelines, which do not recommend routine carotid imaging for screening, in part due to concerns regarding access, cost, and feasibility [17]. POCUS has the potential to address these barriers by offering a rapid, low-cost, radiation-free imaging modality that can be performed at the point-of-care without reliance on centralized imaging infrastructure. As POCUS ultrasound devices become increasingly affordable and accepted (handheld, laptop, tablet, etc.), carotid POCUS may represent an important step in operationalizing imaging-based risk assessment within primary prevention frameworks.

Beyond its diagnostic utility, carotid POCUS may also offer important system-level benefits. Primary care physicians in Canada have identified limited access to diagnostics and outdated technology as major impediments to delivering high-quality preventive care [28]. Integrating carotid POCUS into primary care practice may streamline risk assessment, reduce downstream referrals for diagnostic imaging, and facilitate earlier engagement with preventive therapies. Moreover, visualizing atherosclerosis at the bedside may enhance patient understanding of CV risk and support shared decision-making, although this was not directly assessed in the present study.

Limitations

Some limitations should be acknowledged due to the small sample size. As this was a small pilot study with a limited number of HCPs and patients, it was not powered to assess clinical outcomes. No major adverse CV events were observed during the follow-up period, which was expected given the modest sample size and relatively short follow-up duration. The study did not include a formal comparison with standard risk calculators or conventional carotid ultrasound performed in accredited vascular laboratories. No official competency grading of the HCP was performed for image acquisitions. Scanning was not repeated by the HCP or the expert. Long-term retention of scanning competency and scalability of training were not evaluated. Finally, it is possible that the HCPs involved in this study may have had a greater interest in this kind of approach and hence may have been more engaged in training than a non-select HCP population.

Despite these limitations, this study provides important proof-of-concept evidence supporting the feasibility, reliability, and clinical impact of carotid POCUS in primary care. Future larger, multicentre studies are warranted to evaluate long-term outcomes, cost-effectiveness, patient-centred benefits, and optimal training and quality assurance frameworks. Establishing standardized guidelines for vascular POCUS use by non-traditional ultrasound users will be critical to ensuring safe and effective implementation.

Conclusion

Focused carotid POCUS can be reliably performed by trained primary HCPs and has the potential to meaningfully influence CV risk assessment and preventive management. By enabling direct visualization of subclinical atherosclerosis at the point-of-care, carotid POCUS represents a promising tool to modernize primary prevention strategies and advance personalized CV care.

Acknowledgements

The authors would like to thank the participating primary

care clinics and healthcare providers for their time, enthusiasm, and commitment to integrating carotid point of care ultrasound into routine practice. We are grateful to the patients who volunteered to participate in this study. We also acknowledge the support the clinical and administrative staff at the participating sites for their assistance with study implementation and patient screening. MMAS® 2006 used with permission www.moriskyscale.com.

Ethics Statement

Informed consent was obtained from all participants (healthcare providers (HCPs) and patients) in this study for carotid POCUS and the use of data for publication. This study conforms to the ethical guidelines of the 1975 Declaration of Helsinki. This study was approved by Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (DMED-2735-23).

Disclosure Statement

The authors declare that they have no competing interests or conflicts of interest relevant to this work.

Funding

This study was supported by a grant from the Queen's University Translational Institute of Medicine and University Hospitals Kingston Foundation fund (TIME-UHKF Incubator Grant to AMJ) as well as a grant from the Queen's University Faculty of Health Sciences Garfield Kelly fund (to AMJ). POCUS devices were purchased using donation funds through the University Hospitals Kingston Foundation.

Author Contributions

MFH: study conceptualization, methodology, formal analysis, data curation, project administration, and drafting of the manuscript. TB: manuscript drafting, study implementation, coordination, participant enrollment, data collection, and data curation. AP: study implementation, coordination, participant enrollment, data collection, and data curation. NA: design and development of the carotid POCUS teaching module. TZ, MC, SCH, IT and SW: study implementation, participant screening, carotid POCUS examinations, and manuscript review and editing. TS: design, implementation, and data collection of the medication adherence component. UN: manuscript writing, review and editing. AMJ: conceived and supervised the study, secured funding, and contributed to the study conceptualization, methodology, and manuscript review and editing. All authors reviewed and approved the final manuscript.

References

1. WHO. Cardiovascular diseases (CVDs) fact sheet. 2021

2. WHO. Global burden of disease collaborative network, global burden of disease study 2019. Institute for Health Metrics and Evaluation – IHME 2022

3. Gatto L, Prati F. Subclinical atherosclerosis: how and when to treat it? Eur Heart J Suppl. 2020;22:E87-E90. doi:10.1093/eurheartj/suaa068

4. Almohtasib Y, Fancher AJ, Sawalha K. Emerging Trends in Atherosclerosis: Time to Address Atherosclerosis From a Younger Age. Cureus. 2024;16:e56635. doi:10.7759/cureus.56635

5. Raitakari O, Pahkala K, Magnussen CG. Prevention of atherosclerosis from childhood. Nat Rev Cardiol. 2022;19:543-554. doi:10.1038/s41569-021-00647-9

6. Brooks SC, Sivilotti MLA, Hétu MF, Norman PA, Day AG, O'Callaghan N, Latiu V, Newbigging J, Hill B, Johri AM. Focused carotid ultrasound to predict major adverse cardiac events among emergency department patients with chest pain. CJEM. 2023;25(1):81-89. doi: 10.1007/s43678-022-00395-w

7. Hollander M, Bots ML, Del Sol AI, Koudstaal PJ, Witteman JC, Grobbee DE, Hofman A, Breteler MM. Carotid plaques increase the risk of stroke and subtypes of cerebral infarction in asymptomatic elderly: the Rotterdam study. Circulation. 2002;105(24):2872-7. doi: 10.1161/01.cir.0000018650.58984.75

8. Inaba Y, Chen JA, Bergmann SR. Carotid plaque, compared with carotid intima-media thickness, more accurately predicts coronary artery disease events: a meta-analysis. Atherosclerosis. 2012;220:128-33. doi:10.1016/j.atherosclerosis.2011.06.044

9. Johnsen SH, Mathiesen EB, Joakimsen O, Stensland E, Wilsgaard T, Løchen ML, Njølstad I, Arnesen E. Carotid atherosclerosis is a stronger predictor of myocardial infarction in women than in men: a 6-year follow-up study of 6226 persons: the Tromsø Study. Stroke. 2007;38(11):2873-80. doi: 10.1161/STROKEAHA.107.487264

10. Johri AM, Calnan CM, Matangi MF, MacHaalany J, Hetu MF. Focused Vascular Ultrasound for the Assessment of Atherosclerosis: A Proof-of-Concept Study. J Am Soc Echocardiogr. 2016;29:842-9. doi:10.1016/j.echo.2016.05.003

11. Johri AM, Nambi V, Naqvi TZ, Feinstein SB, Kim ESH, Park MM, Becher H, Sillesen H. Recommendations for the Assessment of Carotid Arterial Plaque by Ultrasound for the Characterization of Atherosclerosis and Evaluation of Cardiovascular Risk: From the American Society of Echocardiography. J Am Soc Echocardiogr. 2020;33(8):917-933. doi: 10.1016/j.echo.2020.04.021

12. Mantella LE, Colledanchise K, Bullen M, Hétu MF, Day AG, McLellan CS, Johri AM. Handheld versus conventional vascular ultrasound for assessing carotid artery plaque. Int J Cardiol. 2019;278:295-299. doi: 10.1016/j.ijcard.2018.12.014

13. Roifman I, Wijeysundera HC, Austin PC, Rezai MR, Wright GA, Tu JV. Comparison of Anatomic and Clinical Outcomes in Patients Undergoing Alternative Initial Noninvasive Testing Strategies for the Diagnosis of Stable Coronary Artery Disease. J Am Heart Assoc. 2017;6. doi:10.1161/JAHA.116.005462

14. Sposato LA, Lam M, Allen B, Shariff SZ, Saposnik G, Group PS. First-Ever Ischemic Stroke and Incident Major Adverse Cardiovascular Events in 93 627 Older Women and Men. Stroke. 2020;51:387-394. doi:10.1161/STROKEAHA.119.028066

15. Matangi MF, Hétu MF, Armstrong DWJ, Shellenberger J, Brouillard D, Baker J, Johnson A, Grubic N, Willms H, Johri AM. Carotid plaque score is associated with 10-year major adverse cardiovascular events in low-intermediate risk patients referred to a general cardiology community clinic. Eur Heart J Cardiovasc Imaging. 2025;26(4):714-724. doi: 10.1093/ehjci/jeae153

16. Matangi MF, Hétu MF, Armstrong DWJ, Shellenberger J, Brouillard D, Baker J, Johnson A, Willms H, Johri AM. ICEBERG-3: carotid plaque score combined with the stress echo improves 5-year major adverse cardiovascular events risk prediction. Eur Heart J Open. 2025;5(3):oeaf065. doi: 10.1093/ehjopen/oeaf065

17. Pearson GJ, Thanassoulis G, Anderson TJ, Barry AR, Couture P, Dayan N, Francis GA, Genest J, Grégoire J, Grover SA, Gupta M, Hegele RA, Lau D, Leiter LA, Leung AA, Lonn E, Mancini GBJ, Manjoo P, McPherson R, Ngui D, Piché ME, Poirier P, Sievenpiper J, Stone J, Ward R, Wray W. 2021 Canadian Cardiovascular Society Guidelines for the Management of Dyslipidemia for the Prevention of Cardiovascular Disease in Adults. Can J Cardiol. 2021;37:1129-1150. doi:10.1016/j.cjca.2021.03.016

18. Paraskevas KI, Musialek P, Lip GYH, Chaturvedi S. Selective Screening for Asymptomatic Carotid Artery Stenosis: An Appraisal of

the 2024 European Society of Cardiology (ESC) Guidelines Position. Am J Med. 2025;138:209-211. doi:10.1016/j.amjmed.2024.10.033

19. US Preventive Services Task Force; Krist AH, Davidson KW, Mangione CM, Barry MJ, Cabana M, Caughey AB, Donahue K, Doubeni CA, Epling JW Jr, Kubik M, Ogedegbe G, Pbert L, Silverstein M, Simon MA, Tseng CW, Wong JB. Screening for Asymptomatic Carotid Artery Stenosis: US Preventive Services Task Force Recommendation Statement. JAMA. 2021;325(5):476-481. doi: 10.1001/jama.2020.26988

20. Kebric A, Petek Ster M, Poljansek Avsenak A, Jug B. Point-of-care ultrasonography of carotid arteries in primary care: sensitivity and specificity of identification of carotid atherosclerosis and prevalence of carotid atherosclerosis in apparently healthy subjects with high and very high cardiovascular disease risk. BMC Prim Care. 2025;26:244. doi:10.1186/s12875-025-02945-4

21. Chang WL, Chen PY, Hsu PJ, Lin SK. Validity and Reliability of Point-of-Care Ultrasound for Detecting Moderate- or High-Grade Carotid Atherosclerosis in an Outpatient Department. Diagnostics (Basel). 2023;13. doi:10.3390/diagnostics13111952

22. Näslund U, Ng N, Lundgren A, Fhärm E, Grönlund C, Johansson H, Lindahl B, Lindahl B, Lindvall K, Nilsson SK, Nordin M, Nordin S, Nyman E, Rocklöv J, Vanoli D, Weinehall L, Wennberg P, Wester P, Norberg M; VIPVIZA trial group. Visualization of asymptomatic atherosclerotic disease for optimum cardiovascular prevention (VIPVIZA): a pragmatic, open-label, randomised controlled trial. Lancet. 2019;393(10167):133-142. doi: 10.1016/S0140-6736(18)32818-6

23. Shen-Wagner J, Deutchman M. Point-of-Care Ultrasound: A Practical Guide for Primary Care. Fam Pract Manag. 2020;27:33-40

24. D'Agostino RB Sr, Vasan RS, Pencina MJ, Wolf PA, Cobain M, Massaro JM, Kannel WB. General cardiovascular risk profile for use in primary care: the Framingham Heart Study. Circulation. 2008;117 (6):743-53. doi: 10.1161/CIRCULATIONAHA.107.699579

25. Kolber MR, Klarenbach S, Cauchon M, Cotterill M, Regier L, Marceau RD, Duggan N, Whitley R, Halme AS, Poshtar T, Allan GM, Korownyk CS, Ton J, Froentjes L, Moe SS, Perry D, Thomas BS, McCormack JP, Falk J, Dugré N, Garrison SR, Kirkwood JEM, Young J, Braschi É, Paige A, Potter J, Weresch J, Lindblad AJ. PEER simplified lipid guideline 2023 update: Prevention and management of cardiovascular disease in primary care. Can Fam Physician. 2023;69 (10):675-686. doi: 10.46747/cfp.6910675

26. Micks T, Braganza D, Peng S, McCarthy P, Sue K, Doran P, Hall J, Holman H, O'Keefe D, Rogers P, Steinmetz P. Canadian national survey of point-of-care ultrasound training in family medicine residency programs. Can Fam Physician. 2018;64(10):e462-e467

27. Peng S, Micks T, Braganza D, Sue K, Woo M, Rogers P, Freedman S, Lewis J, Hu S, Varner C, Patel N, Hameed S, Steinmetz P. Canadian national survey of family medicine residents on point-of-care ultrasound training. Can Fam Physician. 2019;65(12):e523-e530

28. CFPC. Transforming the Foundation of Canada's Health Care System – Solutions to bolster primary care. Mississauga, ON: College of Family Physicians of Canada, 2023

29. Hall JWW, Holman H, Barreto TW, Bornemann P, Vaughan A, Bennett KJ, Chamberlain J, Micks T, Maurer DM, Bergus GR. Point-of-Care Ultrasound in Family Medicine Residencies 5-Year Update: A CERA Study. Fam Med. 2020;52(7):505-511. doi: 10.22454/ FamMed.2020.223648

30. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, McLeod L, Delacqua G, Delacqua F, Kirby J, Duda SN; REDCap Consortium. The REDCap consortium: Building an international community of software platform partners. J Biomed Inform. 2019;95:103208. doi: 10.1016/j.jbi.2019.103208

31. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009;42:377-81. doi:10.1016/ j.jbi.2008.08.010

32. Krousel-Wood M, Islam T, Webber LS, Re RN, Morisky DE, Muntner P. New medication adherence scale versus pharmacy fill rates in seniors with hypertension. Am J Manag Care. 2009;15:59-66.

33. van der Meer IM, Bots ML, Hofman A, del Sol AI, van der Kuip DA, Witteman JC. Predictive value of noninvasive measures of atherosclerosis for incident myocardial infarction: the Rotterdam Study. Circulation.2004;109:1089-94.
doi:10.1161/01.CIR.0000120708.59903.1B

34. Korcarz CE, DeCara JM, Hirsch AT, Mohler ER, Pogue B, Postley J, Tzou WS, Stein JH. Ultrasound detection of increased carotid intima-media thickness and carotid plaque in an office practice setting: does it affect physician behavior or patient motivation? J Am Soc Echocardiogr. 2008;21(10):1156-62. doi: 10.1016/j.echo.2008.05.001

35. Wyman RA, Gimelli G, McBride PE, Korcarz CE, Stein JH. Does detection of carotid plaque affect physician behavior or motivate patients? Am Heart J. 2007;154:1072-7. doi:10.1016/j.ahj.2007.06.046

NOV 2026 vol. 11 iss. 02 | POCUS J | 106

Decades Without Diagnosis: A Case of Aberrant Right Subclavian Artery Diagnosed Using POCUS

Raghav Gupta[1]; NavYash Gupta, MD[2]; Ilan Kedan, MD MPH[3]*

(1) Tulane University School of Medicine, New Orleans, LA, USA
(2) Jim and Eleanor Randall Department of Surgery, Cedars Sinai Medical Center, Los Angeles, CA, USA
(3) Smidt Heart Institute, Cedars-Sinai Hospital, Los Angeles, CA, USA

Abstract

A 62-year-old woman with a history of degenerative spine disease and treated Lyme disease presented with persistent chest pain. She reported reduced exercise tolerance, episodic leg swelling severe enough to impair ambulation, shortness of breath, and dysphagia that had led her to consume primarily soft foods since childhood. During cardiology evaluation, point-of-care ultrasound (POCUS) suggested a separate origin of the right carotid artery from the right subclavian artery, raising suspicion for an aberrant right subclavian artery (ARSA). Computed tomography angiography of the chest confirmed the diagnosis. This case demonstrates the potential utility of POCUS as a bedside tool to identify ARSA and expedite diagnosis in patients with atypical chest pain and dysphagia.

Introduction

The brachiocephalic, or innominate, artery is typically the first vessel to diverge from the aorta, which branches off into the right subclavian and right carotid arteries. The left carotid artery comes off the aorta distal to the brachiocephalic artery, followed by the left subclavian artery. Anatomically normal right subclavian arteries are observed in 98.2%–99.5% of people (Figure 1) [1–4]. In patients with an aberrant right subclavian artery (ARSA), the brachiocephalic artery is not a common origin of the right subclavian and carotid arteries. Instead, the right carotid is the first artery to come off the aorta, followed by the left carotid artery, then the left subclavian artery, and finally the right subclavian artery. Originating directly off the aortic arch after the left subclavian artery, the anatomic path of the ARSA courses from the anatomic left side of the aorta to the contralateral right side of the body to perfuse the right arm [5]. This anatomy is the result of abnormal embryological development of the aortic arch [6,7]. The segment in which the aberrant artery typically originates is prone to aneurysmal degeneration. This site, described as a Kommerell diverticulum, may pose risk of rupture or dissection. The rates of dissection and rupture of Kommerell diverticulum vary greatly between studies, rupturing or dissecting in 19%–53% of cases [8,9].

An ARSA is the aortic arch's most common congenital anomaly, occurring in 0.5%–1.8% of the population [10–12]. Aberrant subclavian arteries are typically first observed in adulthood. Most patients experience no symptoms from an ARSA, with symptoms occurring in 10%–33% of cases [13]. The lack of symptoms in cases of ARSAs, combined with nonspecific symptoms associated with the ARSA, results in many cases being discovered coincidentally during autopsy or incidentally with diagnostic imaging procedures for other indications. Whether or not the ARSA is associated with symptoms—which can include dysphagia, respiratory problems, chest pain, or related symptoms—can depend on numerous factors, including the anatomy of surrounding organs, comorbidities, and the path the ARSA takes from the left side of the aortic arch to the right upper extremity. In 80%–84% of patients with an ARSA, the vessel courses posterior to the esophagus. In some cases, this can compress the esophagus and trachea and may result in dysphagia. Twelve to fifteen percent of ARSAs travel between the trachea and esophagus, and 4%–5% follow a pretracheal path [6,7]. The prevalence of ARSAs differs between populations, although the number of cases in the literature remains rather scarce. ARSA symptoms tend to increase with age and differ between gender and age groups. The gender ratio of ARSA patients demonstrates a slight female predominance, with 55%–57% of patients being female [5,14]. However, Polguj found that the onset of symptoms for men averaged at age 44.9 years, and for women at 54 years of age

*Corresponding Author: Dr. Ilan Kedan (email: kedani@cshs.org)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20276

[5,6,13,15].

In a systematic review of 141 cases of ARSA, dysphagia was found in 71.2% of the cases. Dyspnea was described in 18.7% of cases. Other symptoms, listed by frequency, included retrosternal pain (17.0%), cough (7.6%), weight loss greater than 10 kg over 6 months (5.9%), recurrent pulmonary infections, stomach pain, back pain, and numbness in the right upper limb [5,13]. The study also observed the frequencies of vascular anomalies coexisting with an ARSA. The most common vascular aberration was truncus bicaroticus (appearing in 19.2% of patients), followed by Kommerell's diverticulum (14.9%), and then aneurysm formation distal to the origin of the ARSA (12.8%) [5].

Despite the frequency of ARSA in the population, literature on this anatomic variant remains limited. ARSA is commonly described as being found incidentally in previous case reports [16]. No prior case reports have demonstrated the use of point of care ultrasound (POCUS) to make a bedside diagnosis of ARSA. This case report meaningfully contributes to the scientific literature by demonstrating the potential for expanding bedside diagnoses to include symptom-associated vascular anatomic variants that were previously not described as bedside diagnoses. Such prevalent dysphagia and other concurrent symptoms may have indicated an earlier test for ARSA, especially with our patient's history. Furthermore, this case demonstrates how POCUS may be used as a first response to symptoms of an ARSA.

Case Report

We present the case of a 62-year-old woman with a history of seemingly unrelated symptoms dating back to adolescence. She reported being considered frail by family members, health professionals, and educators, and was unable to participate in typical childhood physical activities, including physical education. Into adulthood, the patient described ongoing symptoms of chest discomfort and shortness of breath, which became hallmarks of daily life. In her 40s, she began to experience symptoms of dysphagia. Difficulty swallowing and eating became daily challenges, with symptoms fluctuating in severity and persisting for days to months at a time. At times, she lost up to 20 lbs. The patient adjusted her lifestyle to refrain from intense physical activity and to eat mostly soft food. Concurrently, the patient's symptoms were explained and diagnosed with Lyme disease, atherosclerosis, anxiety, transient ischemic attack, degeneration of the spine, and hyperlipidemia. Over the prior five years, the patient's symptoms increased in frequency and intensity.

The patient presented to the emergency department twice with left-sided chest pain and left leg swelling and weakness. Both evaluations were unremarkable, including electrocardiograms, serial cardiac enzymes, and assessment for deep venous thrombosis. Due to her nonspecific symptoms, she underwent many diagnostic workups over several years. In the 8 years before her cardiology assessment, she underwent magnetic resonance imaging with and without angiography of the head and neck at 8, 6, 4, and 1 year prior. Esophageal motility studies were normal 7 years prior but demonstrated isolated lower esophageal sphincter dysfunction 4 years prior. The patient had a normal echocardiogram (EKG) 7 years prior and again 4 years prior, and had a normal nuclear perfusion stress test 4 years before her cardiology appointment. The patient was noted to have a computed tomography (CT) coronary calcium scan with an Agatston score of 86 within 8 months of being seen by cardiology. The patient had a negative workup for myasthenia gravis 8 years prior. The patient further had an abdominal ultrasound 1 year prior and a CT scan of her abdomen and pelvis 6 months before being seen by cardiology.

Over the preceding 8 years, the patient was evaluated by specialists in internal medicine, neurology, gastroenterology, primary care, family medicine, integrative medicine, cardiology, endocrinology, orthopedic surgery, ophthalmology, hematology, gynecology, and pain medicine. The patient did not have a record of having had pulmonary function testing.

The patient was referred to cardiology for an evaluation of chest pain and shortness of breath. The bedside POCUS examination suggested the possibility of an ARSA (Figure 2), which was then corroborated with a chest CT scan and cardiac angiography. The routine POCUS examination was extended to include less common possible causes for atypical chest pain symptoms like ARSA as a manner of hypothesis testing with POCUS evaluation. CT angiography revealed an absence of occlusive coronary artery disease and confirmed the diagnosis of ARSA (Figure 3). After the diagnosis was made, a barium swallow study showed significant narrowing of the esophagus from the retroesophageal path of the aberrant artery (Figure 4). This confirmed the suspected connection between the patient's swallowing problems and an ARSA.

The patient was offered surgical evaluation for repair of the ARSA but instead opted for conservative non-surgical observation management.

Discussion

The aid of POCUS in the diagnosis of ARSA in this patient's anatomy is unique. It highlights an opportunity to expand bedside hypothesis testing with POCUS to a

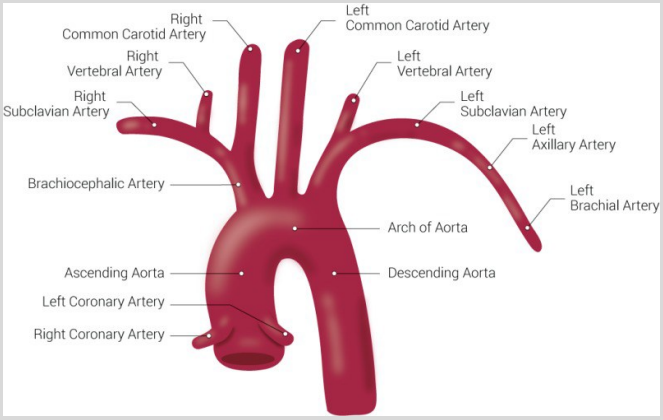


Figure 1. Anatomy of normal aortic arch. The brachiocephalic, or innominate, artery normally branches off into the right subclavian and carotid arteries. In patients with aberrant right subclavian arteries, however, the right subclavian and carotid arteries do not share a branch. Instead, the brachiocephalic artery is replaced by the right carotid and the right subclavian does not diverge from the aorta until after the left subclavian [4]. Copyright © 2026 StatPearls Publishing LLC, licensed under CC BY-NC-ND 4.0.

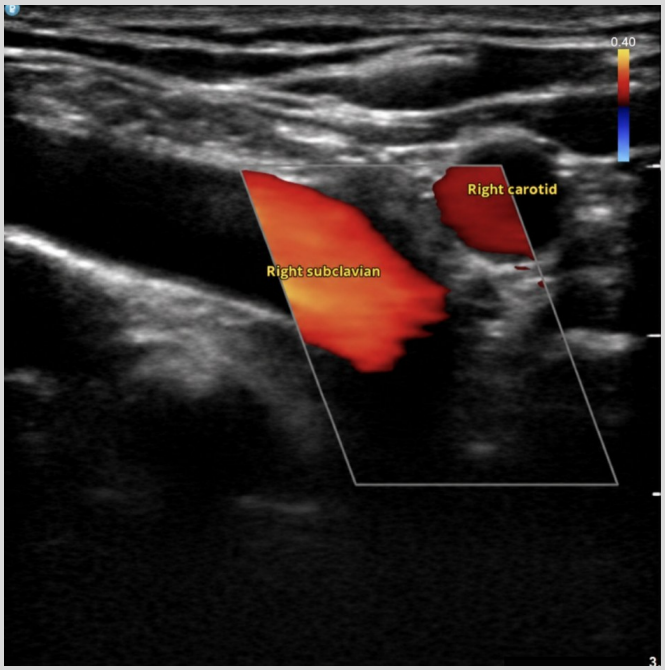


Figure 2. Point-of-care ultrasound image suggesting possible separation of right carotid and right subclavian arteries.

broader list of differential diagnoses that can include anatomic abnormalities as a cause of symptoms of chest pain.

Before diagnosing an ARSA as the unifying cause of the patient's symptoms, the patient had been seen by several cardiologists, emergency physicians, and primary care providers while experiencing, in retrospect, what seems to have been associated symptoms for the predominance of her life. Her medical history showed the most common symptoms of retroesophageal ARSA: dysphagia, dyspnea, retrosternal pain, and weight loss.

Although many patients remain asymptomatic, vigilance and awareness of symptoms may spur early detection of an ARSA. Angiography is the preferred detection method for ARSAs, allowing a three-dimensional reconstruction of the entire aortic arch. This advanced imaging is not always available or cost-effective for evaluating and assessing patients. This case demonstrates the utility of using POCUS to include anatomic assessment of patient vascular systems and to search for anatomic variants like ARSA as possible underlying causes for symptoms.

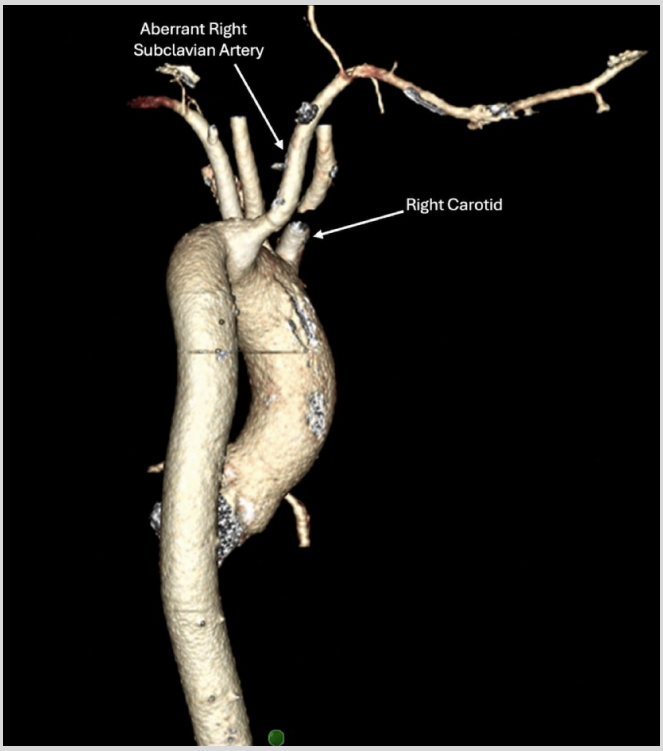


Figure 3. 3-dimensional CT reconstruction showing the aberrant right subclavian artery.

From a technical standpoint, POCUS can be used to trace the course of the common carotid artery in the caudal direction toward the sternum to visualize the carotid artery origin from the right subclavian artery (Figure 5). When the anastomosis site is not visualized or confidently assessed, then the diagnosis of ARSA may be more possible.

The diagnosis of ARSA has relied on imaging modalities such as CT angiography or barium swallow studies, often after a lengthy workup. POCUS has not been previously described as a first-line tool for identifying an ARSA. Our patient benefited from the use of POCUS to further her clinical evaluation toward a unifying diagnosis in the

setting of atypical chest pain and dysphagia. As a readily accessible and rapid bedside tool, POCUS offers the potential to shift the diagnostic paradigm—bringing earlier recognition of ARSA within reach without waiting for advanced imaging. This case opens the door for a broader application of POCUS in evaluating not just functional but also anatomical abnormalities of the mediastinum.

Chest pain is one of the most common, yet diagnostically challenging, symptoms encountered in clinical practice. It often presents vague or atypical characteristics, making it difficult to identify a precise cause based solely on a physical exam, EKG, or history. Conventional imaging modalities like chest X-ray or CT are often the gold

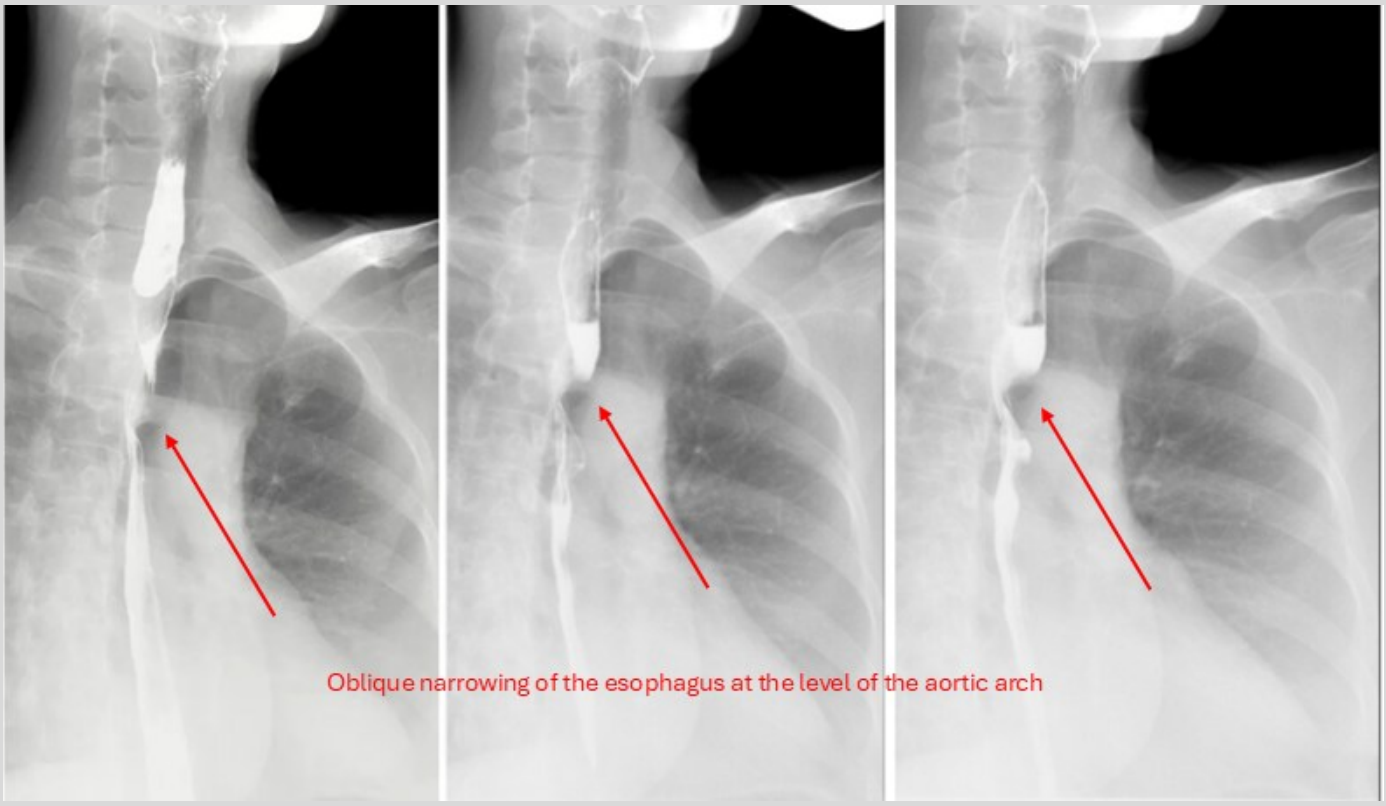


Figure 4. Barium swallow study demonstrating narrowing of the esophagus due to retroesophageal ARSA.

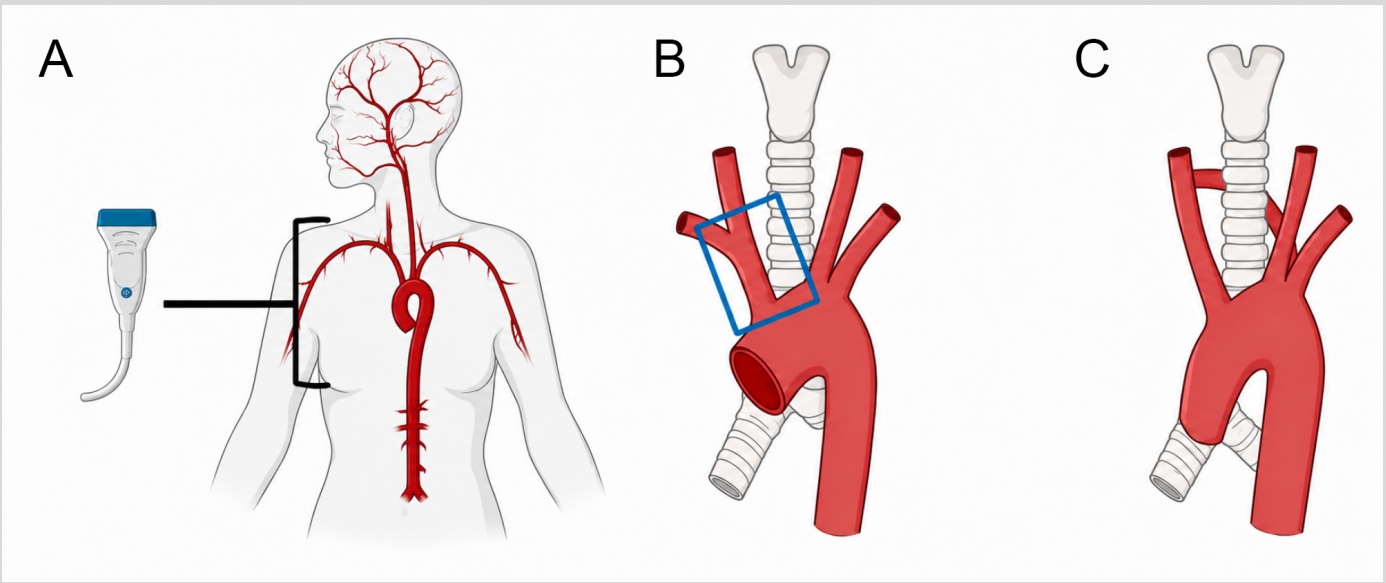


Figure 5. A) A point of care ultrasound of the patient's chest is performed. B, C) Illustration of the different branching points of the right carotid and right innominate arteries seen in patients with a normal subclavian artery (B) and an aberrant right subclavian artery anatomy (C).

standard but are limited by cost, access, and often delay in obtaining them. This case underscores how POCUS is transforming the diagnostic landscape by offering immediate, bedside insight into both cardiac function and vascular anatomy. With POCUS, clinicians can quickly assess structural causes of chest pain and include less common possibilities like aberrant right subclavian artery (ARSA) in the differential—something that might otherwise be overlooked. In cases of atypical chest pain accompanied by symptoms like dysphagia, POCUS may expedite diagnosis, guide further workup, and reduce reliance on more time-consuming or resource-intensive imaging.

Ethics Statement

This case report and details were provided with written consent from the patient, taken on December 20, 2024.

Disclosure Statement

The authors declare no conflicts of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author contributions

RG: writing – original draft, data curation, writing – review and editing. NG: data curation, writing – reviewing and editing. IK conceptualization, writing – original draft, data curation, writing – review and editing.

References

1. Chaoui R, Thiel G, Heling KS. OC29.02: Prevalence of an aberrant right subclavian artery (ARSA) in normal fetuses: a new soft marker for trisomy 21 risk assessment. Ultrasound Obstet Gynecol. 2005;26(4):356-356. doi: 10.1002/uog.2167

2. Choi Y, Chung SB, Kim MS. Prevalence and anatomy of aberrant right subclavian artery evaluated by computed tomographic angiography at a single institution in Korea. J Korean Neurosurg Soc. 2019;62(2):175-182. doi: 10.3340/jkns.2018.0048

3. Song MJ, Han BH, Kim YH, Yoon SY, Lee YM, Jeon HS, Park BK. Prenatal diagnosis of aberrant right subclavian artery in an unselected population. Ultrasonography. 2017;36(3):278-283.

4. Kelley JD, Kerndt CC, Ashurst JV. Anatomy, thorax, aortic arch. StatPearls Publishing. 2025.

5. Polguj M, Chrzanowski Ł, Kasprzak JD, Stefańczyk L, Topol M, Majos A. The aberrant right subclavian artery (arteria lusoria): the morphological and clinical aspects of one of the most important variations—a systematic study of 141 reports. The Scientific World Journal. 2014;2014:1-6.

6. Myers PO, Fasel JHD, Kalangos A, Gailloud P. Arteria lusoria: developmental anatomy, clinical, radiological and surgical aspects. Ann Cardiol Angeiol (Paris). 2010;59(3):147-154.

7. Nedelcu AH, Lupu A, Moraru MC, Tarniceriu CC, Stan CI, Partene Vicoleanu SA, Haliciu AM, Statescu G, Ursaru M, Danielescu C, Ioniuc I, Tepordei RT, Lupu VV. Morphological aspects of the aberrant right subclavian artery—a systematic review of the literature. J Pers Med. 2024;14(4):335.

8. Austin EH, Wolfe WG. Aneurysm of aberrant subclavian artery with a review of the literature. J Vasc Surg. 1985;2(4):571-577.

9. Cinà CS, Althani H, Pasenau J, Abouzahr L. Kommerell's diverticulum and right-sided aortic arch: a cohort study and review of the literature. J Vasc Surg. 2004;39(1):131-139.

10. Dandelooy J, Coveliers JPM, Van Schil PEY, Anguille S. Dysphagia lusoria. CMAJ. 2009;181(8):498.

11. Hart PA, Kamath PS. Dysphagia lusoria. Mayo Clin Proc. 2012;87(3).

12. Pramesh CS, Saklani AP, Parmar V, Acharya S, Badwe RA. Aberrant subclavian artery causing difficulty in transhiatal esophageal dissection. Dis Esophagus. 2003;16(2):173-176.

13. Natsis K, Didagelos M, Gkiouliava A, Lazaridis N, Vyzas V, Piagkou M. The aberrant right subclavian artery: cadaveric study and literature review. Surg Radiol Anat. 2017;39(5):559-565.

14. Dong S, Alarhayem AQ, Meier G, Hardy DM, Lyden SP, Farivar BS. Contemporary management and natural history of aberrant right subclavian artery. J Vasc Surg. 2022;75(4):1343-1348.e2.

15. Polednak AP. Prevalence of the aberrant right subclavian artery reported in a published systematic review of cadaveric studies: the impact of an outlier. Clin Anat. 2017;30(8):1024-1028.

16. Godlewski J, Widawski T, Michalak M, Kmieć Z. Aneurysm of the aberrant right subclavian artery—a case report. Pol J Radiol. 2010;75(4):47-50.

Should the Lung Ultrasound Score Be Used to Evaluate Interstitial Syndrome Severity in Intensive Care Units? A Prospective Observational Study

Eléonore Vasseur, MD[1]*; Florence Dupriez, MD PHD[1,2]; Caroline Poletti, MD[1]; Zoi Papadoyannaki, MD[1]; Aurélien Ledoux, MD[3]; Romain Courcelle, MD[3]; Marco Vinetti, MD[4]; Jean-Baptiste Mesland, MD[5]; Gauthier Nendumba, MD[6]; Paul Geukens, MD[3]

(1) Emergency Department, Clinique Universitaire Saint Luc, Bruxelles, Belgium
(2) Université Catholique de Louvain (UCLouvain), Bruxelles, Belgium
(3) Intensive Care Unit, CHU Helora, Hôpital de Jolimont, Haine-Saint-Paul, Belgium
(4) Intensive Care Unit, Clinique Saint Pierre, Ottignies, Belgium
(5) Intensive Care Unit, Clinique Universitaire Saint Luc, Bruxelles, Belgium
(6) Intensive Care Unit, Centre Hospitalier Universitaire UCL Namur, Yvoir, Belgium

Abstract

Background: The correlation between the lung ultrasound score (LUSS), a quantitative point of care ultrasound (POCUS) method used to evaluate pulmonary interstitial syndrome (IS), and the arterial oxygen pressure-to-fraction of inspired oxygen (P/F) ratio, a severity marker for IS, has been demonstrated in small cohorts of COVID-19 patients, supporting the utility of LUSS as a reliable severity indicator for IS. This post-pandemic study investigated the same correlation in a larger cohort of intensive care unit (ICU) patients with IS of any etiology, potentially supporting the broader application of the LUSS as a severity indicator across all types of IS. **Methods:** This was a prospective multicentre observational study. A sample of adult patients who were admitted to the ICU with acute respiratory failure (ARF) and required arterial blood gas analysis (ABG) was used. The primary endpoint was to assess whether the correlation between the LUSS and P/F ratio in ICU patients with IS reached a prespecified magnitude ($r = -0.70$), defined a priori based on previous findings for sample size estimation. **Results:** In total, 86 patients were included. The results showed a weak negative linear correlation between LUSS and P/F ratio with a correlation of $r = -0.2945$ (95% CI: -0.4767 to -0.0881). **Conclusion:** In this heterogeneous ICU cohort, LUSS showed a weak correlation with P/F ratio. This suggests that although LUSS is a useful tool for assessing disease severity in COVID-19 pneumonia, it may not be appropriate as a standalone severity marker of IS.

Introduction

Due to the presence of multiple artefacts caused by air-water interfaces, lung ultrasound has previously been considered a poor diagnostic tool for lung pathologies. However, lung point of care ultrasound (POCUS) has been developed for use with critically ill patients. This method leverages these artefacts to define ultrasonographic profiles that correspond to different lung conditions [1,2].

Interstitial syndrome (IS) refers to the lung ultrasound pattern characterized by diffuse B-lines [3]. This pattern may be observed in a variety of acute and chronic conditions, including viral or bacterial pneumonia, cardiogenic pulmonary edema, acute respiratory distress syndrome (ARDS), and chronic interstitial lung diseases (CILD). Although chronic obstructive pulmonary disease (COPD) is not classified as an interstitial lung disease, B-lines can be observed in these patients, reflecting chronic interstitial changes [4]. The lung ultrasound score (LUSS) is a lung POCUS method that is based on the quantification of B-lines and developed as a quantitative method to assess lung aeration [5]. LUSS has been associated with mortality in ARDS as well as severity and mortality in COVID-19 pneumonia [6,7].

