

Journal of Point of Care Ultrasound

# POCUS Journal

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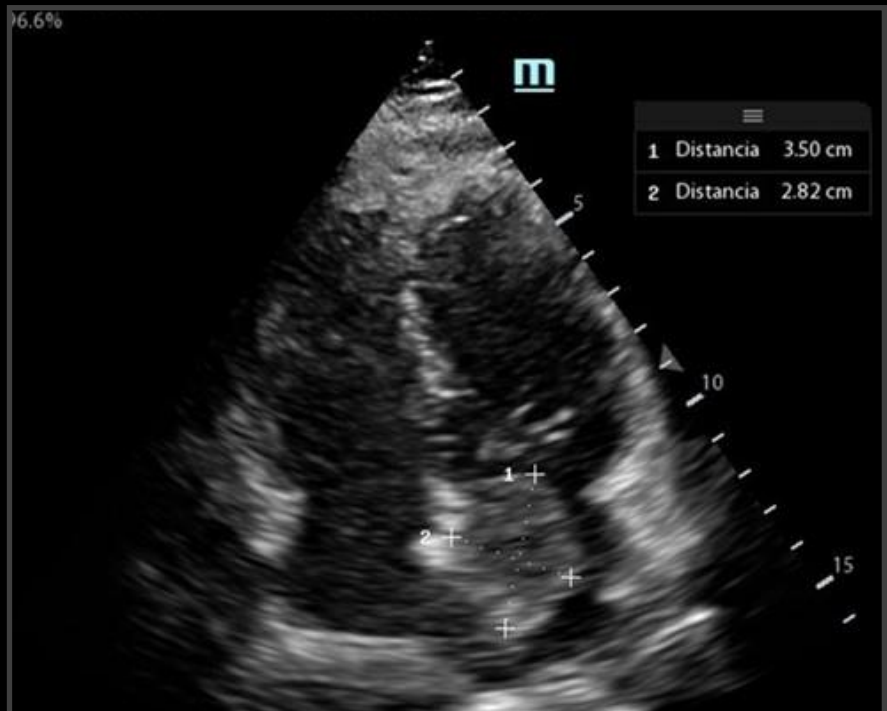
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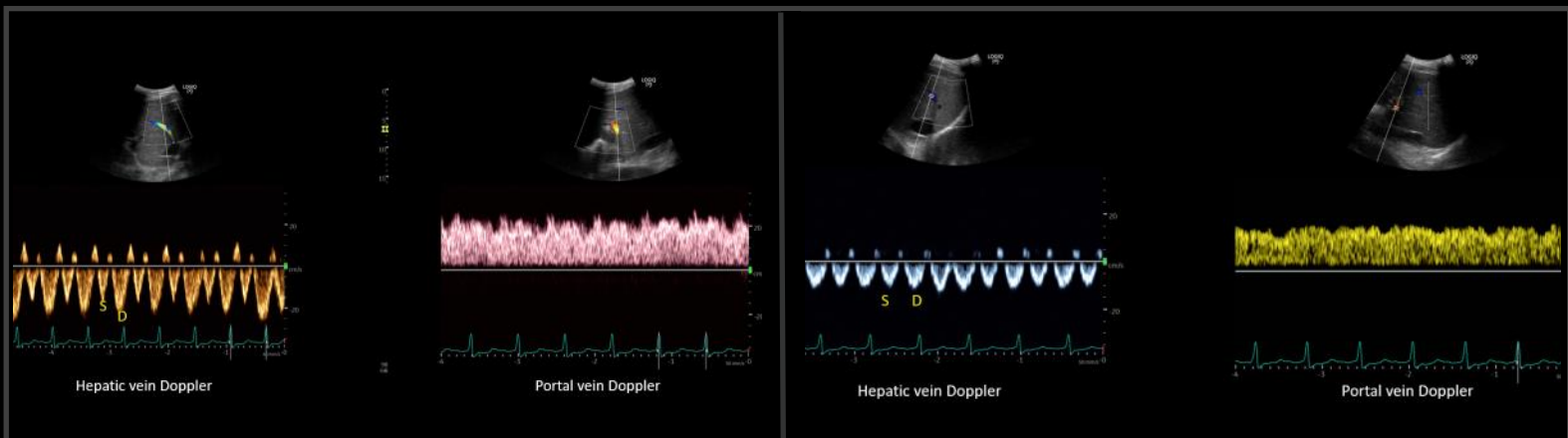
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## Inside the April 2024 Issue

Dear Readers,

We are thrilled to bring you the first issue of the ninth volume of POCUS Journal. Published since 2016, POCUS Journal is the only multi-disciplinary, peer-reviewed, POCUS-focused journal that is free for authors and readers alike. We are grateful for the vision of our founder Dr. Amer Johri and for the support of CINQUILL Medical Publishers, Inc. as we enter our ninth year of publication. POCUS is an ever-changing field as clinicians seek out better and faster solutions for patient care at the bedside. We at POCUS Journal continue to evolve as well. Our editorial board is growing to meet the demands of our high volume and high-quality manuscript submissions. We welcome Dr. Andre Kumar of Stanford University and Dr. Manpreet Malik of Emory University to the Internal Medicine section. We also welcome Dr. Andrea Matho of the University of Southern California to the Pediatrics section. Natalie Kearn joins us from Queen's University as the Social media Editor. If you haven't seen her high-yield infographics on social media I highly encourage you to visit POCUS Journal on X and Instagram for summaries of research articles and other content published in our journal. A journal our size also needs help with statistics, and we are excited that Nicholas Grubic has joined our team from the University

of Toronto as Statistical Editor. We also have a new Editorial Director of Artificial Intelligence, Dr. Bredon Crawford. We are the first journal to feature an AI bot on our website, which is thanks to Dr. Crawford. Its name is "PJ" and you can find it on the bottom right of our website: [www.pocusjournal.com](http://www.pocusjournal.com). And finally, we are excited to have had Kathryn Matsushita join our team as Copyeditor, helping us preserve our standard of high quality publishing as the volume of submitted articles and size of our issues continues to grow.

With the addition of these new members, I also share the bittersweet news that our Managing Editor Braeden Hill will be leaving POCUS Journal to pursue MD/PhD studies at The University of Toronto. Braeden started at POCUS Journal in 2020 as Social Media Editor and his contributions these past few years have been remarkable. We welcome Laura Guzman of Queen's University into the role of Managing Editor.

Every issue I oversee at POCUS Journal strikes me as better than the last, with fascinating cases and important research that answers key questions related to point of care ultrasound. This issue is no exception.

Please find our author guidelines here: <https://pocusjournal.com/author-guidelines/>

Sincerely,

Benjamin T. Galen, MD

Department of Medicine, Albert Einstein College of Medicine and Montefiore Medical Center, Bronx, NY

Editor-In-Chief , POCUS Journal



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

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DOI: <https://doi.org/10.24908/pocus.v9i1.17638>

# Pediatric Emergency Medicine Ultrasound Fellowship Programs

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## Letter

Point of care ultrasound (POCUS) has undergone important growth in the field of Pediatric Emergency Medicine (PEM) in the last 14 years and is recognized as a critical diagnostic tool in the care of ill and injured children. The first PEM POCUS fellowship was established in 2010. Now, there are currently 30 ultrasound fellowships that offer training to PEM physicians. In 2014, 46 PEM POCUS leaders established the P2 (PEM POCUS) Network ([www.P2network.org](http://www.P2network.org)). This serves as a platform for sharing expertise, building research collaborations, and offering mentorship in the use of POCUS in PEM. In 2019, a multinational group of experts in PEM POCUS published the first consensus guidelines for prioritizing core applications of POCUS, which are fundamental to PEM fellowship training [1]. In 2022, the international research priorities for PEM POCUS were published [2]. In the same year, the development of a consensus-based definition of focused assessment with sonography for trauma (FAST) in children was established [3].

Since the first publication of pediatric emergency medicine ultrasound programs in 2021 [4], peer-reviewed educational resources have continued to expand through the P2 Network ([www.P2network.org](http://www.P2network.org)). These include a narrated core content lecture series incorporating the 2019 consensus POCUS applications, a narrated lecture series by pediatric POCUS experts covering advanced topics, and recordings from the Pediatric Emergency POCUS Educational Collaborative (PEPEC) presentations by pediatric POCUS leaders across the globe. The P2Network also collaborates with the World Interactive Network Focused On Critical UltraSound (WINFOCUS) to provide pediatric POCUS educational content, and is developing an online training platform. The project vision is to provide a globally accessible

platform, translated into multiple languages, that will enable pediatricians to receive training and certification in pediatric POCUS through interactive and up-to-date teaching methods.

The following listing provides concise and essential information about each of the Pediatric Emergency Medicine Ultrasound fellowships in the United States, Canada, and United Kingdom (Table 1). The list was compiled from the Society of Clinical Ultrasound Fellowships (SCUF) and updated with input from the program leadership. Changes in the status of ultrasound programs as free-standing PEM POCUS programs or joint PEM/EM programs was similarly updated. Additional sources of information include the 2023 National Resident Matching Program, Match Participant List, and the P2Network membership.

We extend a special thanks to the POCUS Journal for agreeing to publish the listing of this important and expanding area in the field of Pediatric Emergency Medicine.

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4. Kharasch S, Cohen S. Pediatric Emergency Medicine Ultrasound Fellowship Programs. *Pediatr Emerg Care*. 2021;37(8):425-426.

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DOI: <https://doi.org/10.24908/pocus.v9i1.17372>

*Table 1. Pediatric Emergency Medicine Ultrasound Fellowship Program Listing for the United States, Canada, and United Kingdom in 2024.*

| Program   | Program Director                           | PD E-mail   | Fellowship Director                       | FD E-mail   | Joint PEM/EM Fellowship | Website                 |
|---|--|---|---|---|-------------------------|-------------------------|
| Baylor College of Medicine/ Texas Children's Hospital, Houston, TX                                      | Kiyetta Alade, MD                          | alade@bmc.edu   | Stephanie Leung, MD                       | pempocushtx@gmail.com                                     | No                      | <a href="#">Website</a> |
| Bellevue Hospital/ NYU Medical Center New York, NY  | Maya Lin, MD                               | maya.lin@nyulangone.org                                   | Maya Lin, MD                              | maya.lin@nyulangone.org                                   | Yes                     | <a href="#">Website</a> |
| Brown University, Hasbro Children's Hospital, Providence, RI  | Erika Constantine, MD                      | erika_constantine@brown.edu                               | Almaz Dessie, MD                          | almaz@brown.edu   | No                      | <a href="#">Website</a> |
| Children's Hospital Los Angeles, Los Angeles, CA  | Marsha Elkhunovich, MD                     | melkhunovich@chla.usc.edu                                 | Dana Sajed, MD                            | dsajed@gmail.com  | Yes                     | <a href="#">Website</a> |
| Children's Hospital of Michigan, Detroit, MI  | Jennifer Noble, MD                         | jnoble@med.wayne.edu                                      | Jennifer Noble, MD                        | jnoble@med.wayne.edu                                      | No                      | <a href="#">Website</a> |
| Children's Hospital of Eastern Ontario, Ottawa, Canada  | Allan Shefrin, MD                          | ashefrin@cheo.on.ca                                       | Kate Fathi, MD                            | kfathi@cheo.on.ca   | No                      | <a href="#">Website</a> |
| Children's Hospital of Philadelphia, Philadelphia, PA   | Aaron Chen, MD                             | chena2@email.chop.edu                                     | Rachel Rempell, MD                        | rempellr@email.chop.edu                                   | No                      | <a href="#">Website</a> |
| Children's Minnesota, Minneapolis, MN   | Valerie Whitcomb, MD                       | valerie.whitcomb@childrensmn.org                          | Valerie Whitcomb, MD                      | valerie.whitcomb@childrensmn.org                          | No                      | <a href="#">Website</a> |
| Children's National Medical Center, Washington, DC  | Rosemary Thomas-Mohtat, MD                 | rthomasm@cnmc.org   | Simone Lawson, MD                         | slawson@childrensnational.org                             | No                      | <a href="#">Website</a> |
| Cohen Children's Medical Center, New Hyde Park, NY  | David Teng, MD                             | dteng@northwell.edu                                       | Matthew Kusulas, MD                       | mkusulas@northwell.edu                                    | No                      | <a href="#">Website</a> |
| Dalhousie University EM, Saint John Regional Hospital, Saint John, NB & IWK Health, Halifax, NS, Canada | David Lewis MBBS<br>Kirstin Weerdenburg MD | david.lewis@dal.ca<br>kirstin.weerdenburg@iwk.nshealth.ca | David Lewis MBBS<br>Kirstin Werdenburg MD | david.lewis@dal.ca<br>kirstin.weerdenburg@iwk.nshealth.ca | Yes                     | <a href="#">Website</a> |

| Program  | Program Director                 | PD E-mail  | Fellowship Director                | FD E-mail   | Joint PEM/EM Fellowship | Website                 |
|--|----------------------------------|--|------------------------------------|---|-------------------------|-------------------------|
| Denver Health, <i>Denver, CO</i>   | Amanda Greene Toney, MD          | amanda.toney@dhha.org                              | Amanda Greene Toney, MD            | amanda.toney@dhha.org                             | No                      | <a href="#">Website</a> |
| Emory University, <i>Atlanta, GA</i>   | Gregg Helland, MD                | gregg.helland@emory.edu                            | E. Liang Liu, MD<br>Lekha Shah, MD | emberlynn.liang.liu@emory.edu<br>lashah@emory.edu | Yes                     | <a href="#">Website</a> |
| Icahn School of Medicine at Mount Sinai-Peds, <i>New York, NY</i>            | Bret Nelson, MD<br>Jim Tsung, MD | bret.nelson@mssm.edu<br>james.tsung@mountsinai.org | Jim Tsung, MD                      | james.tsung@mountsinai.org                        | Yes                     | <a href="#">Website</a> |
| Indiana University - Riley Hospital for Children, <i>Indianapolis, IN</i>    | Benjamin Nti, MD                 | bnti@iu.edu  | Benjamin Nti, MD                   | bnti@iu.edu                                       | No                      | <a href="#">Website</a> |
| John's Hopkins Children's Center, <i>Baltimore, MD</i>                       | J. Kate Deanehan, MD             | jdeaneh1@jh.edu                                    | J. Kate Deanehan, MD               | jdeaneh1@jh.edu                                   | No                      | <a href="#">Website</a> |
| Maimonides Medical Center, <i>Brooklyn, NY</i>                               | Lawrence Haines, MD, MPH         | lhaines@maimonidesmed.org                          | Leily Naraghi, MD                  | Inaraghi@maimonidesmed.org                        | Yes                     | <a href="#">Website</a> |
| Medical University of South Carolina, <i>Charleston, SC</i>                  | Ryan M. Barnes, DO               | barnesry@musc.edu                                  | Aalap Shah, MD                     | shahaa@musc.edu                                   | Yes                     | <a href="#">Website</a> |
| Morgan Stanley Children's Hospital, Columbia University, <i>New York, NY</i> | Lorraine Ng, MD                  | ln2136@cumc.columbia.edu                           | Joni Rabiner, MD                   | jer2212@cumc.columbia.edu                         | No                      | <a href="#">Website</a> |
| Nationwide Children's Hospital/Ohio State University, <i>Columbus, OH</i>    | Creagh Boulger, MD               | creagh.boulger@osumc.edu                           | Delia Gold, MD                     | delia.gold@nationwidechildrens.org                | No                      | <a href="#">Website</a> |
| New York Presbyterian Brooklyn Methodist Hospital, <i>Brooklyn, NY</i>       | Sharon Yellin, MD                | shy9015@nyp.org                                    | Raymond Chen, DO                   | rmc9019@nyp.org                                   | Yes                     | <a href="#">Website</a> |
| Norton Children's Hospital, <i>Louisville, KY</i>                            | Fred Warkentine, MD              | fred.warkentine@louisville.edu                     | Rebecca Starr, DO                  | rebecca.starr@louisville.edu                      | No                      | <a href="#">Website</a> |
| Sunderland Royal Hospital, <i>Sunderland, United Kingdom</i>                 | David McCreary, MBBS             | david.mccreary2@nhs.net                            | David McCreary, MBBS               | david.mccreary2@nhs.net                           | No                      | <a href="#">Website</a> |



| Program  | Program Director                | PD E-mail                         | Fellowship Director                                 | FD E-mail  | Joint PEM/EM Fellowship | Website                 |
|--|---------------------------------|-----------------------------------|---|--|-------------------------|-------------------------|
| The Hospital for Sick Children, <i>Toronto, ON, Canada</i>                 | Gregory Harvey, MD              | gregory.harvey@sickkids.ca        | Maya Capua, MD                                      | c/o: kelly.sobie@sickkids.ca   | No                      | <a href="#">Website</a> |
| UCSD/Rady Children's Hospital, <i>San Diego, CA</i>                        | Atim Ekpenyong MD               | auya@ucsd.edu                     | Mylinh Nguyen MD                                    | mnguyen12@rchsd.org  | No                      | <a href="#">Website</a> |
| University of Arkansas, <i>Little Rock, AR</i>                             | Gregory Snead, MD               | grsnead@uams.edu                  | Jason Arthur, MD                                    | jarthur@uams.edu   | Yes                     | <a href="#">Website</a> |
| UCSF Benioff Children's Hospital, <i>San Francisco, CA</i>                 | Aaron Kornblith, MD             | aaron.kornblith@ucsf.edu          | Margaret Lin-Martore, MD<br><br>Aaron Kornblith, MD | margaret.lin-martore@ucsf.edu<br><br>aaron.kornblith@ucsf.edu            | No                      | <a href="#">Website</a> |
| University of Massachusetts, <i>Worcester, MA</i>                          | Timothy Gleeson, MD             | timothy.gleeson@umassmemorial.org | Robert Lindsay, MD<br><br>Zachary Binder, MD        | robert.lindsay@umassmemorial.org<br><br>zachary.binder@umassmemorial.org | Yes                     | <a href="#">Website</a> |
| University of Michigan C.S. Mott Children's Hospital, <i>Ann Arbor, MI</i> | Nik Theyyuni, MD                | ntheyyu@med.umich.edu             | Nicole Klekowski, MD<br><br>David Haidar, MD        | nklekows@med.umich.edu<br><br>dahaidar@med.umich.edu                     | Yes                     | <a href="#">Website</a> |
| UPMC Children's Hospital of Pittsburgh, <i>Pittsburgh, PA</i>              | Desiree Noel Wagner Neville, MD | desiree.neville@upmc.edu          | Vipin Philip, MD                                    | philipv@upmc.edu   | No                      | <a href="#">Website</a> |
| Yale University, <i>New Haven, CT</i>                                      | Chris Moore, MD                 | Chris.moore@yale.edu              | Antonio Riera, MD                                   | Antonio.riera@yale.edu   | Yes                     | <a href="#">Website</a> |

# Vaginal Bleeding in a Peri-Menopausal Woman

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## Abstract

Point of care ultrasound (POCUS) is a useful modality to initially identify a molar pregnancy. In this case, we describe a 51-year-old perimenopausal woman who presented to the emergency department (ED) with vaginal bleeding. A transvaginal POCUS was performed, revealing findings concerning for a molar pregnancy. These findings led to prompt diagnosis and treatment.

## Presentation

A 51-year-old peri-menopausal woman with no significant past medical history presented to the ED with painless vaginal bleeding for 1 day. Her vital signs were within normal limits. On physical examination, the patient had a minimal amount of blood in the vaginal vault. She had no adnexal tenderness to palpation or active bleeding. A transvaginal POCUS revealed an enlarged uterus with cystic, hypoechoic lesions, prompting suspicions of a molar pregnancy (Figure 1, Video S1). Evaluation of the adnexa on transvaginal ultrasound was unremarkable. This finding prompted the ED provider to obtain a beta-human chorionic gonadotropin level, which returned

greater than 350,000 mIU/mL (< 5 mIU/mL). The patient remained hemodynamically stable and underwent suction curettage by gynecology as well as pathological examination of the uterine contents. The findings showed hydropic villi, and proliferation of cytotrophoblasts and syncytiotrophoblasts. These confirmed a complete molar pregnancy.

## Discussion

A hydatidiform mole, also known as a “molar pregnancy”, is an abnormal pregnancy characterized by placental villi with focal swelling, trophoblastic proliferation, and reduplication of genetic material. Hydatidiform moles are distinguished as either complete or partial moles [1]. A



Figure 1. Transvaginal POCUS. Transverse view of an echogenic, enlarged uterus with cystic lesions (arrows) representing the classic “snowstorm” appearance consistent with a complete hydatidiform mole.

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DOI: <https://doi.org/10.24908/pocusv9i1.16621>

complete mole is paternally derived, where sperm fertilizes an enucleated ovum [2]. Duplication of a haploid sperm results in genotype 46, either XX or XY [2]. In contrast, when sperm fertilizes a normal, nucleated ovum, this results in a partial mole with genotype 69, XXY [1, 2]. Molar pregnancies occur in approximately 0.5-2 pregnancies per 1,000 [2]. The most common presenting symptom is vaginal bleeding [3]. Risk factors for a molar pregnancy include extremes of ages (<21 or >35 years-old), previous history of molar pregnancy, and nulliparity [2]. Generally, molar pregnancies are not viable, and treatment includes molar evacuation [2]. The definitive diagnosis of molar pregnancies is made by histological evaluation, which is not immediately available. Given that approximately 3% of hydatidiform moles progress to choriocarcinoma [2], prompt diagnosis and treatment of a molar pregnancy is imperative.

Ultrasound has been used as an initial screening modality for detection of molar pregnancy given its accessibility, accuracy, and rapid identification of key features consistent with the diagnosis [4]. Transvaginal ultrasound is more commonly used due to the higher frequency of the endocavitary probe compared to the curvilinear probe used for transabdominal examinations, allowing for a higher resolution image. In both POCUS and comprehensive transvaginal ultrasound, the uterus is viewed in both a transverse and sagittal orientation. It is often requested that the patient empty their bladder prior to scanning as when the bladder is full, it may obscure evaluation of the uterus. Abnormal sonographic findings in molar pregnancy include a focal cystic space within the placenta in patients with partial moles, or an enlarged uterus with multiple hypoechoic cystic lesions in patients with complete molar pregnancy. The classic description of complete molar pregnancy on ultrasound is a “snowstorm” appearance of the uterus due to the numerous hypoechoic cystic lesions present. In this case of complete molar pregnancy, the use of transvaginal POCUS led to prompt diagnosis and treatment.

### Disclosures

The authors report no disclosures related to this work.

### Patient Consent

The authors obtained informed consent from the patient. The patient consented to de-identified images, videos, and health information for the purpose of publishing in this scientific journal.

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# Point of Care Ultrasound Identification and Aspiration of a Neck Lymph Node

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## Abstract

The tissue diagnosis and staging of all types of lung cancer is foundational for prognosis and establishing the optimal treatment plan. In order to appropriately stage lung cancer, the highest stage should be established using the 8<sup>th</sup> edition TNM criteria, where tumor size (T), nodal involvement (N), and metastasis (M) are all taken into account. Establishing a tissue diagnosis may involve the use of CT guided biopsy, navigational bronchoscopy, endobronchial biopsy, endobronchial ultrasound, percutaneous lymph node biopsy and/or excisional biopsy of supraclavicular nodes. It is recommended to proceed with the method that is considered least invasive and provides the highest staging. We present a case of recurrent lung adenocarcinoma diagnosed with real time ultrasound-guided fine needle aspiration of a neck lymph node.

## Case Presentation

A 68-year-old man with a history of orthotopic liver transplant maintained on immunosuppression, right upper lobe adenocarcinoma status post chemotherapy and right upper lobectomy eight years prior, and 45-pack-year history of tobacco disorder presented to the clinic for consultation of his chronic cough. As part of his investigation, he underwent a computed tomography (CT) of the chest that was notable for mediastinal lymphadenopathy in the subcarinal and paratracheal regions (Figure 1A and 1B). There was no reported axillary or supraclavicular adenopathy.

He was subsequently referred to pulmonary medicine for endobronchial ultrasound (EBUS) and transbronchial

needle aspiration (TBNA) for both diagnostic and staging purposes. However, his scans were reviewed and notable for an enlarged right-sided supraclavicular lymph node, which was not palpable on exam (Figure 2). A point of care ultrasound (POCUS) assessment of his right supraclavicular region with a linear probe demonstrated the findings in Figure 3 and Videos S1 and S2. Based on the patient's clinical history and findings from the images and videos, we proceeded with ultrasound-guided fine needle aspiration (FNA). This provided a diagnosis of lung cancer and provided staging in a safer and less invasive way than EBUS.

## Discussion

The tissue diagnosis and staging of all types of lung

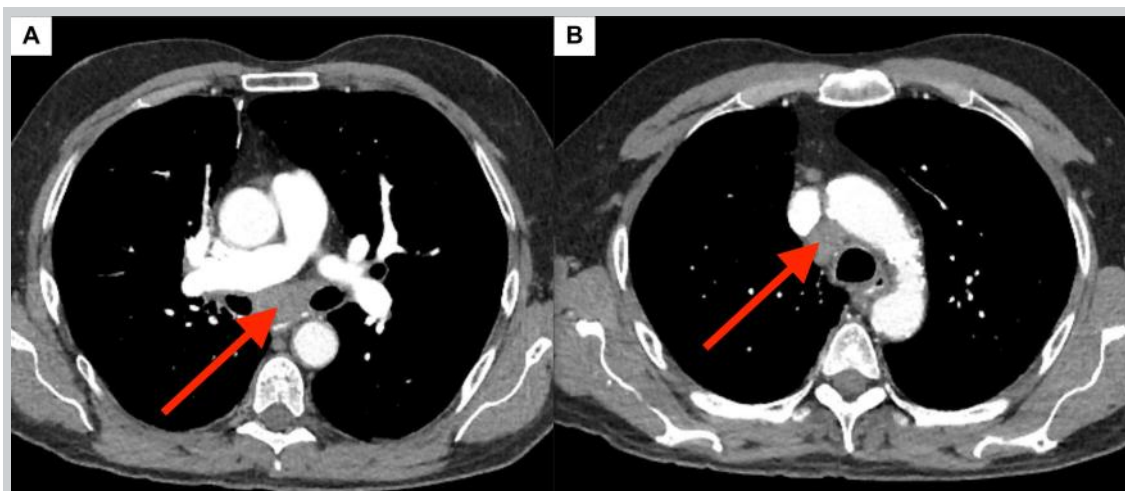


Figure 1. CT scan of the chest with contrast in the mediastinal window and transverse plane showing an enlarged (A) subcarinal and (B) lower right paratracheal lymph node.