The arterial oxygen pressure-to-fraction of inspired oxygen (P/F) ratio obtained by arterial blood gas analysis (ABG) reflects hypoxemia and indicates severity in ARDS [8]. A negative linear correlation between LUSS and P/F ratio has been identified in cohorts of patients admitted to intensive care units (ICU) with COVID-19 pneumonia,

*Corresponding Author: Dr. Eléonore Vasseur (email: e.vasseur@europehospitals.be)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20270

ARDS, or cardiogenic shock [7,9–11]. This finding reinforces the hypothesis that LUSS could reflect IS severity. As the precise etiology of IS is often initially unknown, the O_2LUSS study was designed to assess the correlation between LUSS and P/F ratio in a large group of patients presenting to the emergency department with all types of IS [12]. A moderate negative correlation was shown in 162 patients, suggesting that LUSS could be generalized as a severity assessment tool.

This study aimed to determine the strength of the correlation between LUSS and P/F ratio in ICU patients, as compared to the correlation previously observed in the emergency department in the O_2LUSS study [12]. Additionally, this study evaluated the correlation between the LUSS and P/F ratio at both 24 and 48 hours and assessed the correlation between the LUSS and the sequential organ failure assessment (SOFA) score. The study also explored the influence of the SOFA score, determined pleural effusion and size, and conducted subgroup analyses to understand the potential of the LUSS as a severity assessment tool.

Methods

Design and settings

This prospective, multicentric, observational study was conducted in three Belgian hospitals: one tertiary centre (Clinique Universitaire Saint Luc, CUSL) and two secondary centres (Hôpital de Jolimont and Clinique Saint Pierre Ottignies). Patients were recruited between February 1, 2023, and August 31, 2024.

Patients were eligible for this study if they were admitted to the ICU with signs and symptoms of acute respiratory failure (ARF), and if the treating ICU physician indicated ABG, according to their clinical judgment and standard practice. The investigator then identified patients who were over 17 years of age and who provided signed consent (or from their legal representative or through plausible delayed consent). Patients were not included if they had COPD, active asthma, CILD or severe trauma, required veno-venous or veno-arterial extracorporeal membrane oxygenation, were in the first 24 hours post-operatively, or if lung POCUS was impossible due to anatomical reasons. Inclusion and exclusion criteria are listed in Table 1. If patients met the inclusion criteria, an independent investigator performed lung POCUS to calculate the LUSS. The presence and size of pleural effusion were also documented. Lung POCUS was performed at the patient's bedside within 10 minutes of arterial blood gas sampling to minimize variations in patient condition and respiratory support between measurements. The oxygen delivery mode was recorded at the time of ABG. For patients receiving oxygen via a nasal cannula, simple oxygen mask, or non-rebreathing mask, FiO_2 was estimated by the investigator from the oxygen flow rate in litres per minute (L/min) using a standardized conversion table (Table 2). FiO_2 was recorded directly from device settings for patients who were receiving oxygen through high flow canula (HFNC), non-invasive ventilation (NIV) or invasive ventilation (IV). The etiology of ARF was collected from patient medical records, and the final diagnosis was assigned by the treating ICU team. More than one etiology was allowed. No independent review or formal adjudication were performed. Patients with a LUSS of <2 or for whom delayed consent was not obtained were secondarily excluded. Follow-up LUSS at 24 hours and 48 hours was performed when feasible. This was dependent on the availability of an investigator and whether the patient remained in the ICU and continued to meet all inclusion criteria. Patient-level reasons for missed follow-up were not systematically recorded. Mortality and ventilation-free days at 28 days were collected.

Table 1. Inclusion and exclusion criteria.

Inclusion criteria
Acute respiratory failure (ARF)
Indication for arterial blood gas analysis (ABG)
Age > 17 years
Signed consent or delayed consent plausible
Exclusion criteria
Chronic obstructive pulmonary disease (COPD)
Active asthma
Chronic interstitial lung disease (CILD)
Veno-venous or veno-arterial extracorporeal membrane oxygenation
Severe trauma
<24 hours post-operative
Lung point of care ultrasound (POCUS) non-feasible

The primary endpoint was to evaluate, in ICU patients with IS, whether the correlation between LUSS and the P/F ratio reached a prespecified magnitude (target r = −0.70). The target correlation was defined a priori based on previous findings and was used for sample size planning; there was no formal statistical comparison with the prior cohort. Secondary outcomes included evaluating the correlation between the LUSS and the SOFA score, the impact of the presence and size of pleural effusion on the LUSS-P/F ratio correlation, and subgroup analyses based on ARF etiology, the LUSS, hypoxemia severity, and respiratory rate.

Three different types of ultrasound machines were used for this study: Philips CX5 (Philips, Eindhoven, Netherlands), Philips Spark (Philips, Eindhoven,

Netherlands), and Vivid T9 (GE Healthcare, Chicago, USA). Low-frequency curvilinear transducers were used, and B-lines were assessed at a minimum depth of 12 cm in accordance with current literature [13].

A LUSS was calculated based on the following process. First, the thorax was virtually divided into six zones bilaterally, as shown in Figure 1. The anterior and lateral zones were evaluated in the dorsal decubitus position, and the posterior zones in the contralateral decubitus position. For each zone, a score from 0 to 3 was determined (Table 3). The LUSS (0–36) was calculated by adding the scores for each of the 12 zones. Patients with a LUSS <2 were empirically considered to have no IS and were secondarily excluded from the study. Investigators also reported the presence of unilateral or bilateral pleural effusion. When present, pleural effusion size was evaluated on an end-expiration freeze-frame image, measuring the maximal distance between the parietal and visceral pleura in millimetres (Dmax). The LUSS was not communicated to the treating physician.

The four investigators (GN, AL, RC, PG) were blinded to any other procedures made for diagnostic purposes by the physician involved in the patient's care. Investigators were trained in lung POCUS and evaluated themselves as confident in their ability to use it. This confidence was evaluated using a 5-point Likert scale (Table 4). All participating investigators strongly agreed with the statement that they were qualified to calculate a LUSS.

Patient identification data were collected using an electronic case report form through the RedCap software (REDCap Consortium, Vanderbilt University, Nashville, USA). Access was secured and restricted to the investigator, who could only view the data of patients that they included. The study coordinator (EV) was the sole individual with access to all data. These data were subsequently extracted from the software, anonymized, and stored in a secure computer file for analysis.

Statistical analysis

A sample of 78 patients was used to test a prespecified directional hypothesis that the ICU correlation would reach a target value of r = −0.70, using a one-sided α = 0.05 and 90% power. The correlation from the prior emergency department cohort (r = −0.486) informed the plausibility and choice of the target effect for planning purposes, but no formal between-cohort comparison was planned. Considering an attrition rate at 0.100, the sample size of this study was increased to 86 patients.

Data analysis was performed using JMP Pro 16.0.0 software (SAS Institute, Cary, USA). Continuous variables were expressed as means with minimum and maximum values, standard deviations, and 95% confidence intervals. Discrete variables were reported as categories and expressed in numbers and percentages. Pearson's correlation was used to measure the linear correlation between continuous variables. Comparisons between categorical variables were performed using the Chi-square test. Between-group comparisons of continuous variables were performed using the Wilcoxon –Mann–Whitney test. The significance threshold was set at a p-value of <0.05. Multiple linear regression was used to test the effect of continuous variables on the LUSS and the P/F ratio.

Table 2. Fraction of inspired oxygen (FiO_2) according to oxygen supplementation device.

	Nasal cannula	Simple mask	Non-rebreathing mask
1L	24%		
2L	28%		
3L	32%		
4L	36%		
5L	40%	40%	
6L	44%	44%	
7L		48%	
8L		52%	60%
9L		56%	70%
10L		60%	75%
12L			85%
15L			90%

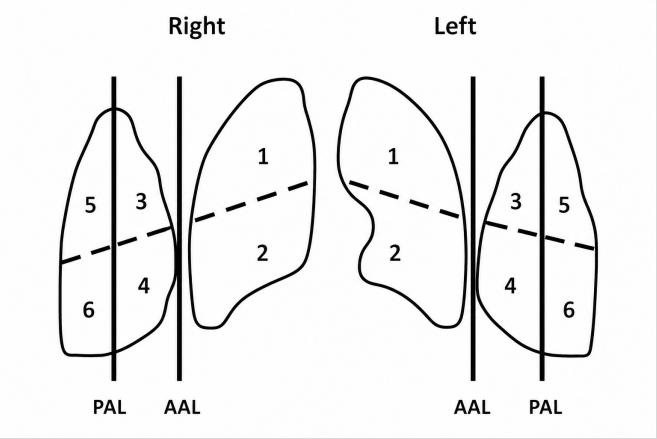


Figure 1. Thoracic zones used for lung ultrasound. AAL = anterior axillary line; PAL = posterior axillary line.

Results

Patients and the availability of data

A flowchart showing patient screening and enrolment is provided in Figure 2. A total of 94 patients were initially included, although 8 were subsequently excluded: 7 due

to the absence of delayed consent, and 1 due to the later discovery of chronic pulmonary fibrosis. Consequently, 86 patients were included in the final data analysis. The population characteristics of the patients included in the analysis are summarised in Table 5. Data for the primary endpoint were available for all included patients. Data at 24 and 48 hours were available for 71 and 44 patients, respectively.

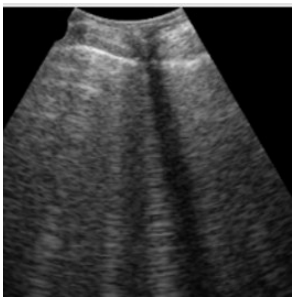
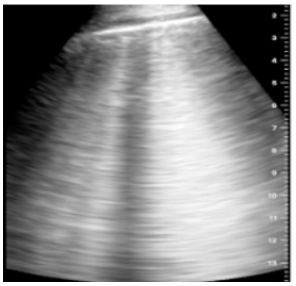
Primary endpoint

A negative correlation of -0.2945 (95% CI: -0.4767 to -0.0881) was found between the LUSS and P/F ratio in the 86 patients admitted to the ICU with IS (Figure 3). Therefore, the study did not support the primary hypothesis that the ICU correlation would reach the prespecified target magnitude (r = −0.70).

Secondary endpoints

Negative correlations between the LUSS and P/F ratio were observed at 24 and 48 hours with a correlation coefficient of -0.1026 (95% CI: -0.3281 to 0.1339) and -0.095 (95% CI: -0.3842 to 0.2116), respectively.

Table 3. Lung ultrasound definition and images illustrating the scores 0–3 used to calculate the lung ultrasound scores (LUSS). LUSS range from 0 to 36; they are calculated by adding together the scores given for each of the 12 thoracic zones.

Score	Description	Image
0	Normal aeration of the lung with the presence of A-lines, persistent pleural sliding, and less than three B-lines	
1	Interstitial syndrome, resulting in moderate loss of aeration with three or more B-lines spaced 7 mm apart	
2	Alveolar-interstitial syndrome, resulting in severe loss of aeration with coalescent B-lines spaced less than 3 mm apart	
3	Alveolar consolidation, leading to a complete loss of aeration with a tissue-like pattern on ultrasound	

Correlations between LUSS and SOFA score were calculated, resulting in a positive correlation of 0.1537 (95% CI: -0.0601 to 0.3640) at admission, a positive correlation of 0.0700 (95% CI: -0.1677 to 0.3001) at 24 hours, and a negative correlation of -0.0088 (95% CI: -0.3015 to 0.2855) at 48 hours. Exploratory multivariable linear regression analyses, including adjustment for the SOFA score and presence and size of pleural effusion, did not materially modify the association between the LUSS and P/F ratio. In the largest subgroup of 46 patients with bacterial pneumonia, the correlation coefficient was -0.2759 (95% CI: -0.5656 to 0.0745). Other subgroup analyses revealed similar weak or negligible correlations between the LUSS and P/F ratio across different ARF etiologies, LUSS categories, hypoxemia severities, and respiratory rates.

Table 4. Likert scale used by operators to self-assess their ability to calculate the lung ultrasound score (LUSS).

Score	Response to statement "I am qualified to calculate a lung ultrasound score"
1	Strongly disagree
2	Disagree
3	Undecided
4	Agree
5	Strongly agree

Supplementary analysis

No statistically significant correlation between the LUSS and P/F ratio was observed in subgroups stratified according to the type of oxygen supplementation. The results are displayed in Table 6.

Discussion

Primary outcome

We found a linear negative correlation between the LUSS and P/F ratio among the patients admitted to the ICU with IS of any cause, although the coefficient of 0.2945 was considered weak [14]. This finding suggests the limited value of the LUSS when assessing the severity of IS in this specific population. Multiple concurrent mechanisms, including ventilator settings, hemodynamic and ventilation/perfusion mismatch may attenuate the relationship between ultrasound aeration patterns and oxygenation, which could partly explain the weak correlation observed in this ICU population. The failure to show a strong correlation may also be partly explained by the study settings. First, unlike the O_2LUSS study, patients in the present study were admitted to the ICU, indicating a potentially higher disease severity. In support of this, the mean P/F ratio, mean FiO_2, mean LUSS, the proportion of patients requiring invasive mechanical ventilation at admission, and 28-day mortality all suggest that the study cohort was critically ill. The mean SOFA score at admission was 5.73, corresponding to an estimated mortality risk of approximately 20% [15]. Furthermore, significant variability exists in the eligibility and inclusion criteria among studies reporting a stronger correlation between the LUSS and P/F ratio. A major distinction lies in the scope of patient populations studied: previous research often focused on a single type of IS, whereas the present study included patients with all types of IS [7,9,11]. Additionally, unlike most studies, the

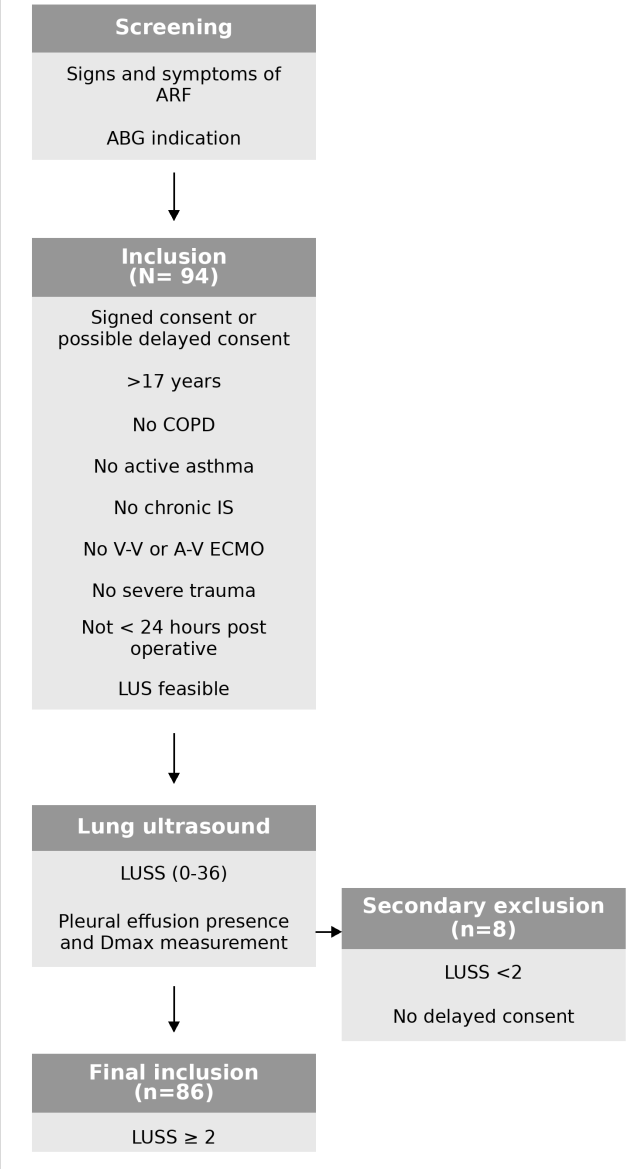


Figure 2. Study flowchart. ARF: acute respiratory failure, ABG: arterial blood gas, COPD: chronic obstructive pulmonary disease, V-V or A-V ECMO: veno-venous or arterio-venous extracorporeal membrane oxygenation, LUS: lung ultrasound, LUSS: lung ultrasound score, Dmax: maximal distance between visceral and parietal pleura.

Table 5. Study population characteristics.

Characteristics	N	Mean (SD) or Number (%)*
Age (years)	86	65 (13.68)
Sex	86	
Male		58 (67.44%)
Female		28 (32.56%)
Weight (kg)	86	79.47 (14.63)
Comorbidities	86	
Pulmonary hypertension		8 (9.3%)
Lung cancer		4 (4.65%)
Chronic pleural effusion		4 (4.65%)
History of heart failure		21 (24.42%)
Chronic kidney failure		7 (8.24%)
Dialysis		2 (2.33%)
Cirrhosis		2 (2.33%)
Acute respiratory failure etiology**	86	
Bacterial pneumonia		46 (54.76%)
Acute heart failure		19 (22.62%)
Acute respiratory distress syndrome (ARDS)		10 (12.05%)
Influenza pneumonia		8 (9.52%)
Atelectasis		5 (6.02%)
Extra-pulmonary restrictive syndrome		3 (3.61%)
Covid-19 pneumonia		1 (1.19%)
Immunotherapy-induced interstitial lung disease		1 (1.19%)
Unknown		2 (2.28%)
LUSS (0–36)	86	14.55 (5.6)
P/F ratio	86	161.44 (70.66)
SOFA Score (0–24)	86	5.73 (3.44)
Pleural effusions	86	
Unilateral		14 (16.28%)
Bilateral		24 (27.91%)
Dmax (mm)		30.31 (17.42)
Arterial blood gas analysis (ABG)	86	
pH		7.43 (0.07)
Lactates (mmol/L)		1.74 (1.85)
HCO_3 (mmol/L)		25.49 (3.94)
$PaCO_2$ (mmHg)		38.65 (8.2)
FiO_2 (%)		55 (23)

Table 5. Continued.

Characteristics	N	Mean (SD) or Number (%)*
Vital signs	86	
Systolic blood pressure (mmHg)		124.48 (26.97)
Heart rate (beat/min)		90.57 (21.93)
Respiratory rate (breath/min)		25.8 (9.25)
Temperature (Celsius °)		36.86 (0.94)
Supplementary oxygen	86	
None		1 (1.16%)
Nasal cannula		24 (27.91%)
Simple oxygen mask		3 (3.49%)
Non-rebreather mask		1 (1.16%)
High-flow nasal cannula		26 (30.23%)
Non-invasive ventilation		10 (11.63%)
Invasive ventilation		21 (24.42%)
LUSS at 24h (0-36)	71	13.62 (6.42)
P/F ratio at 24h (mmHg)	71	200.29 (87.27)
SOFA at 24h (0–24)	71	5.61 (3.91)
LUSS at 48h (0–36)	44	13.87 (6.54)
P/F ratio at 48h (mmHg)	44	191.06 (87.13)
SOFA at 48h (0–24)	44	5.24 (4.17)
Ventilation-free days at 28 days	86	21.76 (10.13)
Mortality at 28 days	86	16 (18.6%)

* Continuous data are expressed as mean (SD) and discrete data as number (percentage).
** More than one etiology allowed.
LUSS, lung ultrasound score; Dmax, maximal distance between visceral and parietal pleura at the end of expiration; FiO2, fraction of inspired oxygen; PacO2, arterial partial pressure of carbon dioxide; PaO2, arterial partial pressure of oxygen; P/F ratio, arterial oxygen pressure-to-fraction of inspired oxygen ratio; SD, standard deviation; SOFA, sequential organ failure assessment.

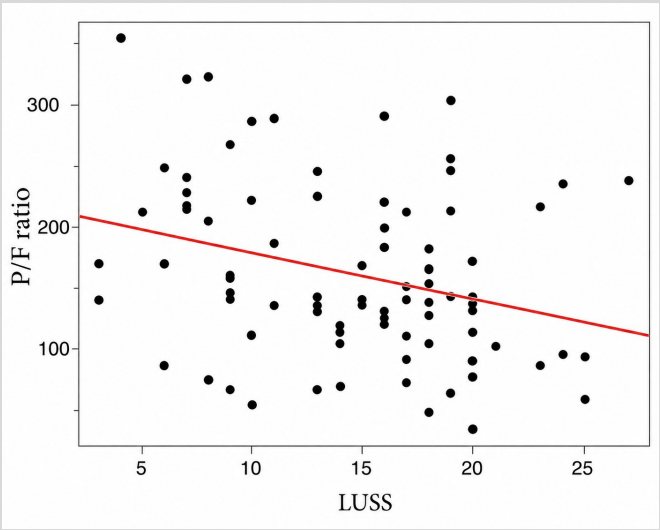


Figure 3. Weak negative linear correlation between lung ultrasound score (LUSS) and arterial oxygen pressure-to-fraction of inspired oxygen (P/F) ratio.

O_2LUSS and O_2LUSS-ICU studies excluded patients with chronic pathologies responsible for an ultrasonographic pattern of IS, as well as other conditions that, while not directly involving the lung interstitium, could nonetheless influence the LUSS or P/F ratio. For example, the presence of pulmonary hypertension in 9.3% of this study population, potentially impacting the P/F ratio independently of LUSS, may have influenced the correlation between the LUSS and P/F ratio. Finally, variability in LUSS calculation methods contributes to these discrepancies. Notably, some studies that identified stronger correlations did not employ the standardized twelve-zone lung ultrasound scoring system, further complicating direct comparisons between findings [16,17].

To our knowledge, besides the O_2LUSS study, no other research has previously evaluated the correlation between the LUSS and P/F ratio regardless of IS type. As

the O_2LUSS study was conducted during the COVID-19 pandemic, 71% of the included patients had COVID-19 pneumonia. This predominance of a single etiology weakens the O_2LUSS study conclusion that LUSS can be used as a tool to evaluate the severity of all types of IS. In the present study, the population was more representative of the post-pandemic ICU population—with bacterial pneumonia, acute heart failure, and ARDS being the three most common causes of IS.

Secondary outcomes

Correlation coefficients between LUSS and P/F ratio at 24 and 48 hours of inclusion were negligible or weak. Follow-up lung ultrasound at 24 and 48 hours was performed when feasible; however, follow-up organization was challenging, as investigators were not always available. This limited the ability to perform follow-up assessments and made repeated evaluations by the same operator almost impossible. Follow-up depended on investigator availability, patient presence in the ICU, and continued fulfilment of inclusion criteria. Any follow-up was discontinued when these conditions were no longer met. Reasons for missing assessments were not systematically recorded, which was a limitation that further restricts the generalizability of our conclusions regarding follow-up findings. Nevertheless, a substantial proportion of patients benefited from follow-up, with 83% evaluated at 24 hours and 51% at 48 hours. Some patients benefited from follow-up only at 24 or 48 hours. Two prior studies assessed the correlation between the LUSS and P/F ratio over time. Both studies examined small patient groups: one identified a negative linear correlation in 278 LUSSs conducted at random intervals in 33 COVID-19 patients, while the other showed the correlation at 72 and 92 hours after the implementation of extracorporeal membrane oxygenation in 22 patients with cardiogenic shock [11,18].

In contrast to earlier studies, this study did not find relevant correlation coefficients between LUSS and SOFA score at inclusion, nor at 24 or 48 hours, thus failing to support the hypothesis that LUSS could serve as a reliable indicator of severity. The use of the SOFA score as a severity marker in patients with IS, despite its original development to assess organ dysfunction in septic patients, may explain the absence of a stronger correlation.

The correlation coefficient was also weak between the LUSS and P/F ratio in the large subgroup of 46 patients suffering from bacterial pneumonia. To our knowledge, this correlation has not been previously assessed in a population of patients with bacterial pneumonia. Bacterial pneumonia is generally responsible for focal lesions, while the LUSS is a global score exploring the whole lung parenchyma, which may explain the weakness of the correlation. Contrary to several previous studies, this study also failed to show relevant correlations in subgroups of 19 acute heart failure patients and 10 ARDS patients [9–11]. The small number of patients in these subgroups may explain the absence of any correlation. These ARF etiology-subgroup analyses should be considered exploratory and interpreted with caution, as the etiology was determined from medical records by the treating ICU team without independent adjudication. Categories were not mutually exclusive, and some overlap between groups was unavoidable.

Supplementary analysis

No statistically significant correlation between the LUSS and P/F ratio was observed in subgroups stratified according to the type of oxygen supplementation. A moderate correlation in the invasive ventilation subgroup ($r = -0.426$, $p = 0.054$, $N = 21$) represents the strongest and closest to significant association observed across all subgroups. This finding is clinically relevant, as FiO_2 is precisely measured in mechanically ventilated patients, supporting the hypothesis that measurement error in FiO_2 may attenuate the overall correlation. These analyses were exploratory, and several subgroups included a limited number of patients. Therefore, these findings should be interpreted with caution, and further research involving larger patient cohorts is warranted.

Strengths and limitations

The ultrasound probe, timing of lung POCUS, and operator's level of expertise may affect the assessment of B-lines [20]. In the present multicentre study, three different ultrasound machines were used, although only low-frequency curvilinear transducers were permitted when performing lung POCUS to minimize the variability in the B-line evaluation. The four investigators involved were all certified ICU specialists using clinical ultrasound in their daily practice. They all regarded themselves as confident in LUSS, with a self-evaluated score of 5 on a 5-point Likert scale. As LUSS images were neither recorded nor reviewed, inter-rater reliability could not be assessed, and no external validation was possible. Although four operators participated, most examinations were performed by a single operator. This may reduce interoperator variability as a source of heterogeneity but also limits the feasibility of formally estimating operator effects using multilevel models. Additionally, in patients receiving supplemental oxygen via nasal cannula, simple mask, or non-rebreathing mask, the amount of FiO_2 delivered could only be estimated as it depends on multiple factors. This non-differential measurement variability would be expected to attenuate correlations toward the null. Additionally, the exclusion of patients with a LUSS <2, considered as having no IS, may have restricted the range of the predictor variable and

mechanically attenuated the correlation coefficient, potentially leading to an underestimation of the true association between the LUSS and P/F ratio. Although a maximum interval of ten minutes was defined between lung POCUS and arterial blood gas sampling to reduce variability in the patient's clinical status, this approach does not fully eliminate the risk of temporal bias. Indeed, even short-term physiological fluctuations, particularly in unstable patients, may have occurred during this interval, potentially contributing to the weak correlation observed. The time from symptom or disease onset to ICU admission was heterogeneous and not systematically recorded, potentially contributing to clinical heterogeneity and affecting the observed correlations. The distribution of patients between centres could be another limitation of the present study, since 85% were included from one of the secondary hospitals. Moreover, the patient population in the hospital is known to be socioeconomically disadvantaged with limited healthcare access. Therefore, it could be assumed that many of the patients included in the present study may present undiagnosed chronic pathologies responsible for chronic IS that impact the P/F ratio.

Conclusions

The correlation between the LUSS and P/F ratio has been widely studied in COVID-19 patients, confirming that LUSS is a reliable severity indicator for this population. This finding caused significant enthusiasm for its use in other types of IS in the ICU. In the present post-pandemic study, the weak or negligible correlation coefficients between the LUSS and P/F ratio or SOFA score suggest that the LUSS may not be sufficiently reliable when used alone as a severity marker of IS. Overall, the study does not support the use of LUSS as a severity marker for patient follow-up, although further investigation is warranted in settings where follow-up can be performed for all patients to fully evaluate its utility and minimize selection bias. The potential of combining LUSS with other severity indicators, and of standardizing its assessment through automated calculation methods, should be explored to improve both its reliability and clinical applicability.

Acknowledgements

Collaborators: Céline Bugli PhD (statistical support); Lara Absil (research support); Victoria Grace (manuscript review).

Ethics Statement

Before the start of patient inclusion, the study protocol was approved by the principal institutional review board: Comité d'éthique Hospitalo-Facultaire Saint Luc-UCL (No: 2022/24NOV/444). Secondarily, the protocol was approved by the institutional review boards of the two other participating hospitals. This study was registered on clinicaltrials.gov (NCT05631756). The publication follows the STROBE statement guidelines

Disclosure Statement

None of the authors of this work have any conflicts of interest, competing statements, financial disclosures or funding to declare.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions

EV: conceptualization, methodology, project administration, validation, formal analysis, supervision, writing – original draft, writing – review & editing. FD: conceptualization, methodology, formal analysis, supervision, writing – review and editing. CP: data curation, writing – review and editing. ZP: data curation, writing – review and editing. AL: investigation, writing – review and editing. RC: investigation, writing – review and editing. MV: supervision, writing – review and editing. JBM: supervision, writing – review and editing. GN: investigation, writing – review and editing. PG: conceptualization, methodology, investigation, supervision, writing – review and editing.

References

1. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, Melniker L, Gargani L, Noble VE, Via G, Dean A, Tsung JW, Soldati G, Copetti R, Bouhemad B, Reissig A, Agricola E, Rouby JJ, Arbelot C, Liteplo A, Sargsyan A, Silva F, Hoppmann R, Breitkreutz R, Seibel A, Neri L, Storti E, Petrovic T; International Liaison Committee on Lung Ultrasound (ILC-LUS) for International Consensus Conference on Lung Ultrasound (ICC-LUS). International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med. 2012;38(4):577-591.

2. Mojoli F, Bouhemad B, Mongodi S, Lichtenstein D. Lung ultrasound for critically ill patients. Am J Respir Crit Care Med. 2019;199(6):701-714.

3. Volpicelli G, Mussa A, Garofalo G, Cardinale L, Casoli G, Perotto F, Fava C, Frascisco M. Bedside lung ultrasound in the assessment of alveolar-interstitial syndrome. Am J Emerg Med. 2006;24(6):689-696.

4. Bilici D, Doğan C, Aşik M, Menek G, Kazci ZN. Thoracic ultrasonography in chronic obstructive pulmonary disease: A and B lines. Am J Med Sci. 2026;371(5):419-425. doi: 10.1016/j.amjms.2026.01.007

5. Via G, Lichtenstein D, Mojoli F, Rodi G, Neri L, Storti E, Klersy C, Iotti G, Braschi A. Whole lung lavage: a unique model for ultrasound assessment of lung aeration changes. Intensive Care Med. 2010;36(6):999-1007.

6. Wang D, Qi Y. Lung ultrasound score and in-hospital mortality of adults with acute respiratory distress syndrome: a meta-analysis. BMC Pulm Med. 2024;24(1):62.

7. Lai SY, Schafer JM, Meinke M, Beals T, Doff M, Grossestreuer A, Hoffmann B. Lung Ultrasound Score in COVID-19 Patients Correlates with PO2/FiO2, Intubation Rates, and Mortality. West J Emerg Med. 2024;25(1):28-39.

8. Fan E, Brodie D, Slutsky AS. Acute respiratory distress syndrome.

JAMA. 2018;319(7):698-710.

9. Zhao Z, Jiang L, Xi X, Jiang Q, Zhu B, Wang M, Xing J, Zhang D. Prognostic value of extravascular lung water assessed with lung ultrasound score by chest sonography in patients with acute respiratory distress syndrome. BMC Pulm Med. 2015;15:98.

10. Todur P, Chaudhuri S, Amara V, Srikant N, Prakash P. Correlation of oxygenation and radiographic assessment of lung edema (RALE) score to lung ultrasound score (LUS) in acute respiratory distress syndrome (ARDS) patients in the intensive care unit. Can J Respir Ther. 2021;57:53-59.

11. Wang R, Zhou M, Man Y, Zhu Y, Ding W, Liu Q, Sun B, Yan L, Zhang Y, Zhou H, Wang L. Lung ultrasound to evaluate pulmonary changes in patients with cardiogenic shock undergoing extracorporeal membrane oxygenation: a retrospective study. BMC Anesthesiol. 2023;23(1):181.

12. Vasseur E, Moureau G, Fasseaux A, Peyskens L, Gendebien F, Thys F, Dupriez F. Correlation between hypoxaemia and lung ultrasound score in patients presenting to an emergency department with interstitial syndrome: a prospective physiological study. Crit Care Resusc. 2023;24(3):233-241.

13. Duggan NM, Goldsmith AJ, Saud AAA, Ma IWY, Shokoohi H, Liteplo AS. Optimizing Lung Ultrasound: The Effect of Depth, Gain and Focal Position on Sonographic B-Lines. Ultrasound Med Biol. 2022;48 (8):1509-1517.

Schober P, Boer C, Schwarte LA. Correlation coefficients: appropriate use and interpretation. Anesth Analg. 2018;126(5):1763-1768.

14. Ferreira FL, Bota DP, Bross A, Mélot C, Vincent JL. Serial evaluation of the SOFA score to predict outcome in critically ill patients. JAMA. 2001;286(14):1754-1758.

15. Rojatti M, Regli IB, Zanforlin A, Ferretti E, Falk M, Strapazzon G, Gamper M, Zanon P, Bock M, Rauch S. Lung ultrasound and respiratory pathophysiology in mechanically ventilated COVID-19 patients-an observational trial. SN Compr Clin Med. 2020;2(11):1970-1977.

16. Perrone T, Soldati G, Padovini L, Fiengo A, Lettieri G, Sabatini U, Gori G, Lepore F, Garolfi M, Palumbo I, Inchingolo R, Smargiassi A, Demi L, Mossolani EE, Tursi F, Klersy C, Di Sabatino A. A new lung ultrasound protocol able to predict worsening in patients affected by severe acute respiratory syndrome coronavirus 2 pneumonia. J Ultrasound Med. 2021;40(8):1627-1635.

17. Dargent A, Chatelain E, Si-Mohamed S, Simon M, Baudry T, Kreitmann L, Quenot JP, Cour M, Argaud L; COVIDLUS Study Group. Lung ultrasound score as a tool to monitor disease progression and detect ventilator-associated pneumonia during COVID-19-associated ARDS. Heart Lung. 2021;50(5):700-705.

18. Li L, Qin A, Yang X, Zhou S, Luo Y, Zhu F, Hu B, Li J, Cai S, Peng Z. Findings and prognostic value of lung ultrasonography in Coronal Virus Disease 2019 (COVID-19) pneumonia. Shock. 2021;56(2):200-205.

19. Pivetta E, Baldassa F, Masellis S, Bovaro F, Lupia E, Maule MM, Tizzani M, Porrino G, Ferreri E, Volpicelli G. Sources of variability in the detection of B-lines using lung ultrasound. Ultrasound Med Biol. 2018;44(6):1212-1216.

Multiparametric POCUS to Differentiate Fluid Overload From Endothelial Complications After Allogeneic Hematopoietic Stem Cell Transplantation: A Case Series

Bastian Wobbe, MD*

Department of Oncology and Hematology, Klinikum Oldenburg, Oldenburg, Germany

Abstract

Allogeneic hematopoietic stem cell transplantation (allo-HSCT) is frequently complicated by early post-transplant fluid accumulation with weight gain and respiratory compromise. Engraftment syndrome and capillary leak syndrome may resemble fluid overload syndrome, although mechanisms and treatment differ. Conventional parameters such as body weight and clinical criteria do not reliably distinguish intravascular congestion from inflammatory fluid redistribution. We report three allo-HSCT recipients with rapid weight gain and respiratory deterioration. Multiparametric point of care ultrasound (POCUS), integrating inferior vena cava assessment, venous Doppler (applying the VExUS-Score), and lung POCUS, was performed at bedside. Despite similar presentations, POCUS helped to identify distinct patterns. One patient demonstrated systemic venous congestion with interstitial B-lines consistent with fluid overload and improved with decongestive therapy. Two patients showed preserved venous Doppler profiles without congestion; lung POCUS was normal in engraftment syndrome but showed B-lines with pleural effusions in capillary leak syndrome, prompting immunomodulatory therapy. Multiparametric POCUS examination enabled pathophysiology-based differentiation and guided management.

Introduction

Allogeneic hematopoietic stem cell transplantation (allo-HSCT) remains a potentially curative therapy for various hematologic disorders, but is associated with substantial early post-transplant morbidity and mortality [1]. During the conditioning phase and the period of neutrophil recovery, patients frequently develop acute complications characterized by systemic inflammation, endothelial dysfunction, and fluid accumulation. Engraftment syndrome and capillary leak syndrome represent inflammatory endothelial disorders that may present with dyspnea, hypoxemia, edema, and rapid weight gain [2]. In parallel, fluid overload syndrome may develop due to excessive fluid administration, inflammation, capillary leak, renal dysfunction, or impaired mobilization of infused volumes. These entities often manifest with overlapping clinical features, particularly during the vulnerable early post-transplant period [2]. Endothelial injury represents a central mechanism in several early complications after allo-HSCT. Conditioning toxicity, inflammatory immune reconstitution, calcineurin inhibitor exposure, and infectious triggers may promote cytokine-mediated endothelial activation and disruption of vascular barrier integrity. This process results in increased vascular permeability and fluid extravasation into the interstitial compartment [3,4].

Distinguishing between inflammatory endothelial syndromes and intravascular volume overload can be challenging. Conventional diagnostic parameters such as body weight changes, cumulative fluid balance, serum biomarkers, and radiographic findings do not reliably distinguish intravascular congestion from extravascular fluid redistribution [5–8]. Weight gain may reflect third spacing rather than hypervolemia, and pulmonary imaging may demonstrate interstitial infiltrates in both inflammatory and congestion-related states [9]. However, the therapeutic implications differ substantially. While inflammatory syndromes are primarily managed with immunomodulatory therapy and supportive care, fluid overload requires active decongestion through minimizing maintenance fluid administration, diuretics, or renal replacement therapy. Misclassification may therefore result in either insufficient decongestion or harmful over-diuresis in patients.

Point of care ultrasound (POCUS) offers a bedside, non-

*Corresponding Author: Dr. Bastian Wobbe (email: wobbe.bastian@klinikum-oldenburg.de)

This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.

DOI: https://doi.org/10.24908/pocusj.v11i02.20532

invasive method for dynamic hemodynamic assessment. In particular, venous Doppler-based approaches, such as the Venous Excess Ultrasound (VExUS) score, allow systemic venous congestion to be estimated by integrating the inferior vena cava (IVC) assessment with hepatic, portal, and intrarenal venous flow patterns [10]. When combined with lung POCUS, this multiparametric approach may provide insight into the distribution of fluid between the intravascular and interstitial compartments [11]. Comprehensive hemodynamic POCUS integrating parameters from cardiac POCUS, IVC assessment, venous Doppler interrogation, and lung POCUS enables bedside evaluation of cardiac function, systemic venous congestion, pulmonary fluid accumulation, and the distribution of fluid between the intravascular and extravascular compartments. Rather than relying on a single parameter, this multiparametric approach provides a physiologically integrated assessment that may be particularly valuable in complex conditions such as allo-HSCT, where several distinct mechanisms of fluid accumulation may coexist. However, its role in differentiating fluid overload syndrome from inflammatory endothelial complications after allo-HSCT has not been systematically investigated. To illustrate this conceptual model of compartment-based fluid accumulation, Figure 1 summarizes the proposed pathophysiological framework.

This case series of three allo-HSCT recipients illustrates the application of a comprehensive multiparametric POCUS approach, including lung POCUS and the VExUS framework, in this clinical setting. To our

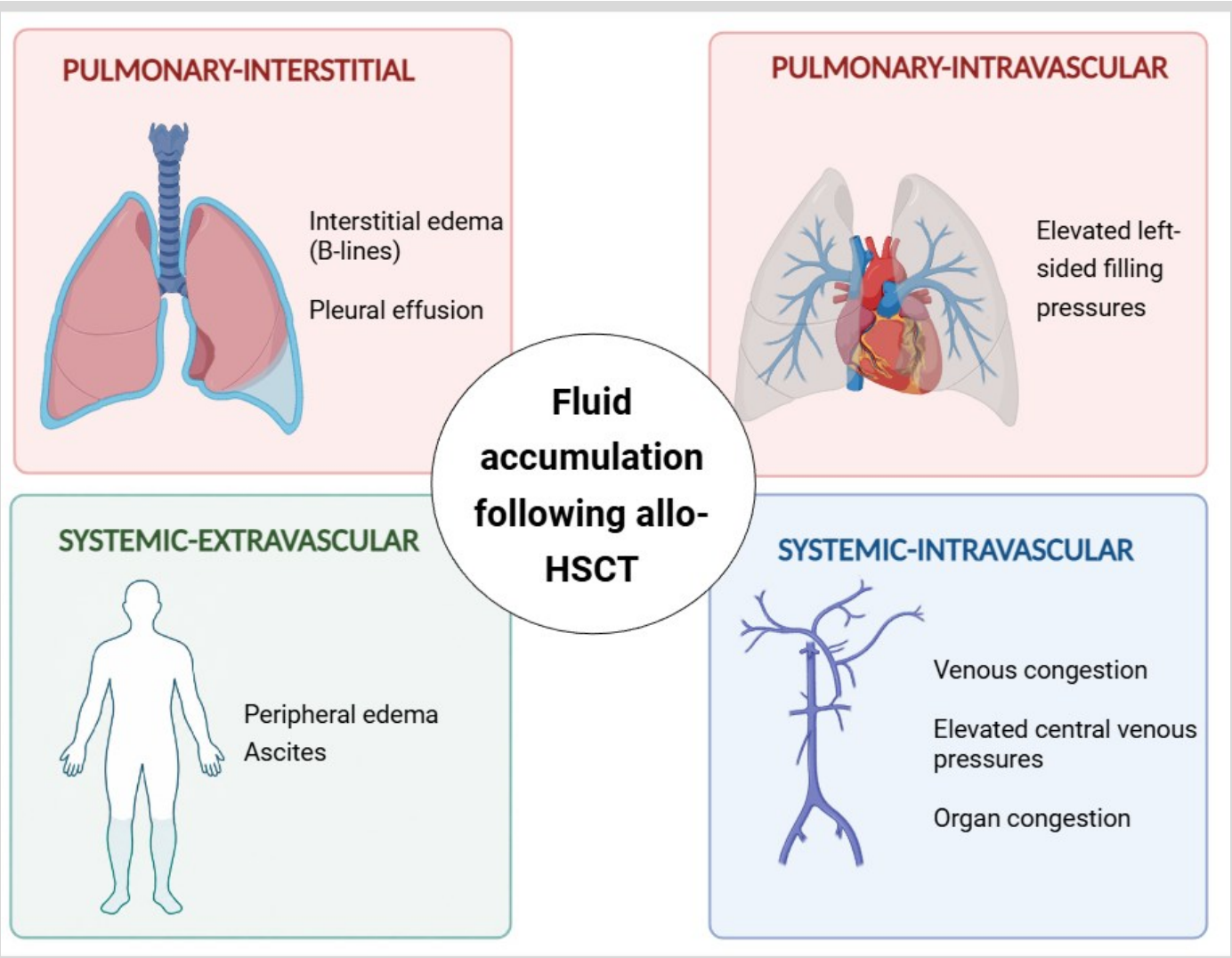


Figure 1. Conceptual compartment-based framework of fluid accumulation following allogeneic hematopoietic stem cell transplantation. Proposed conceptual framework illustrating the compartment-based distribution of fluid accumulation following allogeneic hematopoietic stem cell transplantation. Fluid accumulation is categorized according to its predominant regional distribution (pulmonary versus systemic) and compartmental distribution (intravascular versus extravascular). The framework highlights the heterogeneous nature of post-transplant fluid accumulation and provides the conceptual basis for a physiology-oriented multiparametric POCUS assessment. Created in BioRender. Allo-HSCT, allogeneic hematopoietic stem cell transplantation; POCUS, point of care ultrasound.

knowledge, this represents the first report applying this integrated POCUS approach to the allo-HSCT population. Integrating cardiac POCUS, venous Doppler assessment, and lung POCUS demonstrated how clinically similar presentations of post-transplant fluid accumulation may reflect fundamentally different hemodynamic and pathophysiological mechanisms with direct therapeutic implications.

Methods

This case series was conducted at a tertiary care university hospital and includes three consecutive adult patients who underwent allogeneic hematopoietic stem cell transplantation and developed clinically significant fluid accumulation with diagnostic uncertainty regarding the underlying pathophysiology. Clinical data, laboratory findings, imaging studies, and POCUS examinations were reviewed retrospectively. The case series was prepared in accordance with the CARE guidelines [12]. Written informed consent for publication of clinical data and images was obtained from all patients.

Multiparametric POCUS was performed as part of routine clinical care to support bedside hemodynamic assessment. The examination protocol included IVC assessment, hepatic vein, portal vein, and intrarenal (interlobar) venous Doppler interrogation, lung POCUS, as well as cardiac POCUS if clinically indicated. Renal venous Doppler assessment was performed in the intraparenchymal (interlobar) veins of the right kidney using a mid-axillary acoustic window. Venous congestion was interpreted according to the published VExUS grading system by integrating IVC diameter with hepatic, portal, and intrarenal venous Doppler findings [10].

All POCUS examinations were performed by a board-certified internist with several years of clinical experience in emergency and intensive care medicine and dedicated expertise in POCUS. POCUS examinations were performed using a Siemens ACUSON Juniper ultrasound system (Siemens Healthineers, Erlangen, Germany) equipped with a 5C1 convex transducer for abdominal and lung POCUS and a 5P1 phased-array transducer for cardiac POCUS. Standard abdominal and cardiac imaging presets were used throughout the studies.

Patients were examined in the supine position whenever feasible. In Case 3, the examination was performed in a 45° semi-recumbent position because severe dyspnea and large pleural effusions precluded a fully supine examination.

A comparative overview of the three cases is provided in Table 1, while representative imaging findings are presented in Figure 2.

Case 1: Engraftment Syndrome

A 65-year-old woman with refractory secondary acute myeloid leukemia underwent allogeneic hematopoietic stem cell transplantation after achieving complete remission following salvage chemotherapy. Conditioning consisted of treosulfan, fludarabine, and anti-thymocyte globulin, followed by infusion of a matched unrelated donor peripheral blood stem cell graft. Graft-versus-host disease prophylaxis included cyclosporine and methotrexate. The patient had no history of cardiac, renal, or hepatic disease. Baseline transthoracic echocardiography demonstrated preserved biventricular function without relevant valvular abnormalities.

During conditioning (day –6 to day -1), the patient gained 4 kg in weight (approximately 5% of baseline body weight) and developed bilateral lower-extremity edema. In response to the progressive weight gain, maintenance intravenous fluids were reduced, and intravenous furosemide was initiated to achieve decongestion. Despite escalation of diuretic therapy, body weight further increased to 8 kg above baseline (approximately 10% of baseline body weight at day +11). Simultaneously, serum creatinine rose from 0.69 to 1.34 mg/dL, consistent with KDIGO stage 1 acute kidney injury. Urinary analysis demonstrated a reduced fractional excretion of sodium, suggestive of a prerenal etiology.

Around neutrophil recovery on day +11, the patient developed fever, an erythematous rash, worsening dyspnea, and hypoxemia requiring 4 L/min of oxygen via nasal cannula. The temporal association with engraftment and multisystem involvement was compatible with engraftment syndrome. However, persistent weight gain with peripheral edema and respiratory deterioration despite intensified diuresis raised concern for concomitant fluid overload syndrome, resulting in diagnostic uncertainty. Hemodynamic status remained stable, without elevated jugular venous pressure or pulmonary crackles on auscultation. ProBNP increased to 4,558 pg/mL. A non-contrast chest CT performed on day +7 demonstrated no relevant pulmonary abnormalities. To further characterize the underlying mechanism of respiratory deterioration and fluid accumulation, a comprehensive POCUS examination was performed at day +11. The IVC was less than 2 cm in diameter with preserved respiratory variation. Hepatic, portal, and intrarenal venous Doppler waveforms were normal, corresponding to VExUS grade 0 and indicating the absence of systemic venous congestion. Lung POCUS demonstrated A-lines without significant pleural effusion.

In the absence of POCUS evidence of intravascular congestion, diuretic therapy was discontinued, and intravenous methylprednisolone was initiated for

suspected engraftment syndrome. Within 72 hours, dyspnea and rash improved, oxygen requirements decreased, and body weight progressively declined without further diuretic treatment. Renal function returned to baseline. The patient was later discharged in complete remission.

Case 2: Fluid Overload Syndrome

A 55-year-old man with acute lymphoblastic leukemia underwent allogeneic hematopoietic stem cell transplantation from a matched unrelated donor following myeloablative conditioning with total body irradiation, cyclophosphamide, and anti-thymocyte globulin. Graft-versus-host disease prophylaxis consisted of cyclosporine and methotrexate. The patient had no history of cardiac, renal, or hepatic disease. Baseline echocardiography demonstrated preserved left ventricular systolic function, and renal function was normal before conditioning.

Beginning on day +10, the patient developed progressive weight gain and dyspnea without clinically apparent peripheral edema. By the time of neutrophil engraftment on day +13, body weight had increased by 5.9 kg (baseline weight 84.9 kg), accompanied by hypoxemia requiring supplemental oxygen via nasal cannula. A generalized erythematous rash was present, fulfilling the clinical criteria for suspected engraftment syndrome according to Spitzer et al. [13]. Corticosteroid therapy was initiated, and maintenance intravenous fluid administration was reduced.

Despite appropriate treatment for engraftment syndrome, the patient's respiratory status continued to deteriorate. Oxygen requirements gradually increased to a maximum of 4 L/min via nasal cannula, while body weight further increased to 9.9 kg above baseline by day +20 (11.7 % of baseline body weight). The lack of clinical response to corticosteroid therapy together with persistent weight gain raised concern for an alternative underlying mechanism.

On day +19, chest computed tomography demonstrated interlobular septal thickening and small bilateral pleural

Table 1. Comparative summary of the three cases, providing a comparative overview of clinical presentation, multiparametric POCUS findings, presumed underlying pathophysiological mechanism, POCUS-guided management, and clinical outcome.

Characteristic	Case 1	Case 2	Case 3
Underlying disease	AML	ALL	Severe aplastic anemia
Clinical presentation	Weight gain, leg edema, dyspnea, hypoxemia, rash, fever	Weight gain, dyspnea, hypoxemia, rash	Weight gain, generalized edema, dyspnea, hypoxemia
Timing after allo-HSCT	Peri-engraftment (d+7 to 14)	Peri-engraftment (d+10 to +20)	Conditioning phase and stem cell infusion (d-6 to 0)
Maximum weight gain (absolute in kg and relative in %)	+8.0 kg (10 %)	+9.9 kg (11.7 %)	+5.1 kg (7.8%)
Peak oxygen requirement	4 L/min nasal cannula	4 L/min nasal cannula	Invasive mechanical ventilation
CT findings	No relevant pulmonary abnormalities	Interlobular septal thickening, small bilateral pleural effusions	Pulmonary edema, bilateral pleural effusions
Cardiac POCUS	Not performed; normal baseline echocardiography	Not performed; normal baseline echocardiography	Preserved biventricular function; no significant valvular disease
Lung ultrasound	No relevant pulmonary congestion	Bilateral B-lines	Diffuse bilateral B-lines and pleural effusions
IVC	Small/collapsible	Dilated, reduced respiratory variation	Small, collapsible
VExUS	Grade 0	Grade 3	Grade 0
Systemic venous congestion	No	Yes	No
Presumed mechanism	Engraftment syndrome	Fluid overload syndrome	Capillary leak syndrome
POCUS-guided management	Diuretics discontinued, immunosuppressive treatment initiated	Diuretics intensified, maintenance fluids reduced, corticosteroids tapered	Corticosteroids, albumin, CRRT, ventilatory support
Clinical outcome	Clinical recovery	Clinical recovery	Clinical recovery

AML, acute myeloid leukemia; ALL, acute lymphoblastic leukemia; allo-HSCT, allogeneic hematopoietic stem cell transplantation; CRRT, continuous renal replacement therapy; IVC, inferior vena cava; POCUS, point of care ultrasound; VExUS, Venous Excess Ultrasound.

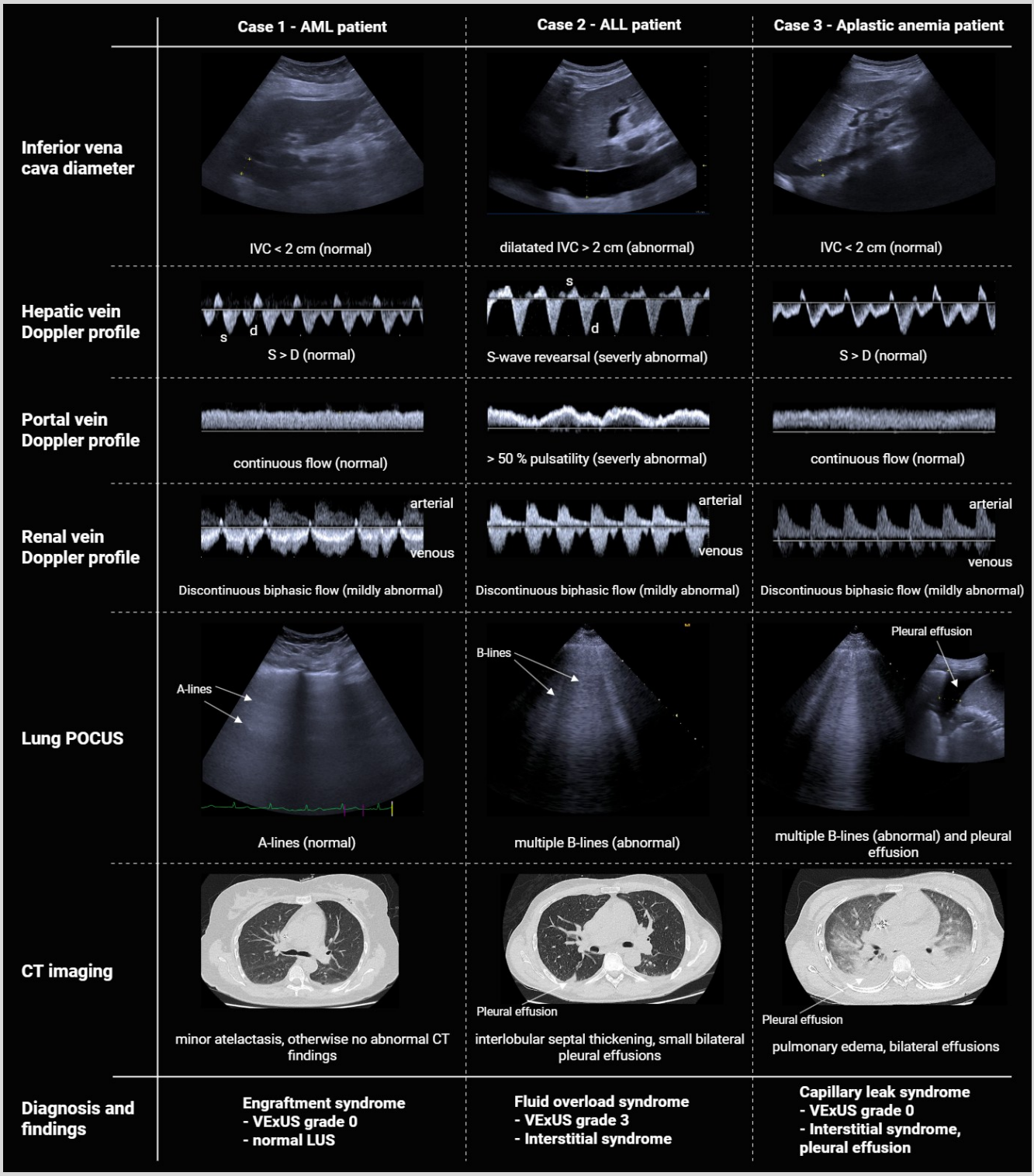


Figure 2. Multiparametric POCUS patterns in post-transplant fluid disorders. Multiparametric POCUS findings in three patients after allogeneic hematopoietic stem cell transplantation. Created in BioRender. Case 1: Engraftment syndrome: preserved IVC cava dynamics, normal hepatic and portal venous Doppler profiles, and mildly abnormal intrarenal venous Doppler flow, resulting in VExUS grade 0; lung POCUS without pathologic findings. Case 2: Fluid overload syndrome: dilated IVC with reduced respiratory variation, abnormal hepatic and portal venous Doppler waveforms, and elevated VExUS grade consistent with systemic venous congestion; lung POCUS demonstrates bilateral B-lines and pleural effusions. Case 3: Capillary leak syndrome: preserved venous Doppler patterns without evidence of systemic congestion (VExUS grade 0) despite diffuse bilateral B-lines and pleural effusions on lung POCUS. IVC, inferior vena cava; VExUS, Venous Excess Ultrasound score; CT, computed tomography; AML, acute myeloid leukemia; ALL, acute lymphoblastic leukemia.

effusions, findings compatible with either inflammatory pulmonary involvement or hydrostatic pulmonary congestion.

As diagnostic uncertainty persisted, a comprehensive multiparametric POCUS examination was performed on the same day. The IVC was dilated (>2 cm) with reduced respiratory variation. Hepatic vein Doppler demonstrated systolic blunting, portal vein Doppler showed marked pulsatility (>50%), and intrarenal venous Doppler revealed abnormal venous flow consistent with VExUS grade 3, indicating clinically significant systemic venous congestion. Lung POCUS demonstrated diffuse bilateral B-lines consistent with pulmonary interstitial edema.

Based on these findings, the working diagnosis was revised from engraftment syndrome to fluid overload syndrome. Corticosteroids were rapidly tapered, maintenance intravenous fluids were further minimized, and intravenous loop diuretic therapy was initiated. Body weight progressively returned to baseline by day +25, accompanied by resolution of hypoxemia, discontinuation of supplemental oxygen, and normalization of follow-up POCUS findings, including regression of B-lines, normalization of venous Doppler waveforms, and restoration of normal IVC dynamics. The patient was later discharged in molecular remission.

Case 3: Capillary Leak Syndrome

A 19-year-old woman with severe aplastic anemia underwent allogeneic bone marrow transplantation from a haploidentical related donor following myeloablative conditioning with cyclophosphamide and anti-thymocyte globulin. The patient had no history of cardiac, renal, or hepatic disease. Baseline echocardiography demonstrated preserved left ventricular systolic function, and renal function was normal before conditioning.

At baseline, the patient weighed 64.3 kg. During conditioning (day –6 to day of transplantation), body weight progressively increased to 69.4 kg (+5.1 kg; +7.8%) over six days despite reduction of maintenance intravenous fluid administration and escalation of diuretic therapy, including continuous intravenous furosemide combined with xipamide. Generalized edema developed together with progressive dyspnea. Laboratory evaluation demonstrated progressive hypoalbuminemia (34.2 g/L on day –4, 29.0 g/L on day –1 despite initiation of albumin substitution, reaching a nadir of 24.6 g/L on day +4), accompanied by elevated inflammatory markers (CRP and ferritin). ProBNP increased from 3,349 pg/mL on day –4 to 58,930 pg/mL on the day of transplantation and subsequently exceeded the upper reporting limit of the local laboratory (>70,000 pg/mL). Repeated echocardiography on the day of transplantation demonstrated preserved biventricular systolic function without relevant structural heart disease or elevated filling pressures.

On the morning of transplantation, supplemental oxygen was at 2 L/min via nasal cannula because of progressive hypoxemia. During infusion of approximately 1,100 mL of bone marrow product, respiratory status rapidly deteriorated despite repeated intravenous furosemide boluses and administration of an additional intravenous prednisolone. Oxygen supplementation was progressively escalated to 8 L/min via face mask. As no clinical improvement was observed, stem cell infusion was temporarily interrupted, and the patient was transferred to the intensive care unit. At this stage of acute clinical deterioration, a comprehensive multiparametric POCUS examination was performed. The IVC was narrow with complete inspiratory collapse. Hepatic, portal, and intrarenal venous Doppler waveforms were normal, corresponding to VExUS grade 0, indicating the absence of clinically significant systemic venous congestion. In contrast, lung POCUS demonstrated diffuse bilateral B-lines and pleural effusions consistent with marked pulmonary interstitial and alveolar fluid accumulation. Initial chest radiography demonstrated pulmonary edema with bilateral effusions. Following escalation to high-flow nasal oxygen and clinical stabilization, stem cell infusion was resumed and completed without further interruption. A chest CT performed on day +9 confirmed diffuse pulmonary edema with bilateral effusions and adjacent compressive atelectasis.

Given the temporal relationship to stem cell infusion, transfusion-associated circulatory overload (TACO), transfusion-related acute lung injury (TRALI), and capillary leak syndrome were considered as the principal differential diagnoses. Although the infusion volume may have contributed to the rapid respiratory deterioration, the absence of cardiac dysfunction and the lack of sonographic evidence of systemic intravascular congestion argued against clinically significant TACO. Likewise, TRALI was considered less likely because hypoxemia had already developed before stem cell infusion and was not accompanied by fever or hypotension.

Based on the combination of generalized edema, progressive hypoalbuminemia, severe pulmonary fluid accumulation in the absence of systemic venous congestion, and preserved cardiac function, capillary leak syndrome was considered the most likely diagnosis. The patient received systemic corticosteroids, albumin substitution, transient vasopressor support with low-dose norepinephrine, and continuous renal replacement therapy to achieve controlled negative fluid balance. Respiratory support escalated from high-flow nasal

oxygen to non-invasive ventilation and finally invasive mechanical ventilation from day +3 to day +7. Continuous renal replacement therapy was required from day +3 until day +26 after transplantation. Follow-up POCUS examinations consistently demonstrated the absence of systemic venous congestion while lung POCUS findings gradually regressed in parallel with clinical recovery. The patient was discharged in stable post-transplant condition.

Comparative synthesis

All three patients presented during the early transplant period with rapid weight gain, respiratory compromise, and clinical features suggestive of endothelial dysfunction. Conventional parameters, including absolute body weight changes and imaging findings, were insufficient to reliably distinguish between inflammatory fluid redistribution and intravascular volume overload. In each case, diagnostic uncertainty directly influenced therapeutic decision-making.

Despite similar clinical presentations, POCUS enabled the identification of distinct phenotypes. In Case 2, sonographic findings demonstrated clear systemic venous congestion, including a dilated IVC with reduced respiratory variation, abnormal hepatic and portal venous Doppler waveforms, and a high VExUS grade, consistent with intravascular volume overload. In contrast, Cases 1 and 3 showed preserved IVC dynamics and normal hepatic, portal, and intrarenal venous Doppler profiles corresponding to VExUS grade 0, indicating the absence of systemic venous congestion. Nevertheless, lung POCUS demonstrated interstitial B-lines in Cases 2 and 3 as well as pleural effusion in Case 3.

Lung POCUS findings alone did not permit differentiation between fluid overload syndrome and inflammatory capillary leak. The integration of venous Doppler assessment with lung POCUS was required to distinguish intravascular congestion from extravascular fluid accumulation. This multiparametric approach enabled pathophysiology-based classification into (1) fluid overload syndrome with systemic venous congestion, (2) engraftment syndrome without venous congestion, and (3) severe capillary leak syndrome characterized by distributive fluid shifts despite preserved venous hemodynamics (Figure 2).

Discussion

This case series illustrates how multiparametric POCUS can help differentiate fluid overload syndrome from inflammatory endothelial complications after allogeneic stem cell transplantation despite overlapping clinical presentations. All three patients developed rapid weight gain, respiratory compromise, and systemic symptoms during the early transplant period. However, venous Doppler–based ultrasound assessment revealed distinct sonographic profiles that directly influenced management decisions. The integration of IVC assessment, hepatic, portal, and intrarenal venous Doppler, together with lung POCUS, enabled classification into intravascular congestion versus non-congestive inflammatory fluid redistribution. This bedside differentiation addressed a clinically relevant diagnostic gap in the setting of hematopoietic stem cell transplantation, where early post-transplant fluid accumulation frequently presents with overlapping clinical features but requires fundamentally different therapeutic strategies.

Fluid accumulation after stem cell transplantation represents a heterogeneous group of pathophysiological processes, reflecting complex interactions between hydrostatic pressure, oncotic pressure, and endothelial permeability that regulate fluid distribution between the intravascular and interstitial compartments [14, 15]. In fluid overload syndrome, intravascular volume expansion leads to elevated central venous pressure and the retrograde transmission of venous congestion to the splanchnic and renal circulations. These changes are reflected by abnormal venous Doppler waveforms and increased portal vein pulsatility [10]. The VExUS framework was developed to identify clinically relevant venous congestion by integrating IVC size with Doppler patterns from abdominal veins [16]. Whereas VExUS primarily reflects systemic venous congestion and elevated right-sided filling pressures, lung POCUS evaluates pulmonary fluid accumulation. Pulmonary B-lines may arise from hydrostatic pulmonary edema due to elevated left-sided filling pressures or from increased alveolo-capillary permeability in inflammatory conditions such as capillary leak syndrome. Consequently, neither modality alone sufficiently characterizes the underlying hemodynamic state. Their combined interpretation provides complementary information regarding fluid distribution across the systemic and pulmonary, intravascular and extravascular compartments. Based on these observations, we propose a multiparametric POCUS-based diagnostic framework for bedside assessment (Figure 3).

Although VExUS has been investigated primarily in patients with acute decompensated heart failure and patients following cardiac surgery, evidence in hematopoietic stem cell transplantation is currently lacking [17]. Therefore, VExUS should not be interpreted as a comprehensive assessment of overall “volume status” but rather as a tool for identifying or excluding clinically significant systemic venous congestion. In the present cases, VExUS was interpreted in conjunction with lung POCUS and the overall clinical context, reflecting the complementary role of multiparametric

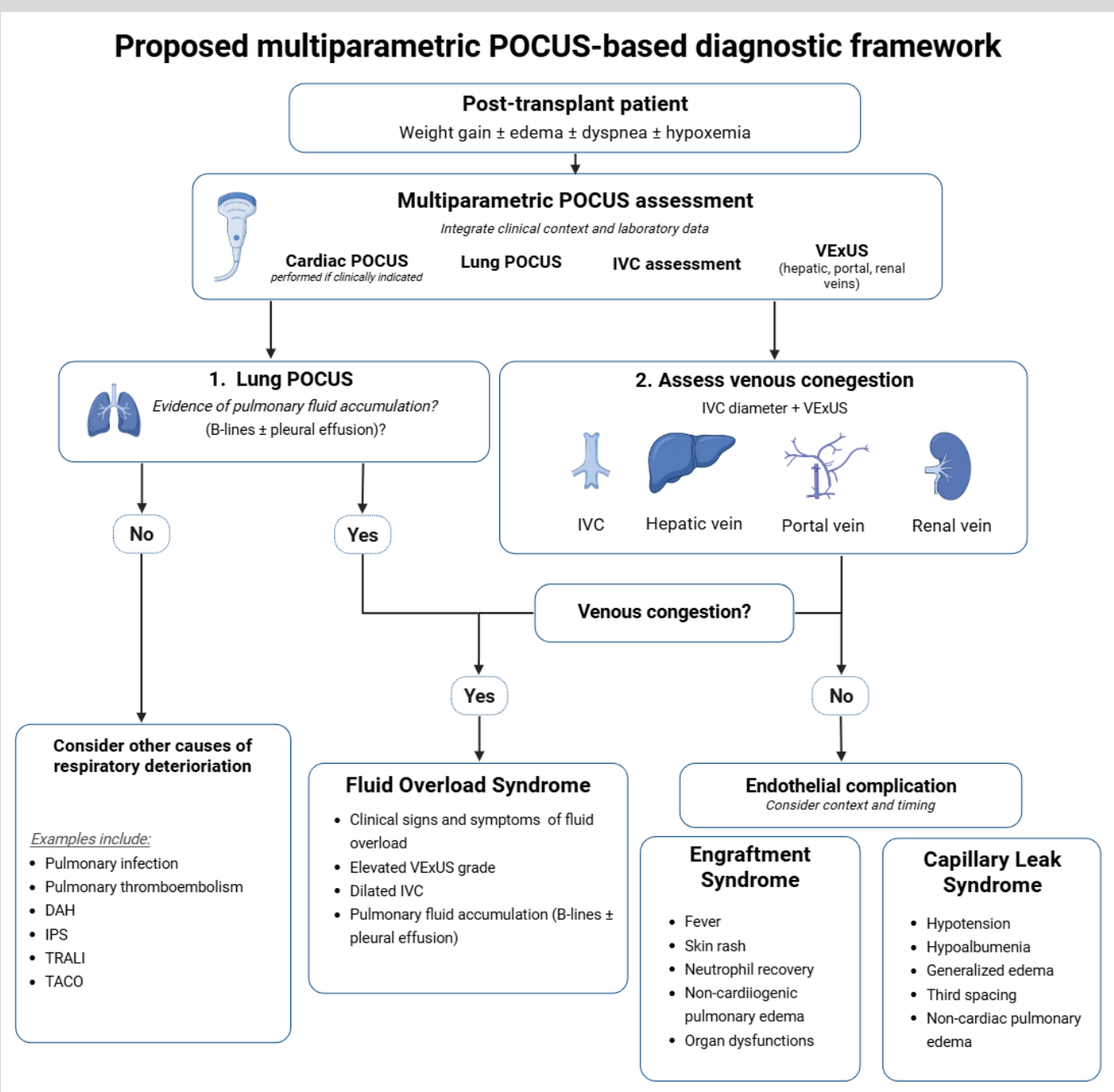


Figure 3. Proposed multiparametric POCUS-based diagnostic algorithm for post-transplant fluid accumulation. Proposed diagnostic framework for the bedside evaluation of patients with suspected fluid accumulation following allogeneic hematopoietic stem cell transplantation. Multiparametric POCUS, integrating cardiac POCUS, lung POCUS, IVC assessment, and the VExUS grading system, facilitates differentiation between systemic venous congestion consistent with fluid overload syndrome and inflammatory endothelial complications, including engraftment syndrome and capillary leak syndrome. Alternative causes of respiratory deterioration should be considered according to the clinical presentation. POCUS findings should always be interpreted in conjunction with the clinical context, laboratory findings, timing after transplantation, and conventional imaging. Created in BioRender. POCUS, point of care ultrasound; IVC, inferior vena cava; VExUS, Venous Excess Ultrasound; DAH, diffuse alveolar hemorrhage; IPS, idiopathic pneumonia syndrome; TACO, transfusion-associated circulatory overload; TRALI, transfusion-related acute lung injury.

POCUS rather than reliance on a single ultrasound parameter.

Engraftment syndrome and capillary leak syndrome are characterized primarily by endothelial activation, increased vascular permeability, and extravasation of fluid into the interstitial compartment [2,13,18]. In these inflammatory phenotypes, intravascular congestion may be absent despite substantial weight gain and pulmonary interstitial edema. Conventional parameters do not reliably distinguish between these mechanisms because they do not differentiate intravascular from extravascular fluid distribution [5-8].

Diagnostic criteria for engraftment syndrome, capillary leak syndrome, and fluid overload syndrome frequently overlap in clinical practice [2]. Moreover, imaging findings such as interstitial infiltrates and pleural effusions are non-specific [9]. Engraftment syndrome is most commonly defined by the criteria proposed by Spitzer or Maiolino, which include non-infectious fever, skin rash, pulmonary infiltrates with hypoxemia, and weight gain occurring around the time of neutrophil recovery [13,19]. Capillary leak syndrome is characterized by increased vascular permeability leading to generalized edema, hypotension, and pulmonary edema due to fluid extravasation into the interstitial compartment. Fluid overload syndrome, in contrast, is generally characterized by significant weight gain, a positive cumulative fluid balance, and clinical signs of congestion, such as peripheral edema, pulmonary edema, or pleural effusions. Despite these conceptual differences, the clinical manifestations of these syndromes frequently overlap in the early post-transplant period, making differentiation based solely on clinical criteria difficult [2]. In this context, lung POCUS alone does not permit mechanistic classification, as B-lines may occur in both venous congestion and inflammatory pulmonary edema [20]. The addition of venous Doppler assessment provides complementary information by identifying or excluding systemic venous congestion. In the present cases, this multiparametric approach allowed differentiation between congestion-driven respiratory compromise and distributive fluid shifts despite similar clinical presentation [11].

The therapeutic implications of this distinction are clinically significant. Real-world management patterns further highlight the diagnostic uncertainty in this setting. In cohorts of patients with engraftment syndrome, treatment has been heterogeneous: most received corticosteroids, while others were managed conservatively or treated with diuretics alone or in combination with corticosteroids [21]. The use of diuretics in a primarily inflammatory syndrome likely reflects the difficulty in distinguishing engraftment syndrome from fluid overload syndrome in the presence of weight gain and respiratory compromise. This overlap underscores that current clinical assessment does not reliably differentiate between intravascular congestion and inflammatory fluid redistribution.

Management of fluid overload syndrome requires active decongestion through reduced maintenance fluids, diuretic therapy, or renal replacement therapy, whereas inflammatory endothelial syndromes primarily require immunomodulatory treatment and supportive care [2,22]. Misclassification may result in inappropriate escalation of corticosteroids or, conversely, harmful overdiuresis in patients without true intravascular volume expansion. POCUS offers a rapid, repeatable, and non-invasive method to guide these decisions. Incorporating multiparametric POCUS into routine peri-transplant assessment may therefore enhance individualized fluid stewardship [23].

The differential diagnosis of respiratory deterioration and fluid accumulation after allo-HSCT is broad and includes hydrostatic fluid overload, engraftment syndrome, capillary leak syndrome, infection, idiopathic pneumonia syndrome, diffuse alveolar hemorrhage, TACO, TRALI, and pulmonary thromboembolism [2]. As these conditions frequently present with overlapping clinical features, laboratory findings, and conventional imaging, establishing the predominant underlying pathophysiology may be challenging.

This study has several limitations. It represents a small retrospective case series from a single center. POCUS findings were interpreted in conjunction with clinical judgment. The observations were, therefore, hypothesis-generating. Larger, prospective studies are needed to validate standardized POCUS algorithms in the hematopoietic stem cell transplantation setting and to determine whether POCUS-guided fluid management improves clinical outcomes. In addition, POCUS assessment is operator-dependent and may vary with the examiner's experience. Several physiological and technical factors may also influence VExUS interpretation, including positive-pressure ventilation, marked hypoalbuminemia, and limited acoustic windows [10,16]. An additional limitation is that lung POCUS findings were evaluated primarily for the presence of B-lines and pleural effusions. Detailed lung POCUS characteristics, including the distribution and density of B-lines, pleural line morphology, and subpleural consolidations, were not systematically documented due to the retrospective nature of this case series. Future prospective studies should investigate whether advanced lung POCUS features provide additional value in differentiating hydrostatic pulmonary edema from inflammatory endothelial complications after allo-HSCT.

Beyond the individual cases presented, this series

highlights the potential value of multiparametric POCUS as a physiological phenotyping tool in allo-HSCT recipients. Rather than identifying fluid accumulation alone, the combined interpretation of cardiac POCUS, VExUS, and lung POCUS may distinguish systemic venous congestion from endothelial permeability-related pulmonary edema, thereby differentiating clinically similar respiratory syndromes with fundamentally different hemodynamic mechanisms. The application of this integrated congestion-focused POCUS framework in the allo-HSCT population has not previously been described and may provide a useful foundation for future prospective studies. The proposed framework is intended as a hypothesis-generating bedside approach rather than a validated diagnostic algorithm and should be prospectively evaluated.

Conclusion

POCUS enabled bedside differentiation between fluid overload syndrome and inflammatory endothelial complications, namely engraftment syndrome and capillary leak syndrome, after allogeneic stem cell transplantation despite overlapping clinical features. The integration of venous Doppler assessment with lung POCUS allowed the identification of distinct fluid distribution phenotypes and guided targeted management strategies. In a clinical setting where weight gain and respiratory deterioration are common but mechanistically heterogeneous, multiparametric ultrasound may support pathophysiology-based decision-making. Prospective studies are warranted to determine whether structured POCUS-guided fluid management improves outcomes in stem cell transplant recipients.

Ethics Statement

Written informed consent was obtained from all patients for publication of this retrospective case series, including the accompanying anonymized clinical information, laboratory data, and images

Disclosure Statement

The author declares that there are no conflicts of interest related to this work.

Funding

No funding to declare.

Artificial Intelligence Statement

During the preparation of this work the author used a large language model (ChatGPT, OpenAI) to edit for clarity and language. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

References

1. Penack O, Peczynski C, Mohty M, Yakoub-Agha I, Styczynski J, Montoto S, Duarte RF, Kröger N, Schoemans H, Koenecke C, Peric Z, Basak GW. How much has allogeneic stem cell transplant-related mortality improved since the 1980s? A retrospective analysis from the EBMT. Blood Adv. 2020;4(24):6283–6290. doi: 10.1182/bloodadvances.2020003418

2. Sureda A, Corbacioglu S, Greco R, Kröger N, Carreras E, editors. The EBMT Handbook: Hematopoietic Cell Transplantation and Cellular Therapies. 8th ed. Cham: Springer International Publishing; 2024. doi: 10.1007/978-3-031-44080-9

3. McEwan A, Greenwood M, Ward C, Ritchie D, Szer J, Gardiner E, Colic A, Sipavicius J, Panek-Hudson Y, Kerridge I. Diagnosis and management of endothelial disorders following haematopoietic stem cell transplantation. Intern Med J. 2023;53(12):2162–2174. doi: 10.1111/imj.16188

4. Vythoulkas D, Tsirigotis P, Griniezaki M, Konstantellos I, Lazana I. Endothelial dysfunction syndromes after allogeneic stem cell transplantation. Cancers 2023;15(3):680. doi: 10.3390/cancers15030680

5. Koratala A, Ronco C, Kazory A. Diagnosis of fluid overload: from conventional to contemporary concepts. Cardiorenal Med. 2022;12(4):141–154. doi: 10.1159/000526902

6. Raco J, Peterson B, Muallem S. Assessment of volume status in hospitalized patients with chronic heart failure. Cardiol Res. 2023;14(1):2–11. doi: 10.14740/cr1434

7. Perren A, Markmann M, Merlani G, Marone C, Merlani P. Fluid balance in critically ill patients. Should we really rely on it? Minerva Anestesiol 2011;77(8):802–811

8. Gonzalez F, Vincent F. The fluid balance in the critically ill patients: what are we talking about? Minerva Anestesiol. 2011;77(8):766–767. 9. Franquet T, Müller NL, Lee KS, Giménez A, Flint JD. High-resolution CT and pathologic findings of noninfectious pulmonary complications after hematopoietic stem cell transplantation. AJR Am J Roentgenol. 2005;184(2):629–637. doi: 10.2214/ajr.184.2.01840629

10. Assavapokee T, Rola P, Assavapokee N, Koratala A. Decoding VExUS: a practical guide for excelling in point-of-care ultrasound assessment of venous congestion. Ultrasound J. 2024;16(1):48. doi: 10.1186/s13089-024-00396-z

11. de la Espriella R, Cobo M, Santas E, Verbrugge FH, Fudim M, Girerd N, Miñana G, Górriz JL, Bayés-Genís A, Núñez J. Assessment of filling pressures and fluid overload in heart failure: an updated perspective. Rev Esp Cardiol (Engl Ed). 2023;76(1):47–57. doi: 10.1016/j.rec.2022.07.009

12. Gagnier JJ, Kienle G, Altman DG, Moher D, Sox H, Riley D, the CARE Group. The CARE guidelines: consensus-based clinical case reporting guideline development. BMJ Case Reports CP 2013;2013:bcr2013201554. doi: 10.1111/head.12246

13. Spitzer TR. Engraftment syndrome following hematopoietic stem cell transplantation. Bone Marrow Transplant. 2001;27(9):893–898. doi: 10.1038/sj.bmt.1703015

14. Milone G, Bellofiore C, Leotta S, Milone GA, Cupri A, Duminuco A, Garibaldi B, Palumbo G. Endothelial dysfunction after hematopoietic stem cell transplantation: a review based on physiopathology. J Clin Med. 2022;11(3):623. doi: 10.3390/jcm11030623

15. Palomo M, Diaz-Ricart M, Carreras E. Endothelial dysfunction in hematopoietic cell transplantation. Clin Hematol Int. 2019;1(1):45–51. doi: 10.2991/chi.d.190317.001

16. Rola P, Miralles-Aguiar F, Argaiz E, Beaubien-Souligny W, Haycock K, Karimov T, Dinh VA, Spiegel R. Clinical applications of the venous excess ultrasound (VExUS) score: conceptual review and case series. Ultrasound J. 2021;13(1):32. doi: 10.1186/s13089-021-00232-8

17. González-Vázquez MD, García Casasola-Sánchez G, Tung-Chen Y. Evidence of the usefulness of VEXUS score in the diagnosis and treatment of the syndrome cardiorenal: a narrative review. Span J Med. 2023;3(2):35–43. doi: http://dx.doi.org/10.24875/SJMED.23000004

18. Saravi B, Goebel U, Hassenzahl LO, Jung C, David S, Feldheiser A, Stopfkuchen-Evans M, Wollborn J. Capillary leak and endothelial permeability in critically ill patients: a current overview. Intensive Care Med Exp. 2023;11(1):96. doi: 10.1186/s40635-023-00582-8

19. Maiolino A, Biasoli I, Lima J, Portugal AC, Pulcheri W, Nucci M. Engraftment syndrome following autologous hematopoietic stem cell

transplantation: definition of diagnostic criteria. Bone Marrow Transplant. 2003;31(5):393–397. doi: 10.1038/sj.bmt.1703855

20. Picano E, Pellikka PA. Ultrasound of extravascular lung water: a new standard for pulmonary congestion. Eur Heart J. 2016;37(27):2097–2104. doi: 10.1093/eurheartj/ehw164

21. Pramanik R, Kancharla H, Bakhshi S, Sharma A, Gogia A, Malik P, Sahoo RK, Batra A, Thulkar S, Kumar L. Engraftment syndrome: a retrospective analysis of the experience at a tertiary care institute. Clin Hematol Int. 2019;1(2):114–119. doi: 10.2991/chi.d.190504.001

22. Elbahlawan L, Qudeimat A, Morrison R, Schaller A. Fluid overload in children following hematopoietic cell transplant: a comprehensive review. J Clin Med. 2024;13(21):6348. doi: 10.3390/jcm13216348

23. Hawkins WA, Smith SE, Newsome AS, Carr JR, Bland CM, Branan TN. Fluid stewardship during critical illness: a call to action. J Pharm Pract. 2020;33(6):863–873. doi: 10.1177/0897190019853979.



NOV 2026 vol. 11 iss. 02 | POCUS J | 132

Ophthalmic POCUS to Evaluate the Pupillary Light Reflex in Critically Ill Children

Vaishnavi Divya Nagarajan, MBBS[1]; Kurt M. Drury, MD MCR[2]; Katherine Barton, MD[3]; Courtney L. Kraus, MD[4]; Misun Hwang, MD[5]; Becky J. Riggs, MD[1,6]*

(1) Division of Pediatric Critical Care Medicine; Department of Pediatrics, Oregon Health & Science University, Portland, OR, USA
(2) Division of Pediatric Critical Care Medicine; Department of Pediatrics, University of Chicago, Chicago, IL, USA
(3) Department of Diagnostic Radiology, Oregon Health & Science University, Portland, OR, USA
(4) Wilmer Eye Institute, Johns Hopkins University; Baltimore, MD, USA
(5) Department of Radiology; Children's Hospital of Philadelphia, University of Pennsylvania, Philadelphia, PA, USA
(6) Division of Pediatric Anesthesiology and Critical Care Medicine, Johns Hopkins University, Baltimore, MD, USA

Abstract

Background: This study evaluated ophthalmic point of care ultrasound (O-POCUS) in critically ill children with difficult-to-assess pupils as a method for quantifying pupillary constriction in response to light, compared with infrared pupillometry and direct visualization. **Methods:** This is a multi-center prospective observational study performed within the pediatric intensive care units at two pediatric academic hospitals. All critically ill children admitted to the pediatric intensive care unit with difficult-to-assess pupils who were less than 18 years old were eligible for enrollment. Children who were wards of the state, had penetrating ophthalmic trauma, or had congenital ophthalmic disorders were excluded. After enrollment, nine sequential measurements of the pupillary light reflex (PLR) were obtained from each eye, including three measurements by direct visualization, three by infrared pupillometry, and three by O-POCUS. **Results:** Forty-six children, aged 7 days to 17 years old, were enrolled, with a total of 92 individual eyes evaluated. Determining PLR was successful in 40 patients (87%) by direct visualization, 32 patients (70%) by infrared pupillometry, and all 46 patients (100%) by O-POCUS. A mixed-effects model demonstrated that ultrasound and pupillometry produced higher mean estimates of pupillary constriction by about 0.18 mm each but did not differ from each other on average. Bland-Altman analysis showed small biases between methods, and modality-specific residual standard deviations revealed that ultrasound had the lowest residual variability at 0.32 mm, compared with direct visualization at 0.46 mm and pupillometry at 0.44 mm. **Conclusion:** O-POCUS was the only modality able to determine the PLR in all patients; therefore, O-POCUS should be considered in children where direct visualization or pupillometry is not possible.

Introduction

Assessing the pupillary light reflex (PLR) in critically ill children is an essential part of evaluating and monitoring their neurological status [1]. Changes in a child's PLR may be one of the earliest signs of a new or evolving neurologic catastrophe [2]. Altered PLR is a strong predictor of adverse outcomes after traumatic and ischemic brain injuries [1,2]. Direct visualization is the most clinically utilized method for evaluating the PLR in most pediatric patients [1,3]. Along with direct visualization, many adult neurocritical care units utilize infrared pupillometry as an objective tool to measure, record, and trend the PLR [4,5]. Both direct visualization and infrared pupillometry measurements of the PLR require the patient's eyelid to be opened, and the pupil to be visualized by the examiner. In patients with severe periorbital edema, facial trauma, corneal opacity, corneal burns, eyelid sutures, or anterior segment pathology, immediate direct visualization of the pupil is challenging, if not impossible. Ophthalmic point of care ultrasound (O-POCUS) is a promising tool that can measure the PLR in critically ill infants and children even when the eyelids cannot be retracted and the pupil cannot be visualized [6–10]. Separate adult studies have shown strong agreement (87%) between direct visualization and ophthalmic ultrasound, as well as strong agreement between ophthalmic ultrasound and pupillometry to evaluate the PLR [6,11]. The aim of this prospective observational study is to compare the PLR determined by O-POCUS and infrared pupillometry in critically ill children

*Corresponding Author: Dr. Becky J. Riggs (email: riggsbe@ohsu.edu)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20720

with difficult-to-assess pupils against the most clinically utilized method of direct visualization.

Methods

All children 0–17 years of age being cared for in the pediatric intensive care unit (PICU) at Johns Hopkins Children's Hospital from October 2020 until January 2021 and in the PICU at Doernbecher Children's Hospital from January 2022 to May 2024 with difficult-to-assess pupils were eligible for enrollment in this prospective observational cohort. Difficult-to-assess pupils were defined as pupils that could not easily be visualized and assessed for their PLR within 1 to 2 minutes of attempting to do so by the patient's front-line provider or assigned PICU nurse. For example, difficult-to-assess pupils were often identified as the inability of the bedside provider to fully retract the eyelid of the eye, preventing full visualization of the pupil. Children who were wards of the state, had penetrating ophthalmic trauma, eyelid denudement, congenital ophthalmic disorders, or whose pupils could be easily assessed were excluded [12]. Basic de-identified demographic and clinical support data were obtained and recorded for all enrolled patients (Table 1).