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DOI: <https://doi.org/10.24908/pocusv9i1.16761>



Figure 2. CT scan of the chest with contrast in the mediastinal window and coronal plane showing an enlarged right supraclavicular lymph node.

cancer is foundational for prognosis and establishing an optimal treatment plan. In order to appropriately stage lung cancer, the highest stage should be established using the 8th edition TNM criteria where tumor size (T), nodal involvement (N), and metastasis (M) are all taken into account [1]. Current guidelines for non-small cell lung cancer defines N0 disease as no regional lymph node involvement, N1 disease as involvement of ipsilateral peribronchial and/or ipsilateral hilar lymph nodes, N2 disease as involvement of the ipsilateral mediastinal and/or subcarinal lymph nodes, and N3 involvement of any of the following lymph node groups: contralateral mediastinal, contralateral hilar, ipsilateral or contralateral scalene, or supraclavicular nodes [1,2]. In order to establish tissue diagnosis, sampling is needed and can involve the use of CT guided biopsy, navigational bronchoscopy, endobronchial biopsy, EBUS, percutaneous lymph node biopsy, and/or excisional biopsy of supraclavicular nodes. All methods come with their own safety and efficacy profile that include, but are not limited to, pneumothorax, bleeding, infection, bronchospasm, laryngospasm, hypoxemia, hypercarbia, and aspiration [3,4]. These risks are first mediated by proceeding with the method that is considered least invasive and provides the highest staging.

To evaluate the neck region, CT or ultrasound can be used. When evaluating lymph nodes, ultrasonographic characteristics that are more suggestive of malignancy include larger size (>5 mm), rounded shape (as opposed to oval or reniform), irregular borders, and lack of visible hilum [5]. If suspicious nodes are found, further

evaluation is needed through either percutaneous needle aspiration or open surgical biopsy. Factors limiting the use of surgical sampling include the need for an incision, bleeding, infection, potential need for sedation and missing the node of interest. All of these factors can be either reduced or eliminated with the use of percutaneous needle aspiration, which has demonstrated its utility in the literature [6,7]. While needle aspiration may have risk of bleeding because of its close proximity to the large neck vessels, it is exceedingly rare when done by a trained provider [8-10]. In a study by El-Shaarawy and colleagues, a neck ultrasound in subjects with evidence of intrathoracic lymphadenopathy found abnormal neck lymph nodes in more than one third of patients [7]. Additionally, they performed neck lymph node biopsies in eligible patients, which had a diagnostic yield of 92%, similar to previous reports [6,7]. Importantly, tissue sampling can be carried out by pulmonary physicians and avoids more imaging studies, procedures, and potential adverse effects from sedation and anesthesia [11-12].

In our case, we were able to review the suspicious CT and noted the enlarged supraclavicular lymph node that failed to be reported on the formal read. This is a documented blind spot that has been demonstrated by Hassan et al., to miss 18% of cases of abnormally enlarged supraclavicular lymph nodes, with 55% of those being positive for malignancy. A critically important consideration for ensuring proper staging [8,13]. Our initial plan was to pursue EBUS-TBNA to provide tissue sampling and mediastinal staging. However, upon further investigating our patient's concerning CT findings with POCUS, a suspicious 15 mm right supraclavicular lymph

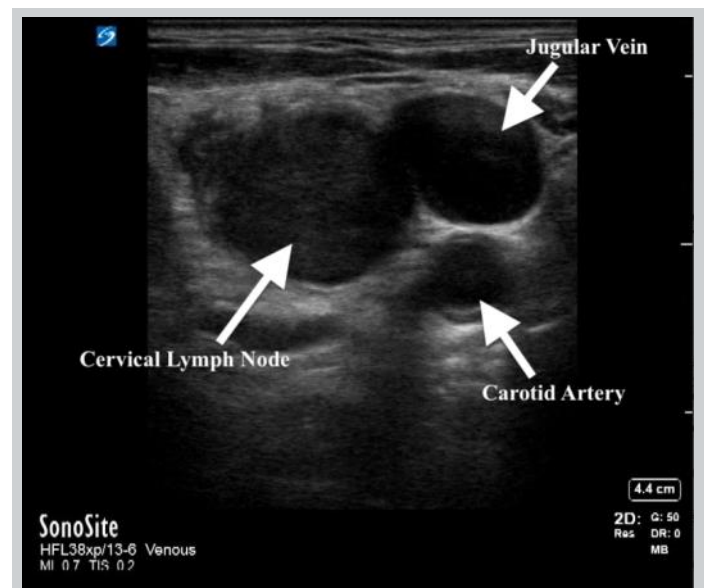


Figure 3. Soft tissue ultrasound image showing an enlarged right supraclavicular lymph node.

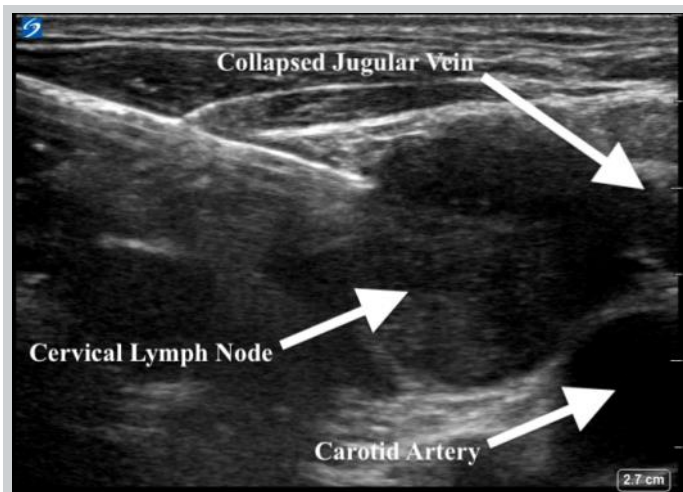


Figure 4. Soft tissue ultrasound image showing an the enlarged right supraclavicular lymph node with the needle visible in its entire length.

node was found. After discussing the risks, benefits, and alternatives, a percutaneous lymph node biopsy was pursued. The results of our lymph node aspiration were consistent with the patient's prior adenocarcinoma of the lung. He was referred to oncology and started on systemic chemotherapy.

Practically, suspicious neck lymph nodes are identified using a linear transducer. Lymph nodes are characterized as echodense structures surrounded by a clearly defined hyperechoic capsule that are not collapsible, may have a fatty central hilum, and do not show evidence of blood flow on color or spectral Doppler [5]. Once location is confirmed, the site is cleaned, a local anesthetic is applied, and if needed, additional sedation mirroring other routine subcutaneous procedures is provided. In our practice, sampling of the identified lymph is done under real-time ultrasound guidance and an in-plane needle approach with 3-5 passes using an 18, 21, or 22 gauge needle and 10 cc syringe assembled in a needle gun (Figure 4, Video S3). This is akin to a version of the traditional view seen with EBUS-TBNA sampling. Each pass is evaluated with rapid on-site examination by the cytopathology team in the procedure room.

## Disclosures

The authors have no conflict of interest to disclose.

## Patient Consent Statement

Written consent was obtained from the patient to publish the details of this case, including images and videos.

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# Hematometra: A Rare Case of Pelvic Pain in Females Identified with Point of Care Ultrasound

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## Abstract

The differential diagnosis for abdominal or pelvic pain in women of child-bearing age that present to the emergency department is broad. A rare cause of abdominal and pelvic pain is hematometra, or a collection of blood products within the uterus. While blood is normally expelled through menses, this process is disrupted in some patients due to congenital or acquired abnormalities. This can lead to progressive uterine distension and pain, which may ultimately require medical or surgical intervention. Hematometra is rare, but is a serious condition that can be diagnosed easily at bedside using point of care ultrasound.

## Case Presentation

An 18-year-old woman with history of unrepaired cervico-vaginal atresia presented to the emergency department (ED) with progressive, diffuse abdominal pain and distension. This patient recently immigrated to the United States and had not yet established gynecologic care. She noted that she had previously been on estrogen therapy to prevent menses but no longer had access to this prescription medication.

On arrival, the patient was distressed due to pain and had a distended and firm lower abdomen that appeared gravid. She had stable vital signs and the remaining physical exam was unremarkable. Her urine pregnancy test was negative and the first imaging performed was a pelvic point of care ultrasound (POCUS) examination by the ED team. The differential diagnosis included hemorrhagic ovarian cyst, ovarian torsion, tubo-ovarian abscess, pelvic-inflammatory disease, urinary retention, and hematometra (collection of blood within the uterine cavity), among other intrabdominal pathology.

A focused assessment for free fluid (FAFF) exam was performed. It was negative for intra-abdominal free fluid, however, it was notable for a distended uterus above the level of the umbilicus that was filled with homogeneous, hypoechoic material – presumed to be blood (Figure 1, 2). The patient was treated with analgesics and gynecology was consulted. She was admitted and ultimately received a pelvic MRI for surgical planning,

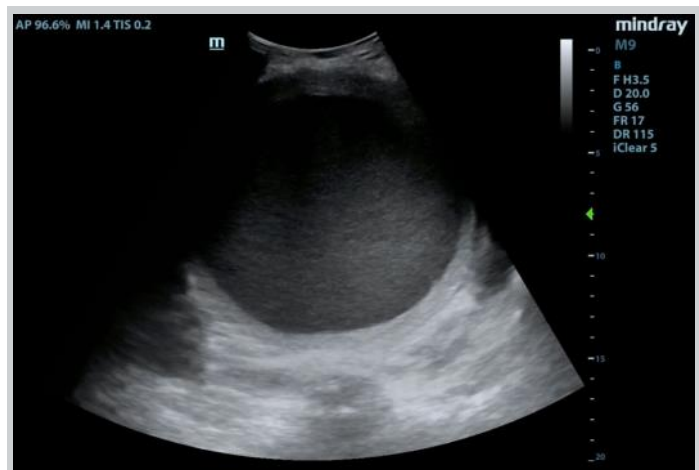


Figure 1. Point of care ultrasound demonstrating an enlarged uterus full of hypoechoic fluid in the transverse plane.

which confirmed the findings of a hematometra (Figure 3, 4). Interventional radiology was consulted and a percutaneous uterine drain was placed, which drained her hematometra and relieved her abdominal distension and pelvic pain. The patient was discharged the next day with plans to schedule outpatient surgery for definitive reconstruction. Notably, no radiologic study with ionizing radiation was required in the work up of this patient by utilizing a POCUS-first strategy.

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DOI: <https://doi.org/10.24908/pocus.v9i1.16988>



Figure 2. Point of care ultrasound demonstrating an enlarged uterus full of hypoechoic fluid in the longitudinal plane.

### *Differential Diagnosis and Imaging Strategy*

While this patient had known cervico-vaginal atresia which brought hematometra to the top of the differential, in a different scenario the diagnosis could be more challenging. Choosing a POCUS-first approach could expedite the gynecologic consult and obviate the need for additional imaging. The treating team chose to perform a FAFF exam which looks specifically for intra-abdominal free fluid; however, because the protocol examines a broad anatomic region, abnormalities other than free fluid may be encountered. POCUS for obstetric or gynecologic pathology would also have been appropriate, which could include transabdominal and transvaginal imaging. Knowledge of hematometra and other pelvic pathologies, as well as the use of POCUS as an imaging modality in their evaluation, is relevant to multiple specialties including pediatrics, pediatric emergency medicine, adult

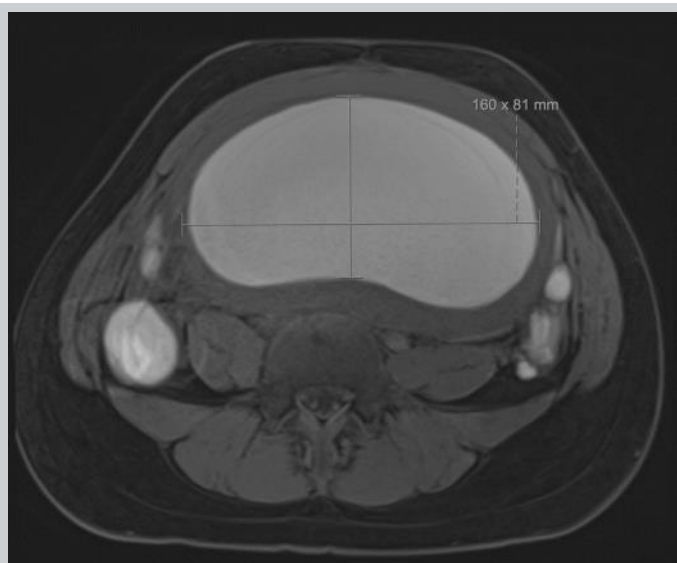


Figure 3. T1 weighted axial MRI image.



Figure 4. T2 weighted sagittal MRI image.

emergency medicine, gynecology, and radiology. Hematometra can be caused by several etiologies that affect multiple age groups, including adolescents with an imperforate hymen and older patients that develop cervical outlet obstructions secondary to tumors, post-surgical scarring, post-radiation complications, or foreign bodies. Hematometra should be on the differential for most women with lower abdominal pain.

It is important to scan intentionally and identify anchoring anatomy so that when pathology is encountered it is recognized. In the pelvis, the bladder is usually a fluid-filled structure. The uterus can be differentiated from the urinary bladder by its relative location to the pubic symphysis and by (on transabdominal imaging) tracking the vaginal stripe to the cervix/lower uterine segment. Usually, the uterus has thick walls and has minimal intrauterine fluid compared to the bladder, which has thinner walls and is filled with anechoic fluid.

### **Conclusion**

In this case we describe a typical physical exam and ultrasound findings in a rare ED case of hematometra. A POCUS-first imaging strategy prevented exposing this woman of child-bearing age to ionizing radiation and expedited care and expert consultation. Additionally, it exposed the vulnerability of patients who do not have access to out-patient care and medications. Knowledge of the condition and sonographic findings is relevant to any physician who cares for women of child-bearing age.

### **Disclosures**

No disclosures

### **Patient Consent**

The patient consented to use of deidentified photos, videos, and recordings for education and research purposes



# VExUS to Guide Ultrafiltration in Hemodialysis: Exploring a Novel Dimension of Point of Care Ultrasound

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## Abstract

Venous Excess Ultrasound (VExUS) is a valuable bedside tool for nephrologists within a multi-organ point of care ultrasound (POCUS) framework. VExUS can address limitations of conventional physical examination in identifying hemodynamic congestion and monitoring treatment efficacy. A 53-year-old man with heart failure and end-stage kidney disease on hemodialysis presented with elevated liver function tests. Despite an unremarkable right upper quadrant ultrasound done by radiology, the review of images by the nephrology team uncovered severe venous congestion, evidenced by a dilated inferior vena cava (IVC) and abnormal hepatic and portal vein flow. Follow-up assessments included VExUS scans and daily ultrafiltration that resulted in a notable 8-liter fluid removal. The dynamic changes in IVC shape and improvement in Doppler waveforms underscored successful decongestion. This case demonstrates the clinical utility of VExUS in guiding therapy for fluid overload in complex patients.

## Introduction

Venous Excess Ultrasound (VExUS) is a novel application of point of care ultrasound (POCUS). It allows for the assessment of systemic venous congestion, which is a function of elevated right atrial pressure and reduced venous compliance [1]. VExUS involves evaluating alterations in Doppler waveforms of hepatic, portal, and intrarenal veins to quantify congestion into three grades, as summarized in Figure 1. Due to the dynamic nature of these waveforms, VExUS is valuable for both diagnosing venous congestion and monitoring the effectiveness of decongestive therapy [2]. Traditional physical examination measures for detecting congestion present various constraints, especially in individuals with heart failure and those undergoing hemodialysis [3, 4]. VExUS, integrated into a multi-organ POCUS strategy, offers an additional tool at the bedside for nephrologists [5]. This case shows where VExUS helped ensure adequate decongestion in a patient on hemodialysis.

## Case Report

A 53 year old man with heart failure with reduced ejection fraction (~37%) secondary to non-ischemic cardiomyopathy and end-stage kidney disease (ESKD) recently initiated on hemodialysis underwent a right upper quadrant ultrasound for elevated liver function tests. Despite a radiology report indicating "normal liver

morphology and hemodynamics," a review of images by the nephrology team revealed severe venous congestion. This was evidenced by a dilated inferior vena cava (IVC) with an approximate anteroposterior diameter of 3 cm, systolic (S-wave) reversal in the hepatic vein flow, and a pulsatile portal vein with some flow reversal (Figure 1).

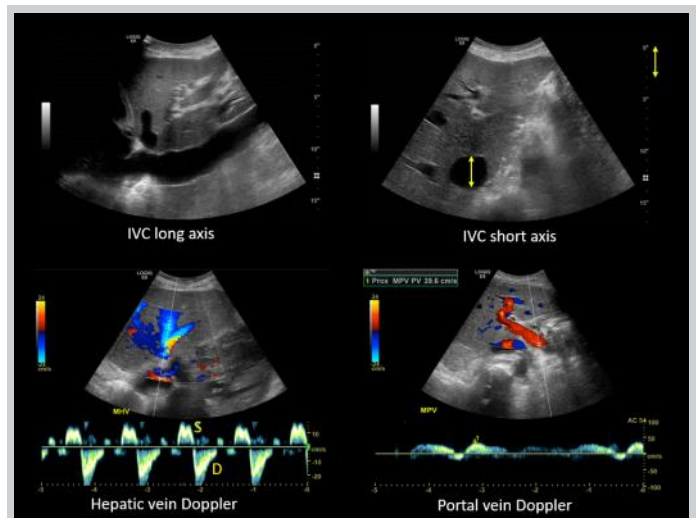


Figure 1. Radiology-performed scan images demonstrating a dilated inferior vena cava (approximately 3 cm), S-wave reversal on hepatic vein Doppler and a pulsatile portal vein (below-the-baseline blebs represent flow reversal).

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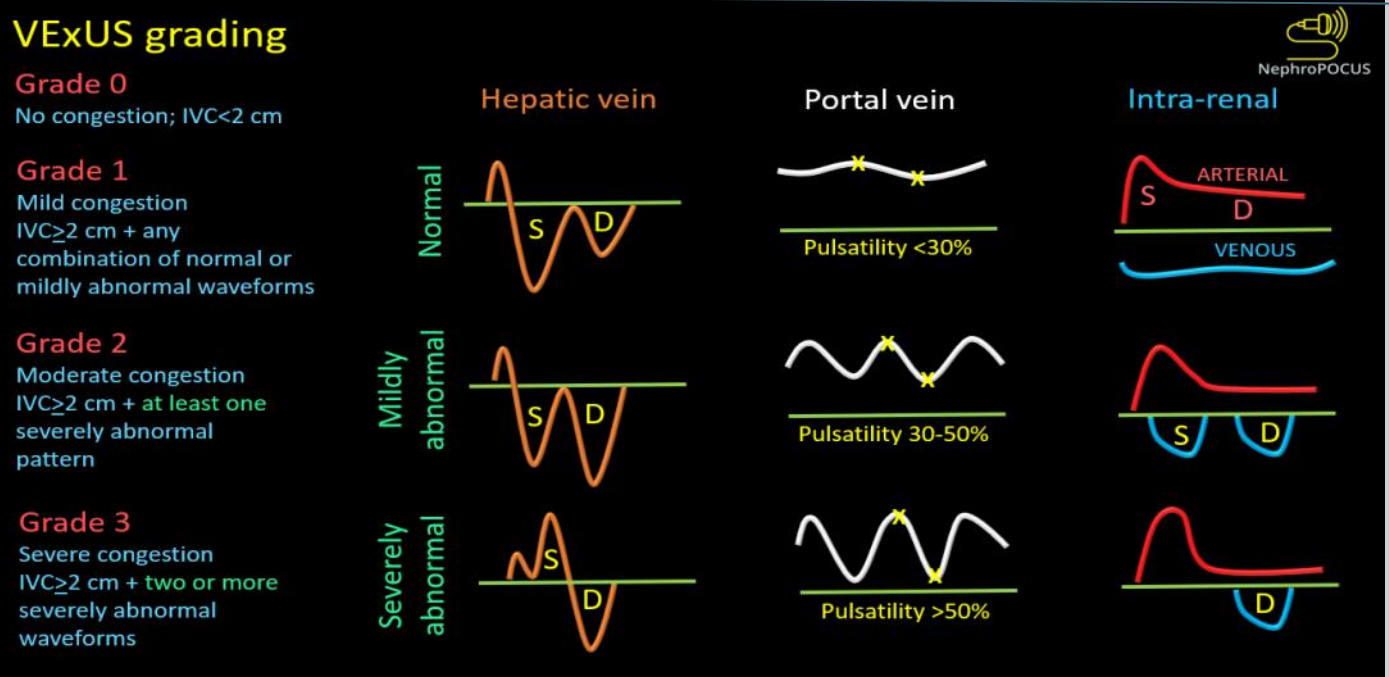


Figure 2. Venous excess ultrasound grading: When the diameter of the inferior vena cava is > 2 cm, three grades of congestion are defined based on the severity of abnormalities on hepatic, portal, and renal parenchymal venous Doppler. Hepatic vein Doppler is considered mildly abnormal when the systolic (S) wave is smaller than the diastolic (D) wave, but still below the baseline; it is considered severely abnormal when the S-wave is reversed. Portal vein Doppler is considered mildly abnormal when the pulsatility is 30% to 50%, and severely abnormal when it is ≥ 50%. Asterisks represent points of pulsatility measurement. Renal parenchymal vein Doppler is mildly abnormal when it is pulsatile with distinct S and D components, and severely abnormal when it is monophasic with D-only pattern. Adapted from NephroPOCUS.com with permission.

These sonographic findings are consistent with VExUS enlargement with interventricular septal flattening (D-sign), grade 3 (Figure 2). Interestingly, the patient lacked pedal and severe functional tricuspid regurgitation, suggestive of edema or shortness of breath. A formal echocardiogram fluid overload (Figure 3). The patient history was not demonstrated reduction of left ventricular ejection fraction suggestive of pulmonary embolism. A nuclear medicine stress test was negative for ischemic changes. Over the

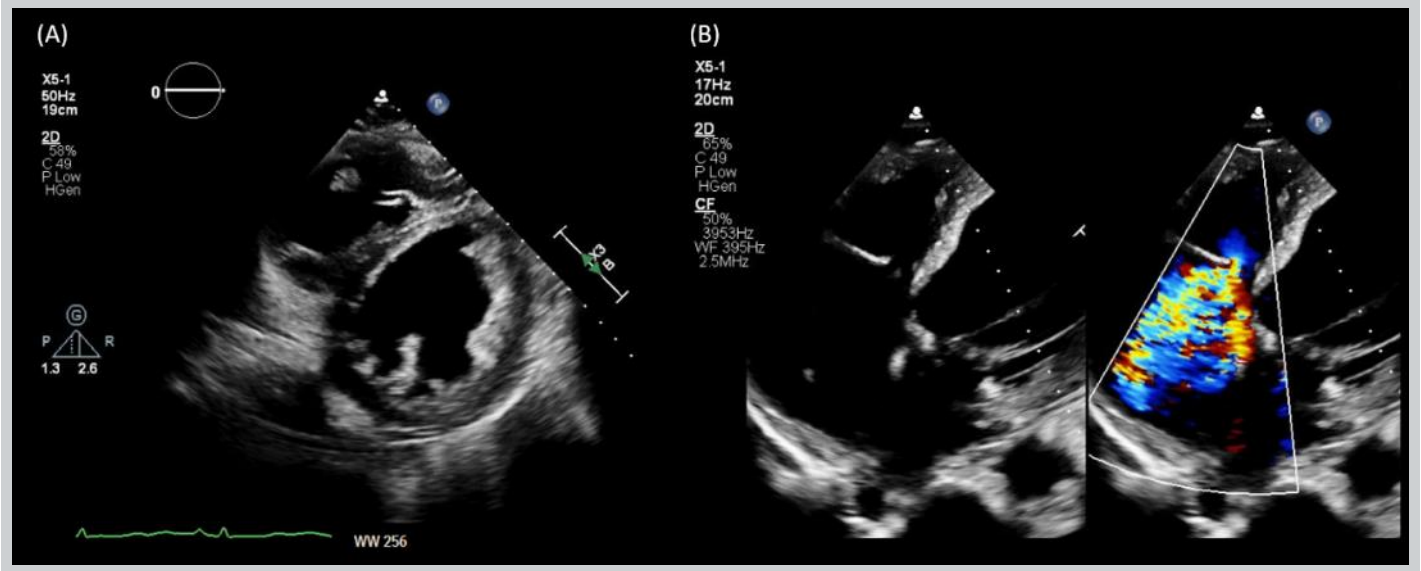


Figure 3. Formal echocardiogram images demonstrating (A) interventricular septal flattening on parasternal short axis view and (B) qualitatively severe tricuspid regurgitation.

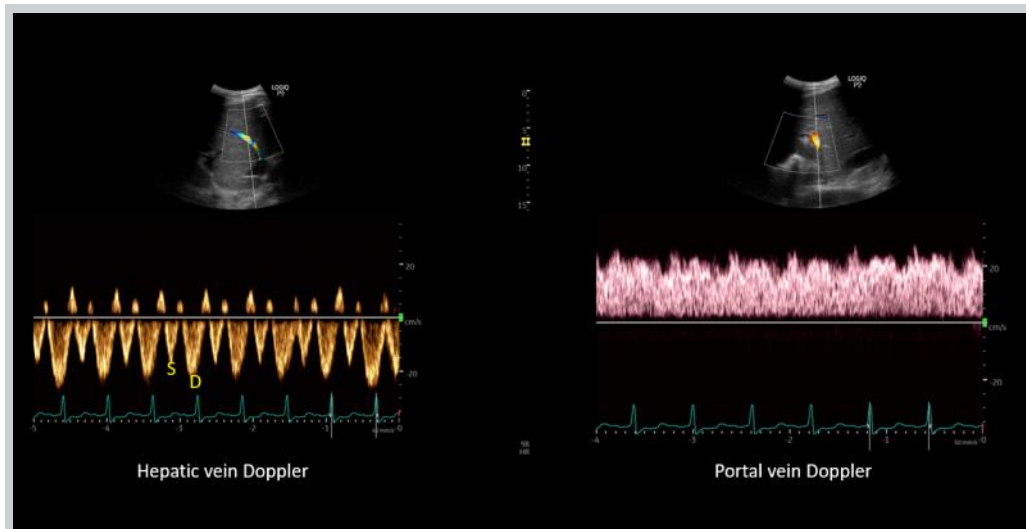


Figure 4. POCUS images demonstrating S<D pattern on hepatic vein Doppler and a normal appearing (pulsatility <30%) portal vein waveform.

subsequent three days, the nephrology team performed daily ultrafiltration, resulting in removal of 8 liters of fluid (net negative 4.5 liters on day 3). At the end of the second session, the nephrology team performed a follow up VExUS scan that showed significant improvement in the congestion. The portal vein was completely normalized, whereas the hepatic vein showed mild congestion with S-wave less than D-wave. A simultaneous ECG tracing was used to avoid errors in misidentification of the waves (Figure 4). The IVC maximal diameter improved to approximately 2.1 cm, with >50% inspiratory collapse with an estimated right atrial pressure of 8 mmHg (Figure 5). Follow up POCUS after the third session demonstrated further improvement in IVC size (<2 cm), and collapsibility consistent with an estimated right atrial pressure of 3 mmHg (Figure 6). Remarkably, the shape of the IVC shifted from circular to oval during the decongestion of the patient, which is a clinically useful qualitative parameter. Hepatic vein Doppler demonstrated further improvement in S-wave amplitude to near-normal configuration, and the

portal vein remained continuous (Figure 7). Intrarenal venous Doppler was not performed, as it is unreliable in ESKD.

Additionally, cardiac POCUS revealed a rounded left ventricle in the parasternal short-axis view. This indicated resolution of the D-sign along with significant improvement in tricuspid regurgitation (Video S1 and S2). Although serum transaminases showed improvement during this time (ALT and AST decreased from 184 to 98 U/L and 156 to 59 U/L, respectively), it cannot be solely attributed to reduction in congestion, as the patient was concurrently diagnosed with a hepatitis C infection (Hep C RNA 141,000 IU/mL). The patient's weight after the third dialysis session was conveyed to his outpatient nephrologist to assist in adjusting dry weight.

This case underscores key lessons: 1. Radiology reports may not encompass information on venous congestion, necessitating nephrologists' awareness of imaging findings related to systemic hemodynamics. 2. Patient symptoms

Figure 5. Inferior vena cava ultrasound short axis demonstrating the maximal anteroposterior diameter (approximately 2.1 cm) and inspiratory collapse.

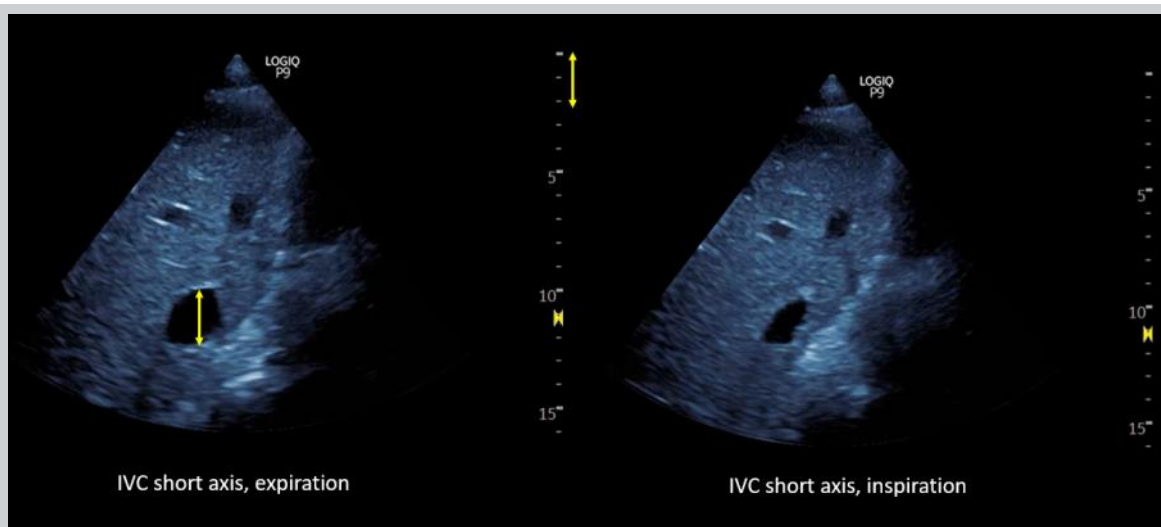


Figure 6. Inferior vena cava ultrasound short axis demonstrating the maximal anteroposterior diameter (approximately 1.9 cm) and inspiratory collapse.

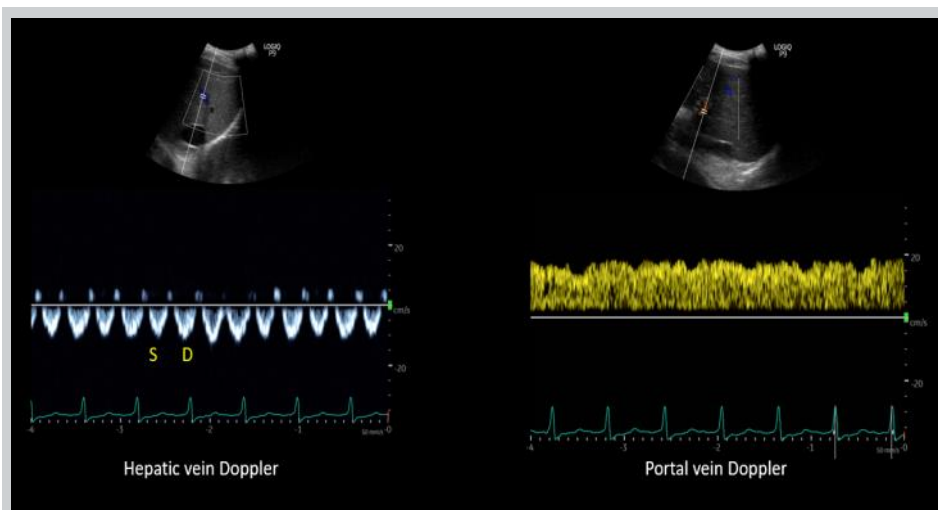
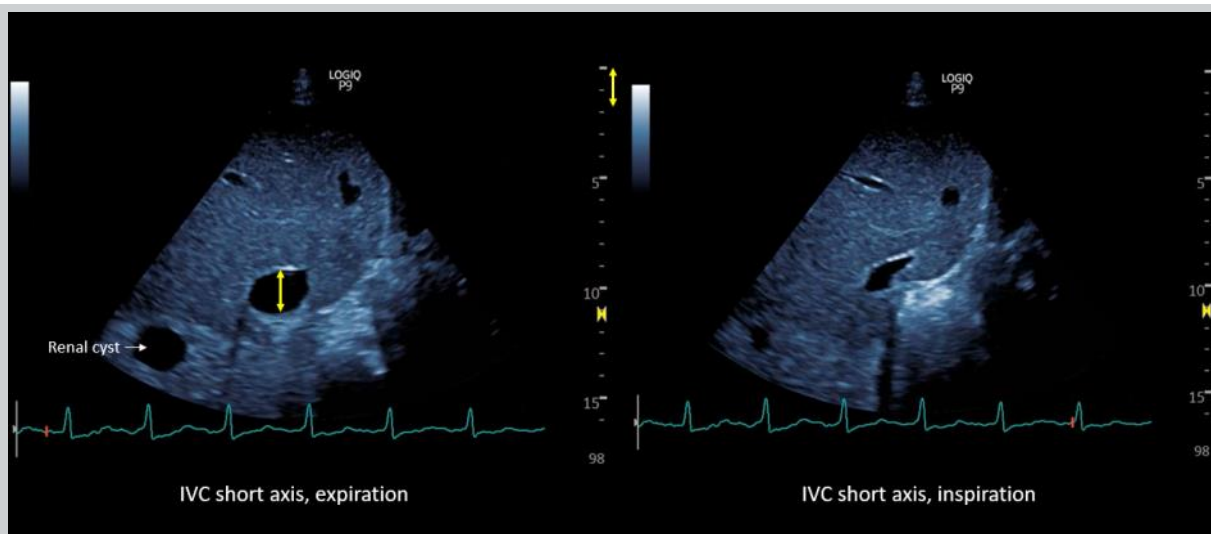


Figure 7. POCUS images demonstrating almost equal S and D waves on hepatic vein Doppler and a normal (pulsatility <30%) appearing portal vein waveform.

and clinical signs might not correlate with hemodynamic congestion, and VExUS can serve as a valuable bedside indicator in such instances (further research is warranted). 3. VExUS serves as a visual bedside guide for decongestion, enabling real-time interpretation and management by clinicians.

### Disclosures

The authors declare no potential conflicts of interest.

### Funding Statement

Abhilash Koratala reports research funding from KidneyCure and the American Society of Nephrology's William and Sandra Bennett Clinical Scholars Grant.

### Patient Consent

Informed consent has been obtained from the patient for the publication of this case study.

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# Point of Care Ultrasound Diagnosis of Maxillary Artery Pseudoaneurysm in the Emergency Department

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## Abstract

A pseudoaneurysm results from a tear in a vessel wall. This leads to extravasation of blood into adjacent tissue and eventual formation of a fibrous sac that maintains continuity with the lumen. These vascular injuries very rarely occur in deeper vessels of the face (e.g. maxillary artery) due to protection from structures like the bony mandible and parotid gland. If left untreated, these pseudoaneurysms can lead to infection, thromboembolism, hemorrhage, and compression of surrounding structures such as facial nerve branches. Pseudoaneurysms are typically diagnosed by advanced imaging techniques including computed tomography angiography and magnetic resonance angiography. However, these tests require time to perform and interpret, are costly, and take place outside the patient care area. Computed tomography also confers ionizing radiation. Fortunately, point of care ultrasound (POCUS) is a readily available, dynamic imaging tool that can be performed at the bedside. Here we present the first known case report of a maxillary artery pseudoaneurysm diagnosed by POCUS in the emergency department. Early differentiation from a typical hematoma led to rapid management in the form of a compression bandage, as well as expedited consultation to the appropriate services.

## Introduction

An aneurysm refers to the dilation of a blood vessel (usually an artery) that involves all three layers of that vessel (i.e. the tunica intima, tunica media, and tunica adventitia). In contrast, a pseudoaneurysm forms from a complete tear through all three layers. This leads to extravasation of blood that is subsequently contained by the surrounding fibrous tissue [1-5]. Generally, pseudoaneurysms present clinically as painful, pulsatile masses, oftentimes with neurologic deficits secondary to nerve compression [3,6,7]. They can be diagnosed using ultrasound, computed tomography angiography (CTA), and magnetic resonance angiography (MRA) [1,7,8]. Management of pseudoaneurysms includes both noninvasive (e.g. observation, ultrasound-guided compression) and invasive measures (e.g. endovascular embolization, open surgical ligation) [1,3,9]. If left untreated, pseudoaneurysms can lead to complications such as infection, thromboembolism, hemorrhage, and compression of surrounding structures [5,7].

Pseudoaneurysms of the maxillary artery are rare due to its anatomic protection by the bony mandible and parotid gland [3,4,10-12]. Prior case reports have described maxillary artery pseudoaneurysms as a complication of

maxillofacial fractures and surgeries, blunt and penetrating trauma, infection, and radiation therapy [1,3,10,11,13-17]. There have also been cases reported from penetrating injury [4,11,14,18-22]. In all these instances, the diagnoses were made using CTA or MRA, both of which confer a delayed diagnosis, transfer of the patient outside the care area, and higher cost. CTA also confers ionizing radiation. There are no known cases of a maxillary artery pseudoaneurysm diagnosed immediately by point of care ultrasound (POCUS) at the bedside.

Here, we present the first known case of a maxillary artery pseudoaneurysm diagnosed by POCUS in the emergency department (ED), stemming from a penetrating stab wound to the face. Rapid bedside use of POCUS facilitated immediate diagnosis, differentiation from a typical hematoma, the application of a tight compression bandage, and expedited consultation to the appropriate services for potential definitive management.

## Case Presentation

A 22 year-old man was brought in by ambulance to the ED after sustaining a stab wound to the left side of the face. Vital signs consisted of blood pressure 155/108 mmHg, heart rate 62 beats per minute, respiratory rate 12 breaths per minute, and 100% oxygen saturation on room

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DOI: <https://doi.org/10.24908/pocus.v9i1.16831>

air. On physical examination, the patient was in severe pain from the wound. There was a 2 cm laceration to the left cheek, along with a large area of swelling to the left side of the face anterior to the tragus of the ear (Figure 1). Initial diagnoses that were considered included traumatic hematoma or parotid gland injury. Using the high-frequency (4-12 MHz) linear transducer, B-mode scanning revealed an anechoic, pulsatile, 2x2 cm rounded structure with adjacent irregular pockets of internal echoes (Figure 2) (Video S1). Color Doppler revealed the “ying-yang” sign – a red and blue swirling pattern resulting from pulsatile blood being ejected from the arterial wall defect into the pseudoaneurysm sac, and then redirected back towards the neck by the surrounding fibrous tissue enclosure (Figure 3) (Video S2). Pulsed wave Doppler revealed pulsatile flow with the largest amplitude at the pseudoaneurysm neck, with a decrease in amplitude towards the distal end of the sac (Figure 4). Interestingly, upon holding compression and then releasing pressure upon the external carotid artery at the neck, the pseudoaneurysm could be visualized collapsing and re-expanding, respectively (Video S3). Altogether, these sonographic findings suggested the presence of a pseudoaneurysm.



Figure 1. The patient had a large area of swelling to the left side of the face anterior to the tragus of the ear, along with a 2 cm laceration to the left cheek.

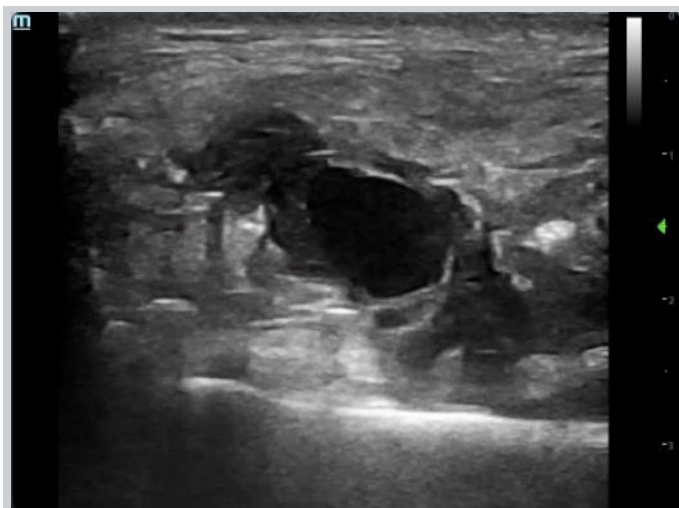


Figure 2. An anechoic, pulsatile, rounded, 2x2 cm structure with adjacent irregular pockets of internal echoes.

Especially given the patient's worsening pain, POCUS findings prompted immediate placement of a tight compression bandage over the swelling. The Vascular Surgery service was consulted emergently, followed by a team discussion with the Oral and Maxillofacial Surgery and Neuroendovascular services as well. These teams requested a CTA, which confirmed the emergency physicians' suspicion of the culprit maxillary artery based on the wound's anatomic location. Given the deep location of the maxillary artery, the consultants decided to manage conservatively with a follow-up CTA in three days to evaluate for potential pseudoaneurysm expansion. At the subsequent 1-month follow-up visit, swelling of the face was no longer present on physical examination, and the patient denied symptoms.

### Discussion

This is the first known case report in which POCUS was used to immediately diagnose a maxillary artery pseudoaneurysm. The prompt diagnosis allowed for differentiation from the typical (and otherwise expected) hematoma, expedited management in the form of a tight compression bandage, early involvement of appropriate consulting services, and further diagnostic investigation of a potentially dangerous injury. Without immediate compression, there could have been continued pseudoaneurysm expansion, worsening pain from stretching of skin fibers, facial nerve compression and paralysis, and potentially hemorrhage.

The maxillary artery's deep anatomic course renders it less susceptible to penetrating injury, so pseudoaneurysm formation from such injury is rare. The maxillary artery branches off the external carotid artery posterior to the mandibular neck, then courses anteriorly

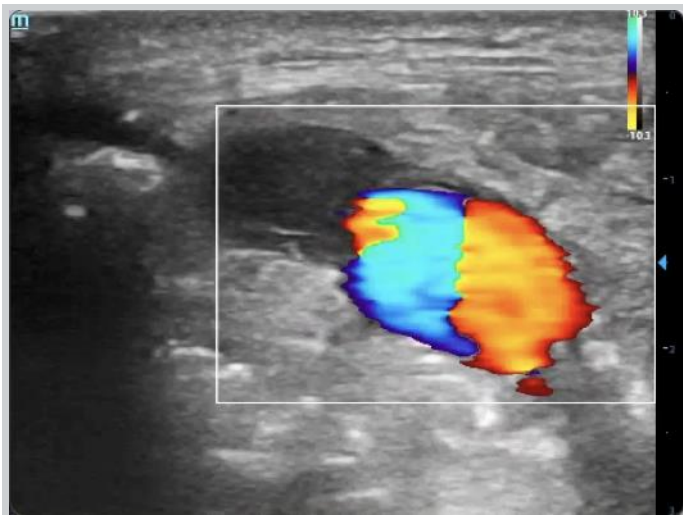


Figure 3. The “ying-yang” sign – a red and blue swirling pattern that appears from pulsatile blood being ejected from the arterial wall defect into the pseudoaneurysm sac, and then redirected back towards the neck by the surrounding fibrous tissue. The gain is properly set high enough to detect the change in Doppler shift from blood flow, but not too high that would result in appearance of artifact.

through the parotid gland and between the mandibular ramus and sphenomandibular ligament (Figure 5). The artery continues on deep to the lateral pterygoid muscle through the infratemporal fossa and dives into the pterygopalatine fossa [23]. Structures throughout the

artery’s course, such as the bony mandible and parotid gland, generally protect the artery from injury [18,21,23]. In this patient’s case, the maxillary artery was pierced by the knife just distal to its branching point from the external carotid artery.

In contrast to CTA and MRA, POCUS is readily available at the bedside (vs. outside the patient care area), able to generate dynamic (vs. static) imaging, devoid of ionizing radiation, and cost-effective. In this patient’s case, physicians initially presumed the facial swelling to be from hematoma formation or parotid gland injury. Hematomas often appear as irregularly or regularly shaped structures, anechoic in the acute setting, but with mixed echogenicity echoes over time as the blood clots [5,9,24]. In contrast, a pseudoaneurysm will appear pulsatile using B-mode, with the ying-yang sign using color Doppler, and showing pulsatile flow using pulsed wave Doppler [5,9,25,26]. The arterial wall defect can also be visualized by tracing the pulsatile flow to its origin. As opposed to a pseudoaneurysm, a simple hematoma does not typically result from ongoing high-pressure pulsatile flow leading to continuous growth. Therefore, it only warrants simple compression at most, whereas management of pseudoaneurysms requires drastically different considerations.

Management of pseudoaneurysms can be divided into non-invasive and invasive methods. Noninvasive methods include observation and trials of direct compression at the pseudoaneurysm’s neck. The goal is

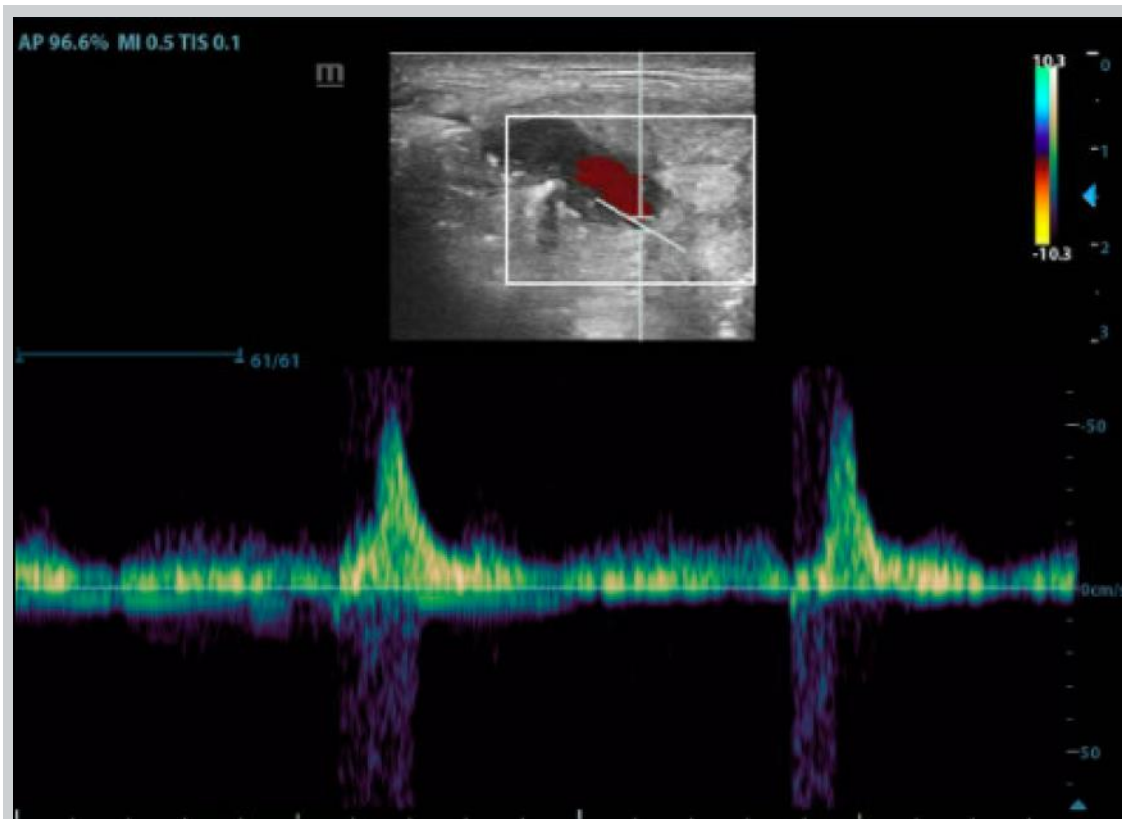


Figure 4. Pulsatile flow with the largest amplitude at the pseudoaneurysm neck. Not pictured is the decrease in amplitude towards the distal end of the sac. The gain is properly set high enough to detect the change in Doppler shift from blood flow, but not too high that would result in appearance of artifact. Also note how the scale along the right side of the screen is adjusted so that the waveform takes up as much of the screen as possible.

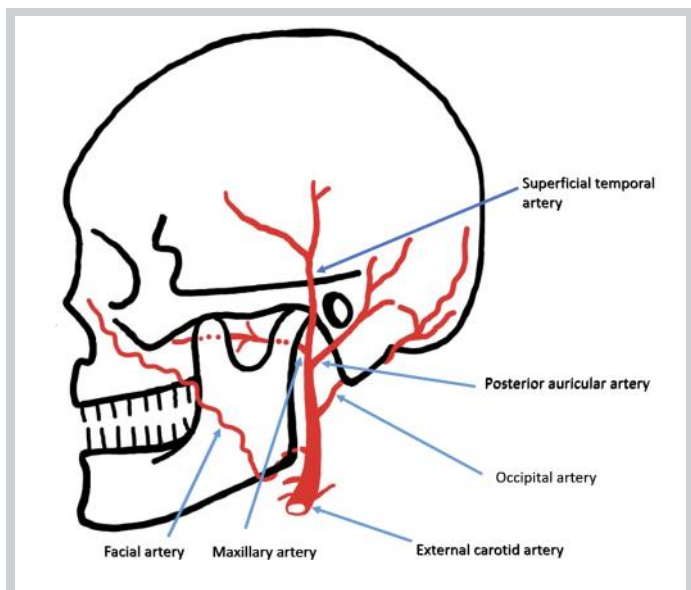


Figure 5. Pictorial diagram of the face's arterial supply, including the maxillary artery.

to eliminate flow towards the aneurysmal sac for 15-30 min to promote spontaneous thrombosis and closure of the arterial wall defect [27]. The success rate across multiple studies demonstrates a 60-90% success rate, with complications including multiple attempts and cessation due to pain [27-29]. Invasive methods consist of percutaneous embolization, endovascular embolization, and open surgical exploration with arterial ligation. Percutaneous embolization involves direct thrombin injection via ultrasound guidance into the pseudoaneurysm sac to promote thrombus formation [27]. Endovascular embolization uses embolic agents to temporarily or permanently occlude the vessel and promote thrombus formation [30-33]. There is no definitive consensus for the management of pseudoaneurysms [34]. In this patient's case, the location of the pseudoaneurysm on the face was not conducive to surgical exploration. Moreover, the early success with the tight compression bandage led consulting services to opt for a trial of non-invasive management.

## Disclosures

All authors have no conflicts of interest to disclose.

## Patient Consent

The authors obtained informed consent from the patient to publish this case report.


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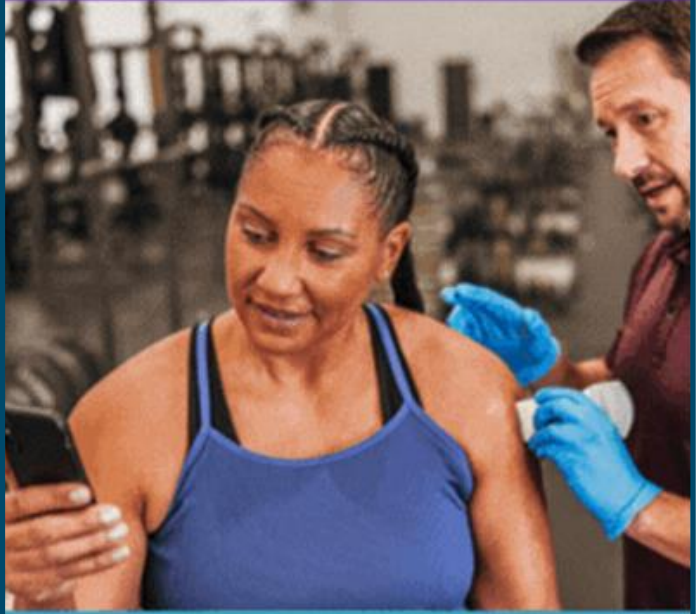
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# Hemodialysis Catheter-Associated Right Atrial Thrombus Diagnosed via Point of Care Transesophageal Echocardiogram

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## Abstract

Catheter-associated right atrial thrombus (CRAT) is a potential complication of central venous catheter placement and is associated with an increase in morbidity and mortality. The precise incidence of CRAT is unknown, and there is a lack of clear screening and management guidelines for this condition. Additionally, the diagnosis is often missed when using transthoracic echocardiography (TTE) alone. Here, we present a case of a 64-year-old female admitted to the medical intensive care unit with multiorgan dysfunction who was diagnosed with hemodialysis catheter-associated right atrial thrombus (HDCRAT) via intensivist-performed point of care transesophageal echocardiography (TEE) after an initial TTE was negative. This patient was successfully treated with systemic anticoagulation, local thrombolysis, and delayed removal of the temporary hemodialysis catheter. Our experience serves to highlight the improved visualization of the right atrium and the diagnostic superiority of HDCRAT with TEE. We suspect that with greater utilization of TEE among intensivists, CRAT and HDCRAT will have increased recognition. It is imperative that intensivists are aware of this complication and various management strategies. Still, more studies are needed to establish clear management guidelines for CRAT and the associated complications.

## Introduction

Catheter-associated right atrial thrombus (CRAT) is a cause of significant morbidity in adult and pediatric patients following the placement of central venous catheters (CVCs). Potential complications of CRAT include pulmonary embolism, infection, septic emboli, arrhythmia, tricuspid regurgitation, catheter malfunction, superior vena cava obstruction, and in cases of CRAT associated with hemodialysis (HD) (hemodialysis catheter-associated right atrial thrombus (HDCRAT)), the loss of vascular access in the affected vein and incomplete dialysis [1,2]. In a retrospective study of published cases of HDCRAT in the adult HD population before 2010, mortality was reported at 18.3% [2]. Thus, early identification and treatment of HDCRAT is crucial. The pathogenesis of HDCRAT primarily arises from the mechanical irritation of the right atrium (RA) by the movement of the catheter tip with cardiac contraction. This persistent irritation leads to endothelial injury, platelet aggregation, and activation of the coagulation cascade, culminating in the development of a thrombus.

Notwithstanding the associated risk of HDCRAT, the Kidney Disease Outcomes Quality Initiative (KDOQI) endorses the placement of the HD catheter tip in the RA, emphasizing that this approach facilitates greater blood flow rates, thereby enhancing dialysis efficiency [3-5].