After enrollment, nine sequential measurements of the PLR of each eye were obtained by three distinct methods: three measurements each by direct visualization, infrared pupillometry, and bedside O-POCUS. Each of these nine measurements was taken uninterrupted in this same order to ensure a similar amount of ambient light exposure for each modality. Each method of evaluation was performed and recorded by different providers in hopes of minimizing carryover bias. Direct visualization measures of the PLR were obtained from each eye by the patient's assigned PICU nurse. The nurse shone a flashlight into the open eye being examined for 1 to 2 seconds before removing the light source. The same standard Eveready D-powered PICU-stocked flashlights were used by the bedside nurse as the light source to obtain the direct PLR. The nurse recorded the pupillary reactivity, followed by the size of the pupil before shining the light (maximal dilation) and the size of the pupil when light was shone (maximal constriction); it was also noted if no change in the pupil occurred or if direct visualization was not successful. Direct visualization was attempted for at least 5 minutes per eye by the PICU nurse before determining if it was unsuccessful and moving on to the next PLR evaluation modality. If the PICU nurse could not visualize the pupil, additional attempts at direct visualization were made by a pediatric neurointensivist (BR) to visualize the pupil for an additional 5 minutes after pupillometer and O-POCUS evaluations were completed. Three additional measurements of the PLR were then obtained for each eye by a PICU fellow (VDN) or PICU nurse using an NPi-300 pupillometer (Neuroptics, Irvine, CA). Maximal pupil dilation, maximal pupil constriction, pupil reactivity, and whether the pupillometer was unable to obtain a reading were recorded. Pupillometer readings were obtained per the manufacturer's instructions [4]. Pupillometer readings were attempted for at least 5 minutes per eye before determining if no measurements could be obtained and moving on to O-POCUS evaluation. If the PICU fellow (VDN) or nurse could not obtain pupillometry readings, additional attempts were made by a pediatric neurointensivist (BR) for an additional 5 minutes after all three modalities of PLR had been attempted. Finally, three O-POCUS measurements of the PLR of each eye were obtained by the same pediatric neurointensivist (BR), with over 12 years of O-POCUS experience. Again, Maximal pupil dilation, maximal pupil constriction, pupil reactivity, and whether the pupillometer was unable to obtain reactivity were recorded. O-POCUS was attempted for at least 5 minutes per eye before determining that no measurements could be obtained by ultrasound.

O-POCUS measurements were obtained using either a Butterfly iQ+ (Butterfly Network, Burlington, MA) ultrasound probe (1–10 MHz) attached to a HIPAA-compliant iPhone or an L10-22-RS ultra-high frequency (10–22 MHz) linear array probe attached to a Venue Go™ (GE HealthCare, Chicago, IL) ultrasound machine. The Venue Go ™ ultrasound machine was preferentially used for all scans. The Butterfly iQ+ probe was used when the Venue Go™ ultrasound machine was not available due to updates or repairs by the vendor. Each B-mode scanning ultrasound probe was set in ophthalmic safety mode with a depth of 1.5–3 cm depending on the age of the patient. In addition to utilizing ophthalmic safety mode, the as low as reasonably achievable (ALARA) principle was followed by minimizing total ophthalmic ultrasound scan time. The ultrasound probe was coated with GenTeal eye lubricant (Novartis Pharmaceuticals Corporation, East Hanover, NJ) and gently placed in the longitudinal/sagittal plane lateral to the closed eyelid (Figure 1B). The probe beam obtained a cross-sectional image of the pupil (Figure 2). If a cross-sectional image of the pupil (Figure 2) could not be obtained, the probe was then gently placed in a transverse plane directly over the closed eyelid (Figure 1A). The probe beam would then obtain a direct image of the pupil (Figure 3). After either a direct (Figure 3) or cross-sectional image (Figure 2) of the pupil was obtained by ophthalmic POCUS, a PICU nurse shone a flashlight beam (same bedside Eveready flashlight used for direct visualization) through the closed eyelid that was not being examined by the ultrasound for 1 second. A 6-second ultrasound cine clip capturing either a direct view

Table 1. Study sample baseline characteristics. Values are presented as numbers and percentages.

Patient Characteristics	<1 year old	1-4 years old	5-9 years old	10-14 years old	15-17 years old	All patients
Demographics						
Age group	18 (39%)	5 (11%)	6 (13%)	9 (20%)	8 (17%)	46 (100%)
Female	5 (11%)	1 (2.2%)	2 (4.4%)	6 (11%)	2 (4.4%)	16 (35%)
Male	13 (28%)	4 (9%)	4 (9%)	3 (6.7%)	6 (13%)	30 (65%)
Admitting Diagnosis						
ARDS	1 (2%)	0	3 (6.5%)	1 (2%)	3 (6.5%)	8 (17%)
Cardiac arrest/HIE	3 (6.5%)	2 (4%)	0	0	2 (4%)	7 (15%)
Uncompensated Shock	3 (6.5%)	0	0	1 (2%)	2 (4%)	6 (13%)
Congenital heart disease	4 (9%)	2 (4%)	0	0	0	6 (13%)
Trauma or burn	1 (2%)	1 (2%)	1 (2%)	3 (6.5%)	0	6 (13%)
Status epilepticus	1 (2%)	0	1 (2%)	2 (4%)	0	4 (9%)
Surgical non-cardiac	1 (2%)	0	2 (4%)	2 (4%)	0	5 (11%)
Bronchiolitis	3 (6.5%)	0	0	0	0	3 (6.5%)
Diabetic ketoacidosis	0	0	0	1 (2%)	0	1 (2%)
Clinical Support						
Awake not sedated	3 (6.5%)	2 (4%)	3 (6.5%)	3 (6.5%)	5 (11%)	16 (35%)
Intubated and sedated	11 (24%)	3 (6.5%)	3 (6.5%)	5 (11%)	3 (6.5%)	25 (54%)
ECMO and sedated	4 (9%)	0	0	1 (2%)	1 (2%)	6 (13%)
Pupillary Light Reflex Evaluations						
Cannot open eyelids*	3 (6.7%)	0	1 (2%)	1 (%)	0	5 (11%)
All modalities successful	8 (17%)	5 (11%)	4 (9%)	8 (17%)	7 (16%)	32 (70%)
Successful direct visualization	15 (33%)	5 (11%)	5 (11%)	8 (17%)	7 (16%)	40 (87%)
Successful pupillometry	8 (17%)	4 (9%)	4 (9%)	9 (20%)	7 (16%)	32 (70%)
Successful Ophthalmic POCUS	18 (39%)	6 (13%)	6 (13%)	9 (20%)	7 (16%)	46 (100%)
Cannot perform direct visualization*	3 (6.7%)	1 (2%)	1 (2%)	1 (%)	0	6 (13%)
Cannot obtain pupillometry reading*	10 (22%)	1 (2%)	2 (4.4%)	1 (%)	0	14 (30%)
Cannot obtain pupillometry despite full pupil exposure*	7 (15%)	0	1 (2%)	0	0	8 (17%)
Mortality	5 (11%)	0	1 (2%)	0	1 (2%)	7 (15%)

ARDS, acute respiratory distress syndrome; ECMO, extracorporeal membrane oxygenation; HIE, hypoxic ischemic encephalopathy; POCUS, point of care ultrasound.

*Unsuccessful after attempting for a minimum of 5 minutes for each eye.

(Supplementary Material - Video S1) or a cross-sectional view of the pupil (Supplementary Material - Video S2) was recorded. This captured 1 to 2 seconds before the light was shone, during the 1 to 2 seconds of light shining in the contralateral eye, and about 2 to 3 seconds after the light was removed. After obtaining three cine clips for each eye, the videos were reviewed, and measurements were obtained using the ultrasound machine calipers to quantify maximal dilation (Figure 2A, Figure 3A), maximal constriction (Figure 2B, Figure 3B), and reactivity of the pupil (Supplementary Material - Video S1, Supplementary Material - Video S2).

Statistical Analysis

We used RStudio, Version 15 for all analyses and considered a p-value of <0.05 as statistically significant [13]. For each eye, we recorded three separate values of the PLR for each of the three modalities: direct visualization, pupillometry, and O-POCUS. We performed descriptive statistics and reported counts with percentages to describe the patient population and ability to detect a PLR. Changes in pupil size were summarized using descriptive statistics (mean, standard deviation (SD), median, and interquartile range (IQR)).

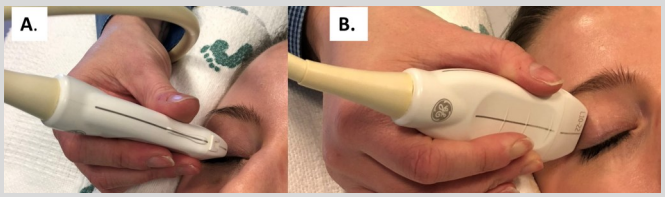


Figure 1. A) Ultrasonographer using a high-frequency linear array probe gently placed over the closed right eyelid in the transverse plane directly over the closed eyelid, with the probe beam obtaining a direct image of the pupil. The ultrasonographer's right hand is securely anchored on a towel next to the patient's face to minimize pressure placed on the eye and maximize control of the probe. B) Ultrasonographer using a high-frequency linear array probe gently placed over the closed right eyelid in the longitudinal plane lateral to the closed eyelid, with the probe beam obtaining a cross-sectional image of the pupil.

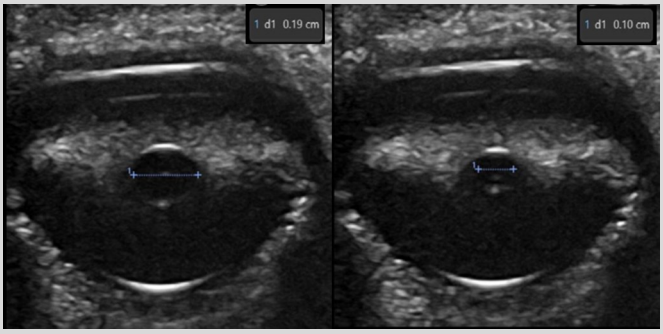


Figure 2. A) Sagittal plane ultrasound image showing a cross-sectional view of the iris surrounding the central black pupil (vertical line transection) with a pupillary diameter measuring 0.37 cm (3.7 mm) before light exposure (GE HealthCare, Chicago, IL). B) Cross-sectional ultrasound image of the same eye showing the iris surrounding the central black constricted pupil (vertical line transection) after light exposure, showing a pupillary diameter of 0.15 cm (1.5 mm) (GE HealthCare, Chicago, IL).

Agreement between left and right eyes for each test was assessed using a repeated-measures Bland-Altman framework via linear mixed-effects models for repeated paired measurements. We report the mean inter-eye bias, the between-participant SD of this difference, and the within-participant SD. To compare modalities, we fit a heteroscedastic linear mixed-effects model with modality as a fixed effect and direct visualization as the reference. An overall modality effect was assessed using the model-based ANOVA for the fixed effect of modality. Pairwise contrasts were used to estimate mean differences between modalities with 95% confidence intervals and multiplicity-adjusted p-values (Holm). Residual measurement variability by modality was summarized using modality-specific SD from the mixed model. Finally, agreement between modalities at the individual-measurement level was assessed using pairwise repeated-measures Bland-Altman analyses for each modality pair, with estimated bias and model-based 95% limit of agreement (LoA) reported.

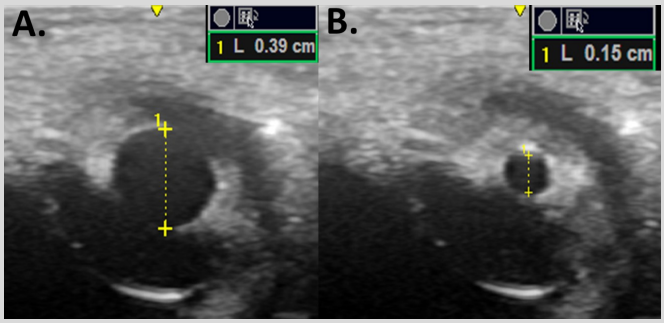


Figure 3. A) Transverse plane ultrasound image showing a direct image of the iris surrounding the central black pupil (line transecting) with a pupillary diameter measuring 0.19 cm (1.9 mm) before light exposure (GE HealthCare, Chicago, IL). B) Ultrasound image of the same eye showing the iris surrounding the central black constricted pupil (line transection) after light exposure, showing a pupillary diameter of 0.1 cm (1 mm) (GE HealthCare, Chicago, IL).

Results

Forty-six critically ill pediatric patients with difficult-to-assess pupils were enrolled in this multi-center IRB-approved prospective observational cohort (Table 1). Participants ranged in age from 7 days to 17 years, with a mean age of 6.2 years (SD = 6.3). This study was initially approved by the IRB at a single institution; however, the COVID-19 pandemic interfered with enrollment, allowing for five patients to be enrolled between October 2020 and January 2021. The study did not enroll patients during 2021. During the pandemic, members of the research team relocated and continued this study at a second institution where 41 additional patients were enrolled. The study concluded enrollment in May 2024 when additional study team members left the institution.

Of the 46 total patients enrolled, 92 individual eyes were evaluated for their PLR. O-POCUS was successful in all 46 patients (92 eyes; 100%); direct visualization was successful in 40 patients (80 eyes; 87%); and infrared pupillometry was successful in 32 patients (64 eyes; 70%) (Table 1). All initial unsuccessful attempts at obtaining both direct visualization (PICU nurse) and pupillometry (VDN) repeated by the attending pediatric neurointensivist (BR) remained unsuccessful after the second 5-minute attempt. Direct visualization of the pupil was not successful in five patients (10 eyes) because the

eyelids could not be opened sufficiently to visualize the pupil. In one additional patient (2 eyes), corneal burns obstructed the view of the anterior chamber, making direct visualization of the PLR impossible despite eyelid retraction. Of the five patients whose eyelids could not be opened enough to visualize the pupil, two were severely fluid overloaded and three had bilateral tarsorrhaphies (for treatment of exposure keratitis), which prevented eyelid retraction. Direct visualization was not possible in these five patients, nor was infrared pupillometry successful in these five patients. Additionally, pupillometry failed to give measurements despite being able to retract the eyelids enough to fully visualize the pupil in nine patients (18 eyes), including the patient who had corneal burns. Additional clinical characteristics of these 14 total patients for whom pupillometry readings were not successful are included in Table 2.

Forty-five of the 46 patients enrolled in this study had bilaterally reactive pupils. One 3-month-old patient who was later declared brain dead did not have any pupillary reactivity to light confirmed by both direct visualization and O-POCUS; however, the infrared pupillometer failed to give any readings, including a reading of non-reactivity. Descriptive statistics for pupil size change by modality are shown in Table 3. The distribution of change scores differed across modalities, with direct visualization showing the highest change and pupillometry showing the greatest dispersion. Scatter plots showing comparisons of changes in pupil size for each modality pair are shown in Figure 4. Inter-eye agreement differed by modality (Table 4). Mean inter-eye bias was small for all three methods, indicating minimal systematic left-right offset on average. The mean inter-eye bias for ophthalmic ultrasound was -0.06 mm, -0.17 mm for pupillometry, and -0.026 mm for direct visualization.

In the heteroscedastic mixed-effects model comparing modalities with direct visualization as the clinical standard reference, there was evidence of a modality effect ($F = 13.39$; $p < 0.0001$). Relative to direct visualization, ultrasound measurements were higher by 0.176 mm (95% CI 0.140 to 0.232, Holm-adjusted $p < 0.0001$) and pupillometry measurements were higher by 0.185 mm (95% CI 0.140 to 0.229; Holm-adjusted $p < 0.0001$). Ultrasound and pupillometry did not differ meaningfully on average (ultrasound was lower than pupillometry by -0.008 mm; 95% CI -0.047 to 0.030; Holm-adjusted $p = 0.8295$). Residual measurement variability differed by modality (Table 4). The estimated residual SD was 0.464 mm for direct visualization, 0.317 mm for ultrasound, and 0.437 mm for pupillometry, indicating the lowest residual variability for ultrasound and the highest for direct visualization. Pairwise repeated-measures Bland-Altman analyses are summarized in Table 5. Biases were centered near zero and small relative to the corresponding LoA, indicating that individual-level differences were larger than the average offset. Direct visualization compared to ultrasound showed a mean bias of -0.182 mm with 95% LoA -1.413 to 1.105 mm; direct visualization to pupillometry showed a mean bias of -0.185 mm with 95% LoA -1.555 to 1.185 mm; and ultrasound and pupillometry showed a mean bias of 0.003 mm with 95% LoA -1.037 to 1.043 mm. Bland-Altman plots displaying these differences are shown in Figure 5.

Discussion

Direct visualization of pupillary constriction in response to light is the most clinically utilized method for evaluating the PLR in critically ill children. The eyelids of most critically ill children can quickly and easily be fully retracted to expose the pupil, allowing for rapid direct assessment of the PLR. However, in critically ill children who are severely overloaded with fluid, have angioedema, suffer facial trauma, have corneal burns, or whose eyelids are sutured shut (tarsorrhaphies), direct visualization might not be possible. While direct visualization is the most clinically utilized qualitative method for evaluating the PLR, recent research suggests that when evaluating the quantitative pupillary change (maximal dilation - maximal constriction) in response to light, infrared pupillometry might provide a more accurate objective measurement of pupillary change [4,5]. However, it is uncertain if the quantitative difference in PLR measurements obtained by direct visualization versus pupillometry is more clinically relevant compared to knowing qualitative reactivity of the pupil (reactive versus non-reactive) in a manner that would impact a patient's medical care [14]. In current pediatric intensive care practice, identifying the initial degree of pupillary reactivity to light and trending this reactivity over time appears to have more clinical relevance than knowing the exact change in pupil size at a fixed time point; however, with the increased utilization of infrared pupillometry, this might change.

Similar to direct visualization, infrared pupillometry requires that the eyelids be opened and the infrared beam aligned with the pupillary space. The pupillometer cannot successfully measure the PLR in patients whose eyelids cannot be retracted to fully expose the pupil. Additionally, infrared pupillometry measurements can be difficult to obtain if the patient is frequently blinking, moving, or looking away from the pupillometer, rendering it dependent on patient cooperation in conscious patients. It has also been suggested that pupillometry readings might be difficult to obtain in premature infants due to their underdeveloped autonomic nervous system, altered myelination, and thicker central corneas with smaller

Table 2. Clinical characteristics of the 14 children for whom pupillometry was unsuccessful and the 6 children younger than 6 months for whom pupillometry was successful.

Age (months)	WGA (weeks)	Weight (kg)	Sedated & Intubated	Pupil Visualized	DV Success-ful	Pupillometry Successful	Death	Pupils Difficult to Assess
0.2	38	3.4	Yes	Yes	Yes	No	No	Fluid overload
0.55	37	2.5	Yes	Yes	Yes	No	No	Fluid overload
1	40	5.6	No	Yes	Yes	No	No	Angioedema
1	40	5.3	No	Yes	Yes	No	No	Fluid overload
2	36	5	Yes	Yes	Yes	No	No	Fluid overload
3	37	6	Yes	Yes	Yes	No	Yes	Fluid overload
4	37	6	Yes	Yes	Yes	No	Yes	Fluid overload
6	39	7.3	Yes	No	No	No	Yes	Fluid overload
6	40	7.8	Yes	No	No	No	Yes	Tarsorrhaphies
8	38	8.2	Yes	No	No	No	No	Tarsorrhaphies
41	38	14	Yes	Yes	No	No	No	Corneal burns
74	37	10.2	No	Yes	Yes	No	No	Angioedema
63	40	27.1	Yes	No	No	No	No	Fluid overload
124	39	38.5	Yes	No	No	No	No	Tarsorrhaphies
0.2	39	3.2	Yes	Yes	Yes	Yes	No	Fluid overload
1	39	3	Yes	Yes	Yes	Yes	No	Fluid overload
1	41	3.6	Yes	Yes	Yes	Yes	Yes	Fluid overload
2	38	5	Yes	Yes	Yes	Yes	No	Fluid overload
2	39	5	Yes	Yes	Yes	Yes	No	Fluid overload
4	39	6	Yes	Yes	Yes	Yes	Yes	Fluid overload

DV, direct visualization; kg, kilogram; WGA, weeks gestational age at birth.

corneal diameters compared to full-term infants [15–17]. It is also possible that the poorly formed pupillary border in infants less than 6 months of age might impact pupillometry readings as well. The majority of infrared pupillometry data have been reported on adult patients [3–5]. There is little pediatric data reporting on the utility and feasibility of infrared pupillometry measuring the PLR in neonates, infants, and children. Winston et al. reported no difficulties in obtaining infrared pupillometry readings in children from 2 to 21 years old [18]. However, when de Vries et al. utilized eye tracking stimulation screens with infrared pupillometry technology to capture the PLR in infants 5 to 24 months old, they were unsuccessful with several infants that were ultimately excluded from the study [19].

In our study, infrared pupillometry failed to measure the PLR in 14 children (30%), of which five patients' eyelids could not be retracted to expose the pupil, and one where the cornea was clouded due to burns (Table 2). Seven of the remaining eight patients (15%) were term infants (≥37 weeks gestational age) with an average age of 7.8 weeks (SD = 5.6) and an average weight of 4.5 kg (SD = 1.4). It was not reported that any of these patients fought against the pupillometer scan (no head shaking or excessive blinking). Six of these eight patients were intubated and heavily sedated. All were term babies ≤ 5 months of age, suggesting that lack of cooperation, corneal thickness, or prematurity should not have contributed to these failed readings; however, it does suggest that young age might have been a contributing factor to the failure of these readings. Small pupillary size was unlikely to be the only contributing factor to these failed readings, given that pupillometry readings were successfully obtained on six other term babies ≤ 5 months of age within our study population (Table 2). Pupillometry failed in the patient who had corneal burns, which most likely blocked the infrared pupillometry beam, causing unsuccessful

Table 3. Descriptive statistics reporting the number of successful pupillary light reflex measurements, average change in pupillary size, and median change in pupillary size in response to light separated by three different measuring modalities.

Modality	Participants with PLR measurements	Total eyes with PLR measurements	Mean change (mm)	SD	Median change (mm)	IQR
Direct Visualization	40 (87%)	80 (87%)	1.0	0.48	1.0	0.67
Pupillometry	32 (70%)	64 (70%)	0.83	0.64	0.56	0.65
Ultrasound	46 (100%)	92 (100%)	0.88	0.44	0.8	0.64

IQR, interquartile range; mm, millimeter; PLR, pupillary light reflex; SD, standard deviation.

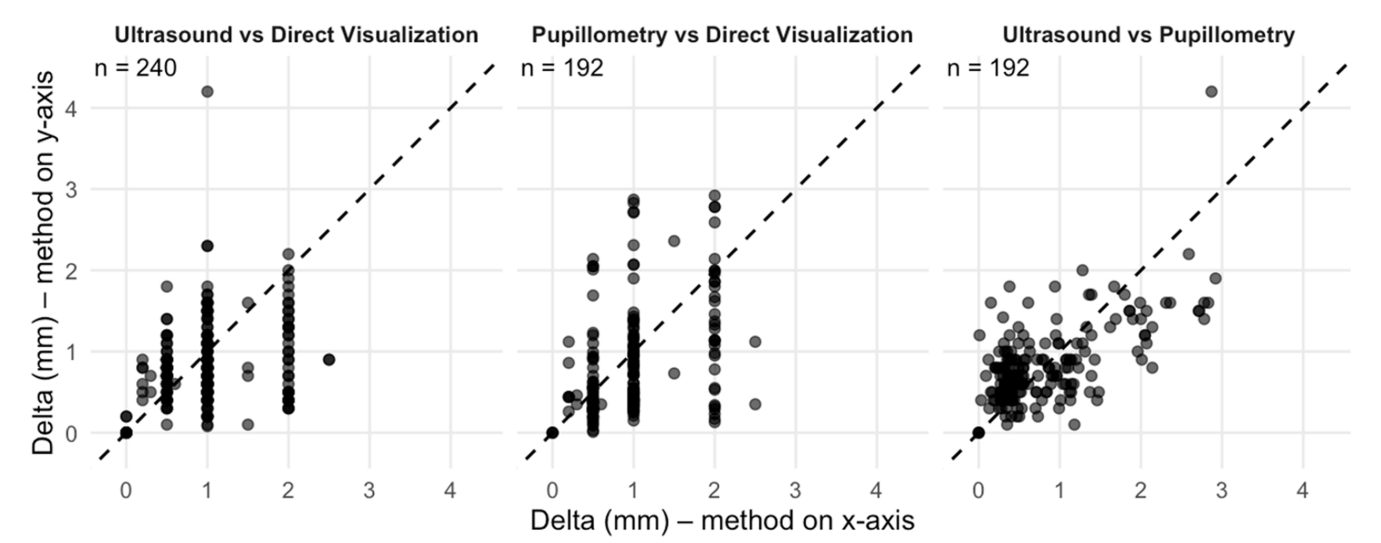


Figure 4. Pairwise scatter plots of change in pupil size across all imaging modalities. Dashed line is identity (y = x). Points shown for all repeats; missingness handled pairwise per panel.

Table 4. Inter-eye agreement and measurement noise within each pupillary response to light separated by three different measuring modalities.

Modality	Mean inter-eye bias (mm)	SD between participants	SD within participants	Lower LoA (mm)	Upper LoA (mm)	Residual SD
Direct visualization	-0.026	0.22	0.37	-0.87	0.82	0.46
Pupillometry	-0.17	0.41	0.42	-1.32	0.99	0.44
Ultrasound	-0.06	0.27	0.40	-1.02	0.89	0.32

LoA, limit of agreement; mm, millimeter; SD, standard deviation.

Table 5. Pairwise repeated-measures Bland-Altman agreement between pupillary light reflex measuring modalities based on a single measurement occasion.

PLR Measuring Method pair	Bias (mm)	Lower LoA (mm)	Upper LoA (mm)	LoA width (mm)
Direct visualization - Ultrasound	-0.182	-1.413	1.105	2.518
Direct visualization - Pupillometry	-0.185	-1.555	1.185	2.740
Ultrasound - Pupillometry	0.003	-1.037	1.043	2.080

Differences were centered near zero relative to the corresponding LoA. LoA, limit of agreement; mm, millimeter; PLR, pupillary light reflex.

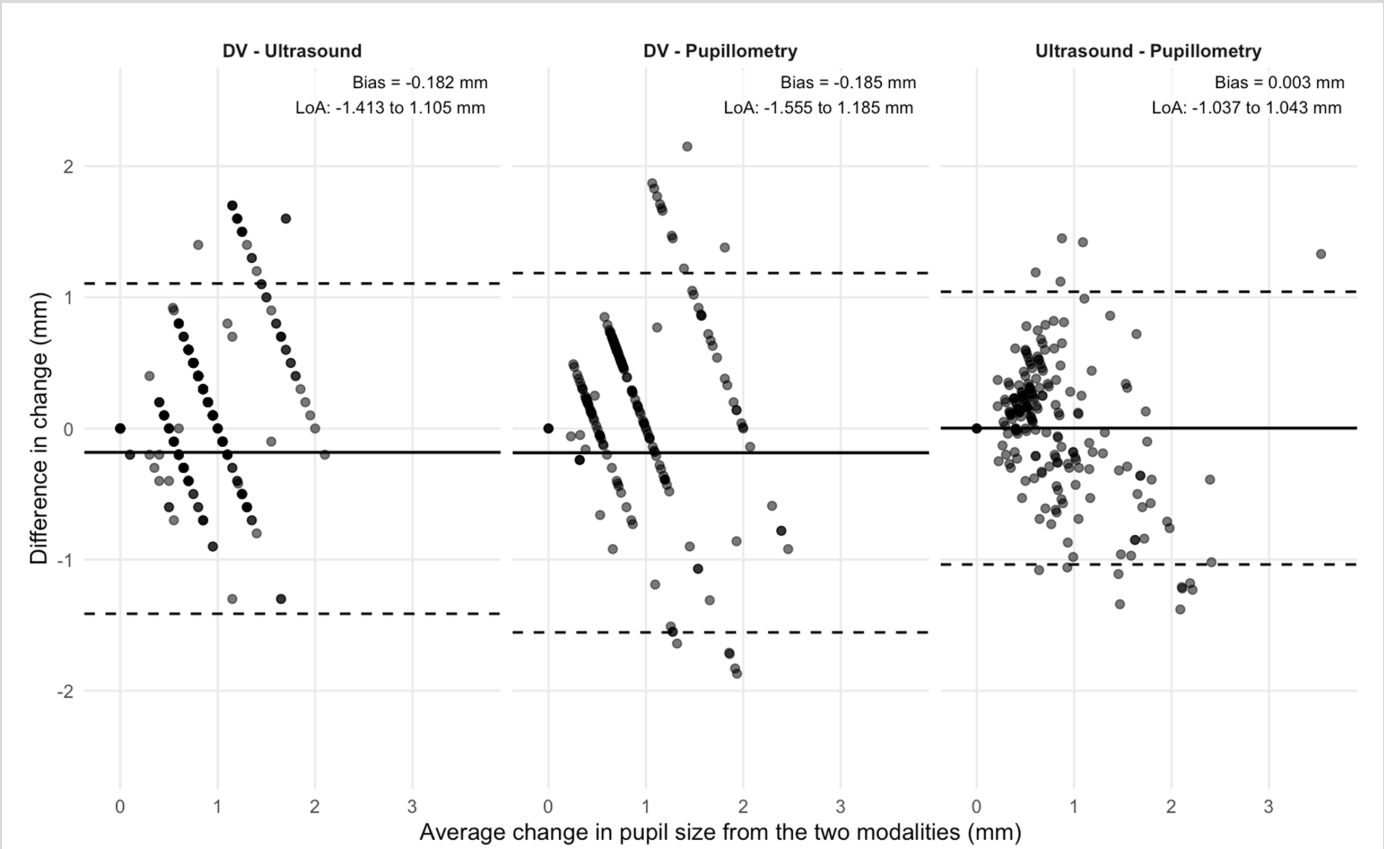


Figure 5. Bland-Altman plots showing agreement in pupillary change across all imaging modalities. Solid line = model-based bias. Dashed lines = model-based 95% limits of agreement (single measurement occasion).

pupillometry readings. The remaining patient in whom pupillometry failed was a 6-year-old with a POLR2A genetic mutation causing refractory epilepsy, significant neurological delays, severe microcephaly (44 cm) and growth retardation (weight 10.2 kg). Additional future pupillometry research can perhaps more accurately determine what contributing factors lead to failed pupillometry readings in babies < 5 months of age.

Unlike both direct visualization and infrared pupillometry, it has been reported that O-POCUS can detect the PLR in adult patients through a closed eyelid, which can be performed despite eyelids being difficult or impossible to retract [20,21]. Studies have shown both feasibility and accuracy of O-POCUS to determine the PLR compared to infrared pupillometry (R 0.83, $p < 0.01$) in critically ill adults [22]. Additionally, Chen et al. reported the use of an automated O-POCUS system produced by Edan Instruments (EDAM AX8 ultrasound system), where the ultrasound probe has a built-in light source that turns on and off while a B-mode cine loop is recorded, with software producing a continuous diameter-time curve in addition to key PLR metrics [11]. This automated O-POCUS system was compared to infrared pupillometry in critically ill adults, showing strong agreement with an inter-observer intraclass correlation coefficient ranging from 0.94–0.999 and an intra-observer intraclass correlation coefficient of 0.89–0.985 [11]. POCUS machines are widely available, safe, and effective at evaluating a wide variety of ophthalmic pathology [23–25]. Additionally, O-POCUS is being increasingly utilized within Emergency Departments and Critical Care Units [26–30].

Both direct and consensual PLR can be obtained through O-POCUS by shining a light directly over the closed eyelid of the eye being scanned (direct) or shining the light over the closed eyelid of the eye not being scanned (consensual) [25,26]. To obtain the direct PLR, a cross-sectional ultrasound view of the pupil must be obtained so as not to block the pupil from the light source with the ultrasound probe. To ensure more consistent shining of light through the closed eyelid and ease of scanning, a consensual PLR was obtained on all patients in this study. The light reaching the pupil is more intense when directed into an open eye than when transmitted through a closed eyelid before reaching the pupil. Therefore, it is possible that the globally decreased change in pupillary size in response to light measured by O-POCUS compared to direct visualization and pupillometry could be due to less light reaching the pupil through a closed eyelid as opposed to more light reaching the pupil through an open eye. Additionally, measuring contralateral PLR instead of direct PLR in this study assumes there is no optic nerve damage. If the optic

nerve is injured, the pupil might not constrict in response to light shining in the eye with the damaged nerve. However, if light is shone directly into the contralateral eye, the pupil with nerve injury will still constrict. No nerve injury was identified in this study; however, this should be considered in future uses of this technology. Despite O-POCUS showing significantly less quantitative change in pupillary size in response to light, it was able to accurately determine qualitatively that the pupils were responsive to light bilaterally in 45 patients. Additionally, O-POCUS accurately identified bilateral non-reactive pupils in one patient.

A clinically normal pupillary response to light is typically reported as “Pupils Equal, Round, and Reactive to Light and Accommodation” (PERRLA). A clinically normal PLR of the right and left eye should be equal unless there is a unilateral defect or injury to the optic nerve, unilateral neural pathway, or afferent pupillary defect. None of these injuries were identified in our cohort; therefore, the research team assumed that the PLR of each patient’s right and left eye was the same. Inter-eye analyses showed small mean left-right bias within each modality (Table 4). Based on these results, direct visualization (performed by several different PICU nurses) most consistently and reliably reported equal quantitative measurements of the PLR between the right and left eye. However, observation bias might have influenced this result, with the bedside nurses knowing that the PLR should be equal in both eyes. Each modality had similar within-participant SD, reflecting minimal differences in measurement repeatability.

In the mixed-effects model comparing PLR measuring modalities, there was a significant overall method effect ($F = 13.39$ with $p < 0.0001$), indicating systematic differences in mean estimated constriction across all modalities. Both pupillometry and ultrasound differed from direct visualization by 0.18 mm on average (Table 5), whereas ultrasound and pupillometry did not differ meaningfully from one another. However, wide limits of agreement in the Bland-Altman analyses suggest that further data are needed to determine whether these are interchangeable for individual-level decision-making that would be driven by magnitude of pupillary constriction. There were clear modality-dependent differences in measurement noise. Ultrasound demonstrated the lowest residual variability, whereas direct visualization showed the highest residual SD. While direct visualization is sensitive to subjective estimation, ultrasound benefits from standardized acquisition and clear anatomical measurements, highlighting the potential benefits of this approach. Pupillometry’s residual variability fell between the other two methods, reflecting a combination of device precision and real-world acquisition challenges such as alignment and patient movement that are not as obvious to the operator as with ultrasound. These findings suggest that O-POCUS may provide a feasible and reproducible quantitative measurement approach, but further studies using standardized acquisition protocols are needed before conclusions can be drawn regarding diagnostic accuracy or superiority over existing methods.

The largest limitation of this study is the small sample size, with only 46 total patients and 92 eyes evaluated. Three separate individuals utilized a single modality to obtain PLR measurements for each patient in hopes of minimizing carryover bias. However, for patients in whom pupillometry and/or direct visualization failed on the first attempt, the same pediatric neurointensivist performed the repeat assessments. Thus, this individual was unblinded to the results of the initial attempt. Carryover bias might have influenced that neurointensivist’s subsequent attempts to obtain the PLR through pupillometry and/or direct visualization. However, in all second attempts, the pediatric neurointensivist (BR) was unable to obtain measurements of the PLR from direct visualization or infrared pupillometry in situations where others had failed. The same critical care fellow (NDV) performed 41 infrared pupillometry readings (91%), and the same critical care attending (BR) performed all of the O-POCUS exams for every patient. However, different PICU nurses obtained direct visualization measurements for each patient and five pupillometry readings. Variation in the skill level of individual nurses obtaining direct visualization of the PLR might have influenced accuracy. Finally, this study was performed at two separate institutions where different patient demographics, environmental factors, and nursing skill levels might have influenced the outcomes.

All O-POCUS exams were performed by a pediatric neurointensivist (BR) with over 12 years of frequent ophthalmic ultrasound experience, allowing for quick and gentle acquisition of O-POCUS measurements. It is possible that a less experienced sonographer might not have successfully obtained PLR measurements in all 46 patients (92 eyes) within the same timeframe. An additional limitation of this study was that 90 of the 92 pupils evaluated were reactive to light. As a result, the ability of these three modalities to detect non-reactive pupils was not sufficiently evaluated. A final limitation was that all children were critically ill; if these modalities were attempted in more vigorous or rowdy children, the PLR detection might have been less successful for some or all modalities.

O-POCUS should not be utilized to detect the PLR in patients with pupils that are easy to assess, given that it is more time-consuming and requires greater skill compared to direct visualization or pupillometry.

However, in clinical scenarios where the pupil is difficult to visualize or assess, O-POCUS should be considered to determine the presence or absence of the PLR in critically ill children.

Conclusion

In this small prospective observational study, we were able to detect pupillary reactivity to light identified by O-POCUS in more critically ill children with difficult-to-assess pupils than infrared pupillometry or direct visualization. Ophthalmic ultrasound proved the most successful tool in obtaining the PLR in our cohort. For critically ill children with difficult-to-assess pupils, O-POCUS should be considered as an additional modality to determine pupillary reactivity to light.

Ethics Statement

Ethical approval for this study was obtained from Institutional Review Boards (IRBs) at both institutions approved this study (IRB: 61747 approved March 2019; IRB:25584 approved May 2022). Parental consent was obtained prior to all PLR evaluations, and patient assent was obtained whenever possible.

Disclosure Statement

The authors do not have any conflicts of interest to disclose.

Funding

The authors did not receive any financial support for the study and have no financial relationships relevant to this article to disclose.

Author Contributions

VN: conceptualization, methodology, formal analysis, investigation, writing-original draft, writing-review & editing. KD: conceptualization, methodology, formal analysis, investigation, writing-original draft, writing-review & editing. KB: data curation, writing-review & editing. CK: data curation, writing-review & editing. MH: data curation, writing-review & editing. BR: conceptualization, methodology, formal analysis, investigation, writing-original draft, writing-review & editing. All authors approved the final manuscript.

References

1. Kim, T.J. Quantitative assessments of pupillary light reflexes in neurocritically ill patients, Journal of Neurocritical Care, 2022;15(2):79-87. doi: https://doi.org/10.18700/jnc.220085

2. Rajagopalan S, Sarwal A. Neuromonitoring in Critically Ill Patients. Crit Care Med. 2023;51(4):525-542. doi: 10.1097/CCM.0000000000005809neuromonitoring_in_critically_ill_patients.9.aspx

3. Lee H, Choi SH, Park B, Hong YH, Lee HB, Jeon SB. Quantitative assessments of pupillary light reflexes in hospital-onset unresponsiveness. BMC Neurol. 2021;21(1):234. doi: 10.1186/s12883-021-02275-9

4. Hsu CH, Kuo LT. Application of Pupillometry in Neurocritical Patients. J Pers Med. 2023;13(7):1100. doi: 10.3390/jpm13071100

5. Zafar SF, Suarez JI. Automated pupillometer for monitoring the critically ill patient: a critical appraisal. J Crit Care. 2014;29(4):599-603. doi: 10.1016/j.jcrc.2014.01.012

6. Modi P, Bhoi S, Aggarwal P, Nayer J, Sinha TP, Ekka M, Mishra PR, Kumar A, Pandey S. Feasibility of USG-Guided Objective Initial Assessment of Pupillary Size and Pupillary Reflexes Versus Clinical Examination in Patients With Altered Mental Status: A Cross-Sectional Study. J Ultrasound Med. 2024;43(2):335-346. doi: 10.1002/jum.16366

7. Fisher YL. The current status of ophthalmic B-scan ultrasonography. J Clin Ultrasound. 1975;3:219-223.

8. Németh J, Végh M, Horóczi Z, Süveges I. Examination of the orbit using a non-ophthalmologic ultrasound equipment. Orv Hetil. 1992;133:2563-2565.

9. Schmidt FA, Ruprecht K, Connolly F, Maas MB, Paul F, Hoffmann J, Harms L, Schreiber SJ. B-mode ultrasound assessment of pupillary function: feasibility, reliability and normal values. PLoS One. 2017;12(12):e0189016. doi: 10.1371/journal.pone.0189016

10. Nagarajan VD, Hunt MF, Hwang M, Kraus CL, Riggs BJ. Pupillary Light Reflex Detected by Ophthalmic Ultrasonography in Critically Ill Children With Difficult to Assess Pupils. J Ultrasound Med. 2024;43(11):2213-2216. doi: 10.1002/jum.16534

11. Chen W, Jiang X, Guo X, Lin J, Dou N, Tang M. Comparison of automated ultrasound pupillometry assessment vs. infrared pupillary in critically ill patients. Front Med (Lausanne). 2026;12:1722645. doi: 10.3389/fmed.2025.1722645

12. Roth FS, Koshy JC, Goldberg JS, Soparkar CN. Pearls of orbital trauma management. Semin Plast Surg. 2010;24(4):398-410. doi: 10.1055/s-0030-1269769

13. Team RC. R: a language and environment for statistics. R Foundation for Statistical Computing; 2017.

14. Couret D, Boumaza D, Grisotto C, Triglia T, Pellegrini L, Occuidant P, Bruder NJ, Velly LJ. Reliability of standard pupillometry practice in neurocritical care: an observational, double-blinded study. Critical Care. 2016;20(1):99. doi: 10.1186/s13054-016-1239-z

15. Cerritelli F, Frasch MG, Antonelli MC, Viglione C, Vecchi S, Chiera M, Manzotti A. A Review on the Vagus Nerve and Autonomic Nervous System During Fetal Development: Searching for Critical Windows. Front Neurosci. 2021;15:721605. doi: 10.3389/fnins.2021.721605

16. Olivieri B, Rampakakis E, Gilbert G, Fezoua A, Wintermark P. Myelination may be impaired in neonates following birth asphyxia. Neuroimage Clin. 2021;31:102678. doi: 10.1016/j.nicl.2021.102678

17. Sehrawat P, Beri S, Garg R, Datta V, Shandil A. Central corneal thickness and corneal diameter in preterm and term newborns and preterm neonates at term. Indian J Ophthalmol. 2019;67(10):1575-1578. doi: 10.4103/ijo.IJO_1988_18

18. Winston M, Zhou A, Rand CM, Dunne EC, Warner JJ, Volpe LJ, Pigneri BA, Simon D, Bielawiec T, Gordon SC, Vitez SF, Charnay A, Joza S, Kelly K, Panicker C, Rizvydeen S, Niewijk G, Coleman C, Scher BJ, Reed DW, Hockney SM, Buniao G, Stewart T, Trojanowski L, Brogadir C, Price M, Kenny AS, Bradley A, Volpe NJ, Weese-Mayer DE. Pupillometry measures of autonomic nervous system regulation with advancing age in a healthy pediatric cohort. Clin Auton Res. 2020;30(1):43-51. doi: 10.1007/s10286-019-00639-3

19. de Vries LM, Amelynck S, Nyström P, van Esch L, Van Lierde T, Warreyn P, Roeyers H, Noens I, Naulaers G, Boets B, Steyaert J; TIARA Team. Investigating the development of the autonomic nervous system in infancy through pupillometry. J Neural Transm (Vienna). 2023;130(5):723-734. doi: 10.1007/s00702-023-02616-7

20. Schmidt FA, Ruprecht K, Connolly F, Maas MB, Paul F, Hoffmann J, Harms L, Schreiber SJ. B-mode ultrasound assessment of pupillary function: Feasibility, reliability and normal values. PLoS One. 2017;12(12):e0189016. doi: 10.1371/journal.pone.0189016

21. Sargsyan, A.E., Hamilton, D.R., Melton, S.L., Amponsah, D., Marshall, N.E., Dulchavsky, S.A. Ultrasonic evaluation of pupillary light reflex. Crit Ultrasound J; 2009;1:53–57. doi: https://doi.org/10.1007/s13089-009-0012-9

22. Farina F, Vosko MR, Baracchini C, Ermani M, Sommer P, Greisenegger S, Laubichler P, Struhal W, Kellermair L, Ransmayr G, Brunner C. Ultrasound Examination of the Pupil - A New Tool for the

Neuro-Ophthalmological Assessment. Ultraschall Med. 2021;42(1):84-91. doi: 10.1055/a-1208-1482

23. Riggs BJ, Trimboli-Heidler C, Spaeder MC, Miller MM, Dean NP, Cohen JS.. The Use of Ophthalmic Ultrasonography to Identify Retinal Injuries Associated with Abusive Head Trauma. Ann Emerg Med.2016; 67(5):620-4.