Although CRAT and HDCRAT are well-known complications of CVC placement, the true incidence has yet to be accurately determined due to limitations in imaging the RA [6]. In the classical approach to identifying masses within the RA, the diagnosis is established through transesophageal echocardiography (TEE). This preference arises from the inherent challenges when using transthoracic echocardiography (TTE) to closely visualize the RA and catheter tip [6-8]. Retrospective studies of diagnosed CRAT cases have shown an incidence of roughly 5%. However, autopsy reports have estimated the incidence to be closer to 30% [6]. Therefore, it is speculated that many cases of CRAT remain clinically undetected until complications arise, which raises further concerns about the inadequacy of TTE.

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DOI: <https://doi.org/10.24908/pocus.v9i1.16895>

When imaging the RA, TEE outperforms TTE primarily because of its multiplane imaging capabilities, which enable a comprehensive 180-degree visualization of cardiac structures [6-8]. However, TTE is more frequently utilized than TEE because of its availability and familiarity by intensivists. Unfortunately, estimates show that TTE may miss as many as 50% of right atrial masses [7-9]. Given the limitations in imaging right atrial thrombi with TTE, physicians have been unable to make this diagnosis at the bedside, leading to delays in identification and treatment [5-7].

Recently, the increasing prevalence of point of care ultrasound (POCUS) TEE within medical intensive care units (ICUs) has afforded intensivists the ability to more readily identify and diagnose CRATs in the ICU setting [10]. Here, we present a case of a 64-year-old female who was diagnosed with HDCRAT via intensivist-performed TEE following an comprehensive TTE.

### Case Presentation

A 64-year-old African American female presented to the ICU with multi-organ dysfunction (including acute kidney injury (AKI), hypoxic respiratory failure, circulatory failure, and severe metabolic acidosis) due to metformin toxicity and aspiration pneumonia. She was initially intubated and subsequently treated with broad-spectrum antimicrobials. She required norepinephrine, vasopressin, and epinephrine to maintain a mean arterial pressure of 65 mmHg. A temporary right internal jugular (IJ) dialysis catheter was placed terminating in the mid-RA, and a left IJ CVC was inserted with the catheter tip positioned at the caval-atrial junction (Figure 1). She started continuous renal replacement therapy (CRRT) for the treatment of severe acidosis and AKI.

Despite improvement of her metabolic derangements, she remained profoundly hypotensive and hypoxic in the setting of three-vasopressor shock. On the second day of CRRT, several clots were extracted from the distal port of the right IJ dialysis catheter. A transthoracic echocardiogram (TTE) of good quality was performed and revealed clear visualization of all left ventricular walls as well as adequate views of the mitral, tricuspid, and aortic valves. This assessment revealed hyperdynamic function of both the right and left ventricles, absence of valvular pathology or pericardial effusion, and a left ventricular outflow tract velocity time integral measured at 26.6 cm. Notably, the right IJ HD catheter was not observed in the RA on the TTE. Following our institutional protocol, a non-diagnostic TTE in a patient with undifferentiated shock necessitates further investigation with a POCUS TEE. Consequently, we performed a POCUS TEE that acquired standard Critical Care TEE views, including midesophageal (ME) four chamber, ME bi-caval, ME long axis, and transgastric

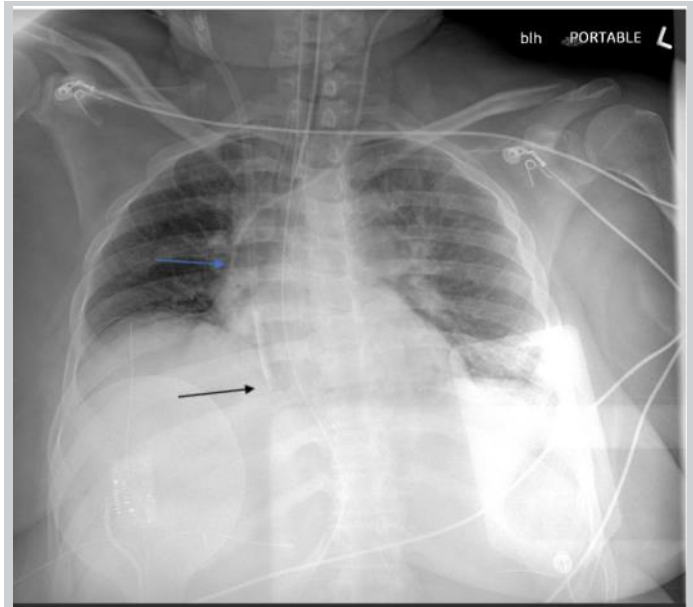


Figure 1. 12 Fr R IJ HD catheter terminating in the mid-RA (black arrow). 7 Fr L IJ CVC terminating in the caval atrial junction (blue arrow)

short axis views. This evaluation excluded cardiac tamponade, dysfunction in both the left and right ventricles, and hypovolemia as potential causes of her shock. Specifically, the normal function of the right ventricle suggested that an acute pulmonary embolism was an unlikely shock cause. Adjustment of the multi-plane to 71 degrees within the mid-esophagus produced the ME right ventricle inflow/outflow view, revealing the presence of a mobile density within the RA (Figure 2 & Video S1). Subsequent adjustment of the multi-plane to 99 degrees created the ME bicaval view, allowing for the visualization and measurement of a 1.8 cm right atrial thrombus affixed to the right IJ dialysis catheter (Figure 2,3 & 4).



Figure 2. ME RV inflow outflow view showing the CRAT (white arrow).

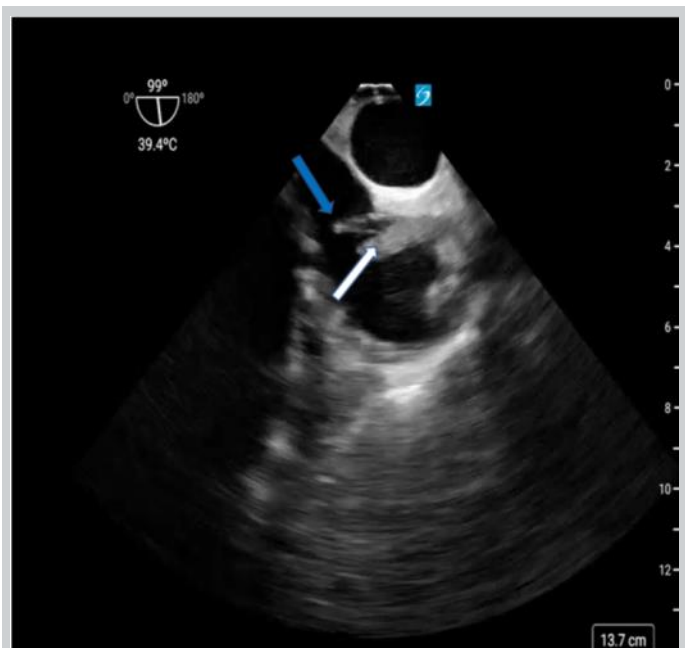


Figure 3. Modified ME bi-caval view showing the CRAT (white arrow) and the HD catheter (blue arrow).

Given the POCUS TEE findings, therapeutic anticoagulation was immediately initiated with intravenous heparin. Due to the clot's location and size, removal of the catheter was deferred because of a high risk of clot embolization. Instead, therapeutic anticoagulation was continued, and tissue plasminogen activator (tPA) locking solution was introduced into the catheter. This combined approach aimed to concentrate the tPA at the catheter tip, effectively serving as a local regional thrombolytic therapy. Subsequently, the patient experienced an improvement in renal function and clinical status, leading to her extubation, discontinuation of vasopressors and CRRT. She remained on anticoagulation for one week, and the right IJ HD catheter was successfully removed without complications. While her clinical improvement was likely not directly attributable to the diagnosis and treatment of HDCRAT, the therapeutic intervention played a crucial role in preventing further clot propagation and reducing the risk of pulmonary embolism in this critically ill patient. Consequently, given her positive clinical trajectory, a decision was made not to perform a repeat POCUS TEE.

### Discussion

CRAT is often insidious and a potentially life-threatening complication that may arise in association with any CVC. However, it predominantly presents in cases involving tunneled HD catheters, typically emerging 12 weeks post-catheter insertion [1]. There is a paucity of data describing the occurrence of HDCRAT in the context of

temporary HD catheters used for acute renal replacement therapy in critically ill medical ICU patients. The practice of positioning HD catheters within the RA is formally recommended by the KDOQI guidelines and is a recognized risk factor for HDCRAT development [2]. In this paper, we presented a case of HDCRAT originating from a temporary dialysis catheter, which eluded detection through TTE and was incidentally diagnosed through intensivist-performed TEE.

The precise incidence of CRAT remains elusive. Reports from clinical studies have presented a wide range, varying from 18% to 30%, accompanied by mortality rates spanning 9% to 18% [4-6]. In its clinical presentation, CRAT often manifests as catheter dysfunction stemming from mechanical obstruction by the thrombus, as in this case. Two predominant forms of CRAT are recognized: mural thrombus and catheter tip thrombus. Both forms share a common etiology, induced by mechanical trauma to the atrial wall caused by the catheter, coupled with myocardial contractions leading to endothelial damage and activation of the clotting cascade. This ultimately culminates in catheter dysfunction and CRAT.

Compared to TTE, TEE has consistently demonstrated its diagnostic superiority with enhanced resolution, multiplane imaging capabilities, and improved visualization of the RA and its contents [11-13]. In the past decade, there has been a noticeable paradigm shift in the application of TEE [14-16]. This shift has extended its utility beyond cardiologists and cardiothoracic anesthesiologists, to employment by intensivists at the bedside [1]. Notably, Lau et al. have substantiated that intensivist-performed limited TEE exhibits diagnostic

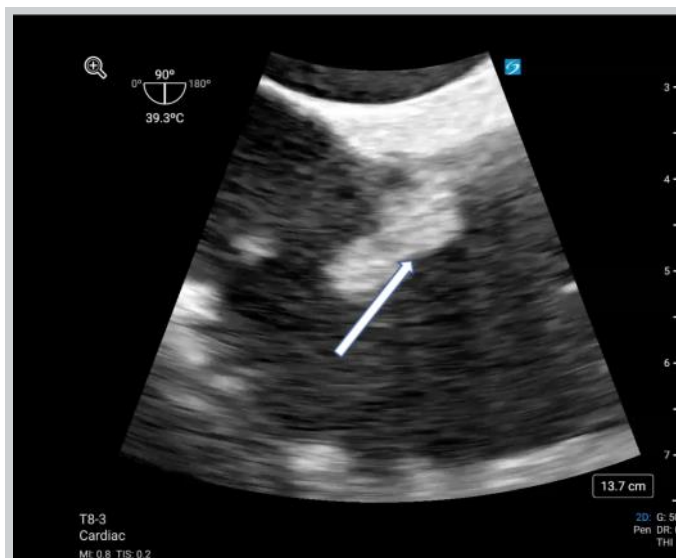


Figure 4. Zoomed ME bicaval view showing the CRAT in the RA (white arrow).

accuracy equal to that achieved by cardiologists [15]. Given the increasing prominence of TEE, it is paramount for intensivists to maintain an acute awareness of CRAT and to acquaint themselves with the array of management strategies at their disposal.

Current management guidelines for HDCRAT in patients undergoing HD and those in the ICU lack clarity. Expert consensus and insights gleaned from clinical case reports favor a multifaceted approach, primarily revolving around systemic anticoagulation and subsequent catheter removal. This approach is further supplemented by the judicious use of antibiotic prophylaxis in less severe cases [6,12]. In instances where CRAT features substantial thrombi exceeding 6 cm in length or accompanied by cardiac abnormalities or endocarditis, the consensus recommends a more aggressive therapeutic approach entailing surgical thrombectomy [11].

Within the specific context of our experience, a nuanced, hybrid strategy was employed. This approach combined the use of anticoagulation with localized thrombolytic therapy – a protocol initially described by Gilon et al. [12]. The decision to employ this hybrid approach was contingent upon the unique clinical intricacies of the patient's condition, offering a tailored solution to optimize management. The evolving landscape of HDCRAT management warrants continual assessment and adaptation to develop a more consistent patient-centered approach. The development of more refined evidence-based guidelines is essential to enhance the management of HDCRAT in critically ill patients. Further research and collaborative efforts are required to determine the most effective and safe treatment strategies.

## Conclusion

We suspect that the detection of HDCRAT cases will increase due to the use of intensivist-performed TEE, allowing for better bedside right atrial imaging. With this increase in use, intensivists should be aware of this diagnosis and possible management strategies. Furthermore, additional investigations are warranted to assess whether the benefits of enhanced high blood-flow rates and increased efficiency of dialysis, attributed to the placement of HD catheter tips in the RA, truly outweigh the accompanying risks.

## Conflicts of Interest

None

## Consent

Written consent was obtained from the patient for publication of this case report including images.

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# Point of Care Ultrasound Used to Diagnose Nontyphoidal Endocarditis

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## Abstract

Point of care ultrasound (POCUS) can make an expedited diagnosis, which might lead to early correct management. POCUS should be used in a systemic and integrated approach to evaluate multiple organs in patients with sepsis and septic shock. We present a rare case of sepsis due to nontyphoidal *Salmonella* endocarditis with splenic abscess in which a multiorgan POCUS examination led to expedited treatment.

## Introduction

Incorporating point of care ultrasound (POCUS) has become the standard care in evaluating critically ill patients. Many adopted protocols for different critical situations have been validated [1]. POCUS facilitates rapid diagnosis, which can expedite management. Sepsis and septic shock are emergencies in which early recognition can lead to improved outcomes [2]. The POCUS exam for sepsis or septic shock should be systematic and integrate the assessment of multiple organ systems [3]. This comprehensive approach improves the provider's ability to diagnose the presence of sepsis, identify the culprit infection, and narrow the differential diagnosis [3]. The initial clinical presentation can be nonspecific in patients with sepsis and septic shock [4]. The diagnosis of sepsis and septic shock requires clinical examination, laboratory results, radiologic tests, and microbiologic data [4]. In acute situations, advanced imaging modalities, such as computed tomography or magnetic resonance imaging, may be difficult to access because of the instability of patients.

POCUS is a clinician-performed bedside modality that can help diagnose sepsis and detect the source of sepsis during the assessment of critically ill patients [5]. POCUS examination in sepsis should be systemic and comprehensive in order to narrow the differential diagnosis [5].

Only 5% of infected patients with nontyphoidal *Salmonella* gastrointestinal illness might develop bacteremia [6]. Immunocompromised patients and patients with diabetes are more likely to develop bacteremia from nontyphoidal *Salmonella* [6]. In patients with nontyphoidal *Salmonella* bacteremia, 25% might develop arteritis or endocarditis, especially patients over 50 years-old [7]. The global incidence of bloodstream infection with nontyphoidal *Salmonella* has been estimated at 50 cases per 100,000, with Africa being the most affected [8]. We present a case of sepsis in which POCUS helped determine the source of sepsis and expedited early treatment.

## Case Presentation

A 60-year-old woman with ischemic heart disease, type II diabetes mellitus, hypertension, and chronic kidney disease presented to the emergency department with two weeks of fever, crampy left sided abdominal pain, and irritability. She had been diagnosed with ischemic heart disease and ST-elevation myocardial infarction, followed by coronary artery bypass surgery ten years prior. The results of echocardiography after surgery were normal. Since the age of 30, she has had poorly controlled diabetes mellitus (HbA1c of 11.7), which has been complicated by diabetic nephropathy, diabetic retinopathy, and multiple vitreous hemorrhages in the left eye. She had been given oral antibiotics from her family physician one week before admission. She reported no

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DOI: <https://doi.org/10.24908/pocus.v9i1.16937>

nausea, vomiting, diarrhea, or constipation. Examination of the patient showed temperature 38.7 °C, heart rate 110 beats per minute, blood pressure 90/45 mmHg, respiratory rate 24 breaths per minute, and oxygen saturation 99% on room air.

The patient was conscious, and chest sounds were normal, with a heart grade 2/6 systolic murmur at the right upper sternal border with radiation to the carotid arteries. Her abdomen was tender on the left upper quadrant. The laboratory test results are shown in Table 1. There was elevated procalcitonin, leukocytosis (mainly neutrophils), and high C-reactive protein. The electrocardiogram revealed normal sinus rhythm. Abdominal POCUS showed splenomegaly with multiple hypoechoic areas measuring a few mm to 6 cm in diameter (Video S1, Figure 1). The kidneys appeared normal and the inferior vena cava collapsed. Cardiac POCUS showed a normal-size hyperdynamic left ventricle. There was aortic sclerosis and a mobile mass attached to the right coronary cusp and left coronary cusp (LCC) with possible vegetation with mild aortic regurgitation (Video S2). Chest POCUS showed bilateral A-lines and no evidence of pleural effusion. Abdominal computed tomography with intravenous contrast showed significant splenomegaly and a large area of hypoattenuation within the spleen,



Figure 1. Abdominal POCUS with multiple hypoechoic areas (arrow) in the spleen (S). D is the diaphragm.

mainly in the peripheral region that was suggestive of splenic infarction with signs of splenic abscess (Figure 2). The patient was diagnosed with septic shock, aortic valve endocarditis, splenic infarction, and abscess. The patient then underwent ultrasound-guided drainage of the splenic abscess which grew *Salmonella* species sensitive to

Table 1. Laboratory values on admission.

| Variable                                | Results (On admission) | 3-Days after admission | Normal Range    |
|---|------------------------|------------------------|-----------------|
| Sodium (mmo/L)                          | 146                    | 139                    | 136–145         |
| Potassium (mmo/L)                       | 5                      | 4                      | 3.8-5.2         |
| Urea nitrogen                           | 8                      | 6                      | 3.5-6.1         |
| Creatinine                              | 87                     | 90                     | 45-110          |
| Lactate                                 | 3                      | 1.2                    | < 1.2           |
| White cell count (per mm <sup>3</sup> ) | 21                     | 15                     | 4,500–11,000    |
| Neutrophils (%)                         | 83                     | 70                     | 48-75           |
| Hemoglobin g/dL                         | 9.4                    | 10                     | 13.5–16.5       |
| Platelet (per mm <sup>3</sup> )         | 390                    | 500                    | 150,000–350,000 |
| International normalized ratio          | 1.21                   | 1.1                    | 0.8 -1.1        |
| Procalcitonin (ng/ml)                   | 57                     | 11                     | < 0.01          |
| C-reactive protein (mg/L)               | 230                    | 180                    | < 20            |
| Glucose (mmol/L)                        | 14                     | 8                      | 4.5-6.2         |



Figure 2. CT with intravenous contrast revealed large area of hypoattenuation within the spleen, mainly in the peripheral region that was suggestive of splenic infarction with signs of splenic abscess. L liver, S spleen.

ceftriaxone. The blood culture was negative, likely because the patient received oral cephalosporin before admission to the hospital. The serology for *Coxiella burnetii*, *Bartonella* spp., *Chlamydia* spp., and *Brucella* was negative.

The patient completed 45 days of ceftriaxone and two weeks of gentamycin with improvement. After one month of follow-up, the patient was stable and afebrile, and repeat imaging showed resolution of the splenic abscess and aortic vegetation.

### Discussion

The patient met one major clinical criterion (echocardiography, new regurgitation, and vegetation) and three minor clinical criteria (fever, splenic infarction, and abscess, positive culture for an organism involved in infective endocarditis from a sterile body site other than cardiac tissue, cardiac prosthesis, or embolus) of the 2023 Duke–ISCID Criteria for Infective Endocarditis, which led to a diagnosis of infective endocarditis [9].

The negative blood culture in the present case was likely due to antimicrobial treatment received prior to admission. Other causes of culture-negative endocarditis are microorganisms with demanding growth characteristics in vitro (such as *Gemella* or *Granulicatella*, intracellular bacteria that cannot be cultured from blood using standard microbiologic testing methods) [10]. In the present case, the organism was isolated from tissue splenic culture.

The International Collaboration on Endocarditis reported

non-HACEK gram-negative bacteria in 49 of 2761 (1.8%) infective endocarditis cases [11].

The management guidelines for non-HACEK gram-negative aerobic bacilli include early surgery and long-term (at least six weeks) antimicrobial drugs [12]. The suggested antimicrobials were beta-lactam and aminoglycoside addition of quinolones. The reported current patient did well with ceftriaxone and aminoglycoside without surgery [12].

POCUS protocols are well-designated for shock and hypoxic respiratory failure, but there is no specific ultrasound protocol for sepsis and septic shock [1,5]. The RUSH protocol differentiates different types of shock, including distributive shock, which could be due to sepsis [1]. Apart from the early diagnosis of septic shock, the identification and effective source control of sepsis and the rapid implementation of resuscitative measures have a positive impact on the outcome of the disease [13]. POCUS can aid in resuscitation measures, is associated with improved clinical outcomes in patients with shock, and helps improve the safety of bedside procedures [3].

### Conclusion

We report a rare case of nontyphoidal endocarditis with splenic infarction and abscess diagnosed by POCUS. This case illustrates the potential benefit of multiorgan POCUS in the evaluation of patients with sepsis.

### Consent

The patient consented and permitted to publish his/her clinical history.

### Conflicts of Interest

The authors declare there are no competing interests.

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# Diagnosis of Cutaneous Larva Migrans using Point of Care Ultrasound

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## Abstract

Larva migrans is a cutaneous parasitic infection that occurs when an immature hookworm larva inadvertently penetrates the dermis of a human, typically on the extremities. Traditionally, a clinical diagnosis is made when a tortuous/serpiginous eruption is seen superficially in the skin with complaints of intense pruritus. Point of care ultrasound (POCUS) is a useful diagnostic tool for soft tissue complaints in the emergency department (ED). We describe a case of an 18-year-old woman who presented to the ED with foot pruritus four days after walking on the beach barefoot. POCUS examination revealed several motile structures in the dermis of the patient's foot, confirming our suspicion of cutaneous larva migrans. The patient was then placed on an oral anthelmintic and her symptoms resolved shortly after.

## Introduction

Cutaneous larva migrans (CLM) is a common zoonotic infection that occurs when the filariform larva of the hookworm penetrates the epidermis of a human's skin. The adult hookworm usually lays its eggs in their natural hosts, cats and dogs [1]. The most common species of these hookworms are *Ancylostoma brasiliense* (cat hookworm) and *Ancylostoma caninum* (dog hookworm), and are commonly seen in the southern United States, the Caribbean, and South America [1]. The prevalence of hookworms has been reported up to 8% in certain populations, most commonly in children [2]. Risk factors include a young age (10-14 years old), male sex, resource-poor region, and walking barefoot [2]. These organisms thrive in warm and moist environments, and are conventionally present amongst travelers in tropical regions.

Humans can become inadvertent hosts, typically from walking barefoot and accidentally stepping on contaminated animal feces infested with the hookworm. The hookworm is unable to travel into deeper layers of the skin to complete its life cycle in a human's gastrointestinal tract due to a deficiency in the collagenase enzyme [3]. Thus, they migrate throughout the epidermis, creating the classic superficial serpiginous

tracks which may last a few weeks to months, and oftentimes fully resolve without treatment [4]. Without an objective diagnostic tool, this classically remains a clinical diagnosis. POCUS is a well-established tool which has been shown to increase diagnostic accuracy in soft tissue infections in pediatric emergency medicine [5]. The most common uses of soft tissue ultrasound (US) include cellulitis, abscesses, and foreign bodies. When there is an increased suspicion of a foreign body, US can be used to detect, localize, and potentially extract it [6]. CLM, a common parasitic infection which may be considered a foreign body, has scarcely been reported to be diagnosed using POCUS. We present a case of CLM confirmed on POCUS in a tertiary pediatric emergency department (ED).

## Case Presentation

An 18-year-old woman with a history of Diabetes mellitus type 1 presented with pain, itching, and swelling of the left heel for one day. Her symptoms worsened with weight-bearing and improved with rest. She stated she was at the beach four days prior but denied any injury or having stepped on anything sharp. Her vital signs were normal. The physical examination was normal except for the soft tissue exam which revealed localized swelling with erythema on the heel that was mildly tender to palpation

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DOI: <https://doi.org/10.24908/pocus.v9i1.17470>

without fluctuance, induration, or swelling. POCUS examination was performed to further examine the area of interest and to evaluate for the presence of a foreign body or abscess. It revealed a serpiginous motile structure in the dermal layer of the foot, confirming the diagnosis of CLM. The patient was given a prescription for a one-time dose of Ivermectin with improvement of symptoms.

### *POCUS Findings*

A high-frequency linear probe was used to evaluate the plantar aspect of the patient's foot. The images revealed several small linear hyperechoic lesions in the subcutaneous layers of the foot exhibiting serpiginous motility (Figure 1). The subcutaneous tissue shifted throughout the migration process. Color Doppler was applied to confirm the moving echogenic lesions were not vasculature structures (Figure 2). The contralateral foot was also scanned for comparison and there was an absence of these motile structures in the epidermis.

### **Discussion**

Cutaneous larva migrans can be diagnosed solely on a patient's clinical presentation, however, additional studies may help confirm the diagnosis. Serological tests, such as enzyme-linked immunosorbent assay, can detect specific antibodies against the causative parasites [7]. As well, skin biopsy can be performed to identify the presence of larvae in the skin, but it may be inconclusive, rather invasive, and unnecessary. In other cases, imaging studies like X-rays may be employed to visualize the larvae in visceral tissues [8]. Optical coherence tomography has been reported to be an effective minimally invasive tool to rapidly detect CLM [9]. However, it is not widely available in the ED and is rarely used outside of an ophthalmology office. Although dermoscopy has been used to detect these cutaneous

parasites, most EDs do not carry these devices. In a recent study, reflectance confocal microscopy confirmed a larva burrow, described as a hyporeflective disruption of the normal honeycomb pattern in the epidermis [6]. As one can imagine, these devices are more commonly found in dermatology offices and are not typically stocked in most EDs. Interestingly, a high-frequency US was also utilized in that same study. A cylindrical mass and shadowing were revealed which the authors believed may have corresponded to the parasite and larva burrow [6].

There are limited studies demonstrating cutaneous larva migrans with minimally invasive imaging tools in pediatric patients in the ED. In contrast to other imaging modalities, POCUS is a valuable noninvasive portable imaging tool, available in most EDs. It has many clinical applications, including distinguishing between different soft tissue complaints. This case report features POCUS used to detect cutaneous larva migrans. We highlighted motile hyperechoic lesions in the epidermal layer of the patient's foot, utilizing a high-frequency linear transducer. When these hookworms tunnel through the skin, their paths are highlighted as anechoic tracks amid the echogenic base representing the dermis. Unfortunately, the individual larvae were not detected. While visualizing the actual larva may require more effort and time, the parasitic tracks can be detected via US, as seen with our patient. This technique may prove to be even more clinically useful as another case demonstrated that suspected larva diagnosed via US imaging, were normal soft tissue [6]. As more POCUS implementation is used by clinicians who suspect CLM, there will be more images available to compare our images against. This will perhaps give insight to diagnostic criteria for CLM.

Our patient complained of swelling and pruritus on the sole of her foot upon her presentation to the ED.

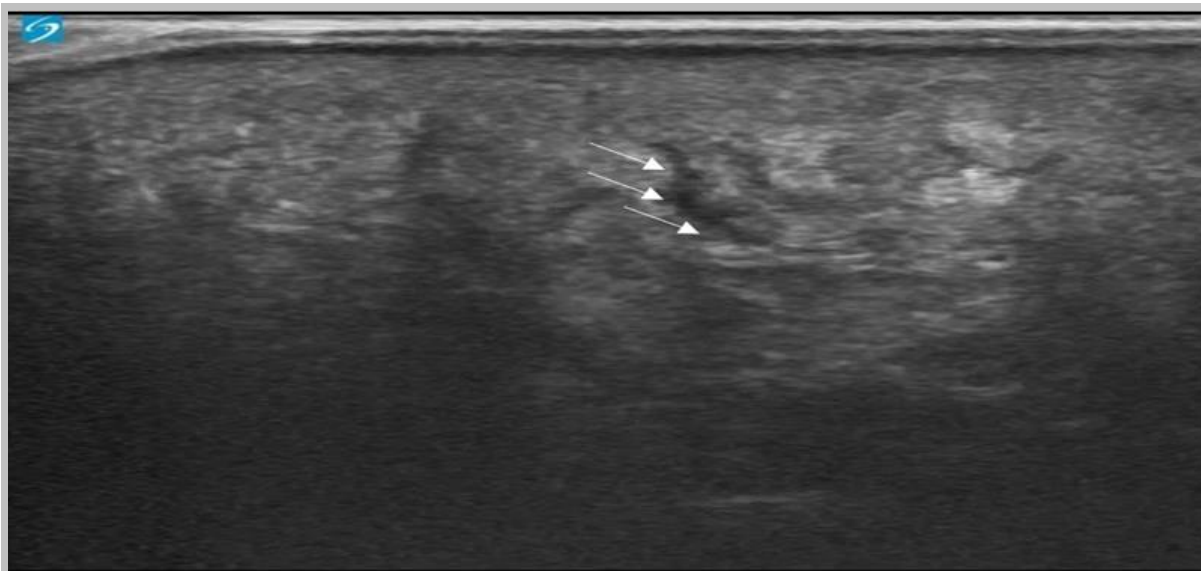
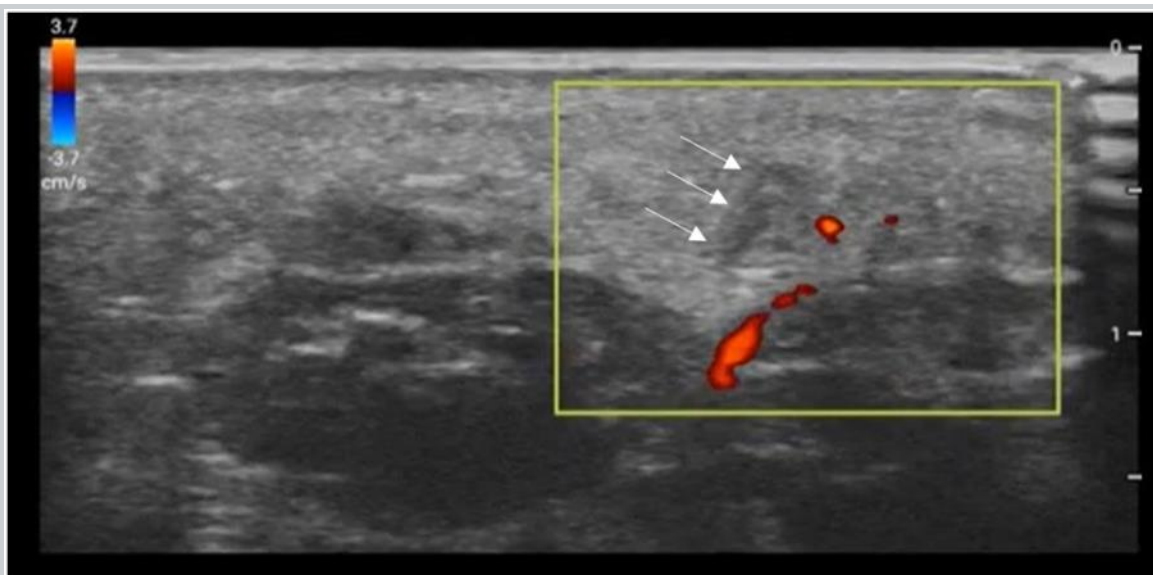


Figure 1. An anechoic motile serpiginous parasite (arrows) detected while tunneling through the epidermis.

Figure 2. Color Doppler was applied near a second anechoic track (arrows). Lack of color flow confirmed anechoic lesion was not a vascular structure.



Although the typical presentation of CLM consists of tortuous, pruritic, and erythematous lesions, presentation and symptoms are variable and CLM may be easily misdiagnosed due to lack of recognition and/or confidence in the diagnosis. As presented in our case, our patient did not have the classic serpiginous lesions, which may have led to a misdiagnosis and inappropriate treatment. POCUS may serve as a useful confirmatory tool prior to initiating treatment of CLM with oral anthelmintics. The first line recommendation for anthelmintics is a one-time dose 200 mcg/kg oral Ivermectin, which usually results in a 100% cure rate. If necessary, Albendazole may be used second line. Topical anthelmintics like Thiabendazole may also be effective if infection is local, but has been reported to have a poor eradication rate. Our patient received one dose of Ivermectin with full resolution of her symptoms. As CLM is very responsive to treatment, early and accurate diagnosis via US evaluation is likely clinically valuable.

### Conclusion

The diagnosis of CLM historically has been made by history and physical exam. Other suggested imaging modalities are either cost restrictive, insufficient, or not readily available. In this case, POCUS helped confirm the diagnosis and is not hindered by the same limitations of other imaging modalities when assessing for CLM. Further studies are needed to confirm the utility of POCUS to aid in the diagnosis of parasitic infections.

### Disclosure Statement

All authors declare no relevant financial relationships.

### Patient Consent

The authors' institutional research ethics board does not

require the obtainment of informed consent for the preparation of de-identified case reports.

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# Terson Syndrome Diagnosed by Ocular Point of Care Ultrasound on the Medical Floor

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## Abstract

In acute care environments, accurately assessing complications of intracranial pathology can be challenging. Ocular complications in acute intracranial disease are not consistently evaluated despite their high morbidity. We report on a case of monocular diplopia in a 63-year-old man with subacute traumatic brain injury with localized subarachnoid hemorrhage. Ocular point of care ultrasound (POCUS) identified features of vitreous hemorrhage in one globe, leading to a diagnosis of Terson syndrome and a timely referral to ophthalmology. This finding was made on the medical floor days after the initial presentation during rehabilitation when ophthalmoscopy was not possible, and vitreous hemorrhage had not been identified on presentation. Terson syndrome is a seldom discussed but important complication of intracranial hemorrhage generally associated with poor patient outcomes. Ocular POCUS can provide a useful alternative in assessing ocular complications of acute intracranial disease on the medical floor, particularly when the practicalities of performing ophthalmoscopy are challenged.

## Introduction

Managing intracranial pathology and its associated complications is a common challenge for acute care providers. Intracranial pathology can present with a myriad of signs and symptoms which may be challenging to elicit through examination alone [1]. As well, many of these complications gain increasing morbidity and mortality in our ageing population [1]. Regardless of traumatic or non-traumatic mechanisms, ocular manifestations of intracranial pathology can range from clinically apparent to subtle, with most presentations having potentially sight-threatening outcomes [2]. As a result, ophthalmoscopy is often advised to complete the evaluation of a patient with suspected intracranial pathology. Such patients can be difficult to interview or examine for visual disturbance – particularly in cases of altered mental status commonly associated with intracranial pathology – complicating accurate clinical evaluation.

It can be challenging to assess the visual system in acute care settings. The challenges include a need to monitor pupillary responses in acute intracranial injury precluding mydriasis, the inability to darken specific environments, and reduced access to ophthalmoscopy equipment in

certain locations, such as resuscitation areas [3]. As a result of these factors, 59% of ocular assessments in the Emergency Department are deemed inadequate [4]. These factors have led to a compounding cycle of increasing reliance on specialist assessment, reduced non-specialist competence, and reduced engagement in medical education [5].

In an era of point of care ultrasound (POCUS) expansion, increasing access to linear sonographic devices and decline of non-specialist ophthalmology, it is worth recalling the benefits of ocular POCUS. Here we demonstrate a case where ocular POCUS identified ocular complications of traumatic intracranial pathology, specifically traumatic cerebral contusion with localised subarachnoid hemorrhage. This complication had not been identified during the patient's initial assessment despite thorough review from numerous clinicians. The diagnosis of this complication in the care of acute intracranial pathology patients can reduce morbidity through expediting access to specialist care to preserve sight as well as provide useful prognostic information at the bedside.

## Case Report

A 63-year-old man presented to the Emergency

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DOI: <https://doi.org/10.24908/pocus.v9i1.16660>

Department suffering with irretractable nausea and vomiting with concomitant severe headache following a fall at home three days prior. The fall occurred from a standing height and was associated with minor abrasions to the forehead. The patient's family highlighted that the patient had seemed increasingly confused in the last 24 hours; this had initially been managed conservatively as a concussion symptom.

On examination, the patient was neurologically intact with mild confusion, reflected in an Abbreviated Mental Test Score (AMTS) of 8 out of 10. The patient reported no visual disturbance, and no further systemic pathology was identified. The patient was referred for computed tomography (CT) of the head which revealed a predominantly left-sided cerebral contusion without fracture to the skull with localized traumatic subarachnoid hemorrhage (Figure 1). This result was discussed with the regional neurosurgical center who elected for local admission and observation. No evidence of ocular pathology was present on the head CT. The patient was admitted to a medical bed for observation and consultation under neurology. Four days following admission, with symptom management and close observation, the patient became increasingly orientated. During a rehabilitative physiotherapy assessment, visual field difficulties were noted and the patient reporting that vision from his left eye was altered.

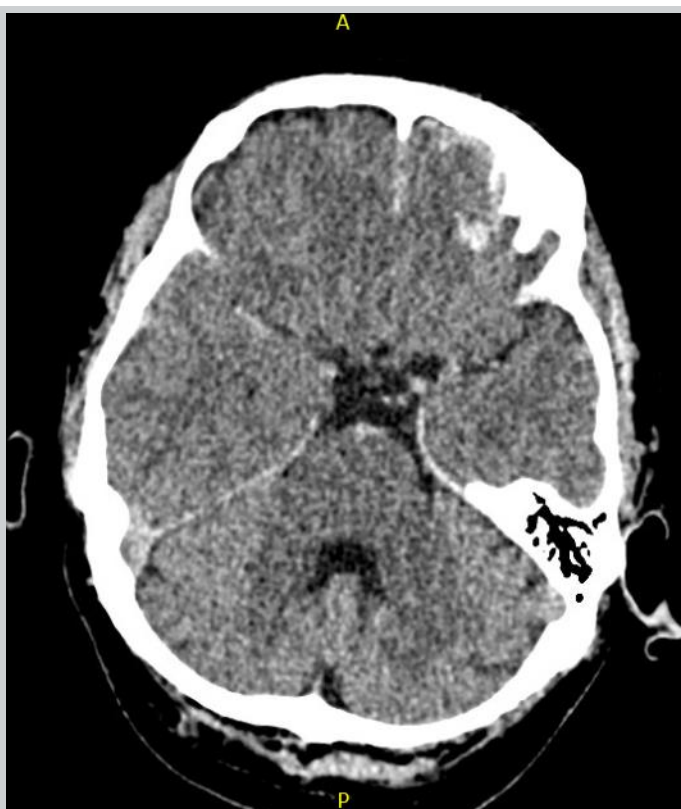


Figure 1. Small left frontal cerebral contusion with localized traumatic subarachnoid hemorrhage.

On examination, the patient demonstrated normal ocular movements and no external ocular injuries were appreciated. The patient described monocular diplopia on isolation of the left eye visual field. Under formal evaluation of his visual acuity using a Snellen chart, the patient had an intact right eye visual acuity (6/6), with a reduction in left eye visual acuity (3/6). The patient could not undergo ophthalmoscopy due to an unfavorable bright ward environment, a lack of mydriatic medication, and difficulty following instructions. As a result, the decision was made to proceed to ocular POCUS in the inpatient ward setting.

#### *POCUS Assessment*

The patient underwent ocular POCUS by a physician experienced in the modality. The patient was placed supine at a 45-degree bed angle. Given the report of left eye monocular diplopia, assessment began on the right eye which revealed optic nerve prominence, increased optic nerve sheath diameter (ONSD) consistent with papilledema (Figure 2 and Video S1). The quoted value

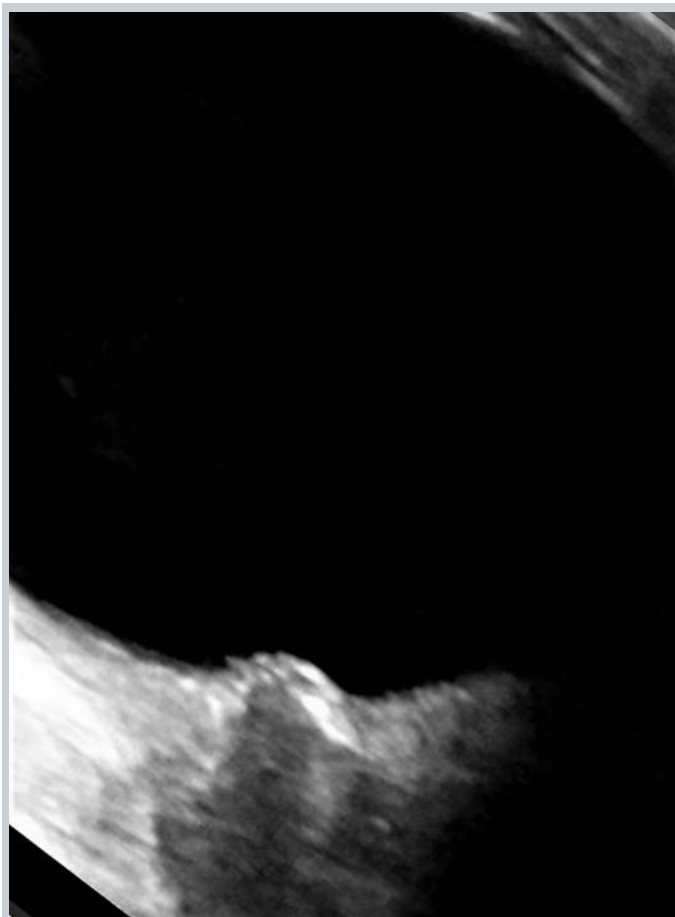


Figure 2. Right eye posterior structures, note the presence of increased optic nerve sheath diameter (ONSD) of 7mm (normal is up to 5mm) and the prominence of the optic nerve into the retina consistent with papilledema measuring 1.4mm from retina base.

of ONSD is taken from 3mm below the retinal insertion, using an upper limit of 5.0mm. The left globe also had papilledema with an ONSD of 7.8 mm (Figure 3)

On the assessment of the left eye, a dense irregular mass not fixed to the retina was also visualized (Figure 4). The dense intraorbital mass was seen rotating and the “washing machine sign” confirmed the lack of tethering of the mass to the retina through counter-rotation of the dense mass to the globe (Videos S2, S3). Given the presence of vitreous hemorrhage, a color waveform is applied to verify that central retinal arterial and venous flow is patent (Video S4). Given the patient’s positioning, the vitreous hemorrhage was seen to move inferioposteriorly from the probe with gravity.



Figure 3. Left eye posterior structures, note the presence of increased optic nerve sheath diameter (ONSD) of 7.8mm (normal is up to 5mm), measuring 1.9mm from retina base. The altered probe position avoids the central mass to allow for accurate assessment.

### Outcome

The ocular POCUS examination strongly supported the presence of intraocular hemorrhage within the left globe, which explained the patient’s monocular diplopia. Given the patient’s cerebral contusion and subarachnoid hemorrhage, the diagnosis of Terson syndrome was made.

The patient was urgently referred to ophthalmology for same-day review, who confirmed the presence of vitreous hemorrhage without complicating ocular features; the patient was referred for visual field testing. The patient remains under ophthalmology care and has an ongoing visual deficit. The current plan is for the patient to undergo regular visual field testing and close observation, aiming to avoid surgical intervention. Community neurorehabilitation continues as the patient suffers from a mild disability, personality changes, and chronic headaches.

### Case Discussion

Terson syndrome is defined by the presence of vitreous or retinal hemorrhage (including pre-, intra-, and sub-retinal hemorrhage) in the context of intracranial hemorrhage, either arising from traumatic brain injury or subarachnoid hemorrhage. In the case of vitreous hemorrhage, this can be identified on ocular POCUS by the presence of a non-tethered dense mass within the globe. The gold standard for the diagnostic evaluation of Terson syndrome remains dilated ophthalmoscopy. However ocular POCUS has been found to have high sensitivity (80%) and specificity (100%) for the diagnosis of Terson syndrome [6].

The Incidence of Terson syndrome remains unclear, with its presence potentially complicating more than 20% of all-cause subarachnoid hemorrhage (SAH) [7]. Terson syndrome is likely under-reported outside of scientific study due to a lack of evaluation and awareness of the syndrome. As a result, patients with monocular Terson syndrome often face significant delay in referral to specialty care [8]. It is important to note that delays in identifying Terson syndrome can result in poorer visual outcomes and associated morbidity. Patients with Terson syndrome who are not adequately managed are at risk of developing perimacular folds, retinal detachment, and ghost cell glaucoma [9].

The diagnosis of Terson syndrome can provide insight into the generalised clinical course in cases of intracranial hemorrhage. When grading head CTs using the Fisher scale, patients with low-grade SAH (grade I/II) are statistically unlikely to develop Terson syndrome when compared to those with high-grade SAH (grade III/IV) [10]. The only independent predictor of Terson syndrome is raised intracranial pressure; however, the



Figure 4. Left eye vitreous hemorrhage can now also be appreciated anterior to the prominent optic nerve.

presence of Terson syndrome is associated with increasingly severe neurological impairment using Glasgow Coma Score and Hunt and Hess grading, higher mortality, and poorer overall neurological outcomes [11]. It is important to note, however, that Terson syndrome may be present in patients with limited neurological compromise who make a full neurological recovery [12].

The mechanism by which Terson syndrome develops remains unclear, although as previously discussed, it is likely that raised intracranial pressure is important to its development [10]. One proposed mechanism is that of glymphatic reflux, in which a reversal of the intraocular to subarachnoid glymphatic flow occurs. This would occur due to intraocular pressures suddenly being overcome by increases in intracranial pressure. In such a mechanism, intraocular blood products are derived directly from the subarachnoid hemorrhage [13]. This mechanism may explain unilateral presentations of Terson syndrome given glymphatic flow is localised to each globe, particularly in cases where hemorrhage is limited to one cerebral hemisphere [14]. Alternatively, optic nerve sheath compression due to raised intracranial pressure and increased central retinal vein pressure may lead to venous vascular dysfunction and associated hemorrhage [15]. Alternative causes of acute raised intracranial pressure seldom propagate intraocular hemorrhage. Given this, it appears likely that the presence of intracranial hemorrhage, even in cases where hemorrhage is localised such as traumatic brain injury, is critical to the development of Terson syndrome.

In the case described above, ONSD was increased, but this was not isolated to the globe adjacent to the cerebral contusion. The role of ONSD generally, as well as its role in determining intracranial pressure, remains controversial. Given the determination of ONSD as a skill can be taught rapidly and in a reproducible manner, its use has expanded rapidly within the field of ocular POCUS [16]. Smaller studies have shown ONSD to have a high correlation with raised intracranial pressure [17]. To this end, meta-analysis has shown that although ONSD correlation with raised intracranial pressure is present, caution should still be taken in its use [18]. Given how glymphatic reflux may play a fundamental role in the development of intraocular hemorrhage in Terson syndrome, ONSD may be less reliable in these patients. There has been no study to date exploring ONSD within the Terson syndrome cohort.

### Conclusion

Terson syndrome is an important but challenging diagnosis in the acute care of patients suffering from intracranial injury. There are often significant delays in the diagnosis of Terson syndrome, leading to increased morbidity in patients requiring already requiring complex neurorehabilitation. This case illustrates that Ocular POCUS can be used to make a rapid diagnosis of Terson syndrome on the medical floor.

### Disclosures

No conflicts of interest to declare, and all ethical guidance is followed where appropriate.



## Patient Consent

Informed patient consent has been given to publish the respective imaging and information; all case data is anonymized in line with General Medical Council, local, and publisher guidance.

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# Gas Forming Pyogenic Liver Abscess Diagnosed by Point of Care Ultrasound

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## Abstract

Gas-forming pyogenic liver abscess (GFLPA) carries a high mortality rate. Early identification of the source of infection in sepsis results in better survival. Bedside point of care ultrasound (POCUS) can be used to help localize a source of infection. A 59-year-old man presented with systemic inflammatory response syndrome (SIRS) and was diagnosed with GFLPA on the initial encounter via clinical assessment and POCUS examination. After commencing antibiotics, optimal glucose control, adequate fluid resuscitation, and early infective source control, he achieved full recovery and was followed up in outpatient medical and surgical clinics. This case illustrates the role of POCUS as a diagnostic tool in sepsis and raises awareness among clinicians to recognize the features of GFLPA on POCUS.

## Introduction

The Asia Pacific region accounts for 60% of the world's population with 4.6 billion people. National sepsis rates in this region range from 120 to 1,600 per 100,000, and sepsis-related mortality rates of up to 35% [1]. The annual incidence rate of pyogenic liver abscess (PLA) ranges from 2 to 45 incidents per 100,000 hospital admissions worldwide [2]. PLA is further subdivided into gas-forming pyogenic liver abscess (GFPLA) and non-GFPLA. GFPLA has a greater fatality rate than non-GFPLA, with symptoms ranging from mild fever and abdominal pain to severe sepsis accompanied by a ruptured abscess, that culminates in fulminant peritonitis.

Point of care ultrasound (POCUS) can be used to localize a source in the evaluation of sepsis, such as PLA. On POCUS examination, liver abscesses are often poorly demarcated and have a variable appearance, ranging from mostly hypoechoic – with or without some internal echoes – to hyperechoic [3]. We report a case of GFPLA that was diagnosed by POCUS, resulting in earlier percutaneous drainage for infective source removal.

A 59-year-old man with hypertension presented to the emergency department with fever, chills, and rigors for 5 days, along with lethargy and poor oral intake. He presented to the emergency department with a heart rate of 110bpm, blood pressure of 101/62 mmHg, respiratory rate of 20 breaths/min, oxygen saturation of 98% on room air, and a temperature of 36.5 degrees C. On physical

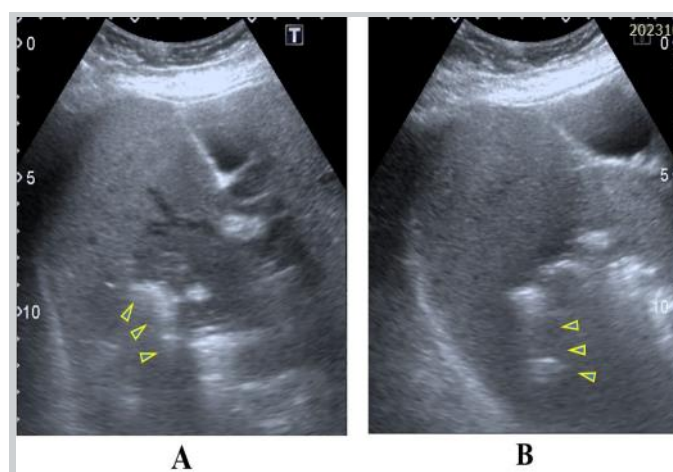


Figure 1. POCUS image A of gas-forming pyogenic liver abscess (GFPLA) demonstrates an ill-defined margin solitary lesion with heterogeneous echogenicity. POCUS image B demonstrates brightly echogenic reflectors with posterior reverberation artefacts noted within the lesion. Yellow triangles on both images show the posterior reverberation artefacts.

examination, his lungs were clear, there were no murmurs on cardiac auscultation, and his abdomen was soft and non-tender, with no pedal edema. He had dry mucous membranes and concentrated urine. Laboratory examination revealed leukocytosis with a white cell count of  $14.2 \times 10^3/\mu\text{L}$  and thrombocytopenia with a platelet

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DOI: <https://doi.org/10.24908/pocus.v9i1.16854>

count of  $126 \times 10^3/\mu\text{L}$ . His hemoglobin level was 10.4g/dl, sodium level was 123mmol/L, potassium level was 4.9mmol/L, and his renal profile revealed acute kidney injury with urea of 90mg/dL and creatinine of 2.79mg/dL (normal range 0.67-1.18mg/dL). Liver function tests revealed mildly elevated transaminases with aspartate transaminase (AST) 89u/L and alanine transaminase (ALT) 57u/L, total bilirubin (TB) 0.64mg/dL and direct bilirubin 0.18mg/dL, and albumin 27g/L. Blood glucose levels were 252mg/dL, indicating hyperglycemia. Further infective screening revealed a negative leptospirosis serology, a negative dengue NS1 antigen, a negative dengue IgM and IgG, and no malaria parasites on blood film microscopy analysis. POCUS was conducted to look for the source of the infection. Cardiac POCUS revealed no large valvular vegetation, but abdominal POCUS revealed a solitary liver lesion with the features of an ill-defined margin with heterogeneous echogenicity and brightly echogenic reflectors, with posterior reverberation artifacts noted within the lesion (Figure 1). The size of the liver lesion measured 8.3cm x 8.7cm x 9.0cm (Figure 2) and the colour doppler demonstrated no colour doppler signal within, indicating the absence of central perfusion (Figure 3). Chest x-ray (CXR) showed gas shadow beneath the right hemidiaphragm (Figure 4).

The presence of relative hypotension, tachycardia, leucocytosis, fever, POCUS features of the liver lesion, and CXR findings favoured the diagnosis of sepsis caused by GFPLA. Standard sepsis management commenced using antibiotics, adequate fluid resuscitation, and optimal glucose control. An urgent referral to radiological and surgical teams was made to expedite drainage for infective source control. Percutaneous drainage catheters were inserted and pus was drained (Figure 5). Both his blood culture and pus culture grew *Klebsiella pneumoniae*. He subsequently

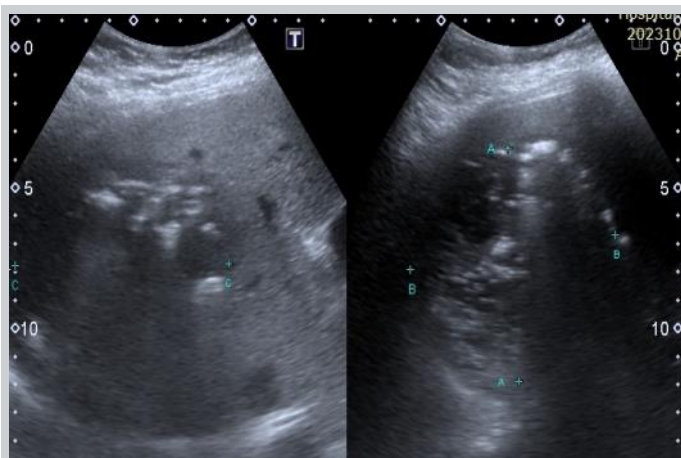


Figure 2. The size of the GFPLA with distance A measuring 8.3cm, distance B measuring 8.7cm, and distance C measuring 9.0cm.