24. Barnett SB, Ter Haar GR, Ziskin MC, Rott HD, Duck FA, Maeda K. International recommendations for the use of diagnostic ultrasound in medicine. Ultrasound Med Biol. 2000;26(3):355-66. doi: 10.1016/s0301-5629(00)00204-0

25. Harries A, Shah S, Teismann N, Price D, Nagdev A. Ultrasound assessment of extraocular movements and pupillary light reflex in ocular trauma. Am J Emerg Med. 2010;28(8):956-9. doi: 10.1016/j.ajem.2009.06.026

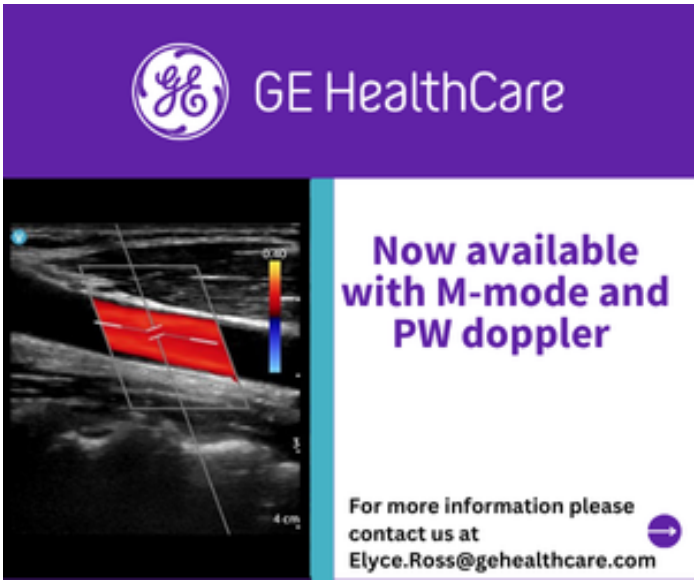
26. Pierre VA, Smith T, Salerno A. Ocular Ultrasound. Emerg Med Clin North Am. 2024;42(4):891-903. doi: 10.1016/j.emc.2024.05.009

27. Skidmore C, Saurey T, Ferre RM, Rodriguez-Brizuela R, Spaulding J, Lundgreen Mason N. A Narrative Review of Common Uses of Ophthalmic Ultrasound in Emergency Medicine. J Emerg Med. 2021;60 (1):80-89. doi: 10.1016/j.jemermed.2020.08.003

28. Abbinante G, Vitiello L, Coppola A, Salerno G, Gagliardi V, Pellegrino A. Optic Nerve Ultrasound Evaluation in Children: A Review. Diagnostics (Basel). 2023;13(3):535. doi: 10.3390/diagnostics13030535

29. Riggs BJ, Cohen JS, Shivakumar B, Trimboli-Heidler C, Patregnani JT, Miller MM, Spaeder MC, Dean NP. Doppler Ultrasonography of the Central Retinal Vessels in Children with Brain Death. Pediatr Crit Care Med. 2017;18(3):258-264. doi: 10.1097/PCC.0000000000001087

30. Riggs BJ, Hwang M, Cohen JS, Barton K, Thimm MA, Hunt MF, Trimboli-Heidler C, Valvano TJ, Kraus CL, Dean NP, Tekes A. Ophthalmic ultrasonography can identify retinal injury associated with abusive head trauma more quickly and accurately than other neuroimaging modalities. Child Abuse Negl. 2025;165:107474. doi: 10.1016/j.chiabu.2025.107474



Technical Pitfalls in Optic Nerve Sheath Diameter POCUS: A Practical Checklist for Image Optimization

Ricardo Bañuelos-Huerta, MD MSc MPH[1]*; Dibanhi S. Ruvalcaba-Trujillo, MD[2]; Jorge A. Lara-Arellano, MD[3]; Gilver Sebastián-Vázquez, MD[4]; Carlos Estrada-Valencia, MD[5]; Wendy J. Ramirez-Salvador, MD[6]; Daniel de J. Vásquez-Hernández, MD[7]; Montserrat Ramírez-Barranco, SSP[8]; Eduardo Y. Aguilar-Lazcano, SSP[8]; Wendy Sartillo-Guerra, SSP[8]

(1) Department of Emergency Medicine, Hospital General Tlaxcala "Lic. Anselmo Cervantes Hernández", Tlaxcala, Mexico
(2) Department of Emergency Medicine, Hospital General Zona No. 30, Instituto Mexicano del Seguro Social, Mexico City, Mexico
(3) Department of Emergency Medicine, Hospital General Zona No. 3, Instituto Mexicano del Seguro Social, Sinaloa, Mexico
(4) Department of Emergency Medicine, Hospital Regional de Alta Especialidad "Bicentenario de la Independencia", Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado, Estado de Mexico, Mexico
(5) Department of Emergency Medicine, Hospital General de Zona No. 1 "Dr. Luis Ernesto Miramontes Cárdenas", Instituto Mexicano del Seguro Social, Nayarit, Mexico
(6) Department of Emergency Medicine, Hospital General de Zona No. 1, Instituto Mexicano del Seguro Social, Chiapas, Mexico
(7) Department of Emergency Medicine, Hospital General de Zona No. 35, Instituto Mexicano del Seguro Social, Puebla, Mexico
(8) Department of Research, Hospital General de Tlaxcala "Lic. Anselmo Cervantes Hernández", Tlaxcala, Mexico

Abstract

Background: Point of care ultrasound (POCUS) measurement of the optic nerve sheath diameter (ONSD) has been established as a non-invasive method for estimating intracranial pressure in critically ill patients. However, the accuracy of the technique depends strongly on proper image acquisition. Errors in system optimization may result in inaccurate measurements and increased inter-operator variability. **Objective:** Our objective was to describe the most common technical errors in ONSD measurement and to propose a checklist to optimize image acquisition. **Methods:** A narrative review of the literature and an analysis of technical errors observed during POCUS training in critical care settings were completed. Emphasis was on ultrasound system parameters and image acquisition. **Results:** Six key technical elements were identified to optimize ONSD measurement. They included preset selection, depth adjustment, focal zone positioning, transducer frequency, gain optimization, and identification of the central retinal artery and vein. **Conclusion:** Standardization of ultrasound system settings may improve image quality and reduce measurement errors in ONSD, increasing reproducibility in emergency and critical care settings.

Introduction

Intracranial hypertension (ICH) is a frequent complication in various acute neurological conditions, including traumatic brain injury, intracranial hemorrhage, neurologic infections, and cerebral edema. Invasive intracranial pressure monitoring remains the diagnostic gold standard; however, its availability is limited in many clinical settings.

Over the past two decades, POCUS measurement of the optic nerve sheath diameter (ONSD) has become a widely used non-invasive method for estimating increased intracranial pressure. Several studies have demonstrated a significant correlation between increased ONSD and elevated intracranial pressure [1,2]. Hansen and Helmke were the first to describe the relationship between the perioptic subarachnoid space and intracranial pressure changes using ultrasound [3,4]. Subsequent clinical studies confirmed that ONSD enlargement correlates with ICH in patients with traumatic brain injury and other neurological conditions [5–7].

Soldatos et al. reported that an ONSD greater than 5.7 mm has high specificity for predicting intracranial pressure above 20 mmHg [8]. Similarly, Moretti and Pizzi demonstrated a strong correlation between ONSD and invasively measured intracranial pressure [9]. A meta-analysis by Dubourg et al. confirmed a sensitivity of approximately 90% and specificity of 85% for detecting ICH using optic nerve ultrasound [1].

Despite its apparent technical simplicity, ONSD measurement is subject to significant errors related to

*Corresponding Author: Dr. Ricardo Bañuelos Huerta (email: dr.banuelos.urgencias@gmail.com)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20719

image acquisition. A considerable proportion of inaccurate measurements results from suboptimal ultrasound system settings rather than clinical interpretation [10] (Figure 1).

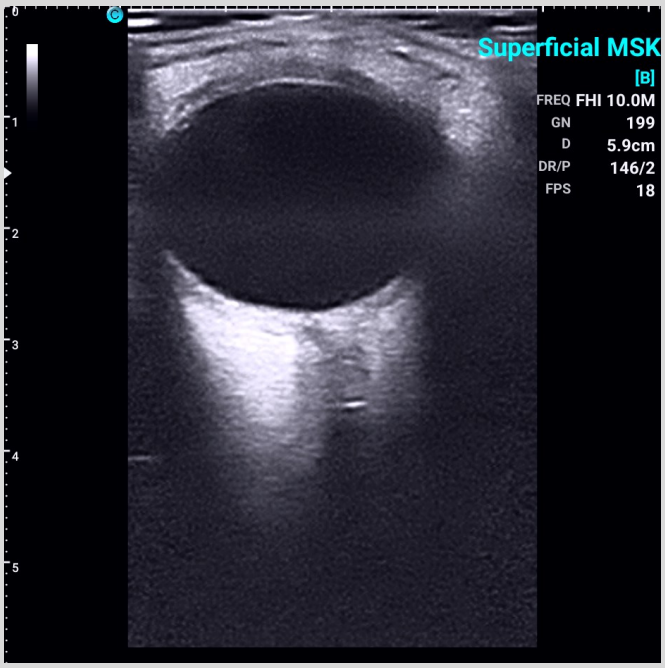


Figure 1. Image obtained using a superficial musculoskeletal (MSK) preset, where the optic nerve is not adequately visualized. The optic nerve sheath cannot be identified, and artifacts related to excessive gain are observed.

In clinical practice, many operators perform ONSD measurements without adequately optimizing image parameters, leading to systematic errors such as overestimation of sheath diameter, misidentification of the optic nerve, or measurements obtained outside the true central axis of the nerve.

Although ONSD measurement has become a valuable non-invasive tool for estimating intracranial pressure, there is still no universal consensus regarding the optimal measurement technique. The CLOSED protocol summarizes essential steps for accurate and safe measurement (Colour Doppler, Low power examination, Optic disc clarity, Safety, Elevated frequency, Dual measurements), allowing for more consistent and reproducible results. However, the limited availability of standardized comparative imaging may contribute to inter-observer variability [11].

Therefore, in order to standardize the technique and improve measurement reproducibility, we propose a technical checklist based on six key steps prior to measurement, focused on image quality optimization and accurate anatomical identification.

Anatomical and Embryological Basis

The optic nerve is a direct extension of the central nervous system that originates from the diencephalon during embryonic development. Unlike peripheral nerves, it is myelinated by oligodendrocytes and is surrounded by the meninges: dura mater, arachnoid mater, and pia mater [12].

Between the arachnoid and pia mater lies the subarachnoid space, which contains cerebrospinal fluid and is continuous with the intracranial subarachnoid space. Due to this anatomical continuity, increases in intracranial pressure are transmitted to the optic nerve sheath, resulting in its distension.

Anatomical and experimental studies have demonstrated that maximal distensibility of the sheath occurs approximately 3 mm posterior to the globe, which is why this point is used as the reference for ONSD measurement [3–4].

Relevant Ultrasound Physics Principles

Ultrasound image quality depends on several technical parameters, including transducer frequency, imaging depth, focal zone positioning, and gain settings.

High-frequency linear transducers (7–15 MHz) provide superior spatial resolution for superficial structures such as the optic nerve. As frequency increases, axial and lateral resolution improve, although tissue penetration decreases [13–15].

Gain controls image brightness by amplifying returning echoes. Excessive gain may produce overexposure artifacts or “blooming artifact,” making it difficult to accurately delineate the anatomical borders of the optic nerve sheath.

Additionally, the vitreous humor behaves as a low-attenuation fluid medium, resulting in the phenomenon known as posterior acoustic enhancement. This artifact causes structures located posterior to the globe to appear artificially brighter, potentially interfering with accurate delineation of the optic nerve [14–15].

Technical Checklist Prior to ONSD Measurement

Based on available literature and clinical experience in ultrasound training in critical care, we propose a technical checklist before ONSD measurement (Table 1).

1. Preset Selection

An ocular or superficial preset should be selected to optimize resolution for near-field structures. These presets are designed to optimize multiple system parameters, including frequency, dynamic range, image processing, and initial gain settings, thereby improving spatial resolution for superficial structures such as the optic nerve.

Table 1. Technical checklist for standardized optic nerve sheath diameter (ONSD) ultrasound acquisition.

Checklist before measuring optic nerve sheath diameter (ONSD)	
✓	1. Select ocular preset (if it is available) or small parts
✓	2. Adjust depth (≈ 3-4 cms)
✓	3. Use high-frequency linear probe
✓	4. Place focal zone at optic nerve
✓	5. Reduce global & TGC gain to avoid artifact
✓	6. Use color Doppler to identify central retinal artery

Additionally, ocular presets typically incorporate automatic limitations in acoustic output, helping to maintain safe values of the thermal index (TI) and mechanical index (MI) during examination. This is particularly important in ocular ultrasound, as the globe is sensitive to thermal and mechanical effects of ultrasound.

For this reason, international recommendations suggest performing ocular ultrasound while maintaining the TI as low as possible, ideally below 0.5 [13–14,16]. The use of non-specific presets (such as abdominal or vascular) may unnecessarily increase acoustic output and reduce optimization for superficial imaging. Therefore, selecting an ocular preset is a critical step for both image quality and patient safety [12–14].

2. Depth Adjustment

Imaging depth should be limited to approximately 3–4 cm, focusing system resolution on the retrobulbar region where measurement is performed. Excessive depth reduces image quality in the region of interest.

From a physical standpoint, increasing depth forces the ultrasound system to:

- Reduce line density
- Decrease effective lateral resolution
- Distribute pixels over a larger field

This results in reduced spatial resolution of superficial structures, making accurate identification of the optic nerve sheath more difficult [7,12]. Therefore, limiting depth allows concentration of resolution in the relevant anatomical region (Figure 2).

3. Frequency Adjustment

High-frequency linear transducers (7–15 MHz) should be used. Higher frequencies provide:

- Improved axial resolution
- Better interface definition
- Enhanced ability to distinguish small structures

This is crucial for ONSD measurement, as small variations in resolution may lead to clinically significant errors [13–15]. The main limitation of higher frequencies is reduced penetration; however, this is not relevant in superficial structures such as the eye.

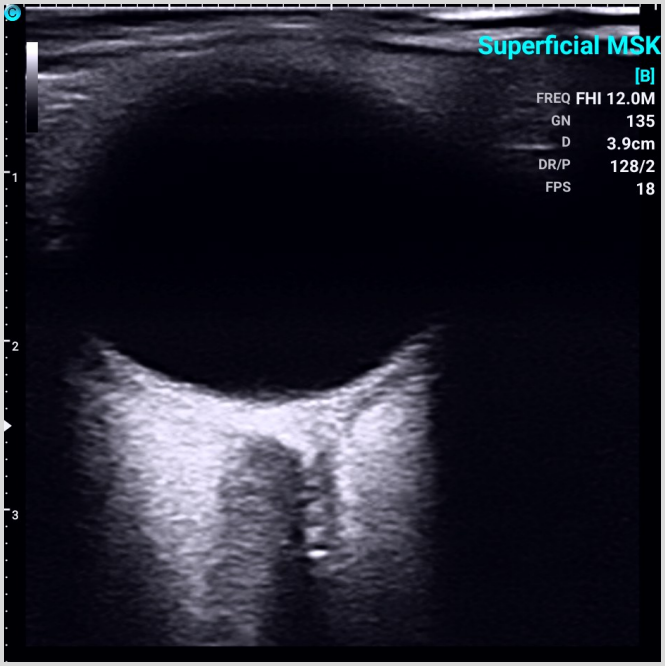


Figure 2. Image with reduced depth, limited to 3–4 cm, allowing improved visualization of the retrobulbar region.

4. Focal Zone Adjustment

The focal zone represents the region where the ultrasound beam reaches its narrowest width and highest lateral resolution. It should be positioned at the level of the optic nerve.

When the focal zone is placed outside the region of interest:

- Beam width increases
- Lateral resolution decreases
- Differentiation between sheath and nerve become more difficult

Proper focal positioning significantly improves delineation of the hyperechoic borders of the optic nerve sheath used for measurement.

5. Gain and Time Gain Compensation (TGC) Adjustment

Global gain and Time Gain Compensation (TGC) must be carefully adjusted to optimize contrast between the optic nerve and its sheath. One of the most common technical errors in ONSD measurement is excessive gain, which leads to:

- Image overexposure
- Reduced contrast
- Blooming artifact that artificially enlarges structures
- Difficulty in delineating retrobulbar anatomy

Additionally, the vitreous humor is a low-attenuation medium, resulting in posterior acoustic enhancement [8]. This artifact occurs because ultrasound waves pass through fluid with minimal energy loss, allowing greater acoustic energy to reach structures posterior to the globe. As a result, retrobulbar structures—including the optic nerve—may appear artificially hyperechoic, making differentiation between the nerve and its sheath more difficult.

To counteract this phenomenon:

- Reduce global gain
- Adjust TGC in the region posterior to the globe
- Optimize contrast to clearly identify sheath borders

In clinical practice, many operators mistakenly interpret increased retrobulbar echogenicity as part of the optic nerve sheath, when it actually represents an artifact caused by posterior acoustic enhancement of the vitreous humor [15–17]. (Figure 3) (Figure 4)

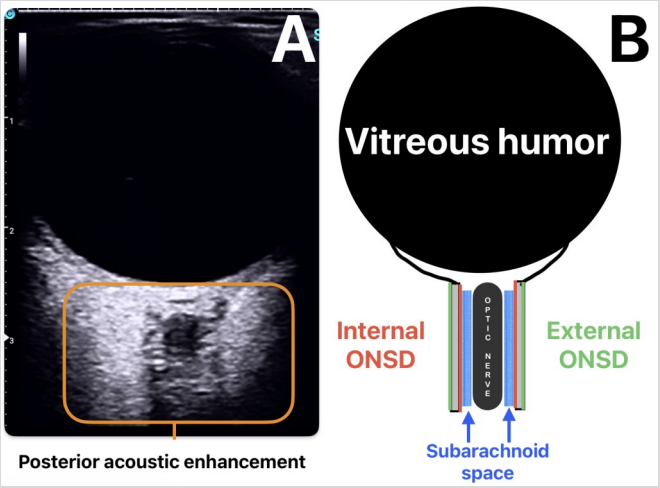


Figure 3. (A) Ultrasound image demonstrating posterior acoustic enhancement within the retrobulbar region after gain optimization. (B) Schematic representation of retrobulbar anatomy demonstrating the optic nerve (gray), the external optic nerve sheath (green), internal optic nerve sheath (red) and subarachnoid space (blue).

6. Identification of the Central Retinal Artery and Vein

Identification of the central retinal artery and vein using colour Doppler provides an additional anatomical reference that enhances the precision and reliability of the measurement. Locating these vessels ensures that the ONSD measurement is performed in the correct plane, reducing errors associated with oblique imaging planes, which may be difficult to detect using B-mode alone due to acoustic shadowing [11,12]. Measurements obtained outside the central axis tend to overestimate or underestimate ONSD, reducing reproducibility [7] (Figure 5).

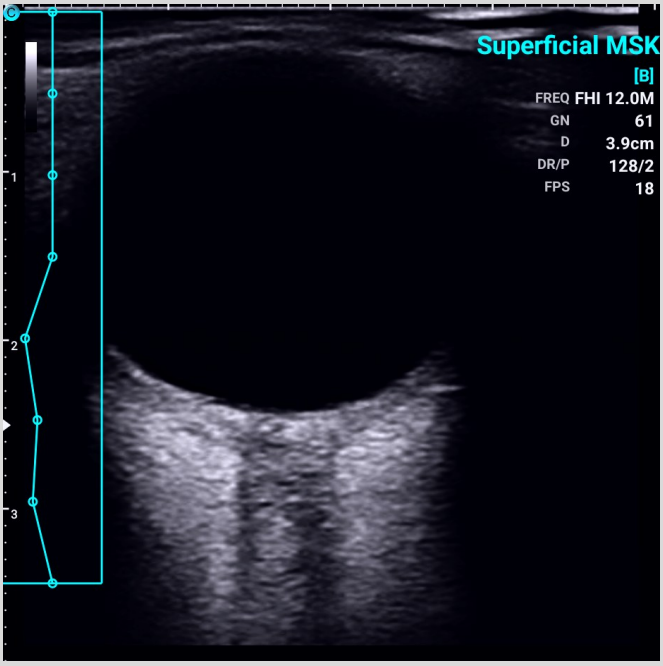


Figure 4. Ultrasound image demonstrating focal zone positioning at the optic nerve sheath measurement site. The left-sided blue adjustment curve corresponds to the Time Gain Compensation (TGC) settings used to optimize retrobulbar contrast and improve delineation of the optic nerve sheath.

Standard Measurement Technique

The patient should be placed in the supine position with the eyelid closed. Sterile gel can be applied over the eyelid to avoid direct pressure on the globe. The linear transducer is then placed in either transverse or longitudinal orientation over the eye. The main ocular structures are identified: anterior chamber, lens, vitreous humor, and posterior globe wall. The optic nerve appears as a hypoechoic tubular structure extending posteriorly from the globe, surrounded by a hyperechoic sheath. ONSD measurement is performed 3 mm posterior to the retinal border by drawing a line perpendicular to the nerve's longitudinal axis, connecting both internal borders [18]. Although observational cohort studies, such as the study by Pansell et al., suggest that external-to-external border measurements may provide comparable diagnostic accuracy, the international consensus statement by Hirzallah et al. prioritizes the use of the inner edge-to-inner edge technique in clinical practice

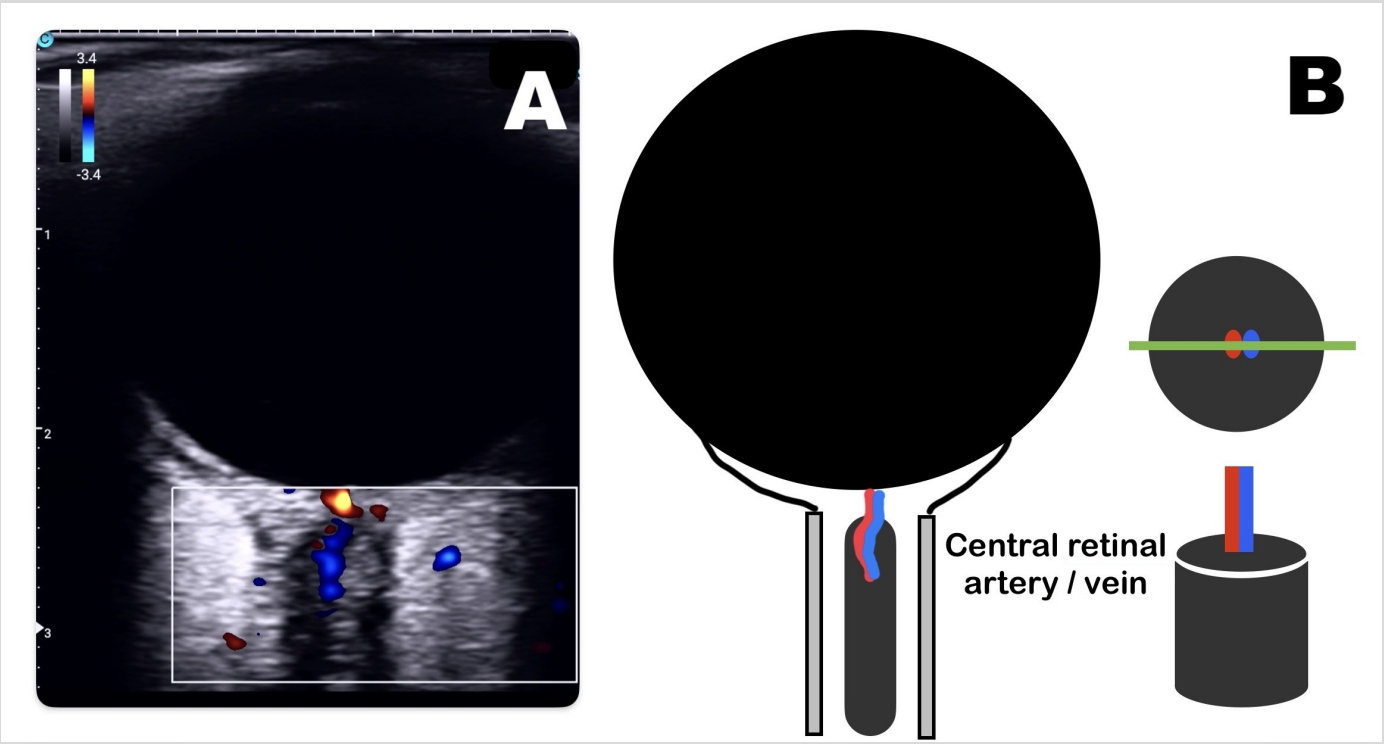


Figure 5. (A) Ultrasound image with colour Doppler demonstrating the central retinal artery and vein. (B) Schematic representation of the central retinal vessels and their anatomical relationship with the optic nerve.

[19,20]. At least three measurements should be obtained and averaged to improve reproducibility [13].

Conclusion

Ultrasonographic measurement of ONSD is a useful, non-invasive tool for assessing intracranial pressure in critically ill patients. However, its accuracy depends heavily on proper image acquisition. Technical errors related to ultrasound system configuration represent a major source of variability in ONSD measurement and may lead to misinterpretation when imaging parameters are not properly optimized. The implementation of a technical checklist—including appropriate preset selection, depth, focal zone, frequency, gain optimization, and the use of colour Doppler—can significantly improve image quality and reduce measurement errors.

Ocular ultrasound should always be performed following acoustic safety principles, maintaining ultrasound output as low as reasonably achievable. The use of ocular presets and monitoring of TI and MI help ensure safe evaluation of the globe during ONSD measurement. Standardization of these parameters may improve diagnostic accuracy and enhance reproducibility among operators, facilitating integration into clinical practice and POCUS training programs.

Ethics Statement

This article is based on a narrative review of the literature and does not involve human participants, patient data, or identifiable patient information. Therefore, institutional ethics approval and informed consent were not required.

Disclosure Statement

The authors declare no conflicts of interest related to this work.

Funding

This work received no external funding or financial support.

Author Contributions

RBH: conceptualization, methodology, formal analysis, writing – original draft, writing – review & editing, supervision. DSRT: methodology, writing – original draft. JALA: methodology, writing – original draft. GSV: writing – original draft. CEV: writing – original draft. WJRS: methodology, writing – original draft. DJVH: writing – original draft. MRB: formal analysis, writing – original draft. EYAL: methodology. WSG: methodology.

References

1. Dubourg J, Javouhey E, Geeraerts T, Messerer M, Kassai B. Ultrasonography of optic nerve sheath diameter for detection of raised intracranial pressure: a systematic review and meta-analysis. Intensive Care Med. 2011;37:1059–68

2. Koziarz A, Sne N, Kegel F, Nath S, Badhiwala JH, Nassiri F, Mansouri A, Yang K, Zhou Q, Rice T, Faidi S, Passos E, Healey A, Banfield L, Mensour M, Kirkpatrick AW, Nassar A, Fehlings MG, Hawryluk GWJ, Almenawer SA. Bedside optic nerve ultrasonography for diagnosing increased intracranial pressure: a systematic review and

meta-analysis. Ann Intern Med. 2019;171:896–905.

3. Hansen HC, Helmke K. The subarachnoid space surrounding the optic nerves: an ultrasound study of the optic nerve sheath. Surg Radiol Anat. 1996;18:323–8.

4. Helmke K, Hansen HC. Fundamentals of transorbital sonographic evaluation of optic nerve sheath expansion under intracranial hypertension. Pediatr Radiol. 1996;26:701–5.

5. Blaivas M, Theodoro D, Sierzenski PR. Elevated intracranial pressure detected by bedside emergency ultrasonography of the optic nerve sheath. Acad Emerg Med. 2003;10:376–81.

6. Geeraerts T, Launey Y, Martin L, Pottecher J, Vigué B, Duranteau J, Benhamou D. Ultrasonography of the optic nerve sheath may be useful for detecting raised intracranial pressure after severe brain injury. Intensive Care Med. 2007;33:1704–11.

7. Chen W, Zhang X, Ye X, Ying P. Diagnostic accuracy of optic nerve sheath diameter on ultrasound for the detection of increased intracranial pressure in patients with traumatic brain injury: a systematic review and meta-analysis. Biomed Rep. 2023;19(6):103. doi:10.3892/br.2023.1685

8. Soldatos T, Karakitsos D, Chatzimichail K, Papathanasiou M, Gouliamos A, Karabinis A. Optic nerve sonography in the diagnostic evaluation of adult brain injury. Crit Care. 2008;12:R67.

9. Moretti R, Pizzi B, Cassini F, Vivaldi N. Reliability of optic nerve ultrasound for the evaluation of patients with spontaneous intracranial hemorrhage. Neurocrit Care. 2009;11:406–10.

10. Ballantyne SA, O'Neill G, Hamilton R, Hollman AS. Observer variation in the sonographic measurement of optic nerve sheath diameter. Eur J Ultrasound. 2002;15:145–9.

11. Aspide R, Bertolini G, Albini Riccioli L, Mazzatenta D, Palandri G, Biasucci DG. A proposal for a new protocol for sonographic assessment of the optic nerve sheath diameter: the CLOSED protocol. Neurocrit Care. 2020;32:327–32.

12. Sadler TW. Langman's medical embryology. 14th ed. Philadelphia: Wolters Kluwer; 2019.

13. Robba C, Santori G, Czosnyka M, Corradi F, Bragazzi N, Padayachy L, Taccone FS, Citerio G. Optic nerve sheath diameter measured sonographically as non-invasive estimator of intracranial pressure: a systematic review and meta-analysis. Intensive Care Med. 2018;44(8):1284–94. doi:10.1007/s00134-018-5305-7

14. Kremkau FW. Diagnostic ultrasound: principles and instruments. 9th ed. Philadelphia: Elsevier; 2015.

15. Rumack CM, Wilson SR, Charboneau JW. Diagnostic ultrasound. 5th ed. Philadelphia: Elsevier; 2018.

16. American Institute of Ultrasound in Medicine. Ocular ultrasound safety guidelines. J Ultrasound Med. 2013;32:1–3.

17. Di Serafino M, Iacobellis F, Schillirò ML, D'Auria D, Verde F, Grimaldi D, Dell'Aversano Orabona G, Caruso M, Sabatino V, Rinaldo C, Guerriero P, Cantisani V, Vallone G, Romano L. Common and uncommon errors in emergency ultrasound. Diagnostics (Basel). 2022;12:631.

18. Mohammadi A, Haghighi M, Adabi M, Samaeili A, Kayedi M. Optic nerve sheath diameter measurement in healthy South Iranian adults from a cross-sectional ultrasonographic study. Sci Rep. 2025;15:17404.

19. Pansell J, Bell M, Rudberg P, Friman O, Cooray C. Optic nerve sheath diameter in intracranial hypertension: measurement external or internal of the dura mater? J Neuroimaging. 2023;33:58–66.

20. Hirzallah MI, Lochner P, Hafeez MU, Lee AG, Krogias C, Dongarwar D, Hartman ND, Ertl M, Robba C, Malojcic B, Valaikiene J, Sarwal A, Hakimi R, Schlachetzki F; Optic Nerve Sheath Diameter Point-of-Care Ultrasonography Quality Criteria Checklist (ONSD POCUS QCC) Expert Panelists. Optic Nerve Sheath Diameter Point-of-Care Ultrasonography Quality Criteria Checklist: An International Consensus Statement on Optic Nerve Sheath Diameter Imaging and Measurement. Crit Care Med. 2024;52:1543–56.

Shiitake Mushroom-Induced Small Bowel Obstruction Diagnosed by POCUS

Yo Ishihara, MD[1,2,3]*; Nana Obata, MD[4,5]; Yoshihito Ota, MD PhD[4]; Daichi Sogai, MD PhD[1]; Kota Takahashi, MD[2,3]; Takaomi Kessoku, MD PhD[2,3]; Yasushi Shinohara, MD PhD[4]

(1) Department of General Medicine, Sanmu Medical Center, Chiba, Japan
(2) Department of Palliative Medicine, International University of Health and Welfare Narita Hospital, Chiba, Japan
(3) Department of Gastroenterology, International University of Health and Welfare School of Medicine, Chiba, Japan
(4) Department of Surgery, Sanmu Medical Center, Chiba, Japan
(5) Department of Surgery, Toho University Ohashi Medical Center, Tokyo, Japan

Abstract

A 61-year-old partially edentulous man presented with one day of epigastric pain. Abdominal point of care ultrasound (POCUS) revealed a dilated small bowel, the “to-and-fro” sign, and a dome-shaped, linear, hyperechoic lesion with a hypoechoic posterior layer. Computed tomography (CT) revealed a mushroom-shaped, hypoattenuating lesion (approximate mean attenuation: −280 HU), accompanied by a calibre change. The patient was diagnosed with a small-bowel obstruction. After the diagnosis, the patient recalled that he had swallowed an unchewed grilled shiitake mushroom the day before. On day 4 of conservative treatment, the mushroom was spontaneously expelled. The patient was subsequently discharged. Although CT remains valuable for definitive diagnosis, POCUS may indicate that shiitake mushrooms are the cause of obstruction.

Introduction

A small bowel obstruction is a common surgical emergency; however, food-induced small bowel obstructions caused by bezoars are rare [1]. Among such cases, several reports from East Asia have revealed obstructions caused by shiitake mushrooms, with a lack of teeth frequently cited as an underlying factor [2–5]. Computed tomography (CT) is considered the gold standard to diagnose shiitake mushroom-induced small bowel obstruction, and the features of such obstructions upon CT have been previously described [4]. However, the identification of shiitake mushroom-induced small bowel obstruction using point of care ultrasound (POCUS) has not been reported. Herein, we report a case of small bowel obstruction caused by the ingestion of whole shiitake mushrooms in a partially edentulous patient, diagnosed using POCUS and confirmed by CT.

Case report

A 61-year-old partially edentulous man visited the emergency outpatient clinic at night with epigastric pain that had developed the previous day. He was diagnosed with constipation based on physical examination, underwent enema treatment, and was discharged home. As his symptoms did not resolve, he visited the Internal Medicine outpatient clinic for further evaluation.

The patient’s medical history included atherothrombotic cerebral infarction and dyslipidemia, but he had not previously undergone abdominal surgery. His chronic medications were atorvastatin and clopidogrel. Upon arrival, his vital signs were as follows: body temperature, 36.4 °C; pulse, 75 bpm; blood pressure, 163/97 mmHg; and SpO_2, 97% on room air. His last bowel movement had been one week prior. He reported experiencing colicky epigastric pain with an intensity of 6/10 on the Numeric Rating Scale.

Upon physical examination, the patient’s abdomen was flat and soft, with mild tenderness in the epigastric and periumbilical regions but no peritoneal signs. Small bowel obstruction was considered in the differential diagnosis. POCUS was performed using a portable ultrasound device (PUD) with a 2–5 MHz convex probe (FWU-1 [iViz air]; Fujifilm, Tokyo, Japan). No fecal retention was noted in the colon; however, when the probe was applied transversely below the umbilicus, dilated small bowel loops with “to-and-fro” signs were observed, along with a dome-shaped, linear, hyperechoic structure with posterior acoustic shadowing (Figure 1). Laboratory tests revealed no remarkable abnormalities. Abdominal CT revealed an

*Corresponding Author: Dr. Yo Ishihara (email: yo-ishihara@ihwg.jp)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20287

obstructive lesion in the ileum with a hypoattenuating area measuring approximately −280 HU at the site of obstruction (Figure 2). The lesion resembled the cap and stalk of a mushroom. The patient reported that four days earlier he had eaten grilled shiitake mushrooms with soy sauce but, as he had lost his teeth and was awaiting new dentures, he had been unable to chew and had swallowed the mushrooms whole. Dental examination revealed that he had no teeth in the right maxilla (Figure 3).

Taken together, a diagnosis of food-induced small bowel obstruction due to shiitake mushrooms was made, and

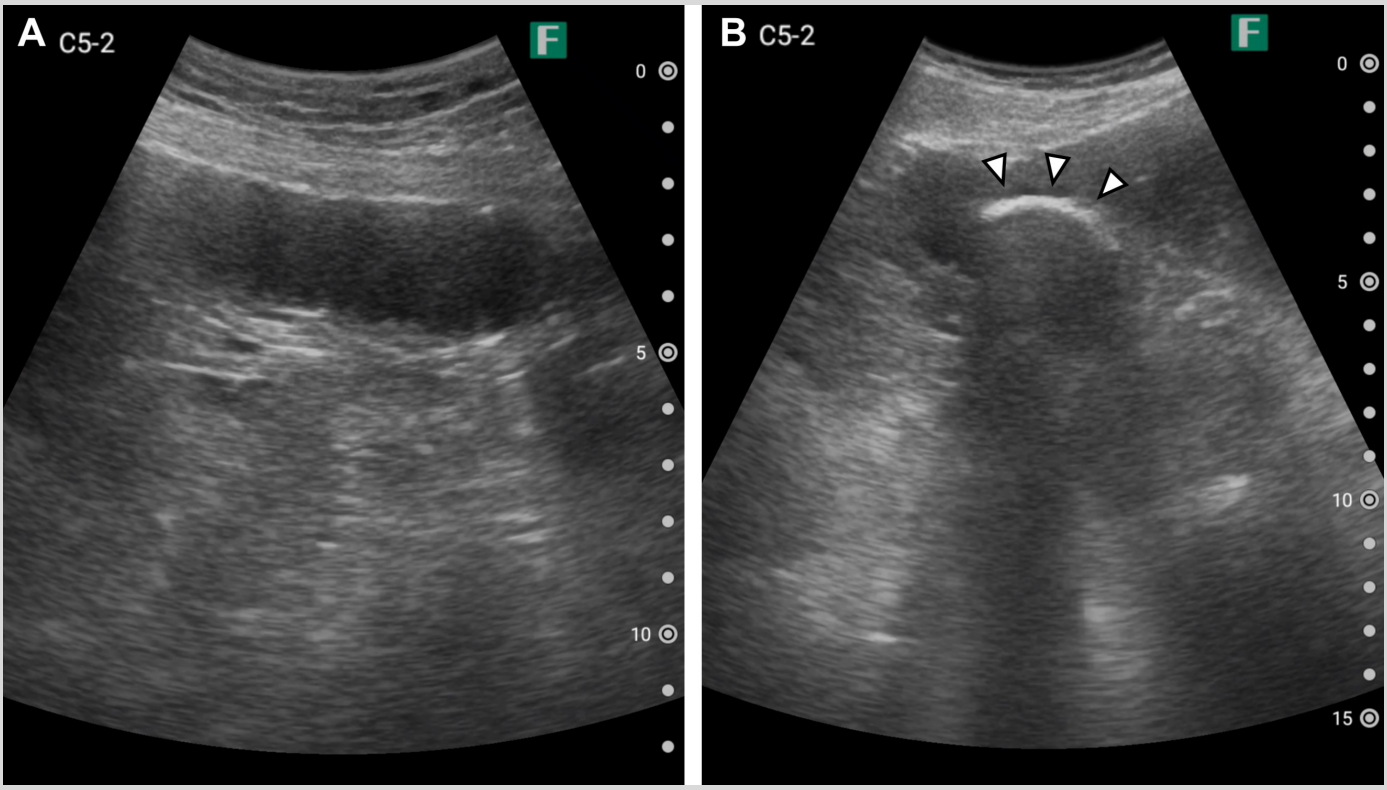


Figure 1. Abdominal point of care ultrasound (POCUS) at the patient's initial visit. A) A dilated small bowel was observed. B) A crescent-shaped, linear, hyperechoic structure (white arrowheads) with posterior acoustic shadowing was found inside the bowel.

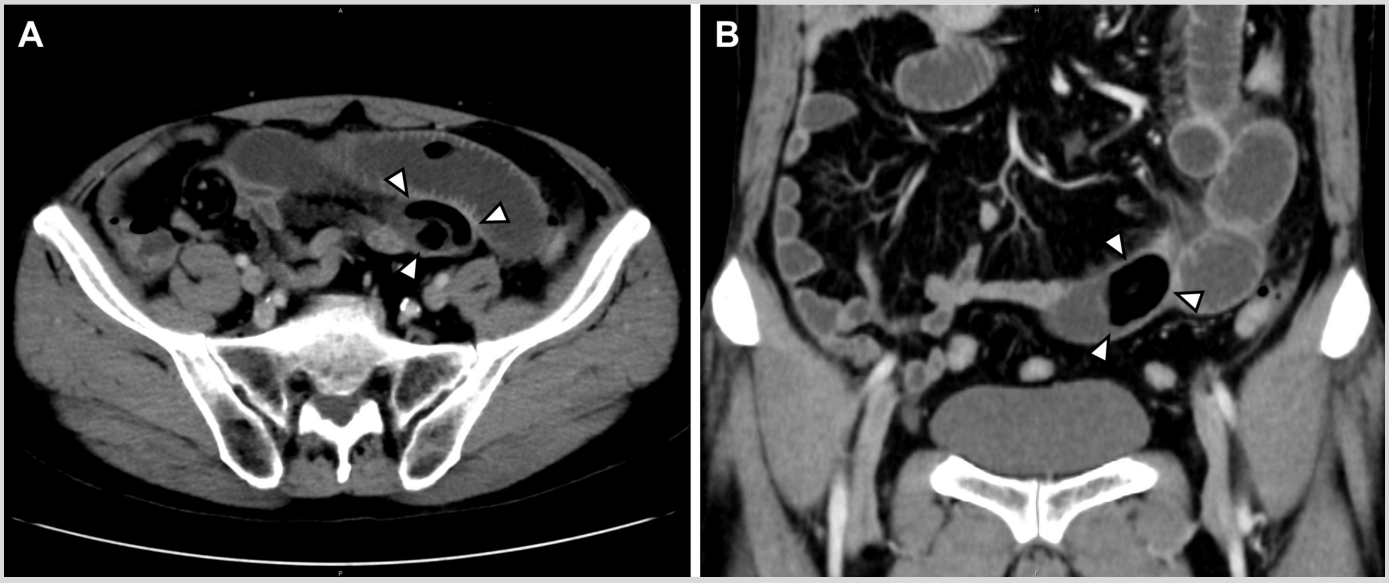


Figure 2. Enhanced computed tomography scan. A) Axial view. B) Coronal view. A mushroom-shaped, hypoattenuating object (white arrowheads) is seen in the ileum, corresponding to the site of calibre change. The mushroom cap was oriented ventrally.

the patient was admitted the same day. A nasogastric tube was inserted for decompression, and the patient was managed conservatively. Surgery was scheduled on hospital day 3; however, as his abdominal pain had reduced, CT was performed, which revealed that the shiitake mushroom had migrated to the descending colon. It was spontaneously defecated on day 4 (Figure 4). The patient was subsequently discharged.

Discussion

Small bowel obstruction is a common surgical emergency, with approximately 80% of cases involving patients who previously underwent abdominal surgery; however, it may also develop in those with a so-called "virgin abdomen." Among cases of small bowel obstruction in virgin abdomens, about 50% are caused by adhesions, whereas obstructions due to bezoars are considered rare [1]. Shiitake mushrooms (*Lentinula edodes*) are one of the most widely cultivated mushrooms in the world [6]. Several reports of food-induced intestinal obstruction caused by shiitake mushrooms have been published in East Asia, including Japan, China, and Vietnam [3,4,5,7–10]. Inadequate mastication led to bezoar formation in one case [10]; patients without dentures developed an intestinal obstruction after the ingestion of shiitake mushrooms in several cases [2–5]. Those studies emphasized the importance of instructing patients with missing teeth in the proper use of their dentures and discouraging them from swallowing food whole to prevent intestinal obstruction. The standard treatments for small bowel obstruction are decompression with a nasogastric or intestinal tube and laparotomy [1]. Shiitake mushrooms may also be fragmented using small bowel endoscopy [8,11]. Nonetheless, a limited number of facilities can perform such fragmentation owing to equipment availability, and the complexity of performing the technique.



Figure 3. Intraoral photograph of the patient. The maxillary right quadrant was edentulous, whereas the remaining dentition was preserved.