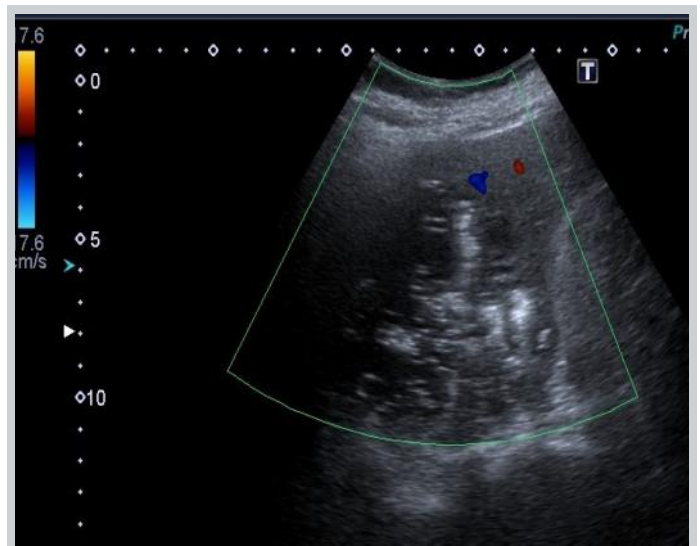


Figure 3. GFPLA with colour doppler, demonstrating no colour doppler signal within indicating the absence of central perfusion

made a full recovery, and was discharged with an oral hypoglycemic agent, an antihypertensive drug, and antibiotics. After being discharged, he was given follow-up appointments at the medical and surgical clinics to optimize his blood pressure, for diabetes management, and for a reassessment of the abscess following a six-week antibiotic course.

GFPLA was described by Smith in 1944 [4]. The common culprit organisms in pyogenic liver abscess are *Escherichia coli* and *Klebsiella pneumoniae*. Diabetes mellitus is an important predisposing factor for pyogenic liver infection [5]. High glucose concentration in tissue and compromised immunity in diabetic patients permits proliferation of these microbes. *Klebsiella pneumoniae* infection in patients with diabetes is a risk factor for the development of GFPLA [6]. GFPLA is associated with a high mortality rate and high frequency of septic shock and bacteraemic presentations [7]. In their study, Chou et al. describe that the duration of symptoms was shorter, and the incidence of septic shock was higher in the GFLPA group than non-GFLPA group [8]. GFLPA generally has a less favourable outcome as it is associated with rapid clinical deterioration and a high mortality rate. Standard sepsis therapy of early initiation of antibiotics, glucose optimization, appropriate fluid management, inotropic supports, nutritional support, and early drainage are crucial in determining the survival of a patient with GFLPA. Thus, early identification of the GFLPA by ultrasound or POCUS examination can be crucial.

According to a recent retrospective study by Lin et al., ultrasonography has a sensitivity of 85.8% for identifying

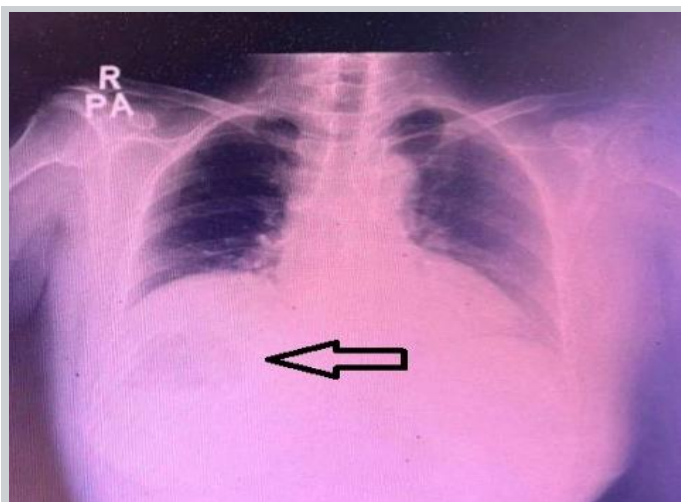


Figure 4. Chest x-ray with gas shadow (depicted by the black arrow) seen beneath the right hemidiaphragm.

pyogenic liver abscess [9]. Utilizing computed tomography imaging in addition to ultrasonography yielded a remarkable 100% diagnosis rate for GFPLA. On ultrasound, liver abscesses are typically poorly demarcated with a variable appearance. This can range from predominantly hypoechoic (with some internal echoes) to hyperechoic, while the colour doppler will demonstrate the absence of central perfusion. GFPLA can appear as a diffuse hyperechoic spot with acoustic shadowing, or as a hyperechoic lesion with reverberation.

POCUS played a pivotal role in this patient's care, aiding in a rapid diagnosis. Early identification of liver



Figure 5. Pus drained from the gas-forming pyogenic liver abscess (GFPLA) via percutaneous drainage catheter.

abnormality on POCUS resulted in an expedited diagnosis and management, which likely contributed to a favorable outcome.

### Disclosures

The authors have no relevant conflicts of interest to disclose.

### Patient Consent

Informed consent and permission for publication of the case and ultrasound images was obtained from the patient.

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# Resolution of Sonographic Appendicitis in Pediatrics: a Point of Care Ultrasound Case-Series

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## Abstract

Studies of pediatric appendicitis treated conservatively show a considerable rate of recurrence. Point of care ultrasound (POCUS) imaging at our facility is routinely performed for abdominal pain and may be more likely than radiology-performed ultrasound to encounter cases that then self-resolve. We present a case series collected from a POCUS quality assurance review from 2019 through 2022. Five children were identified with sonographic appendicitis on review of stored POCUS images, and subsequent improvement of pain. A pediatric radiologist reviewed blinded images and agreed with the POCUS interpretation in all five cases. No child in this series received antibiotics. The national patient database was used to ensure that the patients in this series did not present elsewhere with appendicitis. We suggest that these cases represent early appendicitis that self-resolved. Patients should be aware that POCUS showed signs of appendicitis, and should seek medical attention for recurrence of symptoms.

## Introduction

Appendicitis is the single most common surgical diagnosis in the pediatric emergency department (PED) [1]. Pediatric appendicitis treated conservatively (without surgery but with antibiotics) have a one-year recurrence rate of 18.6% and a five-year recurrence rate of 23.3% [2]. Point of care ultrasound (POCUS) is becoming more widely accepted as a means to diagnose pediatric appendicitis. POCUS is without radiation and can be performed comfortably with adequate analgesia. Here, we present a case series of sonographic appendicitis on POCUS in children discharged without medical or surgical treatment for appendicitis. We suggest that these cases represent early appendicitis that self-resolved. This series brings awareness to pediatric emergency physicians that very early appendicitis may self-resolve, and to patients that may be at increased risk of recurrence.

## Methods

Our pediatric emergency department (PED) sees 27,000 children (to the age of 18 years) annually. In the context of a wider study (approved by our institutional review board as KMC 0202-23), we found 414 cases of appendicitis confirmed by pathology or computed tomography (CT) from 2019 through the end of 2022, of

which 171 were confirmed with POCUS. POCUS was performed on a Zonare Z.One ultrasound by ten pediatric emergency fellows and attendings with 1-6 years of POCUS experience. We use a linear, high frequency probe to diagnose appendicitis. The examination is considered positive if it demonstrates a tubular, noncompressible, aperistaltic structure in the right lower quadrant, greater than 6 millimeters in diameter, with or without secondary findings such as wall thickness above 2 millimeters free fluid, or peri-appendiceal inflamed fat [3].

Our surgical department has traditionally hospitalized children for observation if they have a negative ultrasound in the PED but a clinical examination or laboratory evaluation that cannot exclude appendicitis, or a positive ultrasound with an unremarkable laboratory and physical examination. Children without a diagnosis of appendicitis and hospitalized for observation do not receive antibiotic coverage in the PED or in the inpatient unit, but are re-examined by a pediatric surgeon.

During the study period, five children were identified on quality assurance review to have POCUS images consistent with appendicitis, but were discharged from the PED or hospital without antibiotic therapy or surgery. The country-wide OFEK electronic medical record

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DOI: <https://doi.org/10.24908/pocus.v9i1.16860>

database, which includes all outpatient visits as well as all hospitalizations, was interrogated to verify that the children in our series did not return to a medical facility with appendicitis within at least a year from PED presentation. An experienced pediatric radiologist blinded to the clinical data reviewed anonymized images for this study and agreed with the POCUS interpretations. Scoring systems to assess the likelihood of appendicitis are not used at our facility.

## Case Reports

### Case 1

A 7-year-old female presented with several hours of abdominal pain and emesis, without fever or diarrhea. Visual Analog Scale (VAS) was not recorded. She had right lower quadrant tenderness, without peritoneal findings. White blood cell (WBC) count was 11.8 K/micron, and neutrophil count 10.3 K/micron. POCUS was read by the pediatric emergency fellow as unremarkable, but was flagged on quality assurance review as showing a 7-millimeter appendix surrounded by inflamed fat (Figures 1 & 2). She was discharged from the PED.

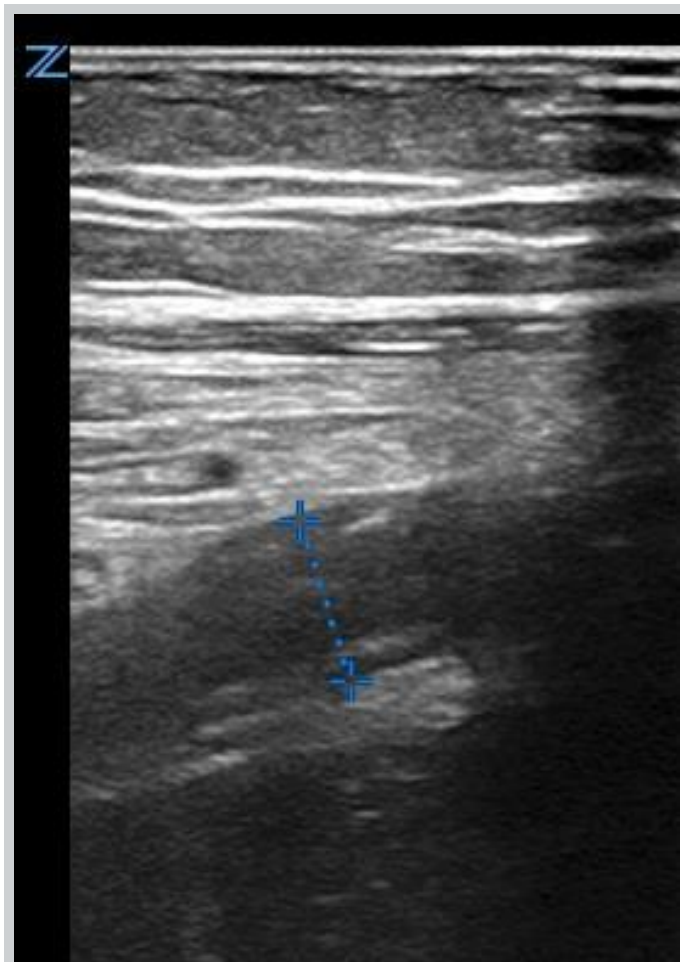


Figure 1. 7-millimeter noncompressible appendix in long-axis.

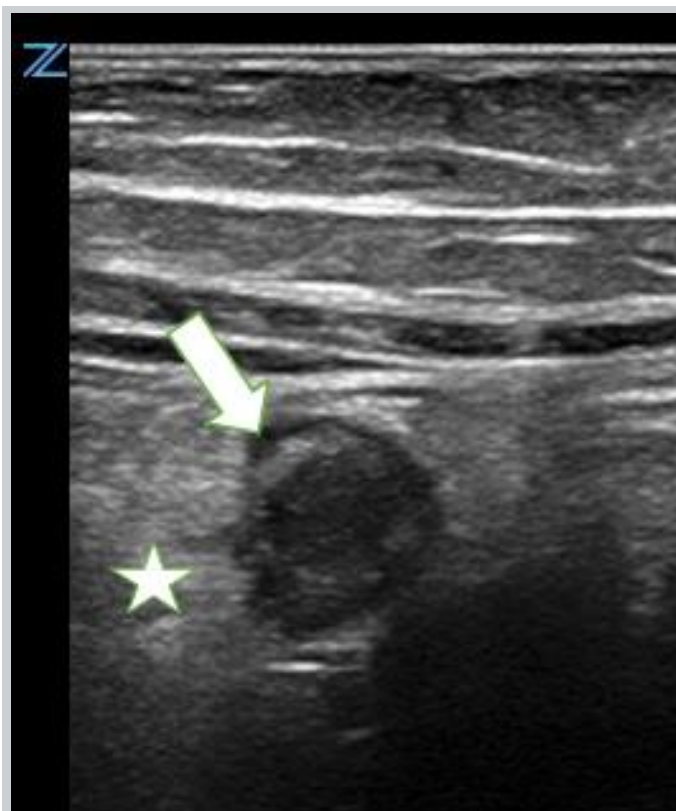


Figure 2. Appendix, noncompressible, in short-axis, surrounded by echogenic mesenteric edema/ inflammation. The arrow's tip sits on a small amount of free fluid surrounding the tubular appendix. The star sits in the center of a cloud of echogenic inflamed fat.

### Case 2

A 13-year-old female presented with hours of periumbilical pain without fever vomiting or diarrhea; VAS was 2. Examination showed bilateral lower quadrant tenderness without peritoneal signs. Complete blood count (CBC) was normal, and C-reactive protein (CRP) was 4.6 mg/dL. POCUS found an enlarged non-compressible appendix that appeared thick-walled and was surrounded by inflamed fat (Figure 3). Radiology-performed ultrasound (RADUS) found a 7.5 millimeter noncompressible tubular structure in the right lower quadrant consistent with appendicitis. She was admitted to surgery for observation. She was discharged the following morning with a nontender abdomen.

### Case 3

A 7-year-old male presented with several hours of severe lower abdominal pain, worse with walking or bending and worse on urination. He had one episode of diarrhea, no fever, and no emesis. Past medical history is significant for a hospital admission for abdominal pain two years prior, and received a dose of intravenous antibiotics. RADUS at that time describes mesenteric lymphadenitis

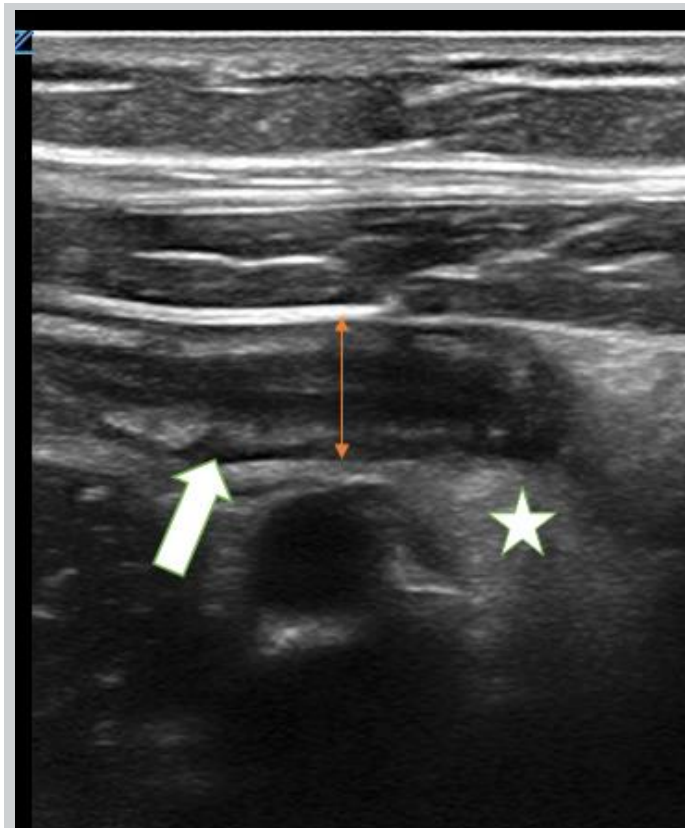


Figure 3. 7.5-millimeter noncompressible appendix in long-axis with wall thickening and surrounding mesenteric edema/ inflammation. The arrow's tip sits on the irregular thickened wall of appendix. The arrow sits in the center of a cloud of echogenic inflamed fat. The double arrow indicates the appendiceal diameter.

and an appendix thoroughly visualized with a maximum diameter of 8 millimeters and no signs of inflammation. VAS at the current visit was 5. Examination showed lower abdominal pain with guarding. CBC and CRP were unremarkable. POCUS showed a 7.3 millimeter noncompressible appendix with free fluid at the tip (Figure 4). RADUS was not completed due to noncompliance with exam. The patient was admitted to surgery overnight for observation and preparations were made to send him for abdominal CT. Examination by the attending surgeon after arrival in the surgical unit showed a soft abdomen that with mild tenderness to deep palpation. Examination 39 hours after arrival in the PED showed a soft nontender abdomen, and he was discharged on hospital day 2.

#### Case 4

A 10-year-old female presented with hours of severe abdominal pain. She reported no fever, vomiting or diarrhea; VAS was 8. CBC was unremarkable, and CRP was 3.63 mg/dL. POCUS showed a 6.9-millimeter noncompressible appendix (Figures 5 & 6). RADUS showed a 7.5-millimeter appendix with wall thickening,

enlarged mesenteric lymph nodes, and a small amount of fluid in the right gutter. She was admitted to surgery, with admission orders to begin fasting and intravenous fluid in preparation for surgery. On admission, the attending surgeon described a soft abdomen with moderate tenderness to deep palpation and no peritoneal signs. On hospital day 1 she reported improvement in abdominal pain and began to eat. Repeat CBC was unremarkable, and CRP was stable at 3.56 mg/dL. Repeat RADUS again showed a 7-millimeter appendix with surrounding mesenteric inflammatory change and an appendicolith at the base, thickening of surrounding small bowel wall, and enlarged nodes, consistent with acute appendicitis. On hospital day 2, CBC was again unremarkable and CRP declined to 1.44 mg/dL. RADUS showed no change from prior. On hospital day 3 she was discharged with mild right lower quadrant (RLQ) tenderness. She returned to the PED 2 days after discharge with abdominal pain, and only mild tenderness on exam. POCUS showed a normal appendix. After surgical consultation, she was discharged.

#### Case 5

A 9-year-old male with a history of Celiac disease presented with hours of abdominal pain that migrated to the RLQ. He denied fever, vomiting and diarrhea. VAS was 4. Examination was significant for right upper and lower abdominal tenderness with positive Rovsing and obturator signs. CBC was unremarkable, CRP 2.37 mg/dL. POCUS showed enlarged mesenteric lymph nodes in the right lower quadrant of the abdomen, with a 7-millimeter noncompressible appendix (Figure 7, Video S1). He was admitted for observation. On hospital day 1 CBC was again unremarkable, CRP 2.27 mg/dL. RADUS found a 6-millimeter appendix partially compressible with

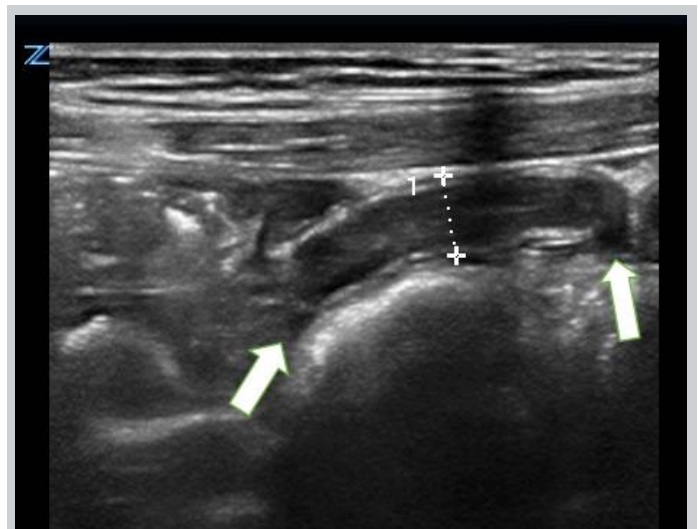


Figure 4. 7-millimeter noncompressible appendix with wall thickening with free fluid adjacent to the tip.

surrounding inflamed fat, “possibly consistent with early appendicitis.” Repeat RADUS on hospital day 2 was unchanged. On both hospital days, examination by the attending gastroenterologist showed a soft abdomen with mild right lower quadrant tenderness. Examination by the attending surgeon was similar and deemed inconsistent with acute appendicitis, and the patient was discharged home.

### Discussion

This is the first series of pediatric sonographic appendicitis that resolved without antibiotic or surgical therapy. Our series comes to bring greater awareness of spontaneous resolution of pediatric appendicitis in the context of increasing availability of POCUS in the PED.

Emergency physician performed POCUS has been shown to have a learning curve outside the context of fellowship training [4]. POCUS for appendicitis in a mixed population has a pooled sensitivity 0.81 and pooled specificity of 0.87, noninferior to RADUS [5,6]. Others have found lower numbers in physicians with basic training in POCUS [3,7].

In the context of a negative ultrasound, prior work has shown a negative predictive value of 96% when the WBC is less than 11,000 cells/micron [8]. There, 25% of children with appendicitis and a normal laboratory evaluation were detected by POCUS and 75% were detected by RADUS. Thus, early in the course, laboratory evaluation may be unremarkable, and POCUS can work side by side with RADUS to prevent missed appendicitis.

Non-operative management – treatment of appendicitis with antibiotics in lieu of surgery – is becoming more

frequent and, in the short-term, has a high rate of success. A systematic review of seven studies of pediatric uncomplicated (unruptured) appendicitis showed a success rate to hospital discharge of 91% [9] and 41.7% of parents would choose non-operative management if their child had appendicitis [10]. However, initiation of antibiotic therapy commits the child to hospitalization and to completing a course of intravenous and oral antibiotics.

Since the 1990s, several authors have reported on cases of spontaneous resolution of appendicitis [11-13]. Cobben, et al. reported on 60 adults with spontaneous resolution of appendicitis. They showed a recurrence rate of 38%, with higher rate of recurrence in cases with an appendiceal diameter above 8 millimeters [14]. Lastunen et al. studied 184 adult patients with an Adult Appendicitis Score of 11-15 and less than 24 hours of symptoms. These patients were allocated to either early imaging (ultrasound and/or CT) or observation arms. Those in the observation arm were reassessed after 6-8 hours. They showed that those imaged early were diagnosed more frequently with appendicitis (72% versus 57% in the observation group) [15]. This result may suggest that there are adult patients with early appendicitis who experience spontaneous resolution. Similarly, a metaanalysis of over 100,000 adult patients found a decrease in the proportion of complicated appendicitis compared with uncomplicated appendicitis during the COVID-19 pandemic year. The decrease in proportion of uncomplicated appendicitis without an increase in the absolute number of complicated appendicitis between the two time periods suggests that a certain amount of

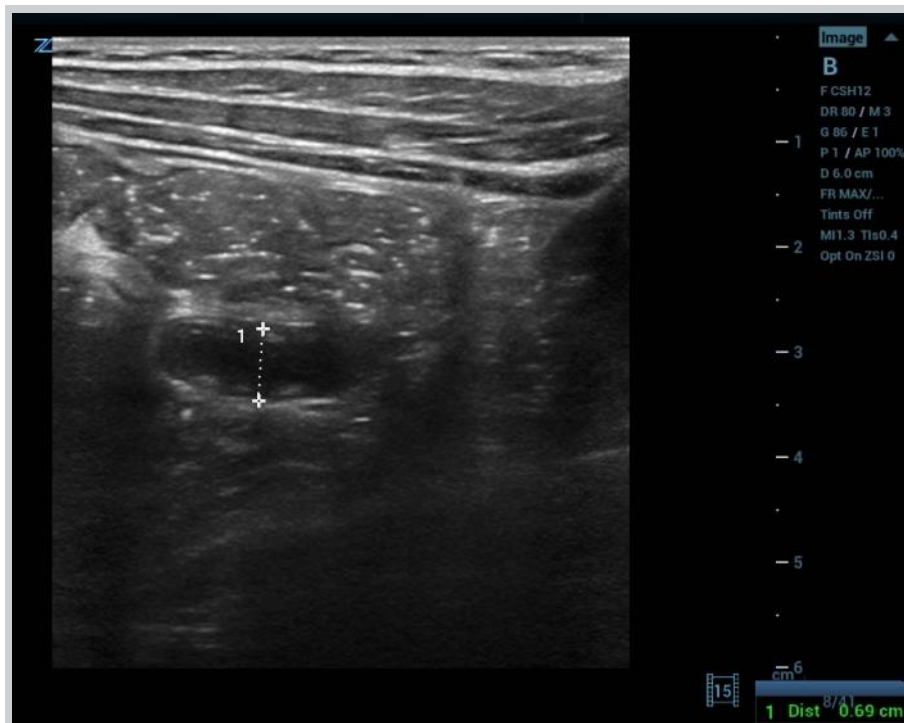


Figure 5. Fluid filled 6.9-millimeter appendix in long-axis, with wall thickening and surrounding mesenteric edema/ inflammation.



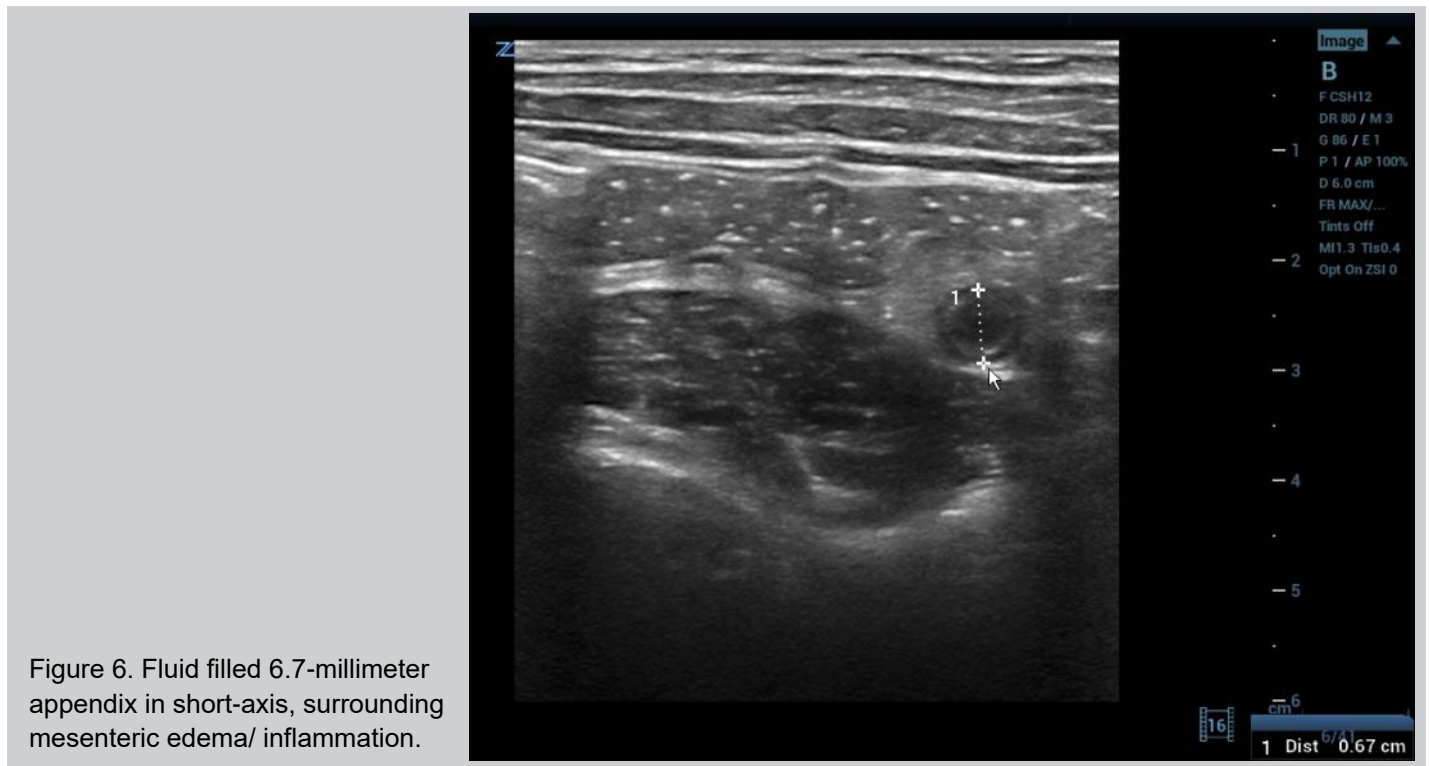


Figure 6. Fluid filled 6.7-millimeter appendix in short-axis, surrounding mesenteric edema/ inflammation.

uncomplicated appendicitis resolved spontaneously during a period of limited access to health care [16]. A 2007 review by the same author concluded that “spontaneous resolution of untreated, non-perforated appendicitis is common” [17].