The usefulness of CT in the diagnosis of small bowel obstruction is well documented [12]. Recently, ultrasound has been recognized as a less invasive alternative to CT for such diagnoses, and the use of POCUS in outpatient internal medicine practice has proven useful and is becoming increasingly widespread [13]. In the diagnosis of small bowel obstruction, the reported sensitivity and specificity of ultrasound are 88%–92.4% and 54%–96.6%, respectively [14,15]. However, identifying the exact cause of obstruction via ultrasound is often difficult; therefore, CT is considered the gold standard [16]. In cases of small bowel obstruction caused by shiitake mushrooms, CT findings vary depending on the method of their preparation, with reported attenuation values of −500 HU for raw, −200 to −350 HU for grilled, and 30–60 HU for boiled mushrooms [4]. In the present case, the attenuation value was −280 HU, consistent with grilled shiitake mushrooms. Thus, it may be useful to obtain a patient's dietary history regarding the method of

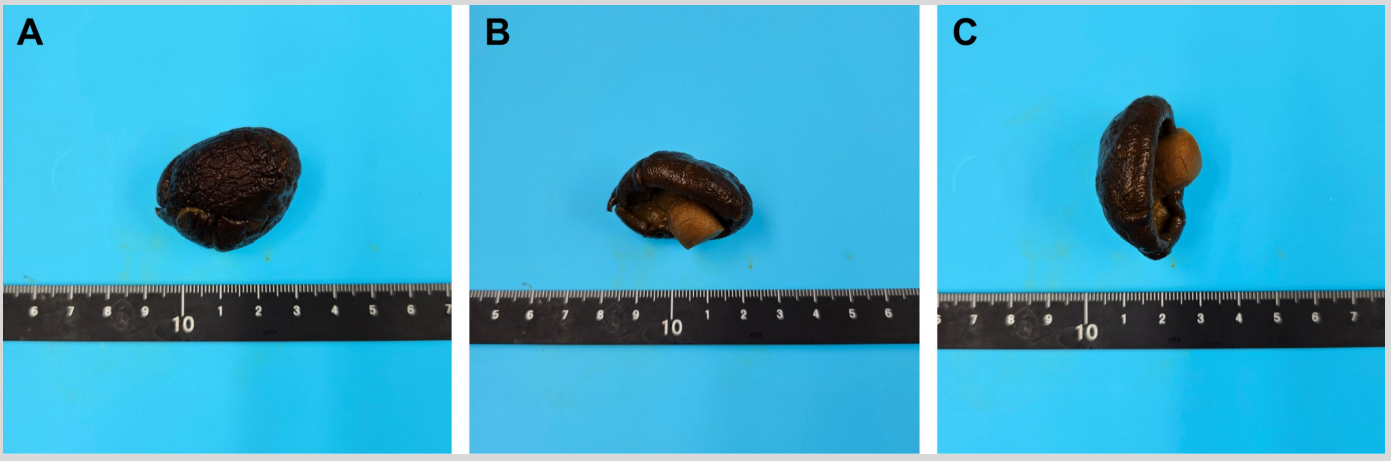


Figure 4. Photographs of the spontaneously expelled shiitake mushroom. A: Superior view. B: Inferior view. C: Lateral view.

preparation of ingested shiitake mushrooms.

Although the usefulness of ultrasound in small bowel obstruction has been reported, we are not aware of previous reports of the POCUS features of ingested shiitake mushrooms. Therefore, we conducted an experimental study by observing raw, grilled, and boiled shiitake mushrooms in gelatin via a PUD (iViz air) (Figure 5). For raw mushrooms, the caps were visualized as linear, dome-shaped, hyperechoic structures. For grilled shiitake, the charred surface appeared as a linear, hyperechoic layer, with an underlying slightly hypoechoic layer (posterior acoustic shadowing). For boiled shiitake, the caps appeared as generally homogeneous hyperechoic structures. When observed superiorly, from the side of the caps, the stalks could not be observed; however, the stalks of raw shiitake contained air and appeared as heterogeneously hyperechoic structures. When the ultrasound probe was inverted and the mushrooms were observed from the side of the stalks, the relationship between the caps and stalks was visualized for all specimens, although the caps' apexes were not delineated. In the lateral view, the caps, but not the stalks, were visualized for all specimens. The linear, hyperechoic appearance of the caps with a posterior, hypoechoic layer in the present case was consistent with the features of grilled shiitake mushrooms. In addition, continuous POCUS images were obtained from both this case and gelatin-embedded shiitake mushrooms by manually sliding the probe; these were reconstructed in 3D by using Fiji software (an expanded version of ImageJ, version 1.54p) (Figure 6). Although the stalks of the mushrooms were not sufficiently visualized, the caps were clearly depicted in this case, including those of grilled and boiled specimens. However, the overall morphology of the mushroom could not be clearly depicted, suggesting a limitation of POCUS in the diagnosis of shiitake mushroom-induced small bowel obstruction. In conclusion, patients with edentulism should receive lifestyle guidance emphasizing thorough mastication to reduce intestinal obstruction. In cases of food-induced small bowel obstruction, CT remains the most useful modality for a definitive diagnosis. However, POCUS may also be a valuable diagnostic tool, particularly for identifying the cap portion of a shiitake mushroom.

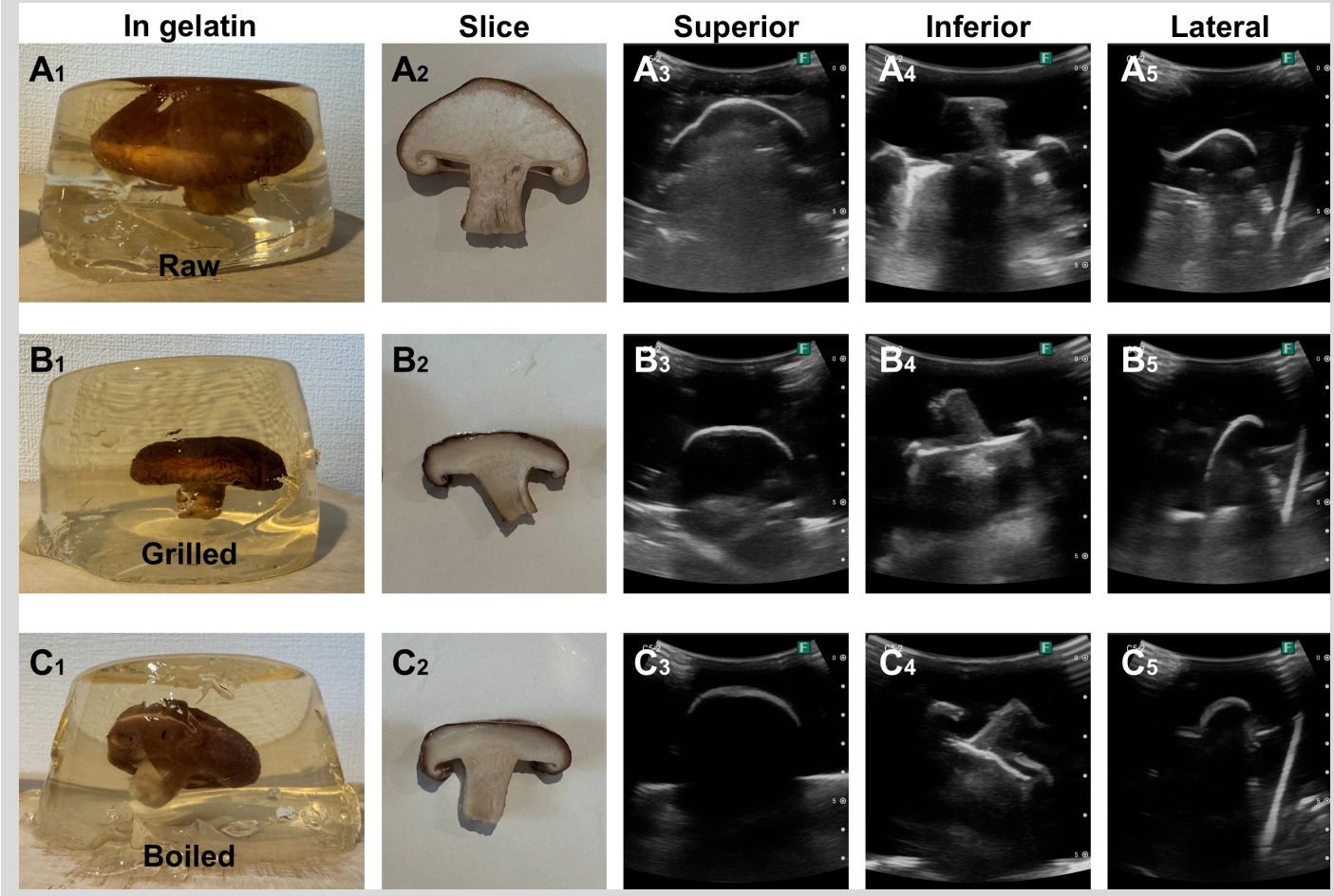


Figure 5. Comparison of the ultrasound appearance of shiitake mushrooms in different views obtained using a portable ultrasound device. Point of care ultrasound (POCUS) images of raw (A3-A5), grilled (B3-B5), and boiled (C3-C5) shiitake specimens embedded in gelatin are displayed in the superior, inferior, and lateral views.

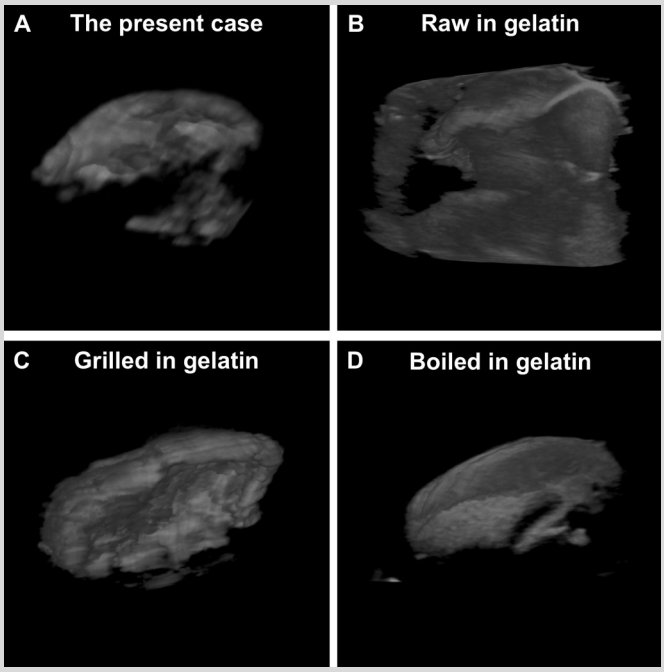


Figure 6. Comparison of 3D-reconstructed shiitake mushrooms from point of care ultrasound (POCUS) images. A) The present case. B) Raw shiitake embedded in gelatin. C) Grilled shiitake embedded in gelatin. D) Boiled shiitake embedded in gelatin.

Acknowledgements

We are grateful to the nurses and administrative staff of the medical and surgical outpatient clinics and wards for their support in patient care. We also thank Ai Miyagaki and O Ishihara for their cooperation in the ultrasonographic experiments with shiitake mushrooms.

Ethics Statement

Written informed consent for publication was obtained from the patient.

Disclosure Statement

The authors declare that they have no potential conflicts of interest.

Funding

The authors received no funding for this work.

Author Contributions

YI: investigation; data curation; writing – original draft; clinical management. NO: investigation; data curation; clinical management; writing – review & editing. YO: investigation; data curation; clinical management; writing – review & editing. YS: investigation; data curation; clinical management; writing – review & editing. DS: investigation; data curation; writing – review & editing. KT: writing – review & editing. TK: writing – review & editing.

References

1. Amara Y, Leppaniemi A, Catena F, Ansaloni L, Sugrue M, Fraga GP, Coccolini F, Biffl WL, Peitzman AB, Kluger Y, Sartelli M, Moore EE, Di Saverio S, Darwish E, Endo C, van Goor H, Ten Broek RP. Diagnosis and management of small bowel obstruction in virgin abdomen: a WSES position paper. World J Emerg Surg. 2021;16(1):36. doi: 10.1186/s13017-021-00379-8

2. Tan J, Yuan K, Zuo J, Dai W, Yuan Y, Feng W, Tan M, Ma J. Two cases of small bowel obstruction due to a shiitake mushroom. Gastroenterol Rep. 2019;7(4):298-300. doi: 10.1093/gastro/gox028

3. Ng GH, Teoh LY, Teh MS, Jamaris S, See MH. A case series of intestinal obstruction secondary to shiitake mushroom intake during Chinese New Year. J Surg Case Rep. 2020;2020(10):rjaa328. doi: 10.1093/jscr/rjaa328

4. Miyagishima D, Inoue M, Kinjo K, Fujimoto K, Suzuki H, Sugimura K, Kubota M, Nakagawa A, Kikuchi Y, Shinozaki M, Fujimoto H. Bowel obstruction due to shiitake mushrooms: diagnostic features on computed tomography. Intern Med. 2022;61(22):3349-3354. doi: 10.2169/internalmedicine.9181-21

5. Pham TN, Tran MQ, Pham PC, Trinh MT, Ngo QD, Le KL. Shiitake mushroom bezoar: a rare cause of small bowel obstruction in Vietnam and lessons in diagnosis and management. Emergency Care Journal. 2025;21(4):13766. doi: 10.4081/ecj.2025.1376

6. Domingo G, Chiodaroli L, Parola S, Marsoni M, Bracale M, Vannini C. Proteomic characterization of Shiitake (Lentinula edodes) post-harvest fruit bodies grown on hardwood logs and isolation of an antibacterial serine protease inhibitor. Fungal Biol. 2023;127(1-2):881-890. doi: 10.1016/j.funbio.2022.11.004.

7. Kusumoto M, Koganemaru M, Nakayama G, Iwamoto R. Dietary small bowel obstruction. BMJ Case Rep. 2013; 2013:bcr2012007950. doi: 10.1136/bcr-2012-007950

8. Shozushima M, Ohata K, Nonaka K, Matsuhashi N. Shiitake mushroom-induced ileus managed using double-balloon enteroscopy. Endoscopy. 2013; 45 Suppl 2 UCTN:E437. doi: 10.1055/s-0033-1359138.

9. Nagaoka T, Ishida N, Nakagawa Y, Kajiwara S. Two cases of food-induced ileus due to shiitake mushroom respectively treated with an operation and conservative treatment. Journal of Abdominal Emergency Medicine. 2017;37(7):1039-1042. doi: 10.11231/jaem.37.1039

10. Baharudin MS, Syazwani AR, Mahamad S, Anita B. Mushroom bezoar: rare cause of small bowel obstruction, a case report and literature review. Asian Journal of Case Reports in Surgery. 2021;4 (2):792-795.

11. Soga K, Mukai H, Kitae H. Management of shiitake mushroom-induced ileus using balloon enteroscopy. Dig Endosc. 2022;34(4):e58-e59. doi: 10.1111/den.14243

12. Li Z, Zhang L, Liu X, Yuan F, Song B. Diagnostic utility of CT for small bowel obstruction: systematic review and meta-analysis. PLOS One. 2019;14(12):e0226740. doi: 10.1371/journal.pone.0226740

13. Pratte M, Gaudreau-Simard M, Ruller S, Harvey K, Ly V, Evans J. Point of care ultrasound (POCUS) applications in the ambulatory internal medicine setting: A scoping review. Eur J Intern Med. 2025;141:106379. doi: 10.1016/j.ejim.2025.06.008

14. Gottlieb M, Peksa GD, Pandurangadu AV, Nakitende D, Takhar S, Seethala RR. Utilization of ultrasound for the evaluation of small bowel obstruction: a systematic review and meta-analysis. Am J Emerg Med. 2018; 36(2):234-242. doi: 10.1016/j.ajem.2017.07.085

15. Becker BA, Lahham S, Gonzales MA, Nomura JT, Bui MK, Truong TA, Stahlman BA, Fox JC, Kehrl T. A prospective, multicenter evaluation of point-of-care ultrasound for small-bowel obstruction in the emergency department. Acad Emerg Med. 2019; 26(8):921-930. doi: 10.1111/acem.13713

16. Expert Panel on Gastrointestinal Imaging, Chang KJ, Marin D, Kim DH, Fowler KJ, Camacho MA, Cash BD, Garcia EM, Hatten BW, Kambadakone AR, Levy AD, Liu PS, Moreno C, Peterson CM, Pietryga JA, Siegel A, Weinstein S, Carucci LR. ACR Appropriateness Criteria® suspected small-bowel obstruction. J Am Coll Radiol. 2020;17(5S):S305-S314. doi: 10.1016/j.jacr.2020.01.025

NOV 2026 vol. 11 iss. 02 | POCUS J | 154

POCUS with Colour Doppler Used to Diagnose a Prostatic Urethral Stone

Sanchit Kaushal, BHSc[1]*; Karlina Fiaes, BSc CCPA[2,3]; Karan Chawla, MD[2,4]

(1) Temerty Faculty of Medicine, University of Toronto, Toronto, ON, Canada
(2) Department of Emergency Medicine, University Health Network, Toronto, ON, Canada
(3) Department of Family Medicine, McMaster University, Hamilton, ON, Canada
(4) Division of Family and Community Medicine, University of Toronto, Toronto, ON, Canada

Abstract

Urethral stones are exceedingly rare, accounting for fewer than 1% of urinary calculi, and can mimic other causes of lower urinary tract obstruction, such as clot retention. The colour Doppler twinkling artifact improves ultrasound-based detection of renal and ureteral stones; however, its utility for identifying stones within the prostatic urethra has not been previously demonstrated. We report a 38-year-old man who presented to the emergency department (ED) with acute urinary retention, gross hematuria, and suprapubic discomfort following a self-reported passage of a kidney stone. After multiple failed catheterization attempts and rising post-void residual volumes, point of care ultrasound (POCUS) with colour Doppler revealed a prominent twinkling artifact within the prostatic urethra, consistent with an obstructing urethral calculus. This prompted reconsultation with urology and revision of the plan from discharge with an indwelling catheter and outpatient follow-up to same-visit bedside manual litholapaxy. This included extraction of impacted stone material, symptom improvement, and likely avoidance of a return visit for persistent stone impaction. To our knowledge, this is the first reported use of the twinkling artifact on POCUS examination to identify a prostatic urethral stone in the ED, which changed clinical management. This report highlights the potential of POCUS with colour Doppler to narrow the differential diagnosis in undifferentiated lower urinary tract obstruction and to facilitate expedited urologic intervention.

Introduction

Urinary stone disease is a common and increasingly prevalent condition worldwide, with significant associated morbidity and healthcare costs [1]. While the majority of urinary calculi present at the ureteropelvic or ureterovesical junction, urethral stones are exceedingly rare, accounting for fewer than 1% of all urinary stones [2,3]. Most urethral stones are migratory in origin, having formed in the upper urinary tract before passing into and lodging within the urethra [4]. Depending on the site of impaction, urethral stones may present with dysuria, perineal pain, or acute urinary retention and hematuria [5,6]. Because urethral stones are rarely encountered in the emergency department (ED), they may not be initially considered in the differential diagnosis, potentially delaying definitive management.

Non-contrast computed tomography (CT) remains the gold standard imaging modality for suspected urolithiasis, given its high sensitivity and specificity [7]. However, CT carries the disadvantage of ionizing radiation exposure—a relevant consideration in the young adult population, and the one most affected by stone disease—as well as greater cost relative to ultrasonography [5,8]. Point of care ultrasound (POCUS) has emerged as an integral bedside tool in emergency medicine, and an ultrasound-first approach to suspected nephrolithiasis has been associated with lower cumulative radiation exposure, reduced ED costs, and comparable clinical outcomes [9,10]. Conventional gray-scale ultrasonography has limited sensitivity for stone detection, particularly for smaller calculi [11]. The colour Doppler twinkling artifact is a promising adjunct that improves the reliability of ultrasound-based stone detection [12]. However, nearly all existing twinkling artifact literature pertains to renal and ureteral stones, and evidence for its application within the prostatic urethra is minimal.

In this case report, we describe the use of POCUS with colour Doppler to identify an obstructing calculus within the prostatic urethra via the twinkling artifact.

*Corresponding Author: Karan Chawla (email: karan.chawla@uhn.ca)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.21566

Case Presentation

A 38-year-old man with a remote history of nephrolithiasis presented to the ED with acute urinary retention and gross hematuria. Three days prior, he had started on tamsulosin after being evaluated at a walk-in clinic for difficulty passing urine. On the morning of presentation to the ED, he reported spontaneously passing a stone while voiding, followed by hematuria with clots and progressive inability to urinate despite repeated attempts. In the ED, he endorsed suprapubic pressure and bladder fullness but denied fever, flank pain, nausea, or penile trauma. His initial post-void residual (PVR) volume was approximately 500 mL. Vital signs included a blood pressure of 130/79 mmHg, heart rate of 85 beats/min, respiratory rate of 18 breaths/min, temperature 36.5 °C, and SpO_2 97% on room air. Physical examination revealed suprapubic tenderness and scant blood at the urethral meatus; the penis was non-tender with retractable foreskin and no penile discharge. Urinalysis demonstrated positive red blood cells with negative leukocyte esterase and negative nitrites.

An initial attempt at Foley catheter insertion was unsuccessful due to resistance preventing advancement of the catheter. The patient subsequently voided a small volume of grossly bloody urine with clots. After multiple failed attempts to catheterize, there was successful insertion of a 22F 3-way catheter, and continuous bladder irrigation (CBI) was initiated for suspected clot retention. The patient's symptoms improved following Foley insertion and CBI; however, hematuria recurred once CBI was discontinued and the PVR volume was again elevated. Urology was consulted at this time. CBI reinitiation was recommended, with the plan to discharge the patient with an indwelling catheter and outpatient follow-up in one week for trial of void. After several unsuccessful attempts at Foley reinsertion, the patient developed worsening urethral pain. Repeat PVR volume rose to 600 mL, raising concern for mechanical obstruction beyond clot retention. Given escalating bladder distension and failed catheterization attempts, POCUS with colour Doppler was performed by the emergency physician. Both kidneys were initially evaluated, with no evidence of hydronephrosis. A curvilinear transducer was then used in the transverse plane to visualize the bladder and prostate. Colour Doppler imaging demonstrated a twinkle artifact at the level of the prostatic urethra (Figure 1).

Based on the POCUS identification of a calculus at the level of the prostatic urethra, urology was reconsulted with concern for urethral stone impaction. Subsequent bedside examination by the urology team revealed palpable stone fragments within the distal penile urethra, suggesting a more extensive urethral stone burden. Following a penile block with 10 mL of lidocaine, manual litholapaxy was performed using small, curved Crile forceps, with fragmentation and extraction of approximately 1.5 cm of stone material. A Foley catheter was subsequently placed over a guidewire, which drained approximately 600 mL of urine. The patient received a prophylactic dose of antibiotics, and the catheter was left in situ for one week to mitigate stricture risk. There was an outpatient trial of void and non-contrast CT of the abdomen and pelvis arranged to evaluate for residual stones. The patient was discharged in stable condition.

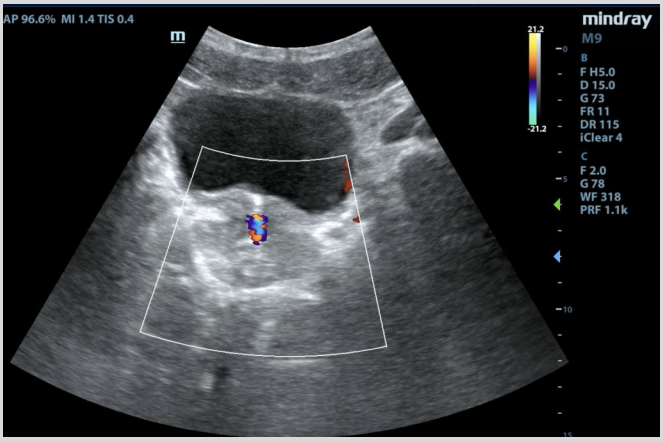


Figure 1. Transverse view of bladder and prostate using POCUS with colour Doppler. Twinkle artifact is demonstrated within the prostatic urethra, consistent with an obstructing urethral calculus.

Discussion

In this case, POCUS with colour Doppler identified an obstructing calculus within the prostatic urethra. The demonstrated prominent twinkling artifact directly changed clinical management from planned discharge to same-visit manual litholapaxy. To our knowledge, this is the first reported use of POCUS with colour Doppler in the ED to localize a stone at this anatomical site via the twinkling artifact.

The twinkling artifact, first described by Rahmouni et al. in 1996, is defined as a rapidly alternating mixture of red and blue colour signals generated posterior to a strongly reflective surface on colour Doppler, resembling turbulent blood flow [13]. This phenomenon is thought to arise from intrinsic phase instabilities at the rough, irregular surface of a calcification, which the Doppler processor interprets as frequency shifts [12]. Since its initial description, the twinkling artifact has gained recognition as a robust adjunct to conventional gray-scale sonographic criteria for detecting urinary stones. In a systematic review and meta-analysis, Laher et al. reported a pooled sensitivity and specificity of 88% and 79%, respectively, for twinkling artifact in the diagnosis of urolithiasis [12]. Wang et al. demonstrated in a 117-patient series that

twinkling artifact was a more consistent and sensitive indicator of ureteral stones than traditional acoustic shadowing, regardless of the physicians' clinical experience level [14]. The twinkling artifact may be of value for small stones (< 5 mm), for which conventional gray-scale sensitivity is markedly reduced [11]. However, these studies have focused on renal and ureteral calculi. The positive twinkling artifact signal observed in our case—at a site where prior data suggested twinkling would be absent—may reflect differences in stone size, surface irregularity, composition, or ultrasound equipment and settings that warrant further investigation [15].

A small number of case reports have described using POCUS to identify urethral calculi at other anatomical sites. One report illustrated a distal penile urethral stone detected by bedside ultrasound with both acoustic shadowing and twinkling at the urethral meatus [16]. Similarly, another report described a penile urethral stone identified on ultrasound, which demonstrated a hyperechoic structure with acoustic shadowing [17]. In both cases, the stones were located in the distal penile urethra. Our case extends the application of bedside Doppler ultrasound and twinkling artifact to the prostatic urethra—a clinically meaningful distinction, as these stones may not be palpable on physical examination and are more likely to evade detection without targeted imaging. Thus, prompt diagnosis and management are pertinent to avoid future ED visits for persistent pain and possible urinary obstruction.

The POCUS findings in this case had a direct and measurable impact on clinical management. The initial urology consultation, performed before POCUS examination, concluded that clot retention was the most likely etiology and recommended CBI with discharge once the urine cleared, an indwelling Foley catheter, and outpatient follow-up in one week for trial of void. After POCUS demonstrated the twinkling artifact within the prostatic urethra, urology was reconsulted with a focused clinical question, and bedside examination confirmed distal stone burden. Same-visit manual litholapaxy was then performed, which extracted approximately 1.5 cm of stone material and successfully placed a catheter. Without the POCUS finding, this patient would likely have been discharged with a delayed diagnosis, potentially prolonging obstruction, worsening urethral trauma, and necessitating a return visit for definitive intervention. This illustrates a core strength of POCUS in the ED: the capacity to narrow a broad differential to a specific, actionable diagnosis that escalates the urgency of specialist involvement [9].

Conclusion

POCUS with colour Doppler is a valuable bedside tool for evaluating patients with lower urinary tract obstruction and suspected urolithiasis. While limited evidence exists for the use of POCUS in the detection of urethral calculi, this case demonstrates that the twinkling artifact on colour can be elicited from a stone within the prostatic urethra and can meaningfully guide clinical decision-making by narrowing the differential diagnosis and facilitating expedited urologic intervention such as bedside litholapaxy. Clinicians should consider transperineal or suprapubic colour Doppler evaluation when catheterization fails and escalating PVR volumes raise concern for distal urinary tract obstruction.

Ethics Statement

Research consent has been obtained from the patient.

Disclosure Statement

The authors declare that they have no conflict of interest related to this publication.

Funding

No funding was received for this work.

Author Contributions

SK: data curation, investigation, writing – original draft, writing – review & editing. KF: conceptualization, data curation, investigation, writing – original draft, writing – review & editing, supervision. KC: conceptualization, data curation, investigation, software, writing – original draft, writing – review & editing, supervision.

References

1. Awedew AF, Han H, Berice BN, Dodge M, Schneider RD, Abbasi-Kangevari M, Al-Aly Z, Almidani O, Alvand S, Arabloo J, Aravkin AY, Ayana TM, Bhardwaj N, Bhardwaj P, Bhaskar S, Bikbov B, Santos FLC dos, Charan J, Cruz-Martins N, Dadras O, Dai X, Digesa LE, Elhadi M, Elmonem MA, Esezobor CI, Fatehizadeh A, Gebremeskel TG, Getachew ME, Ghamari S, Hay SI, Ilic IM, Ilic MD, Jayarajah U, Jazayeri SB, Kim MS, Lee S, Lee SWH, Lim SS, Mahmoud MA, Malik AA, Mentis AA, Mestrovic T, Michalek IM, Mihrtie GN, Mirrakhimov EM, Mokdad AH, Moni MA, Moradi M, Murray CJL, Ortiz A, Pawar S, Perico N, Rashidi M, Rawassizadeh R, Remuzzi G, Schumacher AE, Singh JA, Skryabin VY, Skryabina AA, Tan K, Tolani MA, Tahbaz SV, Valizadeh R, Vo B, Wolde AA, Jabbari SHY, Yazdanpanah F, Yiğit A, Yiğit V, Zahir M, Zastrozhin M, Zhang Z, Zumla A, Misganaw A, Dirac MA. The global, regional, and national burden of urolithiasis in 204 countries and territories, 2000–2021: a systematic analysis for the Global Burden of Disease Study 2021. eClinicalMedicine. 2024;78.

2. Dmochowski RR, Kavoussi LR, Peters CA, Campbell MF, Walsh PC, Wein AJ, editors. Campbell-Walsh-Wein urology. Philadelphia, PA: Elsevier; 2026.

3. Ordon M, Schuler TD, Ghiculete D, Pace KT, Honey RJD. Stones lodge at three sites of anatomic narrowing in the ureter: clinical fact or fiction? J Endourol. 2013;27(3):270–276.

4. Kamal BA, Anikwe RM, Darawani H, Hashish M, Taha SA. Urethral calculi: presentation and management. BJU Int. 2004;93(4):549–552.

5. Brisbane W, Bailey MR, Sorensen MD. An overview of kidney stone imaging techniques. Nat Rev Urol. 2016;13(11):654–662.

6. Akram M, Jahrreiss V, Skolarikos A, Geraghty R, Tzelves L, Emilliani E, Davis NF, Somani BK. Urological Guidelines for Kidney Stones: Overview and Comprehensive Update. J Clin Med. 2024;13(4):1114.

7. Fulgham PF, Assimos DG, Pearle MS, Preminger GM. Clinical

effectiveness protocols for imaging in the management of ureteral calculous disease: AUA technology assessment. J Urol. 2013;189 (4):1203–1213.

8. Blacklock NJ. The pattern of urolithiasis in the Royal Navy. J R Nav Med Serv. 1965;51(2):99–111.

9. Smith-Bindman R, Aubin C, Bailitz J, Bengiamin RN, Camargo CA, Corbo J, Dean AJ, Goldstein RB, Griffey RT, Jay GD, Kang TL, Kriesel DR, Ma OJ, Mallin M, Manson W, Melnikow J, Miglioretti DL, Miller SK, Mills LD, Miner JR, Moghadassi M, Noble VE, Press GM, Stoller ML, Valencia VE, Wang J, Wang RC, Cummings SR. Ultrasonography versus computed tomography for suspected nephrolithiasis. N Engl J Med. 2014;371(12):1100–1110.

10. Ray AA, Ghiculete D, Pace KT, Honey RJD. Limitations to ultrasound in the detection and measurement of urinary tract calculi. Urology. 2010;76(2):295–300.

11. Sim KC. Ultrasonography of acute flank pain: a focus on renal stones and acute pyelonephritis. Ultrasonography 2018;37(4):345–354.

12. Laher AE, McDowall J, Gerber L, Aigbodion SJ, Enyuma COA, Buchanan S, Adam A. The ultrasound 'twinkling artefact' in the diagnosis of urolithiasis: hocus or valuable point-of-care-ultrasound? A systematic review and meta-analysis. Eur J Emerg Med. 2020;27(1):13–20.

13. Rahmouni A, Bargoin R, Herment A, Bargoin N, Vasile N. Color Doppler twinkling artifact in hyperechoic regions. Radiology. 1996;199 (1):269–271.

14. Wang M, Ma Q, Chen Y, Li J, Wang C, Jin Y, Zhang Y, Chen H, Liu S, Wang C, Sheng Y, Bai X, Zhang Y, Lin W, Feng X. The Value of Shadowing and the Twinkling Artifact in the Diagnosis of Ureteral Stones: A Single-center Study. Urology. 2019;126:39–44.

15. Bacha R, Manzoor I, Gilani SA, Khan AI. Clinical Significance of Twinkling Artifact in the Diagnosis of Urinary Stones. Ultrasound Med Biol. 2019;45(12):3199–3206.

16. Higa K, Irving S, Cervantes RJ, Pangilinan J, Slykhouse LR, Woolridge DP, Amini R. The Case of an Obstructed Stone at the Distal Urethra. Cureus. 2017;9(12):e1974.

17. Malik I. Point-of-Care Ultrasound Diagnosis of Urethral Stone in A Patient with History of Urolithiasis: A Case Report. Sch J Med Case Rep. 2025;13(05):1074–1075.



NOV 2026 vol. 11 iss. 02 | POCUS J | 158

Evaluation of Pregnancy and Associated Complications Using POCUS: A Narrative Review

Zachary Boivin, MD*; Christopher L. Moore, MD; Rachel B. Liu, MD

Department of Emergency Medicine, Yale School of Medicine, New Haven, CT, USA

Abstract

Background: Point of care ultrasound (POCUS) in pregnancy is an important diagnostic tool throughout all trimesters, that can help identify intrauterine pregnancies along with pregnancy complications. This narrative review aims to describe the appropriate use of POCUS in pregnancy in conjunction with laboratory testing and how to identify and manage pregnancy complications. **Methods**: A search of PubMed and Google Scholar was conducted through December 31, 2025, and included all relevant studies from the past 25 years. Investigators determined the relevancy of studies. A total of 93 studies were included. **Discussion**: Pregnant patients commonly present to the emergency department in all three trimesters, and POCUS can both reduce a patient's length of stay and quickly and accurately identify pregnancy complications, particularly in unstable patients with large amounts of bleeding. POCUS can be used throughout pregnancy to make diagnoses and prompt intervention in collaboration with obstetrics and gynecology.

Introduction

Point of care ultrasound (POCUS) is an essential tool for evaluating pregnancy-related complaints. A POCUS operator can provide a definitive diagnosis in 80% of symptomatic first-trimester emergency department (ED) patients, and can help guide care regardless of the phase of pregnancy [1]. First-trimester POCUS can diagnose an intrauterine pregnancy (IUP) along with ectopic pregnancies [2–5], molar pregnancies [6–8], fetal demise [9], and subchorionic hematomas [10]. POCUS can continue to be used to measure fetal dating and fetal heart rate (FHR)—both important components as pregnancy progresses. POCUS in pregnancy is a necessary skill in both the community ED setting and internationally [11–14].

This narrative review aims to describe the appropriate use of POCUS throughout pregnancy in conjunction with laboratory testing and how to identify and manage pregnancy complications. This review further addresses questions such as the role of Beta-Human Chorionic Gonadotropin (HCG), the role of a type and screen, transabdominal ultrasound (TAUS) compared to transvaginal ultrasound (TVUS), and the utility of radiology-department-performed ultrasound (RADUS).

Methods

PubMed and Google Scholar were queried for articles using a combination of the keywords: "pregnancy," "POCUS," "ultrasound," and "point-of-care ultrasound," along with specific searches for diagnoses such as "miscarriage," "retained products of conception," "intrauterine pregnancy," "ectopic pregnancy," and "heterotopic pregnancy." This search was inclusive of all studies from database inception until December 31, 2025, and included articles published within the last 25 years. Only studies published in the English language were included. The relevance of studies was determined by one investigator (ZB) with review and feedback from the other investigators (CM, RL). Preference was given to systematic reviews and meta-analyses, followed by randomized controlled trials, prospective studies, and retrospective studies. Case series and case reports were used if no other data were available. A total of 99 articles were included.

First-trimester POCUS

Patients often present to the ED in the first trimester with abdominal pain or vaginal bleeding, offering a broad differential diagnosis. The primary use of POCUS in patients with first-trimester pregnancies is to identify an IUP, which has been shown to decrease patient length of stay and decrease time to diagnosis [2,15–20].

Intrauterine Pregnancy

As a conservative definition, the minimum criteria for a

*Corresponding Author: Dr. Zachary Boivin (email: zboivin.md@gmail.com)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20295

definitive IUP on POCUS is generally considered to be a yolk sac within a well-positioned gestational sac in the uterus (Figure 1, Supplementary Material - Video S1) [21–24]. The POCUS operator should identify the uterine landmarks, bladder, and vaginal stripe, while fanning through the entire uterus in both sagittal and transverse views. Some obstetrics and gynecology (OBGYN) and radiology literature reports that the double decidual sac sign is the earliest sonographic indicator of an IUP. However, a pseudogestational sac—a centrally located intrauterine and often irregularly shaped anechoic fluid collection—can occur in ectopic pregnancy, and the double decidual sign should be used with caution for a novice EP operator [25–29]. Additionally, the gestational sac position is important to evaluate. The myometrial mantle (the smooth muscle surrounding the pregnancy) can be measured from the edge of the gestational sac to the myometrium. A normal measurement is at least 8 mm. An abnormal myometrial mantle measurement of less than 8 mm raises concern for an interstitial (previously called “cornual”) ectopic pregnancy or a cesarean-section (c-section) scar ectopic pregnancy (Figure 2, Supplementary Material - Video S2) [30].

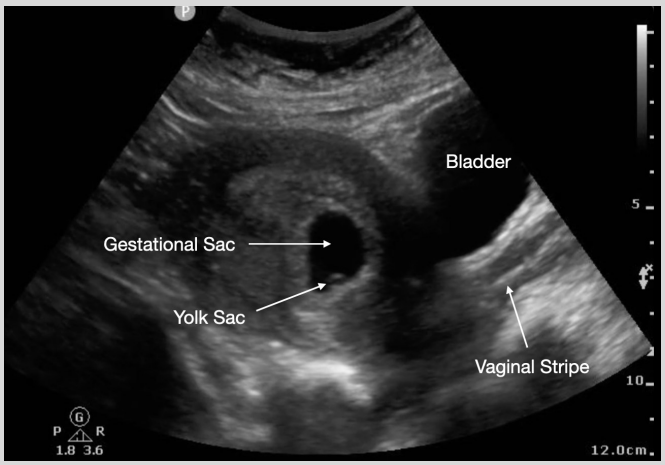


Figure 1. Sagittal transabdominal pelvic point of care ultrasound (POCUS) showing a definitive intrauterine pregnancy with a gestational sac inside a yolk sac.

The American College of Obstetrics and Gynecology (ACOG) recommends that a TVUS be performed only if TAUS is inconclusive, and a recent study showed low TVUS utility if an IUP was identified on TAUS [31,32]. A yolk sac can be visualized on POCUS as early as five weeks using TVUS, and fetal cardiac activity can be detected and FHR measured as early as six weeks [23,24].

A metanalysis found that an IUP on POCUS yielded a pooled sensitivity of 99.3% for ectopic pregnancy, allowing the presence of an IUP to effectively exclude ectopic, although this should be used with caution if patient is undergoing in-vitro fertilization treatment due to an increased risk for heterotopic pregnancies [33]. If a yolk sac cannot be visualized on TAUS, additional abdominal compression using a curvilinear ultrasound probe may improve image clarity, or using a linear ultrasound probe can help diagnose an IUP (Figure 3, Supplementary Material - Video S3) [34–36].



Figure 2. Sagittal transabdominal pelvic point of care ultrasound (POCUS) showing a myometrial mantle measurement (white line) less than 8 mm in a cesarean section scar ectopic pregnancy.

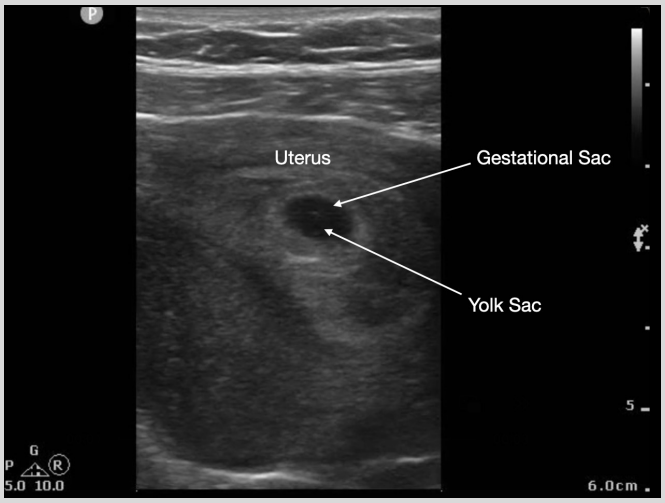


Figure 3. Definitive intrauterine pregnancy using the linear probe.

Intrauterine Pregnancy vs. Pregnancy of Undetermined Location

Early pregnancy POCUS should be interpreted as either an IUP, or “pregnancy of undetermined location” (PUL) [22]. As delineated above, an IUP includes a well-positioned gestational sac with a yolk sac and a sufficiently thick myometrial mantle. A pseudogestational sac should not be mistaken for an IUP, as it can be present in the setting of an ectopic pregnancy. All other POCUS findings can broadly be considered as PUL,

representing early pregnancy, ectopic pregnancy, miscarriage, or molar pregnancy, and should be interpreted in the context of the history, clinical picture, and beta-hCG level and trends.

Ectopic Pregnancy

The incidence of ectopic pregnancy in the ED is as high as 8% of all first-trimester pregnancy presentations [5,33,37,38]. A pseudogestational sac can be seen in approximately 10–20% of all ectopic pregnancies, and can occur due to hormonal stimulation, causing a fluid collection or endometrial bleeding [39]. The irregular shape and lack of yolk sac can suggest a pseudogestational sac as opposed to an early gestational sac. The most common location for an ectopic pregnancy is tubal. While POCUS evaluating for IUP should assess the bilateral adnexa in the setting of PUL, this can be difficult on both TAUS and TVUS, either with POCUS or RADUS [33,37,40]. A ruptured ectopic pregnancy is suggested by a moderate to large amount of free fluid in the pelvis (Figure 4, Supplementary Material - Video S4) or any fluid in the hepatorenal space (Morison's pouch) [38]. The presence of fluid in Morison's pouch in a patient with pregnancy and no visualized IUP strongly suggests the need for operative intervention [38]. Occasionally, the ectopic pregnancy can be visualized on TAUS or TVUS (Figure 5, Supplementary Material - Video S5). The beta-HCG for ectopic pregnancies can be as low as 10 mUI/mL, suggesting the need for ultrasound in early pregnancy, regardless of laboratory results, and should not wait for beta-hCG results [41].



Figure 4. Sagittal transabdominal pelvic point of care ultrasound (POCUS) demonstrating free fluid (white star) superior to the uterus in a ruptured ectopic pregnancy.

In addition to a tubal ectopic pregnancy, those performing POCUS should be aware of the possibility of an interstitial ectopic pregnancy or a c-section scar ectopic pregnancy (Figure 2, Supplementary Material - Video S2). These are abnormal locations for embryo implantation. These should be suspected if the IUP is not well situated in the uterine fundus, or the myometrial mantle measures less than 8 mm [30,42–45]. Myometrial mantle distance should be measured to identify an abnormal pregnancy with a high risk for complications.

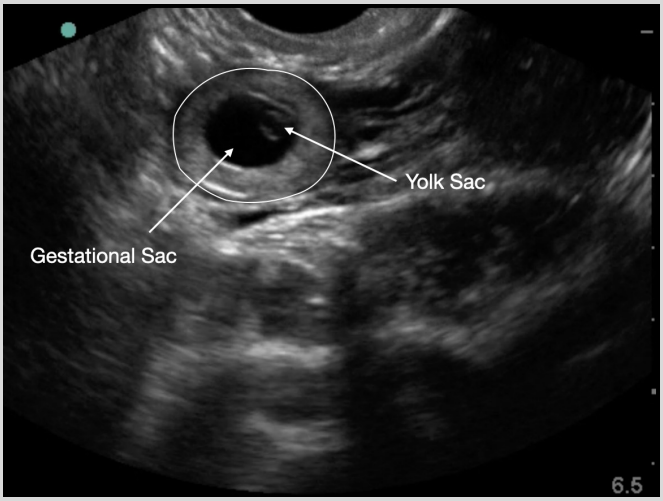


Figure 5. Transvaginal pelvic point of care ultrasound (POCUS) showing a yolk sac and gestational sac outside of the uterus, diagnostic of ectopic pregnancy.

Finally, a heterotopic pregnancy refers to the simultaneous presence of an IUP and an ectopic pregnancy. It occurs in approximately 1 in 4,000 to 1 in 30,000 natural pregnancies, but the incidence increases to about 1 in 100 pregnancies with in vitro fertilization [46–48]. EPs should ask whether the patient had a naturally conceived pregnancy to risk-stratify the patient for heterotopic pregnancy, with any at-risk patient requiring complete visualization of the adnexa before confirming an IUP on POCUS [49]. A heterotopic pregnancy requires an immediate evaluation by OBGYN, as treatment is case-dependent [50].

Miscarriage

Patients who present to the ED with first-trimester pregnancy complications have been found to have a miscarriage rate of 20–25% [51,52]. Patients often present to the ED for the first time in pregnancy without a prior confirmed IUP, making the diagnosis of miscarriage difficult with POCUS alone without a prior ED POCUS or RADUS confirming an IUP. If a fetus is visualized on TAUS, but no FHR is detected, a TVUS should be completed before diagnosing fetal demise, as it allows for better visualization of an FHR. A failed pregnancy should be considered in the ED if there is a fetal pole that is less than 7 mm with no FHR, or if the gestational sac is less than 25 mm without a fetal pole [53]. If there is evidence of an IUP with a normal FHR, with no concern for a

heterotopic pregnancy, a patient can be safely discharged home if they are otherwise stable. Varner et al. showed that an IUP in patients with bleeding in the first 20 weeks of pregnancy was not associated with poor fetal outcomes [54].

The most common cause of first-trimester vaginal bleeding is a subchorionic hematoma (SCH), which can be identified on POCUS as a lens-shaped anechoic collection within the uterus (Figure 6, Supplementary Material - Video S6) [55]. This can appear similar to a pseudogestational sac, and should not be confused with a second gestational sac if present alongside an IUP [56]. A small SCH may not affect pregnancy, while larger ones are associated with an increased risk of miscarriage [57–59]. However, there are no treatment recommendations for this finding in the ED. Patients can be discharged home with outpatient OBGYN follow-up.

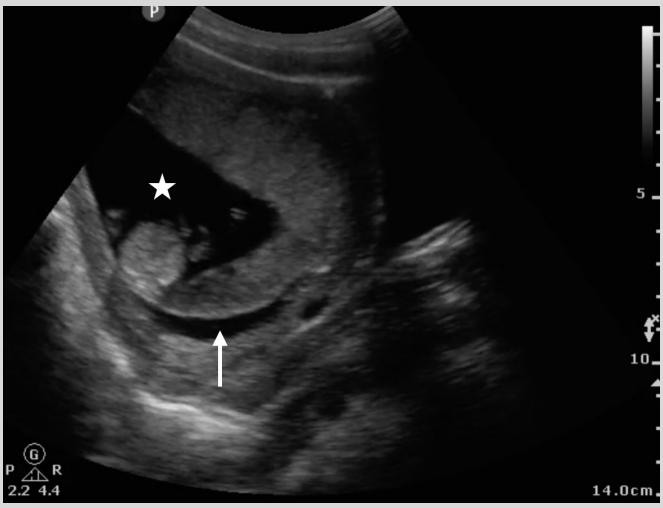


Figure 6. Transabdominal pelvic point of care ultrasound (POCUS) showing a lens-shaped subchorionic hematoma (white arrow) posterior to the gestational sac (white star).

After a miscarriage, patients are at risk for retained products of conception (RPOC). RPOC can be visualized on POCUS as a heterogenous endometrial stripe and a thickened endometrial measurement (Figure 7, Supplementary Material - Video S7) [60–62]. There is no recognized cutoff for the endometrial thickness. Studies vary in cutoffs from 0.5 cm to 3.0 cm, with 1.5 cm being the most cited [63]. While RPOC are typically associated with flow on colour Doppler, one study showed 25% of patients did not have visualized colour Doppler flow [64]. There is limited data on establishing this diagnosis on POCUS, and the diagnosis should be made in conjunction with clinical symptoms and OBGYN consultation [60].

Use of Beta-hCG in Early Pregnancy

A quantitative serum beta-hCG level should be obtained on pregnant patients in the first trimester without an IUP on initial TAUS, as it can help recognize and guide management of abnormal pregnancies [65]. A “discriminatory zone” has been described as the beta-hCG level under which an IUP is unlikely to be seen, often delineated as 1500–2000 mUI/mL for TVUS. This concept has been challenged, as multiple studies show IUP visualization with both TAUS and TVUS at a lower beta-hCG threshold [66-70]. The absence of an IUP on TVUS with an elevated beta-hCG should raise suspicion for ectopic pregnancy. However, early IUPs may not be visible on TVUS even when beta-hCG levels are above the discriminatory zone, so caution should be used when considering empiric treatment for an ectopic pregnancy in patients with a high beta-hCG and PUL [65]. POCUS should be performed regardless of beta-hCG levels, and close follow-up should be arranged with OBGYN, along with strict return precautions. A beta-hCG level may not be necessary in patients without severe pain or bleeding and with a low concern for heterotopic pregnancy when POCUS identifies an IUP, which can substantially expedite ED care.

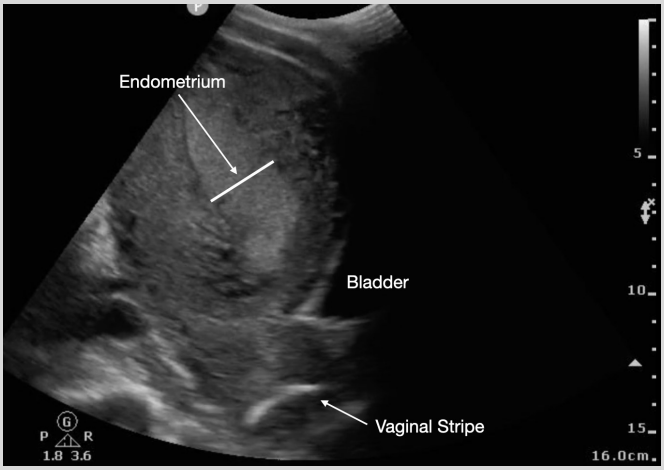


Figure 7. Transabdominal pelvic point of care ultrasound (POCUS) with a heterogenous, thickened endometrium concerning for retained products of conception.

Use of Type and Screen in Early Pregnancy

Previously, in threatened miscarriage, there was concern for the possibility of Rhesus (Rh) sensitization in Rh-negative mothers, with recommended testing for Rh status. However, in early pregnancy, this risk is exceedingly low, and Rh testing is no longer recommended by ACOG for patients less than 12 weeks pregnant experiencing vaginal bleeding or a pregnancy loss [71]. This can decrease the length of stay for patients while using POCUS, as patients can be discharged without labs if they are determined to have an IUP, even if they report vaginal bleeding.

Second and third trimester POCUS

Identifying a second and third-trimester fetus using POCUS is usually straightforward. In most United States hospitals with OBGYN capability, patients with a pregnancy that may be close to viability who are experiencing complaints that could portend delivery (abdominal pain, cramps, bleeding) or who need fetal monitoring (after minor trauma, for example) are optimally triaged immediately to labour and delivery (L&D). In most hospitals, this occurs at 20 weeks of gestational age or greater, though some protocols are as early as 16 weeks [72]. While patients near viability with pregnancy-related complaints are optimally managed by OBGYN, if a specialist is not immediately available, POCUS can provide additional information to guide further care. A rapid fetal assessment should be undertaken and includes FHR, gestational age, fetal motion, fetal presentation, and placental location [73].

Fetal Heart Rate

An FHR measurement should be performed in any patient who may be at or near fetal viability to detect any signs of fetal distress and to determine fetal age. If no fetal cardiac activity is detected, or the rate is outside the normal range of 110–160 bpm, this suggests fetal distress, and OBGYN should be immediately contacted, or the patient should be transferred to a hospital with OBGYN available if there are no signs of an impending delivery [74]. FHR should be determined using m-mode and can be calculated using a one or two-beat peak-to-peak measurement [75].

Gestational Age

POCUS can provide immediate confirmation of fetal gestational age, which is not always clearly known by the patient. The most reliable way to date a fetus over 12 weeks old is using bi-parietal diameter (BPD), which is measured from the outer edge of the proximal parietal bone to the inner edge of the distal parietal bone at the level of the thalami perpendicular to the central axis of the head (Figure 8) [76,77]. Femur length may also be utilized for fetal dating in the second and third trimester. This is calculated using callipers to measure the length of the femur between the greater trochanter and lateral epicondyle [78]. Both BPD and femur length can be difficult to capture at times with fetal motion and can be incorrectly measured if off-axis or if the anatomy was incorrectly identified.

Fetal Motion

Decreased fetal movements in a fetus at or near viability is often best managed by an OBGYN service, which may not always be available in rural EDs or internationally [79]. Normal fetal movements are typically greater than 10 movements in one hour, which is best measured on a non-stress test as opposed to POCUS [80]. POCUS can help reassure patients who are feeling no fetal movements if both fetal movements and a normal FHR are found on ultrasound.

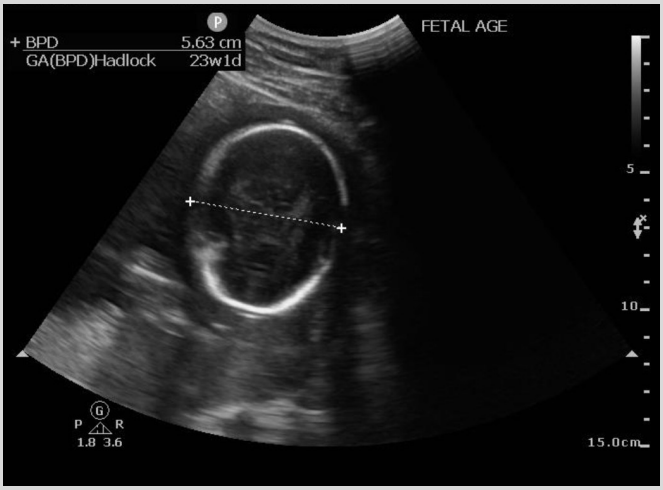


Figure 8. Measurement of bi-parietal diameter using transabdominal point of care ultrasound (POCUS) at the level of the thalami.

Fetal Presentation

Fetal presentation—the part of the fetus oriented towards the birth canal—can be determined by obtaining a view of the fetal head in the sagittal plane to determine if the head is directed towards the pelvis (cephalic/vertex) or if the buttocks or feet are presenting (breech) [81,82]. A breech presentation is often managed with a c-section, as breech vaginal births are associated with increased fetal morbidity and mortality, but precipitous vaginal deliveries in the ED may occur [83]. The fetal presentation can change throughout the second and third trimester and is most important for patients at risk of precipitous delivery.

Placental and Amniotic Fluid Evaluation

The placenta can be evaluated for any evidence of placenta previa or placental abruption, which can complicate an impending delivery [84,85]. A normal placenta on POCUS has a homogenous echogenicity along the inner uterine wall that is discoid in shape. Most commonly, it is attached to the fundus of the uterus, but it is considered normal to attach to the anterior, posterior, or lateral uterine wall [86]. A normal placenta should not extend over the internal os of the cervix. Placenta previa is identified when the placenta covers the cervical os, and if identified in the second trimester, outpatient follow-up is indicated with pelvic rest precautions given, although studies have shown that up to 90% of second-trimester placenta previa resolve with placental migration [87]. Third-trimester placenta previa should result in prompt

OBGYN evaluation if the patient is experiencing any signs or symptoms concerning for labour.

Placental abruption is a clinical diagnosis; however, there may be findings on POCUS such as a collection of anechoic fluid between the placenta and the uterine wall, subchorionic hematoma, intraamniotic hematoma, and a placental thickness greater than 5 cm [88]. POCUS should not be used to rule out this condition. An OBGYN consultation should be immediately obtained in cases of suspected placental abruption.

The amniotic sac can be evaluated with either an amniotic fluid index (AFI) or a maximum vertical pocket (MVP) [89]. AFI requires multiple views and may be time-intensive for a POCUS operator, whereas a MVP requires a single view and measurement of the single deepest unobstructed pocket of fluid. A normal MVP ranges from 2–8 cm, and is recommended over AFI in the third trimester or in patients with multiple gestations [90,91]. If a patient presents with concern for amniotic sac rupture, there is no reliable way to detect amniotic sac rupture on POCUS, even with a low AFI or MVP, as there can be small pockets of amniotic fluid remaining after a membrane rupture [92].

Emerging applications

Artificial intelligence (AI) is emerging across multiple POCUS modalities, including pelvic ultrasound [93,94]. The current commercially available AI products for POCUS in pregnancy include automatic FHR and automated fetal measurements [95–97]. Future AI applications could include the automatic detection of pelvic free fluid, along with determining an IUP or PUL. Automated image guidance could help nonexperts obtain adequate pelvic POCUS images, especially in low-resource settings [98]. One potential application for automated image guidance, or blind sweep imaging, includes POCUS in triage by non-experts to assist with triage decisions [96,99].

Conclusion

Pregnancy evaluations are common in the ED and using POCUS as a screening tool to identify an IUP can decrease time to diagnosis and length of stay compared to RADUS. POCUS may identify or raise the suspicion of ectopic pregnancy, particularly those that are potentially unstable with large amounts of bleeding. POCUS can be used throughout pregnancy to make diagnoses and prompt intervention in collaboration with OBGYN.

Ethics Statement

No IRB approval was required for this narrative review.

Disclosure Statement

The authors declare no conflicts of interest related to this work.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions

ZB: conceptualization, methodology, writing-original draft, writing-review & editing. CLM: methodology, writing-original draft, writing-review & editing. RBL: methodology, writing-original draft, writing-review & editing, supervision

References

1. Ultrasound Guidelines: Emergency, Point-of-Care, and Clinical Ultrasound Guidelines in Medicine. Ann Emerg Med. 2023;82(3):e115-e55. https://doi.org/10.1016/j.annemergmed.2023.06.005

2. Stone BS, Muruganandan KM, Tonelli MM, Dugas JN, Verriet IE, Pare JR. Impact of point-of-care ultrasound on treatment time for ectopic pregnancy. Am J Emerg Med. 2021;49:226-32. https://doi.org/10.1016/j.ajem.2021.05.071

3. Stone MB. Emergency ultrasound diagnosis of ruptured ectopic pregnancy. Acad Emerg Med. 2009;16(12):1378. https://doi.org/10.1111/j.1553-2712.2009.00538.x

4. Schonert J, Minardi J, Denne N, Pagenhardt J, Dorinzi N. Near Miss Ruptured Ectopic Pregnancies: A Case Series of Diagnosis With Point-of-Care Ultrasound and an Independent Review of Radiology Images. Cureus. 2025;17(7):e87153. https://doi.org/10.7759/cureus.87153

5. Ren Y, Shao X. Impact of emergency point-of-care ultrasound on time to diagnosis and treatment amongst patients with ectopic pregnancy: a systematic review and meta-analysis. Arch Med Sci. 2025;21(5):1997-2006. https://doi.org/10.5114/aoms/192513

6. Avers E, Langley DM, Karalic K, Snitowsky R. Point-Of-Care Ultrasound to Diagnose Molar Pregnancy in the Emergency Department: A Case Report and Topic Review. Cureus. 2024;16(8):e68223. https://doi.org/10.7759/cureus.68223

7. Lin YH, Liu YC, Lee WJ. Young Female With Lower Abdominal Pain. Ann Emerg Med. 2021;77(6):591-612. https://doi.org/10.1016/j.annemergmed.2020.12.001

8. Shivarajpur A, Kohen B. Vaginal Bleeding in a Peri-Menopausal Woman. Pocus j. 2024;9(1):9-10. https://doi.org/10.24908/pocus.v9i1.16621

9. Collins K, Collins C, Kothari A. Point-of-care ultrasound in obstetrics. Australas J Ultrasound Med. 2019;22(1):32-9. https://doi.org/10.1002/ajum.12133

10. Bondick CP, Das JM, Fertel H. Subchorionic Hemorrhage. StatPearls, Treasure Island (FL): StatPearls Publishing. Copyright © 2025, StatPearls Publishing LLC.; 2025.

11. Dalmacion GV, Reyles RT, Habana AE, Cruz LMV, Chua MC, Ngo AT, Tia-Jocson MJ, Baja ES. Handheld ultrasound to avert maternal and neonatal deaths in 2 regions of the Philippines: an iBuntis® intervention study. BMC Pregnancy Childbirth. 2018;18(1):32. https://doi.org/10.1186/s12884-018-1658-8

12. Kimberly HH, Murray A, Mennicke M, Liteplo A, Lew J, Bohan JS, Tyer-Viola L, Ahn R, Burke T, Noble VE. Focused maternal ultrasound by midwives in rural Zambia. Ultrasound Med Biol. 2010;36(8):1267-72. https://doi.org/10.1016/j.ultrasmedbio.2010.05.017

13. Salerno A, Lewiss RE. Rekindling the Relevance of Obstetrical Transvaginal POCUS: Overcoming Barriers to Ensure Patient-Centered Care. Pocus j. 2023;8(2):106-8. https://doi.org/10.24908/pocus.v8i2.16855

14. Smalley CM, Simon EL, Muir MR, Fertel BS. A Real-World Experience: Retrospective Review of Point-of-Care Ultrasound Utilization and Quality in Community Emergency Departments. West J Emerg Med. 2023;24(4):685-92. https://doi.org/10.5811/westjem.58965

15. Beals T, Naraghi L, Grossestreuer A, Schafer J, Balk D, Hoffmann B. Point of care ultrasound is associated with decreased ED length of stay for symptomatic early pregnancy. Am J Emerg Med. 2019;37 (6):1165-8. https://doi.org/10.1016/j.ajem.2019.03.025

16. Morgan BB, Kao A, Trent SA, Hurst N, Oliveira L, Austin AL, Kendall JL. Effect of Emergency Physician-Performed Point-of-Care Ultrasound and Radiology Department-Performed Ultrasound Examinations on the Emergency Department Length of Stay Among Pregnant Women at Less Than 20 Weeks' Gestation. J Ultrasound Med. 2018;37(11):2497-505. https://doi.org/10.1002/jum.14607

17. Thamburaj R, Sivitz A. Does the use of bedside pelvic ultrasound decrease length of stay in the emergency department? Pediatr Emerg Care. 2013;29(1):67-70. https://doi.org/10.1097/PEC.0b013e31827b53f9

18. Urquhart S, Barnes M, Flannigan M. Comparing Time to Diagnosis and Treatment of Patients with Ruptured Ectopic Pregnancy Based on Type of Ultrasound Performed: A Retrospective Inquiry. J Emerg Med. 2022;62(2):200-6. https://doi.org/10.1016/j.jemermed.2021.07.064

19. Chiem AT, Chan CH, Ibrahim DY, Anderson CL, Wu DS, Gilani CJ, Mancia ZJ, Fox JC. Pelvic ultrasonography and length of stay in the ED: an observational study. Am J Emerg Med. 2014;32(12):1464-9. https://doi.org/10.1016/j.ajem.2014.09.006

20. Urquhart S, Stevens K, Barnes M, Flannigan M. Point of Care Ultrasound First: An Opportunity to Improve Efficiency for Uncomplicated Pregnancy in the Emergency Department. Pocus j. 2021;6(1):42-4. https://doi.org/10.24908/pocus.v6i1.14762

21. Sheppard G, Stolz L, Boyd JS, Pusic M, Baez J, Minges P, Swarm M, Hilbert M, O'Brien M, Harris K, Varner C, LeBlanc C, Boutis K. First Trimester Point of Care Ultrasound: Imaging Features and Review Behaviors Associated With Diagnostic Accuracy. Acad Emerg Med. 2025;32(11):1224-34. https://doi.org/10.1111/acem.70094

22. Stolz L, Sheppard G, Boyd J, Baez J, Minges P, Pusic M, Swarm M, Hilbert M, O'Brien M, Harris K, Varner C, LeBlanc C, Boutis K. Effectiveness of a Web-Based Training Intervention in Teaching Emergency Physicians First-Trimester Point-of-Care Ultrasound Image Interpretation. Ann Emerg Med. 2025;85(6):541-54. https://doi.org/10.1016/j.annemergmed.2025.01.005

23. Sohoni A, Bosley J, Miss JC. Bedside ultrasonography for obstetric and gynecologic emergencies. Crit Care Clin. 2014;30(2):207-26, v. https://doi.org/10.1016/j.ccc.2013.10.002

24. King SA, Salerno A, Sommerkamp S. Ultrasound in Pregnancy. Emerg Med Clin North Am. 2023;41(2):337-53. https://doi.org/10.1016/j.emc.2022.12.006

25. Richardson A, Hopkisson J, Campbell B, Raine-Fenning N. Use of double decidual sac sign to confirm intrauterine pregnancy location prior to sonographic visualization of embryonic contents. Ultrasound Obstet Gynecol. 2017;49(5):643-8. https://doi.org/10.1002/uog.15966

26. Doubilet PM, Benson CB. Double sac sign and intradecidual sign in early pregnancy: interobserver reliability and frequency of occurrence. J Ultrasound Med. 2013;32(7):1207-14. https://doi.org/10.7863/ultra.32.7.1207

27. Lee IT, Rubin ES, Wu J, Koelper N, Barnhart KT. The incidence and importance of the pseudogestational sac revisited. Am J Obstet Gynecol. 2022;226(4):537.e1-.e7. https://doi.org/10.1016/j.ajog.2021.10.033

28. Phillips CH, Benson CB, Durfee SM, Heller HT, Doubilet PM. "Pseudogestational Sac" and Other 1980s-Era Concepts in Early First-Trimester Ultrasound: Are They Still Relevant Today? J Ultrasound Med. 2020;39(8):1547-51. https://doi.org/10.1002/jum.15243

29. Utomo A, Aditiyono A, Marlina D, Disastra YP, Susilo AFP, Adinda Adriansyah PN. Diagnostic Challenges in Ectopic Pregnancy: Identifying Pseudo Sacs in Suspected Heterotopic Cases. Am J Case Rep. 2025;26:e944924. https://doi.org/10.12659/ajcr.944924

30. Lewiss RE, Shaukat NM, Saul T. The endomyometrial thickness measurement for abnormal implantation evaluation by pelvic sonography. J Ultrasound Med. 2014;33(7):1143-6. https://doi.org/10.7863/ultra.33.7.1143

31. Thom C, Kongkatong M, Moak J. The Utility of Transvaginal Ultrasound After Intrauterine Pregnancy Identification on Transabdominal Ultrasound in Emergency Department Patients. Open Access Emerg Med. 2023;15:207-16. https://doi.org/10.2147/oaem.S409920

32. Practice Bulletin No. 175: Ultrasound in Pregnancy. Obstet Gynecol. 2016;128(6):e241-e56. https://doi.org/10.1097/aog.0000000000001815

33. Stein JC, Wang R, Adler N, Boscardin J, Jacoby VL, Won G, Goldstein R, Kohn MA. Emergency physician ultrasonography for evaluating patients at risk for ectopic pregnancy: a meta-analysis. Ann Emerg Med. 2010;56(6):674-83. https://doi.org/10.1016/j.annemergmed.2010.06.563

34. Çelik A, Yazıcı MM, Oktay M. The impact of high-frequency linear transducer on the accuracy of pelvic ultrasound in early pregnancy pelvic pain and bleeding. Am J Emerg Med. 2022;61:105-10. https://doi.org/10.1016/j.ajem.2022.08.045

35. Saadat S, Nguyen MT, Nepomuceno I, Thai E, Kurzweil A, Choi H, Lahham S, Fox JC. Using a Linear Probe Ultrasound for the Detection of First-Trimester Pregnancies in the Emergency Department. Diagnostics (Basel). 2023;13(15)https://doi.org/10.3390/diagnostics13152564

36. Tabbut M, Harper D, Gramer D, Jones R. High-frequency linear transducer improves detection of an intrauterine pregnancy in first-trimester ultrasonography. Am J Emerg Med. 2016;34(2):288-91. https://doi.org/10.1016/j.ajem.2015.11.001

37. Adhikari S, Blaivas M, Lyon M. Diagnosis and management of ectopic pregnancy using bedside transvaginal ultrasonography in the ED: a 2-year experience. Am J Emerg Med. 2007;25(6):591-6. https://doi.org/10.1016/j.ajem.2006.11.020

38. Moore C, Todd WM, O'Brien E, Lin H. Free fluid in Morison's pouch on bedside ultrasound predicts need for operative intervention in suspected ectopic pregnancy. Acad Emerg Med. 2007;14(8):755-8. https://doi.org/10.1197/j.aem.2007.04.010

39. Papageorgiou D, Sapantzoglou I, Prokopakis I, Zachariou E. Tubal Ectopic Pregnancy: From Diagnosis to Treatment. Biomedicines. 2025;13(6)https://doi.org/10.3390/biomedicines13061465

40. Richardson A, Gallos I, Dobson S, Campbell BK, Coomarasamy A, Raine-Fenning N. Accuracy of first-trimester ultrasound in diagnosis of tubal ectopic pregnancy in the absence of an obvious extrauterine embryo: systematic review and meta-analysis. Ultrasound Obstet Gynecol. 2016;47(1):28-37. https://doi.org/10.1002/uog.14844

41. Sato AK, Jang TB. Short answer question case series: symptomatic first-trimester pregnancy. Emerg Med J. 2013;30(2):170-1. https://doi.org/10.1136/emermed-2012-201804

42. Noble VE, Liteplo A, Miller RM, Murray AF, Villen T. Cornual ectopic pregnancy diagnosed by emergency physician-performed bedside ultrasound in the emergency department. J Emerg Med. 2011;40(4):e81-2. https://doi.org/10.1016/j.jemermed.2008.04.033

43. Carius BM, Houston EJ, Griffith SP. A Case Report of Massive Intraperitoneal Hemorrhage from Rare Cornual Pregnancy. Clin Pract Cases Emerg Med. 2022;6(1):41-4. https://doi.org/10.5811/cpcem.2021.10.54388

44. Smith DJ, Chenkin J. Cesarean scar ectopic pregnancy diagnosed by point-of-care ultrasound: A case report. Cjem. 2020;22(5):723-5. https://doi.org/10.1017/cem.2020.452

45. Zanaboni A, Magee M, Gibbons RC, Costantino TG. Point-of-Care Ultrasound Diagnosis of Cesarean Scar Ectopic Pregnancy: A Case Series. J Emerg Med. 2021;60(2):216-9. https://doi.org/10.1016/j.jemermed.2020.09.035

46. Holley IJ, Stickles SP. Heterotopic Pregnancy Diagnosed with Point-of-care Ultrasound in the Emergency Department: A Case Report. Clin Pract Cases Emerg Med. 2020;4(2):178-80. https://doi.org/10.5811/cpcem.2020.2.45933

47. Doyle WN, Jr., Giagni CC, Roth K, Amaducci A. Diagnosing Emergent Heterotopic Pregnancy via Point-of-Care Ultrasound: A Case Report. Cureus. 2023;15(8):e43663. https://doi.org/10.7759/cureus.43663

48. Andruko J, Kim DJ. Pregnant Woman With Abdominal Pain. Ann Emerg Med. 2019;73(5):e67-e8. https://doi.org/10.1016/j.annemergmed.2018.10.011

49. Breyer MJ, Costantino TG. Heterotopic gestation: another possibility for the emergency bedside ultrasonographer to consider. J Emerg Med. 2004;26(1):81-4. https://doi.org/10.1016/j.jemermed.2003.06.004

50. Li JB, Kong LZ, Yang JB, Niu G, Fan L, Huang JZ, Chen SQ. Management of Heterotopic Pregnancy: Experience From 1 Tertiary Medical Center. Medicine (Baltimore). 2016;95(5):e2570. https://doi.org/10.1097/md.0000000000002570.

51. Panebianco NL, Shofer F, Fields JM, Anderson K, Mangili A,

Matsuura AC, Dean AJ. The utility of transvaginal ultrasound in the ED evaluation of complications of first trimester pregnancy. The American Journal of Emergency Medicine. 2015;33(6):743-8. https://doi.org/https://doi.org/10.1016/j.ajem.2015.02.023

52. Kanmaz AG, İnan AH, Beyan E, Budak A. The effects of threatened abortions on pregnancy outcomes. Ginekol Pol. 2019;90(4):195-200. https://doi.org/10.5603/GP.a2019.0035.

53. Doubilet PM, Benson CB, Bourne T, Blaivas M, Barnhart KT, Benacerraf BR, Brown DL, Filly RA, Fox JC, Goldstein SR, Kendall JL, Lyons EA, Porter MB, Pretorius DH, Timor-Tritsch IE. Diagnostic criteria for nonviable pregnancy early in the first trimester. N Engl J Med. 2013;369(15):1443-51. https://doi.org/10.1056/NEJMra1302417

54. Varner C, Balaban D, McLeod S, Carver S, Borgundvaag B. Fetal outcomes following emergency department point-of-care ultrasound for vaginal bleeding in early pregnancy. Can Fam Physician. 2016;62 (7):572-8

55. Kahn A, Kahn AL, Fox JC, Langdorf MI. Subchorionic hemorrhage appearing as twin gestation on endovaginal ultrasound. West J Emerg Med. 2008;9(2):115-7

56. Hill LM, Kislak S, Martin JG. Transvaginal sonographic detection of the pseudogestational sac associated with ectopic pregnancy. Obstet Gynecol. 1990;75(6):986-8

57. White R, Kilgour Venables H. The significance of ultrasound features of sub-chorionic haemorrhage as a predictor of adverse perinatal outcome: A retrospective review. Eur J Obstet Gynecol Reprod Biol. 2023;289:23-8. https://doi.org/10.1016/j.ejogrb.2023.08.009

58. Naert MN, Khadraoui H, Muniz Rodriguez A, Naqvi M, Fox NS. Association Between First-Trimester Subchorionic Hematomas and Pregnancy Loss in Singleton Pregnancies. Obstet Gynecol. 2019;134 (2):276-81. https://doi.org/10.1097/aog.0000000000003360

59. Pearlstone M, Baxi L. Subchorionic hematoma: a review. Obstet Gynecol Surv. 1993;48(2):65-8

60. Boivin Z, Barber D, Chimileski B, Fetherston T, Li JJ, Liu R, Moore CL. Accuracy of point-of-care ultrasound in diagnosing retained products of conception. The American Journal of Emergency Medicine. 2025https://doi.org/https://doi.org/10.1016/j.ajem.2025.01.032

61. Kishimoto N, Miyamoto M, Imauji A, Takada M, Nishitani S, Tanabe R, Ito T, Hada T, Otsuka Y, Takano M. Clinical significance of retained products of conception in placenta previa: a retrospective analysis. BMC Pregnancy Childbirth. 2023;23(1):481. https://doi.org/10.1186/s12884-023-05805-0

62. Sellmyer MA, Desser TS, Maturen KE, R. Brooke Jeffrey J, Kamaya A. Physiologic, Histologic, and Imaging Features of Retained Products of Conception. Radiographics. 2013;33(3):781-96. https://doi.org/10.1148/rg.333125177

63. Hamel CC, van Wessel S, Carnegy A, Coppus S, Snijders M, Clark J, Emanuel MH. Diagnostic criteria for retained products of conception-A scoping review. Acta Obstet Gynecol Scand. 2021;100(12):2135-43. https://doi.org/10.1111/aogs.14229

64. Ashkar Majadla N, Abu Shqara R, Haj S, Sgayer I, Ghanem N, Lowenstein L, Odeh M. Sonographic evaluation of retained products of conception within 48 h following delivery: a retrospective cohort study. Arch Gynecol Obstet. 2024https://doi.org/10.1007/s00404-024-07688-8

65. Hahn SA, Promes SB, Brown MD. Clinical Policy: Critical Issues in the Initial Evaluation and Management of Patients Presenting to the Emergency Department in Early Pregnancy. Ann Emerg Med. 2017;69 (2):241-50.e20. https://doi.org/10.1016/j.annemergmed.2016.11.002

66. Condous G, Kirk E, Lu C, Van Huffel S, Gevaert O, De Moor B, De Smet F, Timmerman D, Bourne T. Diagnostic accuracy of varying discriminatory zones for the prediction of ectopic pregnancy in women with a pregnancy of unknown location. Ultrasound Obstet Gynecol. 2005;26(7):770-5. https://doi.org/10.1002/uog.2636

67. Doubilet PM, Benson CB. Further evidence against the reliability of the human chorionic gonadotropin discriminatory level. J Ultrasound Med. 2011;30(12):1637-42. https://doi.org/10.7863/jum.2011.30.12.1637

68. Eisaman DM, Brown NE, Geyer S. Relationship of Beta-Human Chorionic Gonadotropin to Ectopic Pregnancy Detection and Size. West J Emerg Med. 2024;25(3):431-5. https://doi.org/10.5811/westjem.18396

69. Park KE, Latack KR, Vestal NL, Ingles SA, Paulson RJ, Awadalla MS. Association of HCG Level with Ultrasound Visualization of the Gestational Sac in Early Viable Pregnancies. Reprod Sci. 2023;30 (12):3623-8. https://doi.org/10.1007/s43032-023-01308-7

70. Wang R, Reynolds TA, West HH, Ravikumar D, Martinez C, McAlpine I, Jacoby VL, Stein JC. Use of a β-hCG discriminatory zone with bedside pelvic ultrasonography. Ann Emerg Med. 2011;58(1):12-20. https://doi.org/10.1016/j.annemergmed.2010.12.023

71. ACOG Clinical Practice Update: Rh D Immune Globulin Administration After Abortion or Pregnancy Loss at Less Than 12 Weeks of Gestation. Obstet Gynecol. 2024;144(6):e140-e3. https://doi.org/10.1097/aog.0000000000005733

72. VanBlaricom A, Simon MN. Triage Versus Obstetric Emergency Department and Main Emergency Department: Best Practices. Obstet Gynecol Clin North Am. 2024;51(3):485-94. https://doi.org/10.1016/j.ogc.2024.05.005

73. AIUM-ACR-ACOG-SMFM-SRU Practice Parameter for the Performance of Standard Diagnostic Obstetric Ultrasound Examinations. J Ultrasound Med. 2018;37(11):E13-e24. https://doi.org/10.1002/jum.14831

74. Gravett C, Eckert LO, Gravett MG, Dudley DJ, Stringer EM, Mujobu TB, Lyabis O, Kochhar S, Swamy GK. Non-reassuring fetal status: Case definition & guidelines for data collection, analysis, and presentation of immunization safety data. Vaccine. 2016;34(49):6084-92. https://doi.org/10.1016/j.vaccine.2016.03.043

75. Varthaliti A, Fasoulakis Z, Lygizos V, Zolota V, Chatziioannou MI, Daskalaki MA, Daskalakis G, Antsaklis P. Safety of Obstetric Ultrasound: Mechanical and Thermal Indexes-A Systematic Review. J Clin Med. 2024;13(21)https://doi.org/10.3390/jcm13216588

76. Wong L, Paul E, Murday HK, Fang J, Lavender I, Coombs PR, Teoh M. Biparietal diameter measurements using the outer-to-outer versus outer-to-inner measurement: A question of pedantry? Australas J Ultrasound Med. 2018;21(3):161-8. https://doi.org/10.1002/ajum.12091

77. Salerno A, Flanagan K, Ghaffarian K, Al Hazmi A, Witting MD, Euerle BD. Quantitative and Qualitative Analysis of Emergency Physician Performed Biparietal Diameter Estimate for Gestational Age. J Emerg Med. 2022;62(3):342-7. https://doi.org/10.1016/j.jemermed.2021.09.001.

78. Honarvar M, Allahyari M, Dehbashi S. Assessment of gestational age based on ultrasonic femur length after the first trimester: a simple mathematical correlation between gestational age (GA) and femur length (FL). Int J Gynaecol Obstet. 2000;70(3):335-40. https://doi.org/10.1016/s0020-7292(00)00205-8

79. Turner JM, Cincotta R, Chua J, Gardener G, Petersen S, Thomas J, Lee-Tannock A, Kumar S. Decreased fetal movements-the utility of ultrasound to identify infants at risk and prevent stillbirth is poor. Am J Obstet Gynecol MFM. 2023;5(2):100782. https://doi.org/10.1016/j.ajogmf.2022.100782

80. Franks Z, Nightingale R. Decreased fetal movements: a practical approach in a primary care setting. Aust Fam Physician. 2014;43 (11):782-5

81. Knights S, Prasad S, Kalafat E, Dadali A, Sizer P, Harlow F, Khalil A. Impact of point-of-care ultrasound and routine third trimester ultrasound on undiagnosed breech presentation and perinatal outcomes: An observational multicentre cohort study. PLoS Med. 2023;20(4):e1004192. https://doi.org/10.1371/journal.pmed.1004192

82. Ferreira JC, Borowski D, Czuba B, Cnota W, Wloch A, Sodowski K, Wielgos M, Wegrzyn P. The evolution of fetal presentation during pregnancy: a retrospective, descriptive cross-sectional study. Acta Obstet Gynecol Scand. 2015;94(6):660-3. https://doi.org/10.1111/aogs.12626

83. Yaouzis Olsson N, Bartfai ED, Åmark H, Wallström T. Outcomes in term breech birth according to intended mode of delivery-A Swedish prospective single-center experience of a dedicated breech birth team. Acta Obstet Gynecol Scand. 2024;103(11):2296-305. https://doi.org/10.1111/aogs.14945

84. Anderson-Bagga FM, Sze A. Placenta Previa. StatPearls, Treasure Island (FL): StatPearls Publishing. Copyright © 2025, StatPearls Publishing LLC.; 2025.

85. Shih P, Tsai T-Y, Gozari G. Pregnant Woman With Vaginal Bleeding. Ann Emerg Med. 2021;77(1):137. https://doi.org/10.1016/j.annemergmed.2020.07.019

86. Schiffer V, van Haren A, De Cubber L, Bons J, Coumans A, van Kuijk SM, Spaanderman M, Al-Nasiry S. Ultrasound evaluation of the placenta in healthy and placental syndrome pregnancies: A systematic review. Eur J Obstet Gynecol Reprod Biol. 2021;262:45-56. https://

doi.org/10.1016/j.ejogrb.2021.04.042

87. Ahn KH, Lee EH, Cho GJ, Hong SC, Oh MJ, Kim HJ. Anterior placenta previa in the mid-trimester of pregnancy as a risk factor for neonatal respiratory distress syndrome. PLoS One. 2018;13 (11):e0207061. https://doi.org/10.1371/journal.pone.0207061

88. Shinde GR, Vaswani BP, Patange RP, Laddad MM, Bhosale RB. Diagnostic Performance of Ultrasonography for Detection of Abruption and Its Clinical Correlation and Maternal and Foetal Outcome. J Clin Diagn Res. 2016;10(8):Qc04-7. https://doi.org/10.7860/jcdr/2016/19247.8288

89. Moise KJ, Jr. Toward consistent terminology: assessment and reporting of amniotic fluid volume. Semin Perinatol. 2013;37(5):370-4. https://doi.org/10.1053/j.semperi.2013.06.016

90. Hebbar S, Rai L, Adiga P, Guruvare S. Reference ranges of amniotic fluid index in late third trimester of pregnancy: what should the optimal interval between two ultrasound examinations be? J Pregnancy. 2015;2015:319204. https://doi.org/10.1155/2015/319204

91. Whittington JR, Chauhan SP, Wendel MP, Ghahremani TL, Pagan ME, Carter MM, Magann EF. Historical Assessment, Practical Management, and Future Recommendations for Abnormal Amniotic Fluid Volumes. J Clin Med. 2024;13(16)https://doi.org/10.3390/jcm13164702

92. Weissmann-Brenner A, O'Reilly-Green C, Ferber A, Divon MY. Values of amniotic fluid index in cases of preterm premature rupture of membranes. J Perinat Med. 2009;37(3):232-5. https://doi.org/10.1515/jpm.2009.078

93. Della Ripa S, Santos N, Walker D. AI-enabled obstetric point-of-care ultrasound as an emerging technology in low- and middle-income countries: provider and health system perspectives. BMC Pregnancy Childbirth. 2025;25(1):729. https://doi.org/10.1186/s12884-025-07796-6

94. Ginsburg AS, Liddy Z, Alkan E, Matcheck K, May S. A survey of obstetric ultrasound uses and priorities for artificial intelligence-assisted obstetric ultrasound in low- and middle-income countries. Sci Rep. 2025;15(1):3873. https://doi.org/10.1038/s41598-025-87284-1

95. Chen Z, Liu Z, Du M, Wang Z. Artificial Intelligence in Obstetric Ultrasound: An Update and Future Applications. Front Med (Lausanne). 2021;8:733468. https://doi.org/10.3389/fmed.2021.733468.

96. Pokaprakarn T, Prieto JC, Price JT, Kasaro MP, Sindano N, Shah HR, Peterson M, Akapelwa MM, Kapilya FM, Sebastião YV, Goodnight W, 3rd, Stringer EM, Freeman BL, Montoya LM, Chi BH, Rouse DJ, Cole SR, Vwalika B, Kosorok MR, Stringer JSA. AI Estimation of Gestational Age from Blind Ultrasound Sweeps in Low-Resource Settings. NEJM Evid. 2022;1(5)https://doi.org/10.1056/evidoa2100058

97. Sappia MS, de Korte CL, van Ginneken B, Ninalga D, Kondo S, Kasai S, Hirasawa K, Akumu T, Martín-Isla C, Lekadir K, Campello VM, Fabila J, Beverdam A, van Dillen J, Neff C, Murphy K. ACOUSLIC-AI challenge report: Fetal abdominal circumference measurement on blind-sweep ultrasound data from low-income countries. Med Image Anal. 2025;105:103640. https://doi.org/10.1016/j.media.2025.103640

98. Gleed AD, Chen Q, Jackman J, Mishra D, Chandramohan V, Self A, Bhatnagar S, Papageorghiou AT, Noble JA. Automatic Image Guidance for Assessment of Placenta Location in Ultrasound Video Sweeps. Ultrasound Med Biol. 2023;49(1):106-21. https://doi.org/10.1016/j.ultrasmedbio.2022.08.006

99. Enrici Baion D, Schettino C, Vita L, Luison D, Caprioli S, Lombardo M, La Ferrara A, Locascio F, Galluzzo E, Ciampi V, Ianiro A, Maserin D, Malara F, Urso N, Morello F, Marchisio D, Lupia E, Pivetta E. Feasibility of point-of-care ultrasound during the emergency department triage: a prospective cohort study. Ultrasound J. 2025;17(1):60. https://doi.org/10.1186/s13089-025-00463-z

POCUS Used to Diagnose a Diaphragmatic Rupture Due to a Pyogenic Liver Abscess

Martine A. Valk, PA[1]; Daan J. Lips, MD PhD[2]; Marleen M. Duivenvoorden, MD[1]; Bart P. X. Grady, MD PhD[1]*

(1) Hospital Group Twente, Department of Intensive Care, Almelo, the Netherlands
(2) Medisch Spectrum Twente, Department of Surgery, Section Gastrointestinal/Oncological Surgery, Enschede, the Netherlands

Abstract

A diaphragmatic rupture due to a liver abscess is a serious condition with a high mortality that mostly requires surgical intervention. We report a case in which point of care ultrasound (POCUS) demonstrated a diaphragmatic rupture with pleural empyema due to a pyogenic liver abscess in a patient in the intensive care unit (ICU). POCUS demonstrated abscess contents herniating into the chest cavity when the diaphragm contracted during inspiration. The patient underwent minimally invasive surgery to drain the subphrenic abscess and right thoracic cavity. He was discharged and returned home 28 days after his initial presentation.

Case presentation

A 48-year-old man presented to the emergency department with a one-month history of right-sided intermittent aching and sharp, progressive abdominal pain, and a three-day history of vomiting and no oral intake. He had lost five kg of body weight over the last three months. The patient had recurrent chronic pancreatitis due to pancreas divisum, for which he received a pancreatic duct stent. His history included a splenectomy following a motorcycle accident and he also used tobacco. Five months prior, he had been admitted to the hospital with septic shock due to cholecystitis and a pyogenic liver-hilum abscess for which he received six weeks of oral amoxicillin, in addition to adequate abscess drainage.