Park et al. randomized 245 adult patients with uncomplicated appendicitis (defined as appendiceal diameter no larger than 11-millimeters and without any signs of perforation) to antibiotic or supportive therapy. The percentages of treatment failure were similar between the two groups (23.4% in the no-antibiotic group and 20.7% in the antibiotic group), further supporting the notion that spontaneous resolution of uncomplicated appendicitis may not be a rare occurrence [18].

A series of 182 pediatric patients with low-grade sonographic appendicitis (defined there as “an appendix with a smooth submucosal layer or irregular submucosal layer with increased blood flow and no appendiceal mass, abscess, or perforation”) were observed without surgery or antibiotic therapy. Their series showed a long-term event free rate of 60%, with recurrences at an average of two years post-diagnosis [19].

In a multi-center study, Bachur et al. found that the use of ultrasound in boys less than 5 years-old increased negative appendectomy rates [20]. Bachur et al.’s study relied on coding data, and therefore could not arrive at a mechanism that would explain this increase in negative appendectomy rate. Perhaps appendicitis was overcalled by an overreliance on secondary signs, and perhaps the

appendicitis resolved by the time of surgery.

In children, 21% of radiology-performed ultrasounds contain language that renders diagnosis of appendicitis uncertain [21]. Our cases may have represented appendiceal thickening as the sonographic sign of enteritis. Early appendicitis without fecalith may be overcome by a healthy immune system, like other bacterial infections. Complicated appendicitis is unusual before 12 hours of abdominal pain [22], and repeating sonography after a brief observation may eliminate the

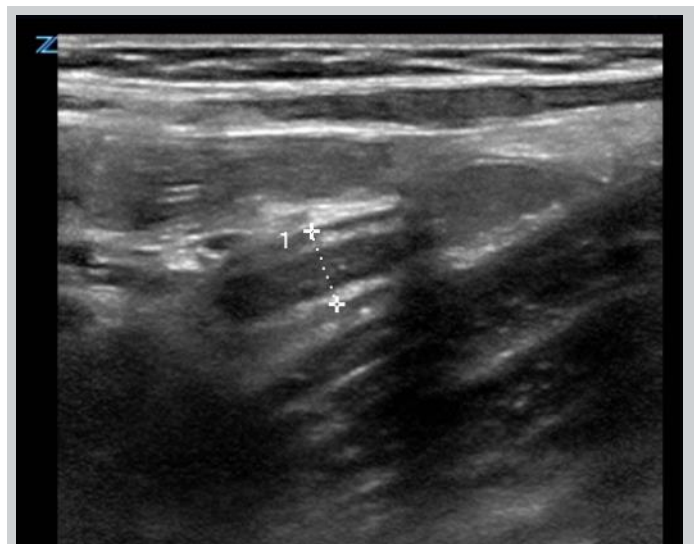


Figure 7. 7-millimeter appendix with wall thickening in long-axis.

burden of cases that have resolved. Others demonstrate that pediatric perforated appendicitis occurs more commonly after the first 24 hours of symptoms [23,24]. In Narsule's study of 197 children with appendicitis, none with less than 12 hours of symptoms were perforated at time of surgery [25]. Thus, observation in cases of very early appendicitis may be reasonable.

Children may develop chronic appendicitis, characterized by intermittent, colicky right lower quadrant pain and fibrosis of the appendix on pathological examination [26]. Chronic appendicitis is thought to be related to a partial or chronic appendiceal obstruction, and the incidence in children is unknown. We suggest that spontaneously resolving appendicitis may be an episode within the trajectory of chronic appendicitis.

### Limitations

Our study is retrospective and did not provide a CT or pathologic confirmation of appendicitis. As these cases review sonographic appendicitis without a confirmatory study, we cannot exclude that the appendix was inflamed in the context of a developing gastrointestinal illness that subsequently resolved. Our PED does not use a validated scoring system to assess the pretest probability of appendicitis. Our PED patients are examined by physicians at different levels of training, and we therefore felt that the physical examination documentation was subjective and not sufficiently reliable to create an appendicitis pretest score retrospectively.

### Conclusion

Children with POCUS findings suggestive of appendicitis may not necessarily need treatment (antibiotics or surgery) prior to a certain duration of symptoms as symptoms may self-resolve. Cases that present with only several hours of abdominal pain may warrant a brief observation and repeat ultrasound if the clinical context results a low pretest probability for clinically significant appendicitis. Patients who experience spontaneous resolution of appendicitis may be at an increased risk of recurrence.

### Patient Consent

Patient consent for a case series is not required by our institutional review board.

### Conflict of Interest Statement

The authors declare no relevant conflicts of interest.

### Financial Support

We declare no financial support/sponsorship.

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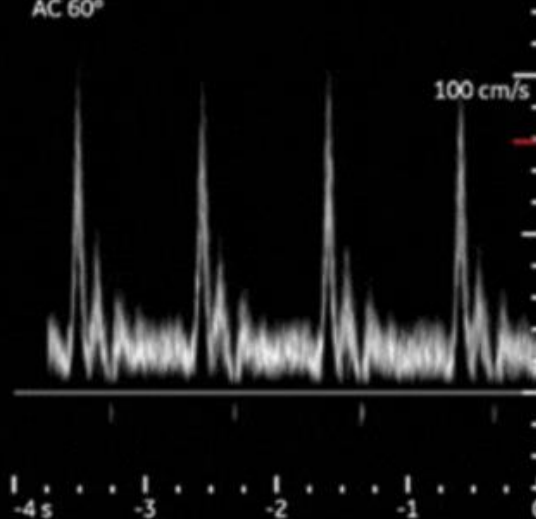
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# Return of the Living Dead Gut – A Case Report of Ischemic Colitis Identified on Point of Care Ultrasound

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## Abstract

Ischemic colitis is the most common form of gastrointestinal ischemia [1]. The diagnosis of ischemic colitis is made by clinical data and computed tomography (CT) imaging of the abdomen and pelvis [1]. While colonoscopy is considered the gold standard for diagnosis, this is not performed in the emergency department (ED) [2]. Few studies have been performed to describe the sonographic findings of ischemic colitis using point of care ultrasound (POCUS). We report a case that highlights the sonographic findings of ischemic colitis in a patient who had two separate visits to the ED, showcasing the utility of POCUS in making this diagnosis. POCUS can be used as a diagnostic tool for early detection of ischemic colitis leading to prompt treatment with antibiotics, CT imaging, and surgical consultation.

## Introduction

Ischemic colitis is one of the most common causes of gastrointestinal ischemia. This disorder has two major types: gangrenous and non-gangrenous, with gangrenous being the most severe given higher associated morbidity and mortality [3]. Non-gangrenous ischemic colitis is more common, representing approximately 80-85% of cases of ischemic colitis and is transient and self-limiting. Non-gangrenous ischemic colitis is often caused by acute episodes of hypoperfusion, generally secondary to a low-flow state [4].

The incidence of ischemic colitis is often underestimated due to its vague presenting symptoms, including abdominal pain, rectal bleeding, diarrhea, nausea, and vomiting [5]. Although it can occur at any age, ischemic colitis increases with age, especially after age 49-years. Risk factors include hypertension, diabetes, coronary artery disease, dyslipidemia, chronic obstructive pulmonary disease, acute hypotension, and atrial fibrillation [6]. In the emergency department (ED) these patients often require a computed tomography (CT) scan of the abdomen and pelvis to make the diagnosis; however, this can lead to a delay in making the diagnosis. Abdominal POCUS is increasingly performed in the ED for patients presenting with acute abdominal pain and can

potentially help aid in making the difficult diagnosis of ischemic colitis. The sonographic findings of ischemic colitis include symmetric bowel wall thickening greater than 3mm, segmental (greater than 10 cm) colonic involvement, hyperechoic pericolonic fat enhancement, decreased or absence of bowel wall Doppler flow, pneumatosis, and/or the presence of free fluid [3,7-10]. In the ED abdominal POCUS is often performed using a curvilinear transducer due to the depth of the bowel and the large area that needs to be evaluated.

We report a case that highlights the progression of sonographic findings of ischemic colitis in a patient who had two separate ED visits for abdominal pain.

## Case Report

An 82-year-old female with a past medical history of aortic insufficiency and prior surgical history of a right incarcerated femoral hernia repair and incisional hernia repair with mesh placement presented to the ED with abdominal pain, vomiting, and non-bloody diarrhea for the last couple of days. The patient reported diffuse constant abdominal pain, which was worse in the lower abdomen, and decreased oral intake. Upon arrival to the ED, the patient's blood pressure was 156/81mm Hg, heart rate was 156 beats per minute, respiratory rate was 24 breaths per minute, and temperature was 37.5 degrees

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DOI: <https://doi.org/10.24908/pocus.v9i1.16950>

Celsius (99.5 Degrees Fahrenheit). On physical exam, the patient was well appearing, tachycardic with an irregular heart rate. The patient's abdomen was soft, diffusely tender to palpation, with normal bowel sounds and no peritoneal signs. Abdominal POCUS was performed, which showed bowel wall thickening of 0.54 cm (Figure 1a) and free fluid surrounding an area of thickened bowel with enhancement of pericolic fat (Figure 1b).

Laboratory findings were significant for an elevated white blood cell count (WBC) of 15.39 K/uL, an international normalized ratio (INR) of 3.14, and a venous blood gas (VBG) lactate of 1.9 mmol/L. A CT Angiography (CTA) of the abdomen and pelvis was ordered for concern for bowel ischemia versus colitis, in the setting of atrial fibrillation, and abdominal pain. The CTA demonstrated a thickened transverse colon wall concerning for colitis, small volume ascites in the pelvis, and no evidence of mesenteric arterial stenosis. The patient received a dose of piperacillin/tazobactam, intravenous fluids, and morphine. Surgery was consulted and the patient was advised to be admitted to the hospital for antibiotics and possible surgical intervention. However, symptoms

improved with pain medication, fluids, and antibiotics, and the patient decided to leave against medical advice.

Two days later, the patient returned with worsening abdominal pain, diarrhea, and vomiting. Her vital signs were within normal limits and her abdominal exam was unchanged. A repeat POCUS was performed which revealed free intraabdominal fluid, dilated loops of small bowel (Figure 2a, b), evidence of hyperechoic foci within the bowel wall (Figure 2b), and a-lines within the abdomen concerning for pneumatosis (Figure 2c).

A repeat CTA of the abdomen and pelvis showed long segment bowel colitis with associated hypo-enhancement concerning for bowel ischemia. Significant laboratory findings were a WBC of 17.60 K/uL, an INR of 4.02, and a VBG lactate of 3.9 mmol/L. The patient was admitted to the surgical service and taken emergently to the operating room (OR). Operative reports indicated a long segment of ischemic small bowel requiring resection, with associated mesenteric edema and ascites, and required a bowel resection for ischemic necrosis of the small bowel. The patient was then taken to the surgical intensive care unit. The patient was taken back to the OR at a later time for repeat evaluation showing poor perfusion of the terminal ileum requiring an ileocecectomy. The patient improved after being monitored in the intensive care unit and was transferred to the floor. Her course was complicated by a urinary tract infection. She remained in the hospital for 16 days and was discharged to a rehab center.

## Discussion

Abdominal pain is one of the most common presenting symptoms in the ED [11]. In the evaluation of a patient presenting with abdominal pain, emergency physicians must keep the diagnosis of ischemic colitis in mind. It is a challenging diagnosis to make due to its wide spectrum of clinical symptoms and non-specific clinical, laboratory, and imaging findings [5]. The differential for patients with these presenting symptoms of pain, nausea, vomiting, and diarrhea is broad, so ischemic bowel can be overlooked due to more common pathologies. Often, patients undergo CT imaging of the abdomen and pelvis to help elucidate the cause of their abdominal pain; however, as was in the case of our patient, findings can be non-specific. Additionally, CT imaging is associated with higher cost, increased length of stay, and ionizing radiation.

Abdominal POCUS in the ED has become an invaluable tool to help guide management of patients presenting with abdominal pain. More recently, the use of POCUS has expanded to the evaluation of bowel pathologies including small bowel obstruction, diverticulitis, and colitis [12-15]. Previous studies have shown that ultrasound

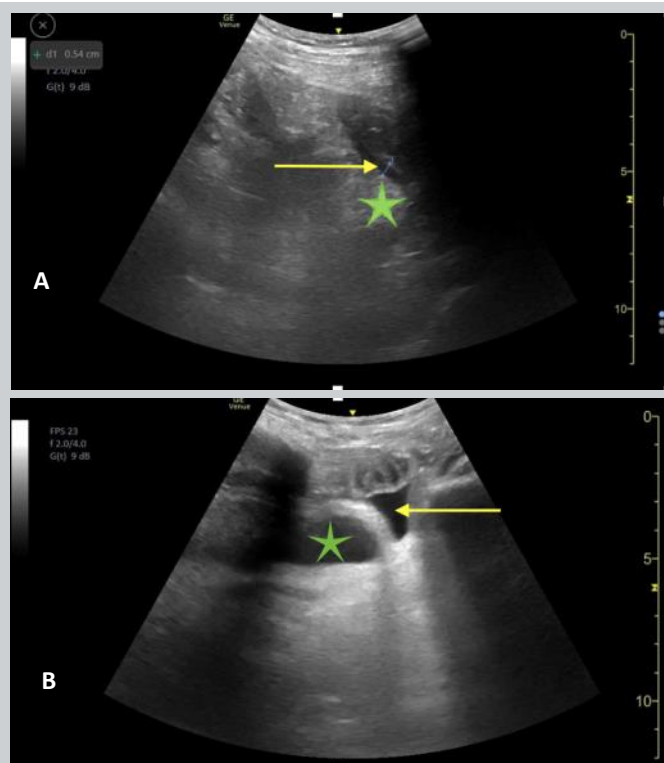


Figure 1. (a): A point of care ultrasound (POCUS) image of the lower abdomen using a curvilinear probe showing a thickened and edematous bowel wall (arrow) and enhancement of the pericolic fat (star). (b): A point of care ultrasound (POCUS) image of the lower abdomen showing a dilated loop of bowel by the bladder (star) with evidence of free-fluid (arrow) and enhancement of pericolic fat.

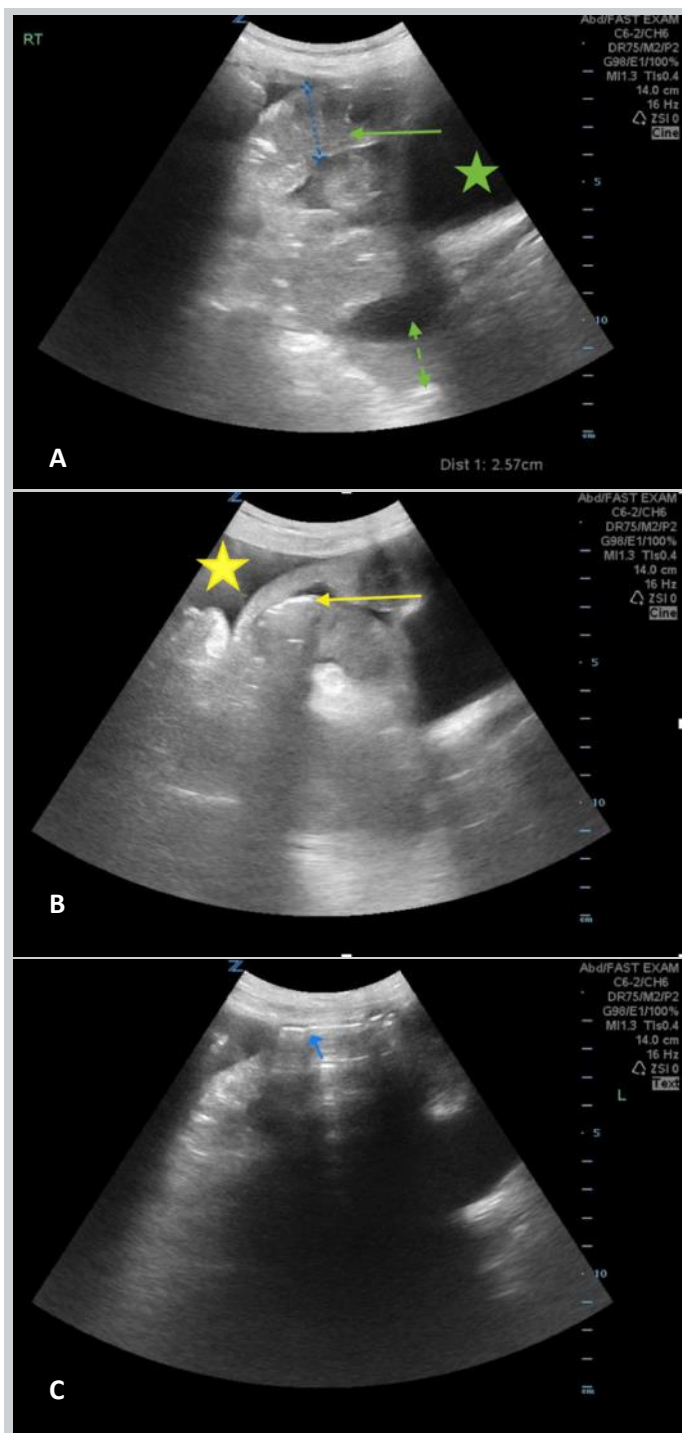


Figure 2. (a): A point of care ultrasound (POCUS) image of the abdomen with a curvilinear probe showing a dilated loop of small bowel (arrow) with free fluid (dashed arrow), and a visualization of the bladder (star). (b): A point of care ultrasound (POCUS) image of the abdomen showing dilated loops of small bowel with evidence of hyperechoic foci within the bowel wall (arrow) and the presence of free intra-abdominal fluid (star). (c): A point of care ultrasound (POCUS) image of the right upper quadrant in sagittal orientation showing a-lines within the abdomen (arrow) with reverberation artifact.

has a sensitivity of 95% and a positive predictive value of 87.5% when evaluating for ischemic colitis [3,10]. One study found that altered pericolic fat and pancolitis on ultrasonography predicted a more severe case of ischemic colitis [7]; another study found that the absence of arterial flow in the wall of an ischemic colon is more associated with an unfavorable outcome than early clinical and laboratory findings with a sensitivity and specificity of 82% and 92% [9]. Doppler images were not available for our case. The use of POCUS in evaluating bowel pathology is expanding. It is often performed with either a low frequency curvilinear transducer or a high frequency linear transducer depending on the patient's habitus or depth of the structure of interest. Image acquisition often begins at the point of maximal tenderness on the patient's abdomen. The bowel is then scanned using a lawn mower technique to ensure that the entire bowel is visualized. Bowel wall thickness measurement requires accurate identification of the mucosa-lumen interface and serosal interface. The thickness measurements are best taken with a linear probe that has better resolution compared to a curved array probe. For this patient, a curvilinear transducer was chosen due to the depth of the bowel. A limitation of using the curvilinear transducer is decreased resolution of the bowel wall; however, even with this transducer the edematous bowel wall, free fluid, and pneumatosis were still visible.

Our case highlights the progression of ischemic colitis clinically, as well as on POCUS. On initial presentation, the patient had non-specific findings of colitis on POCUS: free fluid and a dilated bowel wall. However, our clinical suspicion was high for ischemic colitis. On the second ED visit, the patient presented with worsening symptoms of abdominal pain and diarrhea. Her second POCUS revealed signs of worsening disease, including significant enhancement of the pericolic fat, increasing amounts of free intra-peritoneal fluid, and evidence of bowel pneumatosis. Previous reports have shown that pneumatosis intestinalis was associated with severe ischemic colitis (e.g., requiring surgical intervention) [7]. Our case echoes what previous studies have found and supports the use of ultrasound in patients with suspected colitis. Our case also suggests not only the utility of POCUS in diagnosing colitis but also in predicting the severity of disease.

### Conclusion

Vague symptomatology and variable physical findings make ischemic colitis a challenging diagnosis for emergency physicians. POCUS has shown significant utility in diagnosing a variety of conditions of the bowel, including diverticulitis, colitis, and bowel obstruction [12-15]. In this case, abdominal POCUS was essential in

making the early diagnosis of severe colitis, and prompted early initiation of antibiotics, CT imaging, and surgical consultation. Large-scale studies are needed to further evaluate the role of POCUS in diagnosing ischemic colitis.

## Disclosures

AC is a consultant for Phillips Healthcare. All other authors report no relevant disclosures.

## Patient Consent

Informed consent was obtained from the patient prior to study inclusion.

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# Testicular Torsion with Intact Blood Flow: A Point of Care Ultrasound Case-Series

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## Abstract

Studies have demonstrated the high sensitivity and specificity of pediatric emergency department (PED) point of care ultrasound (POCUS) in the evaluation of testicular torsion. Rarely, testicular torsion may present with intact blood flow. Here, we present a case series of four children with testicular torsion confirmed intraoperatively, who had intact blood flow on POCUS. Markers of testicular torsion can include surrounding hydrocele, heterogenous echotexture, absent venous or high resistance arterial flow, or a torsed cord complex. POCUS practitioners should be familiar with these findings, and the presence of any one or more of these findings should prompt urgent urology consultation to avoid missed torsion.

## Introduction

Studies have demonstrated the high sensitivity and specificity of pediatric emergency department (PED) point of care ultrasound (POCUS) in the evaluation of testicular torsion. Studies have also shown a significantly decreased length of stay for children evaluated with POCUS prior to or without radiology-performed ultrasound.

Rarely, testicular torsion may present with intact blood flow. Here, we present a case series of four children with testicular torsion confirmed intraoperatively, who had intact blood flow on POCUS. These cases illustrate that the sonographic diagnosis of torsion is not solely based on the presence or absence of testicular blood flow.

## Materials and Methods

This study was performed in an academic hospital PED. The study was approved by the Kaplan Medical Center Institutional Review Board in accordance with the Declaration of Helsinki. Informed consent was not required. All POCUS images in our department are reviewed for quality control by the author – a pediatric emergency physician with seven years of experience using POCUS. The study period was calendar year 2023. During the study period there were 16 cases of surgically-confirmed testicular torsion. All images were acquired by the author, and in each case the POCUS interpretation

was testicular torsion.

All POCUS images were obtained on a Zonare Z.one ultrasound using a linear high frequency transducer and scrotal presets. Images were obtained on the unaffected side first, both in B-mode and color Doppler, and adequate depth and gain were verified before proceeding to the affected testis. After B-mode and color Doppler imaging were obtained in sagittal orientation on both testes, a “buddy view” or transverse color Doppler image of both testes in the same image was obtained. Spectral Doppler was used in a number of cases (Figure 1). Spectral Doppler is a useful modality to evaluate resistance to forward flow, as discussed further in our cases.

Our facility did not require radiology confirmation of testicular torsion prior to surgery. POCUS was performed at the earliest opportunity, usually in parallel with physical examination. Urology was notified immediately if the POCUS findings were consistent with torsion. The need for surgical exploration was determined by the consulting urologist after examination and either POCUS or radiology-performed ultrasound.

## Case Presentations

### Case 1

A 13-year-old presented with swelling and tenderness of the left testes over the past three days, which worsened

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DOI: <https://doi.org/10.24908/pocus.v9i1.17201>



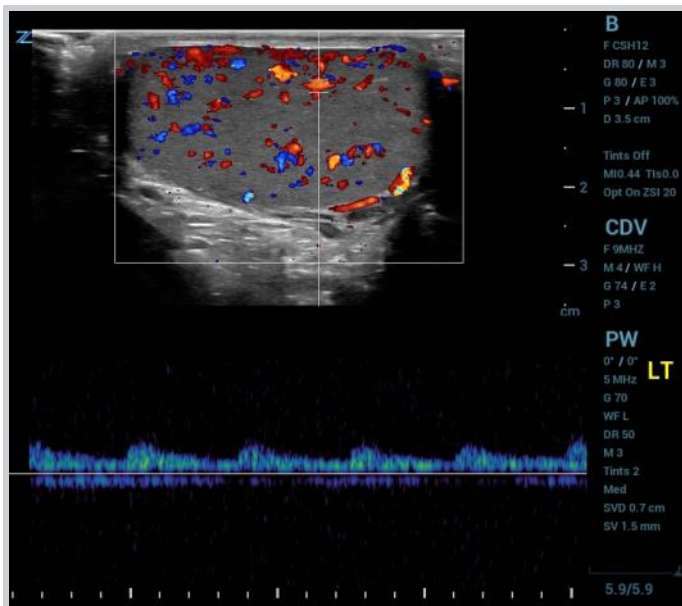


Figure 1. Spectral Doppler image of normal, low-resistance testicular arterial blood flow. Note the homogenous echogenicity and low velocity blood flow that consistently stays above the baseline.

overnight. He denied injury, dysuria, vomiting and fever. In triage he reported his pain on the visual analog score (VAS) to be 8. On examination, his left testis was enlarged, hard, and high-riding with an absent cremasteric reflex. POCUS demonstrated a left testis with heterogenous echogenicity and surrounding hydrocele (Video S1) adjacent to the 'whirlpool sign', indicating torsed spermatic cord (Video S2). Color Doppler demonstrated scant but central flow with an intratesticular resistive index of 0.75 (normal range 0.48-0.75 in children) (Figure 2) [1]. Surgical examination revealed a left testis torsed 720 degrees with adequate color and no sign of ischemia. He underwent bilateral orchiopexy.