On examination, his heart rate was 91 bpm, blood pressure was 122/83 mmHg, and temperature was 36.4 C. An abdominal examination revealed rigidity in the right upper and lower quadrants of the abdomen. Cardiac and pulmonary examinations were normal, as was the electrocardiogram.

Laboratory testing showed the following: white cell count of 12.4 $x10^9$ cells/L, C-reactive protein 417 mg/L, hemoglobin 14.5 gm/dL, platelet count 634 (H) $x10^9$/L, alkaline phosphatase 879 IU/L, Aspartate aminotransferase 117 IU/L, alanine aminotransferase 68 IU/L, gamma-glutamyl transferase 444 U/L, total bilirubin <17 µmol/L, Lipase 52 U/L, Urea 44.5 (H) mmol/L, and serum creatinine 869 µmol/L. Blood cultures were obtained before initiating antibiotics.

A computed tomography (CT) scan of the abdomen showed a 20.7 cm x 14.7 cm subcapsular abscess in the liver. For this, a percutaneous catheter drainage yielded 160 cc of purulent fluid. The patient was admitted to the department of gastroenterology and was empirically treated with intravenous ceftriaxone in addition to metronidazole. Pus cultures from the aspirate grew *Enterococcus faecium* and *Candida glabrata*. Anidulafungin and vancomycin were added. Over time, sequential CT scans of the abdomen and a Magnetic Resonance Cholangio-Pancreatography demonstrated a persistent liver abscess without source control, despite drainage.

From day 12, the patient developed shortness of breath and fever with a clinical suspicion of hospital-acquired pneumonia. However, a chest X-ray did not show signs of pulmonary infiltrate. Based on pragmatic considerations and our microbiologist's advice, the antibiotic regimen was changed to piperacillin/tazobactam, anidulafungin, and vancomycin.

Over the next few days, the patient remained febrile, and his pulmonary status deteriorated. Molecular testing was positive for the influenza A virus. Given the suspicion of pneumonia, a CT Pulmonary Angiogram was performed. It showed extensive atelectasis and consolidation of the right lower and middle lobes, next to left lower lobe consolidations and moderate bilateral pleural effusion. Pulmonary embolism was excluded. The patient was

*Corresponding Author: Dr. Bart Grady (email: b.grady@zgt.nl)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20344

admitted to the intensive care unit (ICU) for High-Flow Nasal Oxygen therapy, and a bronchoscopy with bronchoalveolar cultures was performed.

The following day, a point of care ultrasound (POCUS) of the thorax conforming to the BLUE protocol [1] was performed by an intensive care physician assistant with advanced training in POCUS. A Philips CX50 machine (Koninklijke Philips Healthcare N.V., Eindhoven, Nederland) with a 5-1 MHz curved probe in a long preset was used. A diaphragmatic rupture with liver abscess contents herniating into the chest cavity was revealed at the right Postero-Lateral Alveolar Pleural Syndrome (PLAPS) point, which is the most posterior point above the diaphragm (Figure 1a; Supplementary Material - Video S1). This was subsequently confirmed by a CT scan of the abdomen/chest (Figure 1b and 1c). CT-guided percutaneous catheter placement in the liver abscess was followed immediately, yielding 500 cc of purulent fluid. Pus culture from the aspirate remained positive for *Candida glabrata* and *Candida albicans* as well as *Staphylococcus epidermidis*. *Enterococcus faecium* was no longer detected. The antimicrobial therapy was continued.

Unfortunately, percutaneous drainage of the liver abscess did not provide sufficient source control. It was therefore decided that day to transfer the patient to a nearby hospital that specialized in hepato-pancreato-biliary surgery. There, he underwent minimal invasive surgical drainage of the subphrenic abscess and right thoracic cavity. There was no per-operatively visualized diaphragm perforation due to adhesions. Following surgery, the patient returned to the ICU, where his pulmonary function improved rapidly. He fully recovered without any new complications. Piperacillin/tazobactam, anidulafungin, and vancomycin were continued until he was discharged from the hospital on day 28.

Discussion

A pleural empyema following diaphragmatic rupture of a pyogenic liver abscess is a very rare yet potentially fatal complication. When left untreated, mortality approaches 100% [2]. In previous case reports, a ruptured liver abscess in the thoracic cavity was diagnosed by CT scan [3]. Our case illustrated that POCUS can reveal a ruptured liver abscess. This report highlights the importance of POCUS in the acute care setting.

The use of POCUS in hepatology is relatively new but has been increasingly implemented to augment diagnostic and therapeutic strategies, including the management of liver abscesses [4,5]. Although CT can be more sensitive than conventional ultrasound to diagnose a liver abscess (95% vs. 85%), POCUS offers several advantages [6]. Apart from closely monitoring a liver abscess, our case demonstrates that POCUS could also be used for the early and rapid detection of complications, such as diaphragmatic rupture. This diagnosis can then facilitate prompt treatment. Moreover, the simplicity, minimal logistical challenges, accessibility, and the absence of radiological hazards are important qualities of POCUS in acute clinical care.

Although the use of POCUS is widespread in multiple clinical settings, it still requires skills and appropriate training [4]. Intra-abdominal and retroperitoneal liver abscesses may be more difficult to detect using POCUS, due to obscuration by bowel gas or adjacent organs, their location between intestinal loops, and the limited ability to adequately compress the abdomen [5]. Nevertheless, this case report demonstrates that bedside POCUS has a valuable role in critical care, this time through rapid assessment and monitoring of large liver abscesses.

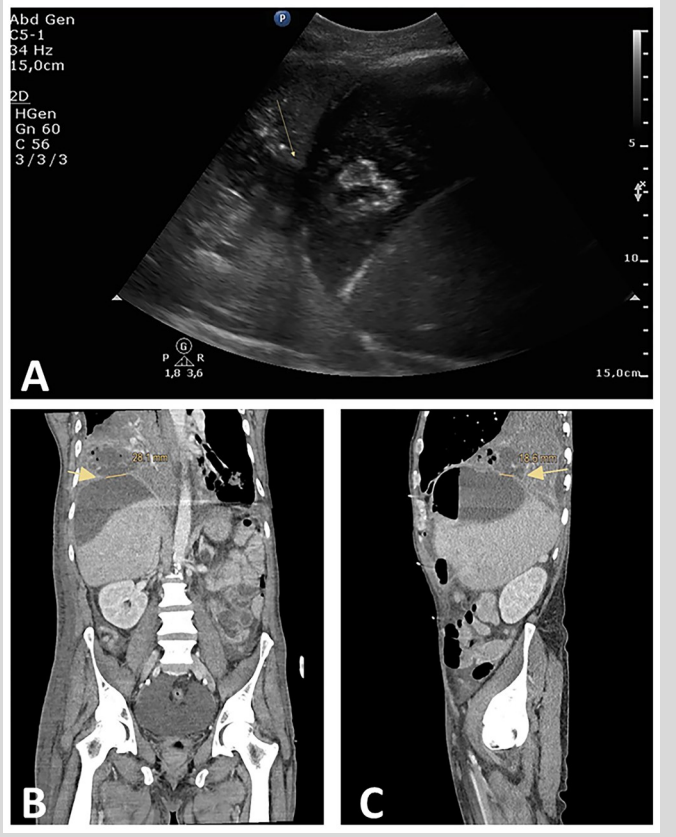


Figure 1. A) Point of care ultrasound (POCUS) demonstrating a diaphragmatic rupture with liver abscess contents herniating into the chest cavity. Image of video POCUS thorax. B) Coronal view of Computed Tomography (CT) scan of the chest and abdomen, demonstrating a diaphragmatic rupture of the liver abscess. C) Sagittal view of Computed Tomography (CT) scan of the chest and abdomen, demonstrating a diaphragmatic rupture of the liver abscess.

Ethics Statement

The authors obtained consent directly from the patient.

Disclosure Statement

The authors declare no conflicts of interest.

Funding

The authors received no financial support, funding, or material support for the research, authorship, and/or publication of this manuscript.

Author Contributions

MAV: writing - original draft, writing - review & editing, visualization. DJL: writing - review & editing. MMD: writing - review & editing. BPXG: conceptualization, writing - original draft, writing - review & editing, visualization.

References

1. Lichtenstein DA, Mezière GA. Relevance of Lung Ultrasound in the Diagnosis of Acute Respiratory Failure. Chest. 2008 ;134(1):117-125.

2. Cho E, Park SW, Jun CH, Shin SS, Park EK, Lee KS, Park SY, Park CH, Kim HS, Choi SK, Rew JS. A rare case of pericarditis and pleural empyema secondary to transdiaphragmatic extension of pyogenic liver abscess. BMC Infect Dis. 2018;18(1):40-1-40-6.

3. AlGhamdi ZM, Boumarah DN, Alshammary S, Elbawab H. Pleural Empyema as a Complication of Pyogenic Liver Abscess: Can the Minimum Achieve the Optimal? A Comparison of 3 Approaches. AM J Case Rep. 2021;20(22): e935169-1-e935169-9.

4. Premkumar M, Karvellas CJ, Kulkarni, AV, Bhujade H, Reddy KR. Role of point-of-care ultrasound (POCUS) in clinical hepatology. Hepatology. 2024; 83(4):931-947.

5.Shankar N, Kuo L, Cleveland NK, Galen B, Samel NS, Perez-Sanchez A, Nathanson R, Coss E, Echavarria J, Rubin DT, Soni NJ. Point-of-Care Ultrasound in Gastroenterology and Hepatology. Clinical Gastroenterology and Hepatology. 2025; 23(8):1277-1290. doi:10.1016/j.cgh.2024.09.040

6. Blomquist M, Brinkerhoff T, Weech D, Choi H. Point-of-care ultrasound identification of hepatic abscess in the Emergency Department. Clin Pract Cases Emerg Med. 2023; 7(2):115-117.

The Effect of POCUS on Pediatric Acute Scrotum: A Ten-Year Retrospective Analysis

Eric Scheier, MD[1,2]*; Aviad Nachmany, MD[1]; Layah Alkoby-Meshulam[3]

(1) Pediatric Emergency, Kaplan Medical Center, Rehovot, Israel
(2) Faculty of Medicine, Hebrew University of Jerusalem, Israel
(3) Pediatric Emergency, Schneider Children's Medical Center, Petah Tikva, Israel

Abstract

Background: Timely and accurate diagnosis of testicular torsion (TT) is critical to preserve testicular viability. This study describes the utility of pediatric emergency department (PED) point of care ultrasound (POCUS) in pediatric acute scrotum over ten years. **Methods:** We reviewed hospital charts for all children with diagnoses of TT, orchiopexy or orchiectomy from June 2015 to June 2025. We defined length of stay (LOS) as the time from PED registration to the initiation of anesthesia. **Results:** We included a total of 145 children in our study. We confirmed TT on surgical examination in 121 cases. Among the 60 cases of surgically confirmed TT in which POCUS was performed, POCUS correctly identified torsion in 57 cases. This yielded a sensitivity of 94% ($p < 0.001$). LOS with Radiology-performed ultrasound (RADUS) was 108 minutes (IQR 22 minutes), and LOS with POCUS was 81 minutes (IQR 47 minutes). LOS with POCUS then requiring RADUS confirmation was 199 minutes (IQR 82 minutes) ($p < 0.05$). Twenty-four children underwent scrotal exploration without TT. In 9 of 11 cases, POCUS was consistent with TT. In 8 of 14 cases, RADUS was compatible with TT. In three cases, no imaging was performed. LOS with POCUS in children without TT was 95 minutes (IQR 62 minutes) vs. 164.5 minutes (IQR 71 minutes) for RADUS. LOS with POCUS that required RADUS confirmation was 213 minutes (IQR 113 minutes) ($p < 0.05$). **Conclusion:** PED POCUS for TT is accurate, even when used by pediatric trainees and when utilized in cases with atypical TT presentation. POCUS reduces time from presentation to surgical detorsion. No statistically significant difference in the rate of positive imaging findings between POCUS and RADUS was identified in the non-TT surgical cohort.

Introduction

Testicular torsion (TT) is a high-stakes, low-frequency pediatric urological emergency, responsible for 15 25%– of acute scrotum cases presenting to the pediatric emergency department (PED) [1,2]. Timely and accurate diagnosis of TT is critical to preserve testicular viability, which rapidly decreases after 6 hours of symptom onset and risks impaired fertility and orchiectomy [3,4].

TT commonly presents with acute scrotal pain, erythema, and swelling; however, these symptoms are non-specific and are often caused by more benign conditions such as torsion of the appendix testis or epididymo-orchitis. Conversely, relatively specific indicators of TT, such as absent cremasteric reflex or scrotal pain accompanied by vomiting, may be absent [5–7]. Prepubertal males are more likely than postpubertal males to lack classic symptoms such as testicular pain [7]. Atypical presentations of torsion that have no scrotal pain recorded (e.g., only abdominal pain), low reported pain levels and the absence of specific indicators (such as the aforementioned cremasteric reflex) may delay diagnosis.

The gold standard of diagnosis of TT is surgical exploration, which is invasive and reserved for cases where the diagnosis of TT is under consideration. Clinical scoring systems (e.g., the TWIST score) have aided physicians in ambiguous cases [8–10]. Radiology-performed ultrasound (RADUS) and point of care ultrasound (POCUS) are frequently employed, with the former having sensitivity and specificity exceeding 90%, and the latter with promising but limited medical literature [1,11,12].

The primary outcome of our study was the length of stay (LOS), defined as the time from PED registration to initiation of anesthesia, stratified by imaging modality. The secondary outcome was the diagnostic accuracy of POCUS. Specifically, we studied the frequency and accuracy of POCUS in both typical and atypical presentations of TT, and the frequency and accuracy of

*Corresponding Author: Dr. Eric Scheier (email: eric.scheier@gmail.com)
This work is licensed under a Creative Commons Attribution 4.0 International License.
Author(s) retain the copyright for their work. At the time of submission to POCUS Journal the author(s) grant the journal a limited and non revokable right to publish in the Journal under a Creative Commons Attribution 4.0 International License.
DOI: https://doi.org/10.24908/pocusj.v11i02.20213

POCUS in cases of acute scrotum determined to result from pathologies other than TT.

Methods

We performed a retrospective chart review of patients with an acute scrotum who presented to our tertiary-care facility over ten years. The Kaplan Medical Center institutional review board approved this study (0068-24). We identified all children ages 0–18 years who were treated in the PED or any inpatient unit with a diagnosis of TT, orchiopexy, or orchiectomy from June 2015 to June 2025. Our inclusion criterion was an acute scrotum with surgically confirmed or disproved extravaginal TT. We excluded cases of elective orchiopexy and children without a PED visit.

We reviewed hospital charts to extract details of PED presentation, POCUS and RADUS results, and surgical outcome. We defined weekend presentation as a visit from 08:00 Friday to 08:00 Sunday. We defined atypical presentation of TT as presentation solely with abdominal pain without a report of testicular pain, normal cremasteric reflex, or mild pain with a visual analog score (VAS) less than 7. We defined LOS as the time from PED registration to the initiation of anesthesia.

Pediatric residents work independently from 23:00 to the morning. Both fellows and residents receive POCUS lectures several times annually and hands-on training from pediatric emergency medicine attendings. If they are working independently, pediatric residents are required to confirm their sonographic examination with RADUS. Urologists who performed POCUS did not receive dedicated POCUS training. The sonographic diagnosis of TT was based on the absence or significant asymmetry of colour and power Doppler flow within the affected testis, heterogeneous echotexture, or a coiled spermatic cord. All POCUS examinations throughout the study period were performed using the same ultrasound platform (Zonare z.1, Zonare Medical Systems, Mountain View, CA) with a high-frequency linear array transducer (5–14 MHz). RADUS examinations were performed by the radiology department using a GE Logiq S8 platform (GE HealthCare, Chicago, IL) with a 9 L high-frequency linear array transducer.

We reported prevalence as percentages, and reported categorical variables, nominal variables, and continuous variables as medians and IQR. Continuous variables between the various study groups were tested for normality by the Shapiro-Wilk test, and when the distribution was abnormal, we performed non-parametric tests. We performed the Kruskal-Wallis test to compare three or more groups, and the Wilcoxon rank sum test to compare two groups. We analyzed categorical and nominal variables by Pearson's chi-square (χ^2) test or Fisher's exact test. Results were considered significant when the p-value was less than 0.05.

Results

We reviewed a total of 158 charts. Of these 158 charts, we excluded 10 cases from the analysis since orchiopexy was unrelated to acute scrotum (e.g., elective procedures due to a history suggestive of intermittent torsion-detorsion, or evaluation of other pathologies). We excluded an additional three children before chart review: a 10-year-old with decreased flow on RADUS on the symptomatic testis who left against medical advice, a one -month-old with ischemic testis as a result of an incarcerated hernia without torsion as confirmed during surgical examination, and a child who was successfully detorsed by the first author in the PED due to a delay in surgical care. Thus, we included a total of 145 children with acute scrotum leading to surgical exploration and orchiopexy for analysis.

Testicular torsion

TT was confirmed on surgical examination in 121 cases. The median age of children with torsion was 14 years (IQR, 2.2 years) (Tables 1 and 2). Most cases were left-sided (70, 58%). Early presentation within 6 hours of symptom onset occurred in 83 cases (69%), while presentation within 12 hours occurred in 12 cases (11.6%), and late presentation (> 12 hours and < 24 hours) in 12 cases (9.9%). Eleven cases (9%) had a normal cremasteric reflex. In 101 cases, the operative note recorded the degree of torsion. Degree of torsion was less than 180 degrees in 6 cases (6%), 180–360 degrees in 24 cases (24%), 360–720 degrees in 44 cases (44%), and greater than 720 degrees in 27 cases (27%). The median LOS was 99 minutes (IQR 59 minutes). The median VAS was 7 (IQR 4.5).

Thirteen children (11%) had orchiectomy. There was no significant association between orchiectomy and any of the data collected.

Over the study period, POCUS became more frequent, while RADUS became less frequent (Figures 1 and 2). In fact, from June 2023 to June 2025, RADUS diagnosed only two cases of TT (Figure 1). Analysis of the longitudinal adoption curve showed that from June 2015 to June 2020, POCUS was performed in only 13.0% of cases. In contrast, from June 2020 to June 2025, POCUS became the primary imaging modality, utilized in 79.1% of cases. The median LOS during the earlier five-year period (when RADUS predominated) was 99 minutes (IQR 60 minutes) compared with 89 minutes (IQR 54 minutes) during the later period ($p = 0.323$).

While overall LOS did not shift significantly by era, modality-specific comparisons revealed significant differences. LOS with RADUS alone was 108 minutes

(IQR 22 minutes), whereas LOS with POCUS alone was 81 minutes (IQR 47 minutes). In cases where POCUS required RADUS confirmation, the median LOS was longer at 199 minutes (IQR 82 minutes) ($p < 0.05$).

Among the 60 cases of surgically confirmed TT in which POCUS was performed, POCUS correctly identified torsion in 57 cases, yielding a sensitivity of 94% ($p < 0.001$). There were no significant differences in clinical presentation characteristics between patients assessed with POCUS alone and those assessed with RADUS alone. Over the study period, PED POCUS missed two cases of TT, which were subsequently diagnosed correctly on RADUS. Neither presented atypically. Urology POCUS missed one case of TT that presented atypically. Notably, in 25 cases of TT (46%), RADUS noted intratesticular blood flow ($p < 0.05$).

The first instance of missed torsion on PED POCUS was performed by an attending in 2018 (180-degree twist), and the second by a fellow in 2022 (no twist on surgical examination but noted to be recently detorsed by venous congestion and a dusky testis). RADUS diagnosed both cases, and neither had an orchiectomy. The case missed by a urology trainee described localized heterogenous echotexture and increased blood flow. However, TT was not included in the differential diagnosis as documented. RADUS diagnosed torsion-detorsion of the spermatic cord, and he was found intraoperatively to have a 180-degree TT.

Table 1. Patient demographics. Demographic characteristics, imaging pathway, length of stay, and POCUS operator for children undergoing scrotal exploration, stratified by surgically confirmed testicular torsion (N=121) versus exploration without confirmed torsion (N=24). Values are n (%) except median age and length of stay, which are reported as medians. Percentages are calculated within each cohort. Length-of-stay subcategories report the median for each imaging pathway. Percentages under POCUS performer are calculated among cases in which POCUS was performed (60 in the torsion cohort, 11 in the no-torsion cohort).

	Torsion (N=121)	No Torsion (N=24)
Median age (years)	14	12
Affected side		
Right	51 (42.1%)	12 (50.0%)
Left	70 (57.9%)	12 (50.0%)
Orchiectomy	13 (10.7%)	—
Imaging modality		
POCUS alone	48 (39.7%)	7 (29.2%)
POCUS before RADUS	12 (9.9%)	4 (16.7%)
RADUS alone	43 (35.5%)	10 (41.7%)
No imaging	18 (14.9%)	3 (12.5%)
Length of stay		
Median LOS (minutes)	99	129
LOS with POCUS alone (minutes)	81	95
LOS without POCUS (minutes)	108	165
LOS with POCUS and RADUS (minutes)	199	213
POCUS performer		
Resident POCUS	10 (16.7%)	1 (9.1%)
Fellow POCUS	24 (40.0%)	1 (9.1%)
Attending POCUS	15 (25.0%)	6 (54.5%)
Urology POCUS	11 (18.3%)	1 (9.1%)
Not recorded	—	2 (18.2%)

POCUS, point-of-care ultrasound; RADUS, radiology department ultrasound; LOS, length of stay.

Children with atypical presentation of TT were comparable in age to those with typical presentation (mean 12.9 vs. 13.3 years, p = 0.091). The time from symptom onset to presentation was also similar, with 71% of children with typical presentation and 60% of those with atypical presentation arriving within six hours (p = 0.205). Vomiting occurred in 30% of the typical group and 26% of the atypical group (p = 0.607).

PED LOS differed significantly between atypical and typical TT. Median LOS was longer in children with atypical presentation (107 minutes [IQR 76–179]) compared with those with typical presentation (94 minutes [IQR 65–120]) (p = 0.019). When stratified by POCUS use, LOS among children with atypical presentation was shorter in children receiving POCUS than in children who did not receive POCUS (101 minutes with POCUS vs. 119 minutes without, p = 0.654). In contrast, among children with typical presentation, LOS tended to be shorter when the patient received POCUS (83 vs. 99 minutes), without statistical significance (p = 0.096).

Acute scrotum due to other pathologies

Twenty-four children underwent scrotal exploration without TT (Tables 1 and 2). The median age was 12.2 years (IQR 5.2 years). The median LOS was 128.5 minutes (IQR 100 minutes). The median VAS was 4 (IQR 4). On surgical examination, eight children were found to have a torsed appendix testis. Two children had epididymitis. One had torsion of the appendix epididymis.

Of the 24 children without TT, 15 (62.5%) presented atypically. Children in this cohort were more likely to be examined with POCUS than RADUS if they presented with abdominal pain (57% vs. 10%, p < 0.05). However, children who met criteria for atypical presentation were more likely to be examined by RADUS than POCUS (90% vs. 27%, p < 0.05).

Overall, 21 of 24 children (87.5%) had at least one imaging study suggesting TT. POCUS was performed in 11 cases (7 POCUS alone and 4 who received both modalities) and was interpreted as consistent with TT in 9 (81.8%). RADUS was performed in 14 cases (10 RADUS alone and 4 who received both modalities) and was interpreted as compatible with TT in 8 (57.1%). No statistically significant difference was identified between modalities in this cohort. However, as our dataset was limited to patients who underwent surgical exploration, true negative cases — children evaluated and correctly discharged without surgery — were absent by design. Accordingly, a formal false-positive rate could not be derived for either modality, and no conclusion regarding their relative false-positive rates could be drawn from

Table 2. Patient presentations. Clinical presentation of children undergoing scrotal exploration, stratified by surgically confirmed testicular torsion (N=121) versus exploration without confirmed torsion (N=24), grouped by time to presentation, presenting symptoms, and time of presentation. Values are n (%), with percentages calculated within each cohort.

	Torsion (N=121)	No Torsion (N=24)
Time to presentation		
Presenting within 6 hours	83 (68.6%)	14 (58.3%)
Presenting within 12 hours	14 (11.6%)	1 (4.2%)
Presenting within 24 hours	12 (9.9%)	5 (20.8%)
Unclear length of illness	12 (9.9%)	4 (16.7%)
Presenting symptoms		
Presenting with vomiting	39 (32.2%)	3 (12.5%)
Presenting with abdominal pain	35 (28.9%)	7 (29.2%)
Presenting only with abdominal pain	8 (6.6%)	1 (4.2%)
Presenting with intact cremasteric reflex	11 (9.1%)	5 (20.8%)
VAS 6 or less	24 (19.8%)	11 (45.8%)
Atypical presentation	37 (30.6%)	15 (62.5%)
Time of presentation		
Weekend presentation	39 (32.2%)	2 (8.3%)
Morning shift	52 (43.0%)	10 (41.7%)
Evening shift	42 (34.7%)	8 (33.3%)
Overnight	27 (22.3%)	6 (25.0%)

VAS, visual analogue (pain) score; POCUS, point-of-care ultrasound; RADUS, radiology department ultrasound.

these data.

LOS with POCUS in this cohort was 95 minutes (IQR 62 minutes) vs. 164.5 minutes (IQR 71 minutes) for RADUS. LOS with POCUS then requiring RADUS confirmation was 213 minutes (IQR 113 minutes) ($p < 0.05$).

Only one child had a false-positive diagnosis based on pediatric resident POCUS. In that case, there was no RADUS, but the attending urologist felt that physical examination warranted exploration, which revealed a torsed appendix testis.

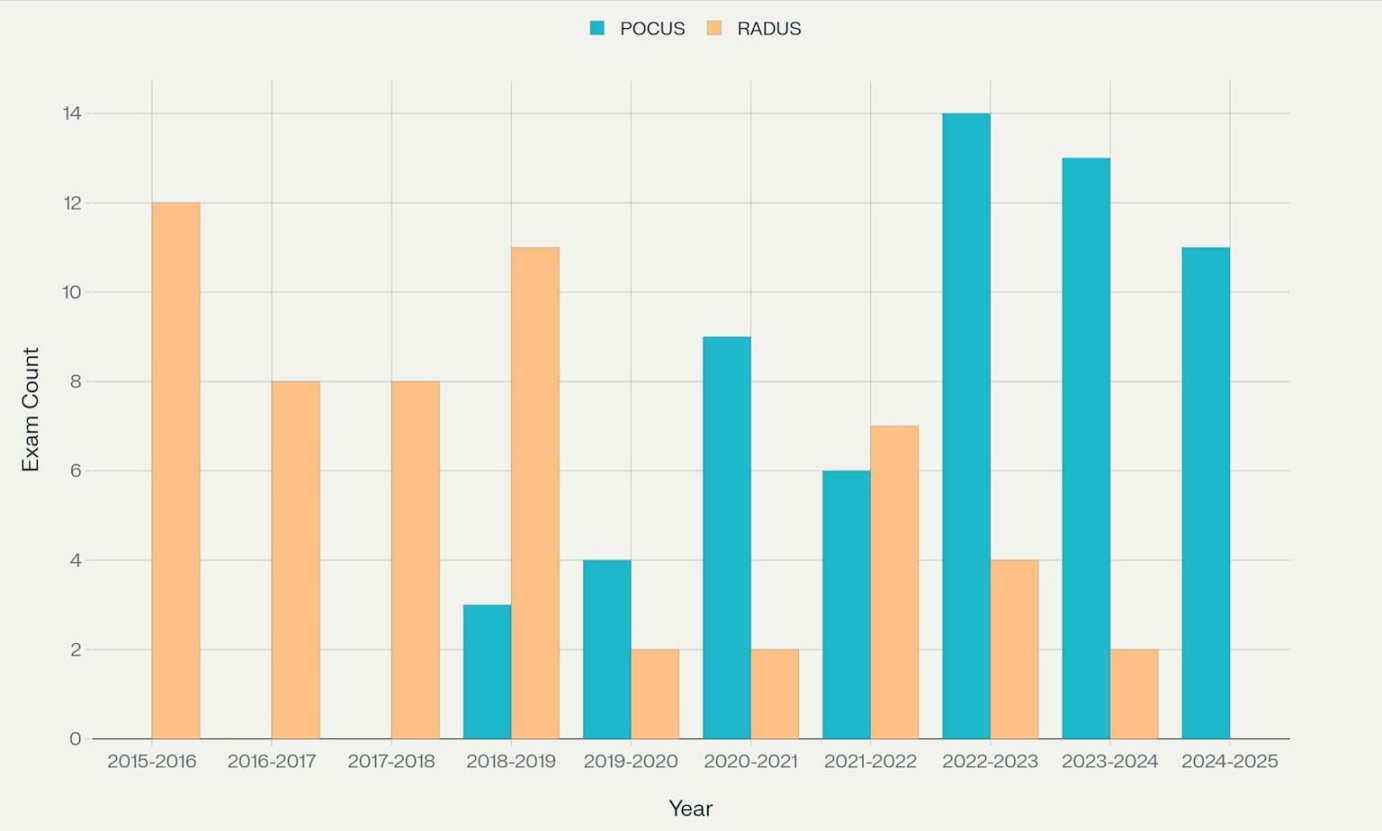


Figure 1. Frequency of point of care ultrasound (POCUS) and radiology-performed ultrasound (RADUS) examinations for acute scrotum over the study period (June 2015 to June 2025).

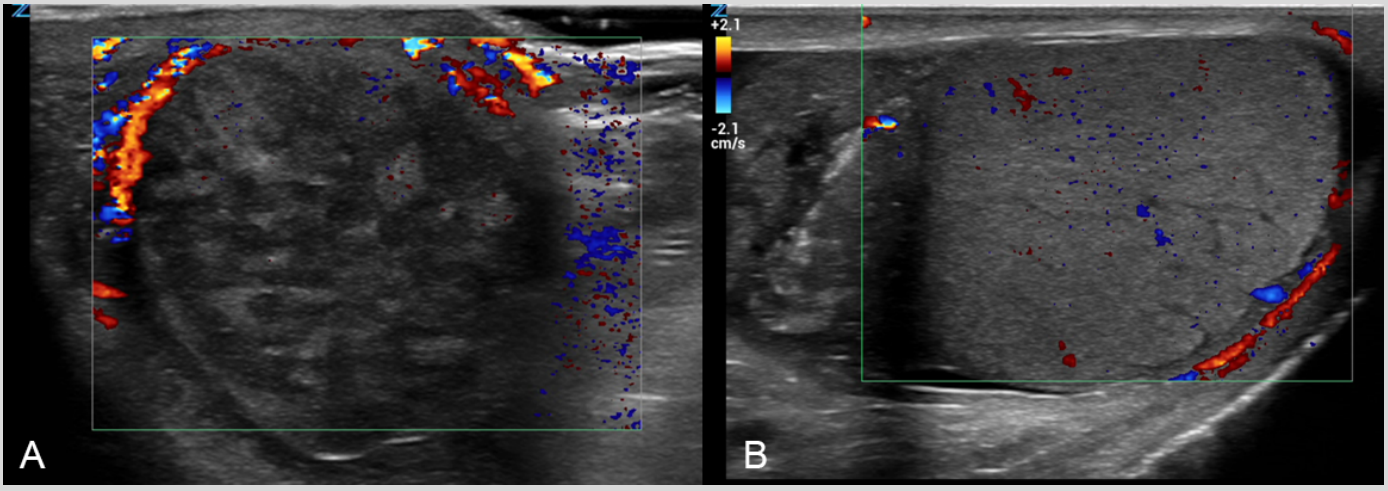


Figure 2. A) Point of care ultrasound (POCUS) examination of late-stage testicular torsion (TT) acquired independently by a first-year pediatric emergency medicine fellow in the middle of the study period. B) POCUS examination of TT demonstrating scant blood flow and heterogenous echogenicity. The image was acquired by a pediatric resident toward the end of the study period.

Discussion

TT is a time-sensitive urologic emergency requiring rapid diagnosis and intervention to maximize testicular salvage. The growing use of POCUS by pediatric emergency physicians has demonstrated potential to expedite diagnosis and reduce treatment delays. Prior studies support its diagnostic accuracy, efficiency, and operational impact. However, our study was unique in several ways. First, we developed the largest single-center series with surgical confirmation in all cases. Second, we were the first to specifically analyze POCUS performance in atypical presentations of TT, which comprise nearly one-third of cases and represent a diagnostically challenging subgroup. Third, we included cases without confirmed TT because the possibility of interval spontaneous detorsion between imaging and surgical exploration could not be excluded. Fourth, we demonstrated that accurate POCUS can be performed safely by multiple provider levels (residents, fellows, attendings, and urologists). Finally, our 10-year time horizon captured the natural adoption curve of POCUS, showing the transition from RADUS-dominant to POCUS-dominant practice (Figure 1). Our data demonstrated that POCUS confirmed most TT cases either alone or in conjunction with RADUS. While this trend is evident in our center, similar shifts are occurring elsewhere, highlighting the need to further validate the diagnostic accuracy, limitations, and applicability of POCUS.

Importantly, our findings revealed that 31% of TT cases presented atypically. The accessibility and ease of use of POCUS may facilitate timely, cost-effective screening in such cases. Our study showed that PED POCUS is capable of accurately diagnosing both typical and atypical presentations of TT and was not associated with a statistically significantly higher rate of positive imaging findings compared to RADUS among patients explored without confirmed TT. However, the limited size of this subgroup precluded definitive conclusions.

Our results aligned with previous literature. Park et al. reported a sensitivity of 94.7% and a negative predictive value of 99.6% for POCUS [13]; Mori et al. found a sensitivity of 98.4% and a specificity of 97.2% [1]; and Friedman et al. demonstrated a specificity of 99.1% with full interobserver agreement [12]. Another retrospective study of 23 cases further confirmed all POCUS-diagnosed TT intraoperatively or required manual detorsion, suggesting a high true-positive rate [14]. However, that study did not provide sensitivity/specificity calculations [14].

POCUS also demonstrated time efficiency, with reduced PED LOS and time to surgery compared to RADUS. These findings were consistent with prior studies. One reported a median time to surgery of 121 vs. 184 minutes ($p = 0.036$) and a 77-minute reduction in PED LOS; another found the median time to POCUS was 23 minutes vs. 61 minutes for RADUS ($p < .001$), with a corresponding emergency department LOS of 93 vs. 170 minutes ($P < .001$) [13,14]. One reported a median time to surgery of 121 vs. 184 minutes ($p = 0.036$) and a 77-minute reduction in PED LOS; another found median time to POCUS was 23 minutes vs. 61 minutes for RADUS ($p < .001$), with a corresponding ED LOS of 93 vs. 170 minutes ($p < .001$) [3,14].

Although atypical presentation was associated with significantly longer overall LOS compared to typical presentation (107 vs. 94 minutes, $p = 0.019$), stratification by POCUS use yielded subgroups too small to detect a significant effect, and neither the POCUS nor the non-POCUS subgroup reached significance ($p = 0.654$ and $p = 0.096$, respectively). These subgroup analyses should therefore be interpreted as exploratory and hypothesis-generating. Adequately powered prospective studies will be required to determine whether atypicality and imaging modality interact to influence time to surgical intervention.

There is limited literature assessing POCUS performance for acute scrotum based on provider training level or time of use (e.g., nights vs. weekends). A recent and similar study to ours demonstrated that POCUS significantly decreased time to urology consultation and time to surgery [15]. However, that study included half the number of children as in our study, and only seven cases went to surgery based on POCUS alone. Further exploration of missed TT cases—especially regarding operator experience, patient age, or clinical complexity—is warranted. While POCUS shows promise, clinicians must remain cautious. TT may occur even in the presence of preserved intratesticular blood flow, necessitating assessment of additional sonographic signs such as the whirlpool sign, asymmetry, and echotexture changes [16–18]. In equivocal cases, surgical exploration remains essential.

Given the potential role of POCUS in PEDs and remote or low-resource settings, further research is needed to evaluate its performance relative to RADUS and surgical exploration. Future studies should continue assessing outcomes based on provider experience, diagnostic timing, surgical delays, testicular salvage rates, image quality, and patient satisfaction.

Limitations

Extrapolation of data is limited as this was a single-center study. We limited our study to children who underwent surgery for suspected TT and cannot comment on children examined with PED POCUS who may have suffered missed torsion. We are unaware of any missed presentations that subsequently arrived at a different

facility. As children with acute scrotum who were correctly identified as not having TT (true negatives) were not captured in our data, specificity and AUC could not be calculated, and we cannot present the test characteristics of POCUS for testicular pain. The availability of RADUS at any time of day may limit the generalizability of our data. Moreover, since the utilization of POCUS in the evaluation of TT has increased substantially over the past decade, earlier data may not accurately represent its current diagnostic performance. POCUS examinations performed during the study period were performed by physicians with varying levels of experience, so training heterogeneity is an inherent limitation of our study.

Conclusion

PED POCUS for TT is accurate, even when used by pediatric trainees and when utilized in cases with atypical presentation. POCUS reduces time from presentation to surgical detorsion. No statistically significant difference in the rate of positive imaging findings between POCUS and RADUS was identified in the non-TT surgical cohort. Since 'time is testicle,' there should be a low threshold to credential this modality for routine use in the PED.

Acknowledgements

We thank our statistician, Merav Greenstein, for her dedicated work on this project.

Ethics Statement

Ethical approval for this study was obtained from the Kaplan Medical Center Institutional Review Board (approval number 0146-23).

Disclosure Statement

The authors declare no conflict of interest.

Funding

The authors received no funding and have no financial relationships relevant to this article.

Author Contributions

ES: data curation; formal analysis; writing – review & editing. AN: formal analysis; writing – original draft; visualization. LA: formal analysis; writing – original draft; cisualization.

References

1. Mori T, Ihara T, Nomura O. Diagnostic accuracy of point-of-care ultrasound for paediatric testicular torsion: a systematic review and meta-analysis. Emerg Med J. 2023;40(2):140-146. doi: 10.1136/emermed-2021-212281

2. Howe AS, Vasudevan V, Kongnyuy M, Rychik K, Thomas LA, Matuskova M, Friedman SC, Gitlin JS, Reda EF, Palmer LS. Degree of twisting and duration of symptoms are prognostic factors of testis salvage during episodes of testicular torsion. Transl Androl Urol. 2017;6 (6):1159-1166. doi: 10.21037/tau.2017.09.10

3. Mellick LB, Sinex JE, Gibson RW, Mears K. A Systematic Review of Testicle Survival Time After a Torsion Event. Pediatr Emerg Care. 2019;35(12):821-825. doi: 10.1097/pec.0000000000001287

4. Ramachandra P, Palazzi KL, Holmes NM, Marietti S. Factors influencing rate of testicular salvage in acute testicular torsion at a tertiary pediatric center. West J Emerg Med. 2015;16(1):190-4. doi: 10.5811/westjem.2014.11.22495

5. Kapp A, Troxler D, Prüfer F, Holland-Cunz S, Frech M, Gros SJ. Testicular Torsion in the Absence of Severe Pain: Considerations for the Pediatric Surgeon. Children (Basel) 2021;8(6). doi: 10.3390/children8060429.

6. Moran GW, Wang CN, Chung R, Movassaghi M, Carpenter CP, Finkelstein JB. Atypical Presentation Delays Treatment of Pediatric Testicular Torsion. Pediatr Emerg Care. 2024;40(4):255-260. doi: 10.1097/pec.0000000000002969

7. Goetz J, Roewe R, Doolittle J, Roth E, Groth T, Mesrobian HG, Rein LE, Szabo A, Kryger J. A comparison of clinical outcomes of acute testicular torsion between prepubertal and postpubertal males. J Pediatr Urol. 2019;15(6):610-616. doi: 10.1016/j.jpurol.2019.07.020

8. Sheth KR, Keays M, Grimsby GM, Granberg CF, Menon VS, DaJusta DG, Ostrov L, Hill M, Sanchez E, Kuppermann D, Harrison CB, Jacobs MA, Huang R, Burgu B, Hennes H, Schlomer BJ, Baker LA. Diagnosing Testicular Torsion before Urological Consultation and Imaging: Validation of the TWIST Score. J Urol. 2016;195(6):1870-6. doi: 10.1016/j.juro.2016.01.101

9. Qin KR, Qu LG. Diagnosing with a TWIST: Systematic Review and Meta-Analysis of a Testicular Torsion Risk Score. J Urol. 2022;208 (1):62-70. doi: 10.1097/ju.0000000000002496

10. Chinta SS, Gray MP, Kopetsky M, Baumer-Mouradian SH, Drendel AL, Roth E, Ferguson CC, Nimmer M, Boyd K, Brousseau DC. Quality Improvement Project to Improve the Timeliness of Care for Children With Testicular Torsion in the Emergency Department. Pediatr Qual Saf. 2022:18;7(4):e576. doi: 10.1097/pq9.0000000000000576

11. Kalfa N, Veyrac C, Lopez M, Lopez C, Maurel A, Kaselas C, Sibai S, Arena F, Vaos G, Bréaud J, Merrot T, Kalfa D, Khochman I, Mironescu A, Minaev S, Avérous M, Galifer RB. Multicenter assessment of ultrasound of the spermatic cord in children with acute scrotum. J Urol. 2007;177(1):297-301. doi: 10.1016/j.juro.2006.08.128

12. Friedman N, Pancer Z, Savic R, Tseng F, Lee MS, Mclean L, Bagli DJ, Tessaro MO. Accuracy of point-of-care ultrasound by pediatric emergency physicians for testicular torsion. J Pediatr Urol. 2019;15 (6):608.e1-608.e6. doi: 10.1016/j.jpurol.2019.07.003

13. Park JS, Kim D, Chun MK, Choi SJ, Lee JS, Ryu JM, Lee JY. Implementing Point-of-Care Ultrasound for Acute Scrotal Pain in the Pediatric Emergency Department: Screening Testicular Torsion and Patient Flow Analysis. J Ultrasound Med. 2023;42(12):2757-2764. doi: 10.1002/jum.16312

14. Koppel JH, Patt YS, Berant R. Point-of-Care Ultrasound for the Diagnosis of Pediatric Testicular Torsion: A Retrospective Case Series Analysis. Pediatr Emerg Care. 2023;39(8):623-628. doi: 10.1097/pec.0000000000002863

15. Takadera T, Bularan C, Sarathy K, Lee HJ. Assessing Outcomes of Point-of-Care Ultrasound Use in Testicular Torsion in a Pediatric Emergency Department. Pediatr Emerg Care. 2026;1;42(2):e26-e29. doi: 10.1097/PEC.0000000000003505

16. Lee DY, Lee SH, Yoon JA, Kang C, Cho YC, Ahn HJ, Park JS, Ryu S, You Y, Kim SW, Lee JW, Jeong WJ. Detection of Testicular Torsion With Preserved Intratesticular Flow By Point of Care Ultrasound in the Emergency Department: A Case Report. J Emerg Med. 2022;62(4):e88-e90. doi: 10.1016/j.jemermed.2021.11.018

17. Scheier E. Testicular Torsion with Intact Blood Flow: A Point of Care Ultrasound Case-Series. Pocus j. 2024;9(1):55-59. doi: 10.24908/pocus.v9i1.17201

18. Hsu CT, Chiu PW. Successful Outcome of Manual Testicular Detorsion Using Point-of-Care Ultrasound Guidance: A Clinical Experience. Pediatr Emerg Care. 2023;39(10):813-815. doi: 10.1097/pec.0000000000003048



Canadian Society of Echocardiography

CSE Echo Weekend Beyond Borders

CSE 2027
HYBRID ECHO WEEKEND
APRIL 8-10
HOTEL BONAVENTURE
MONTRÉAL, QC

cseweekend.ca

CINQUILL Publishing

UNIVERSITY HOSPITALS KINGSTON FOUNDATION

POCUS Journal is a publication by **CINQUILL**

POCUS Journal is published by CINQUILL Medical Publishers Inc. with support from the Queen's University Library.

CINQUILL
76 Stuart St.,
Kingston, ON, Canada
K7L 2V7