### Case 2

A 14-year-old presented with six hours of right scrotal pain. He denied injury, dysuria, vomiting and fever. He had been seen four months earlier due to injury to the right testis. POCUS at that time was unremarkable and he was discharged home. Since then, he had brief episodes of right scrotal pain. He reported a VAS of 7. Examination showed a tender right testis with normal texture and horizontal lie. Cremasteric reflex was absent on the right. POCUS demonstrated heterogenous echotexture with surrounding hydrocele and scant arterial flow, demonstrating a tardus parvus pattern (Figure 3, Video S3). During examination, spontaneous increase in blood flow was seen (Figure 4, Video S4,S5), as was a kinked spermatic cord (Video S6). Given

concern for recurrent torsion, bilateral orchiopexy was performed. Surgical examination showed a 90-degree twist.

### Case 3

A 14-year-old presented with three hours of right inguinal pain that began during exercise. On urination he noted right inguinal swelling and reported a single episode of emesis. His medical history was significant for orchiopexy at one year of age to treat a left undescended testis. Examination showed that his right testis was in the inguinal canal and was tender to palpation. POCUS showed a testis in the inguinal canal adjacent to the cord complex (Figure 5). Color Doppler showed intact central flow (Video S7). Surgical exam revealed a testis that was torsed 180 degrees. Normal color returned with warming, and he underwent right orchiopexy.

### Case 4

A fifteen-year-old presented with several hours of left testicular pain. He denied emesis and dysuria. Examination showed tenderness to the left epididymis and intact cremasteric reflexes. POCUS was significant for decreased blood flow to the left testis in comparison with the unaffected right testis. There was a small reactive hydrocele adjacent to the left testis (Videos S8, S9). Intraoperatively the left testis was found to be torsed 90 degrees, and the patient underwent orchiopexy.

## Discussion

Here, we present a case series of testicular torsion with blood flow present to the affected testis on presenting POCUS examination. Physicians using POCUS should

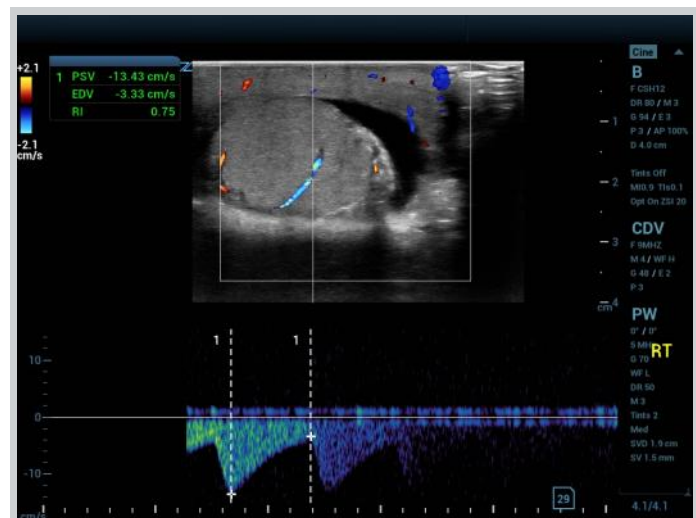


Figure 2. Color Doppler image with linear transducer. The Doppler gate is placed over a blood vessel and shows peaked, high amplitude flow, indicating increased resistance. Hashes are placed at points indicating peak systolic velocity and end diastolic velocity.

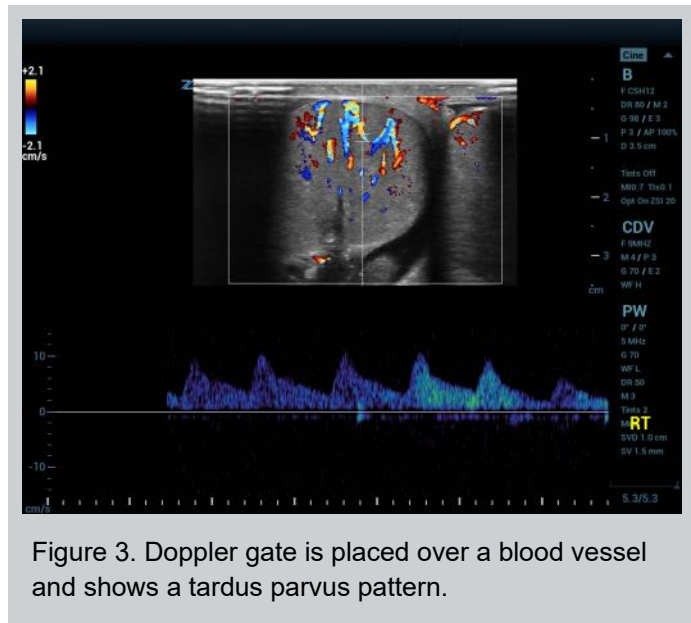


Figure 3. Doppler gate is placed over a blood vessel and shows a tardus parvus pattern.

be aware that intact blood flow does not rule out testicular torsion.

Testicular torsion is a true surgical emergency and time to detorsion is crucial [2,3]. Absence of venous flow is an early sign of torsion. Absence of venous outflow causes edema to the testes, resulting in swelling and heterogenous echotexture of the testis, and a sterile hydrocele. Edema of the scrotum can be seen as well [4]. However, the presence of venous flow in the testis is difficult to record, and its presence or absence does not confirm presence or absence of torsion [5].

Testicular edema causes loss of the mediastinum testis, a hyperechoic stripe traversing the normal testis. Following venous occlusion, arterial flow is decreased. In

a case of testicular torsion, arterial flow will be decreased compared with the unaffected testis. This can result in absent or reversed waveforms as edema impedes or reverses forward flow; absence of a diastolic notch resulting in a monophasic waveform (absence of diastolic flow between systolic peaks); or high amplitude waveforms indicating increasing resistance to flow (Figures 1, 2) [6,7]. Conversely, arterial waveform may show a 'tardus parvus' pattern with low amplitude and slow upstroke, as seen in stenotic vessels (Figure 3) [8]. Resistive index (peak systolic velocity minus end diastolic velocity, with the difference divided by peak systolic velocity) normally ranges from 0.48-0.75 in children, and an elevated resistive index is indicative of compromised perfusion [1,9]. Peripheral flow is not uncommon in testicular torsion and areas of increased echogenicity may be seen secondary to local hemorrhage. Typically, a twist of 450 degrees or more causes complete occlusion of blood flow to the testis [5]. Prolonged ischemia will cause marbling of the testis and correlates with poor prognosis [10].

Presence of the 'whirlpool sign' indicating a knotted cord complex (Figure 4, Video S2) is diagnostic of torsion, even in the presence of intact testicular blood flow [8]. While the 'pseudomass' is used to denote the knotted cord, it actually refers to the complex of edematous epididymis, vas deferens, and distal cord vessels that cannot be distinguished sonographically [4]. Spermatic cord should not be found adjacent or below the testis, and redundant tortuous cord in the scrotum is abnormal (Video S6) [8].

This is the first case series of testicular torsion with preserved blood flow on POCUS. Friedman et al. found

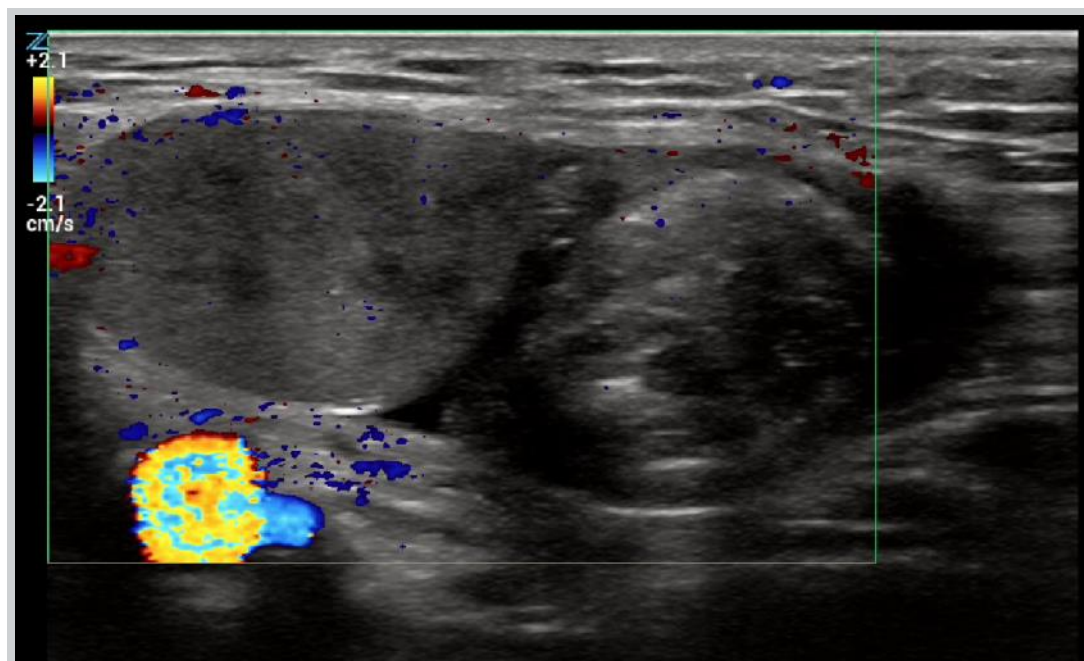
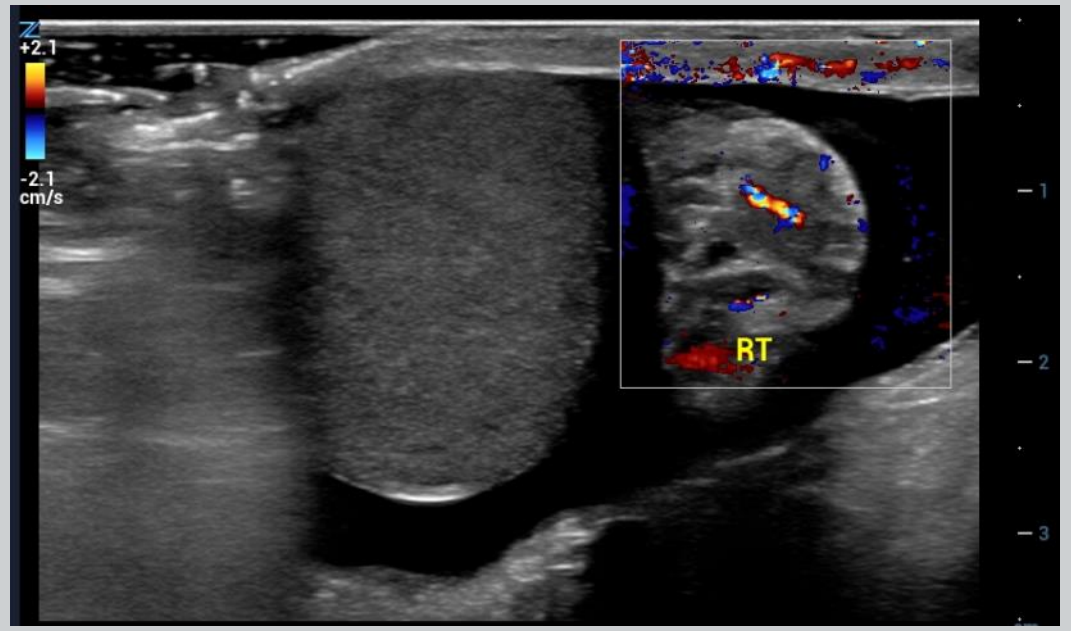


Figure 4. Color Doppler image with linear transducer. The Doppler gate is placed over a blood vessel and shows peaked, high amplitude flow.

Figure 5. Color Doppler image with linear transducer. The testis is on the left of the color window and the circular cord complex (“whirlpool sign’) is on the right. The cord complex can be difficult to distinguish from epididymis. Here, there is very little flow in the cord complex, as can be seen in torsion. In contrast, epididymitis would present with epididymal swelling and increased blood flow.



that POCUS for evaluation of acute scrotum identified testicular torsion with a specificity of 99.1%, and all true-positive cases were identified by POCUS. On image review, they found agreement between POCUS reviewers for all cases of true testicular torsion [11]. A subsequent meta-analysis found that POCUS had pooled sensitivity and specificity of 98.4% and 97.2% for testicular torsion [12]. Scrotal POCUS can be performed an average of 38-73 minutes before radiology performed ultrasound [11-13], has been shown to decrease PED length of stay by 77 minutes [13], and to decrease time to orchiopexy by over an hour [14].

However, none of the above POCUS studies address the rare event of torsion with preserved flow. Central testicular blood flow can be seen in an incompletely torsed testicle or in children with thinner spermatic cords that limit the pressure placed on the vessels [8]. Testicular pain that resolves suddenly, with normal flow on POCUS, may warrant urology consultation to evaluate for intermittent torsion [15]. Continued pain requires urology consultation as well. False-negative ultrasound examinations have been shown to be as high as 41.7% in cases of surgically confirmed testicular torsion [16]. Secondary signs on ultrasound that increase the likelihood of testicular torsion include hypoechogenic regions of testis, a surrounding hydrocele, scrotal edema, and a swollen spermatic cord [16] as well as testicular enlargement, edema, and abnormal axis in comparison with the unaffected side [17]. While the ‘whirlpool sign’ is diagnostic of torsion, radiology-performed ultrasound showed poor correlation between the degree of torsion on ultrasound and on surgical exam [18].

## Conclusion

Rarely, testicular torsion may present with preserved blood flow. Markers of torsion can include surrounding hydrocele, heterogenous echotexture, absent venous or high resistance arterial flow, or a torsed cord complex. POCUS practitioners should be familiar with these findings, and the presence of any one or more of these findings should prompt urgent urology consultation to avoid missed torsion.

## Disclosures

The authors received no funding have no financial relationships relevant to this article to disclose. The authors declare no conflict of interest.

## Author Contributions

Dr. Scheier collected the images and wrote the manuscript.

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# Point of Care Ultrasound as a Key Tool in the Evaluation of a Woman with Syncope

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## Abstract

Using point of care ultrasound (POCUS) to evaluate patients with syncope in the emergency department facilitates the timely diagnosis of life-threatening pathologies. **Case:** A 56-year-old woman presented to the emergency department of a hospital in Bogotá, Colombia, for a syncopal episode. Vital signs, physical examination, electrocardiogram, and routine laboratory tests were normal. Cardiac POCUS was performed, which identified an echogenic mass located in the left atrium, measuring 35x28mm, which in left atrial systole appeared to occupy the entire chamber. She underwent surgical resection of the mass and histopathology revealed atrial myxoma. **Conclusions:** POCUS was useful in the rapid diagnosis of atrial myxoma in a woman presenting with syncope.

## Introduction

Syncope is a frequent reason for consultation in clinical practice. Syncope has a prevalence of approximately 40% and accounts for 1-3% of emergency department visits and 6% of hospital admissions [1,2]. The causes can be divided into cardiovascular, cerebrovascular, vascular tone, blood flow disorders, and others that mimic syncope. The most relevant causes in this latter group are seizures, metabolic events (hypoglycaemia, hypoxia, symptomatic anaemia), and psychogenic [3]. It has been estimated that syncope has a recurrence rate of 13.5%, of which 6-30% of these involve cardiac causes. Cardiovascular causes of syncope include cardiac neoplasms [4]. Primary intracardiac tumours occur infrequently with an incidence of 1.38-30 per 100 000 persons per year. In comparison, secondary cardiac tumours are 20-30 times more common [5]. Most primary cardiac neoplasms are benign tumours (75%) and within this group the most frequent, although rare, is atrial myxoma. Myxoma is more common in women (65-70%), and although it can be found in any age group, its peak incidence is between the fourth and sixth decade of life [6]. Its clinical presentation is highly variable in relation to its embolic and obstructive effects, as well as its location, size, and mobility [7]. In addition to syncope, myxoma can

manifest as systemic embolism, heart failure, or even sudden cardiac death [8].

Point of care ultrasound (POCUS) has become an essential tool for physicians in the emergency department, enabling faster patient care and serving as a guide for performing procedures and making therapeutic decisions. POCUS can be used to identify life-threatening pathologies in which timely detection can have an impact on reducing mortality [9].

In the emergency department, POCUS has become a fundamental tool for patient evaluation. In this particular case it was very useful for the diagnosis of atrial myxoma, which was the basis for rapid decision-making in a patient who presented with syncope.

## Case

A 56-year-old woman with no significant medical history presented to the emergency department for an episode of loss of consciousness with loss of postural tone lasting approximately 60 seconds with complete recovery. Syncope was preceded by chest pain, but not associated with dizziness, sensation of heat, sweating, nausea, vomiting, or related to changes in position or exertion. She reported that she had been suffering for one week from oppressive chest pain in the left hemithorax with

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DOI: <https://doi.org/10.24908/pocus.v9i1.17329>

irradiation to the left upper limb that was self-limiting, intermittent, not associated with exertion or stress, and exacerbated before loss of consciousness.

On initial assessment by the emergency department, the patient had normal vital signs, no signs of acute respiratory distress, normal cardiopulmonary auscultation, no carotid bruit, soft abdomen with no signs of peritoneal irritation, no peripheral edema, preserved distal perfusion, and no focal neurological findings.

The initial electrocardiogram documented sinus rhythm, a heart rate of 67 bpm, normal axis, no signs of chamber enlargement, no atrioventricular conduction disturbances or intraventricular block, ST without alterations, and QTc 419 ms. Troponin was negative, and the laboratory exam was within normal limits. The chest x-ray was also normal.

Given that the patient had no history of structural heart disease or coronary artery disease, her examination in the emergency department was normal and her six-hour observation stay was asymptomatic, hospital discharge was considered for outpatient referral to transthoracic echocardiography. However, cardiac POCUS revealed a 35x28mm echogenic mass in the left atrium that occupied the entire chamber in left atrial systole. There was no pericardial effusion. E-point septal separation (EPSS) was 4mm with adequate global contractility of the left ventricle, normal right ventricle/left ventricle ratio, and aortic root of 33mm without dissection flap (Figure 1, Video S1).

Due to the large left atrial mass, discharge was cancelled and the patient was assessed by the cardiology department. They performed a transthoracic echocardiogram and found a slightly dilated left atrium of 34 ml/m2 occupied by a heterogeneous mass of

33x34mm with well-defined borders. This occupied more than 50% of the atrial area and adhered to the interatrial septum without compromising the mobility of the mitral valve, as suggestive of myxoma. The left ventricle was of normal size and shape, had mild eccentric hypertrophy, and a left ventricular ejection fraction (LVEF) of 61% with signs of type II diastolic dysfunction.

The patient was referred to cardiovascular surgery, who considered her to be a candidate for urgent surgery due to the size of the atrial lesion and the high risk of obstruction of the left ventricular inflow tract as a generator of embolism and sudden death. Left heart catheterization was performed and the coronary arteries were found to be angiographically normal without significant stenosis. The open excision procedure to remove the cardiac tumour was performed. Intraoperative findings were a 4x4cm left atrial mass with a 2cm pedicle, adhered to the interatrial septum and the posterior wall. Resection was performed from its pedicle without macro residues adhering to the wall and without rupture of the septum. The procedure was uncomplicated and the patient was monitored in the intensive care unit in the postoperative period with adequate recovery. For this reason she was transferred to general hospitalisation with comprehensive cardiovascular rehabilitation therapy. On the fifth postoperative day, the patient was discharged from the hospital. Pathology study confirmed the diagnosis of cardiac atrial myxoma.

**Discussion**

POCUS is a non-invasive diagnostic tool that has been gaining popularity in the emergency department due to the significant value it provides in decision-making. POCUS enables early narrowing of the differential diagnoses and can guide decisions regarding adjunctive

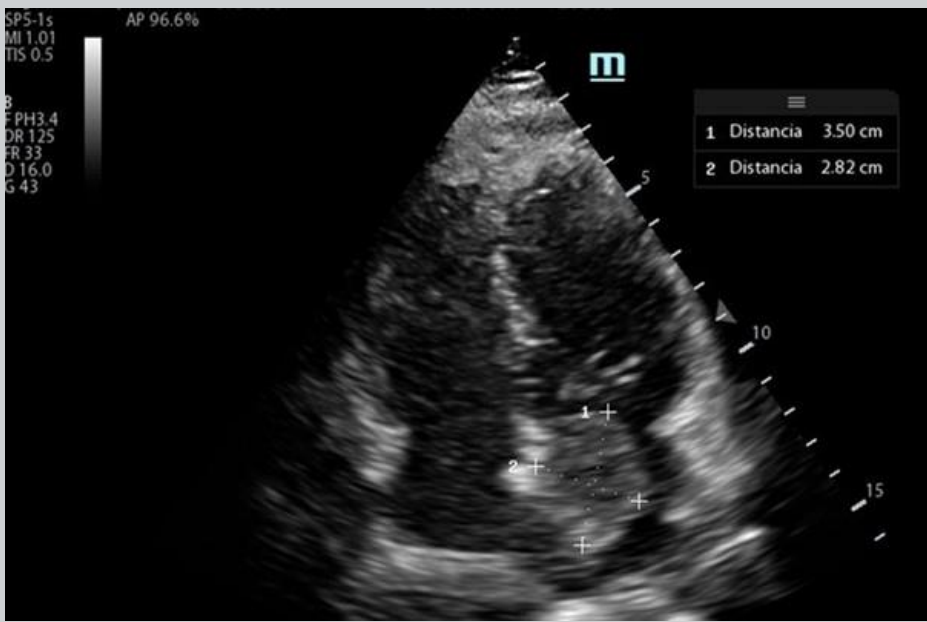


Figure 1. Apical 4 chamber view. Mass in left atrium.

testing while facilitating faster treatment initiation. The benefits of using POCUS have been demonstrated in a wide variety of clinical conditions such as undifferentiated shock, cardiac arrest, trauma, chest pain, dyspnoea, syncope, and abdominal pain, among others [9].

Concerning syncope, different methods have been described for clinical decision-making in the emergency department for risk stratification based on clinical history, physical examination, and electrocardiographic findings. However, none of these methods can be widely used and are not superior to clinical judgement in predicting short-term adverse outcomes [10].

As previously mentioned, although infrequent, myxoma can be a cause of syncope. The clinical presentation varies widely from an asymptomatic incidental mass to severe, life-threatening cardiovascular complications, depending on location, size, and mobility. There is a classic triad that raises diagnostic suspicion consisting of intracardiac obstruction, embolization and constitutional symptoms. Despite the diverse clinical presentations, POCUS may be beneficial in suspected cases in the emergency department [11].

It is the primary task of the emergency specialist to identify patients with high-risk cardiovascular disease requiring urgent testing with hospital admission. Patients presenting with high-risk syncope are most likely to have presented with syncope of cardiac origin. Structural heart disease and primary electrical disorders are the most important risk factors for sudden death and total mortality in patients with syncope [3]. Within the admission history, clinical features such as new presentation of chest pain, dyspnoea, abdominal pain or headache, syncope on exertion, in supination or preceded by sudden onset palpitations guide the clinician in suspecting that the patient may be presenting with high-risk syncope.

A single-centre prospective observational cohort study conducted at the Hospital of "Città della Salute e della Scienza di Torino", Turin, Italy tested the accuracy of the integrated POCUS approach with clinical assessment and electrocardiographic findings in risk-stratifying patients in the emergency department. They included patients who had presented with a history of syncope in whom the etiology had not been identified despite a structured approach with clinical history, physical examination, and electrocardiogram that classified them in neither high nor low-risk group (NHNL) [12]. This increased diagnostic accuracy by approximately 10% and reduced risk categorisation errors by 4% after including the integrated POCUS approach to clinical assessment [12].

In the case of our patient, she was suffering from high-risk syncope because of the presentation associated with chest pain. POCUS was the key diagnostic tool in

identifying structural cardiac pathology in this case by visualising the presence of an atrial mass with a high risk of mechanical obstruction and sudden death. Without its use, diagnosis would have been delayed, increasing the risk of complications.

## Conclusions

Syncope is a frequent reason for consultation with the emergency department. Its causes may be multiple, including cardiovascular causes that can be life-threatening. Implementation of POCUS with clinical assessment in the ED can increase diagnostic accuracy in the work-up of a patient with syncope, helping to identify patients at high risk of adverse events in the short term. Emergency providers should be trained in POCUS and be able to identify life-threatening etiologies.

## Disclosures

The authors report no conflicts of interest or funding sources.

## Patient Consent

Consent to publish this case was obtained from the patient via an informed consent form.

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# Diagnostic Accuracy of Abdominal Point of Care Ultrasound in Primary Care: Study Design and Protocol

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## Abstract

The aim of this study is to estimate the diagnostic accuracy of abdominal point of care ultrasound (POCUS) performed by family physicians (FPs) in primary care (PC), in comparison with the findings in the medical record (MR) at 12 months of follow-up. This study is conducted entirely in PC healthcare centers in Spain. Abdominal ultrasound scans performed by FPs (selected on the basis of their ultrasound knowledge and experience) are compared with the findings, or not, in the patient's MR after a 12-month follow-up period. The study will involve 100 FPs in Spain and an estimated sample size of 1334 patients who are to undergo abdominal POCUS at the indication of their physician. The results of the abdominal POCUS will be collected and compared with the findings of the MR. This comparison will be performed by another physician of the research team, different from their FP after one year of follow-up. The diagnostic accuracy of abdominal POCUS has been addressed in the hospital setting but not in PC. This lack of evidence can begin to be resolved with studies such as the one we present, designed for unselected populations such as those treated in PC and taking the patient's MR as the gold standard, which will allow us to make comparisons with the patient's clinical course.

## Background

Abdominal point of care ultrasound (POCUS) has been employed as a diagnostic tool by family physicians (FPs) for years both in Spain and globally. Furthermore, literature has described curricula for training in this technique [1]. Specifically, the Madrid Health Service has developed a training program of which some authors have contributed to teaching teams, providing instruction in the acquisition of abdominal POCUS skills. In other parts of Spain, there is an uneven advancement in the implementation of ultrasound equipment and training programs, although the scientific societies of family medicine (FM) in Spain provide access to POCUS training programs to FP professionals nationwide.

Several studies have demonstrated a strong correlation in POCUS interpretation between FP and hospital specialists other than radiologists, with concordances reaching up to 93% (95% CI 87-99%) [2,3]. Similarly, correlations between FPs and radiologists have been

reported in studies made in Spain, with Kappa indexes above 0.8 [4,5].

In the assessment of diagnostic tests, it is crucial to calculate the likelihood ratio (LR). The LR is independent of disease prevalence and informs us about the probability that a patient has or does not have the disease given a positive or negative result. Evidence-based guidelines for physical examination recommend utilizing diagnostic or exploratory tests based on this information [6,7].

Therefore, it is important to assess the diagnostic accuracy of POCUS in cases where FPs utilize it for a specific clinical suspicion and compare it to the findings of the patient's medical records (MRs) during medium-to-long term follow-up. However, there is a limited number of studies conducted in primary care (PC) settings [8].

In PC, it is crucial to optimize time. The use of POCUS during the clinical act of the medical practitioner takes additional time. Quantifying the effectiveness of

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DOI: <https://doi.org/10.24908/pocus.v9i1.16987>



ultrasound for diagnosing certain pathologies could support its practical use. Although there are studies in other fields on this subject, there are a lack of studies examining diagnostic accuracy in abdominal pain [9-13].

Performing abdominal ultrasounds on asymptomatic adult patients can result in discovering lesions in 22% of those explored. Merely 3% necessitate therapy after a two-year follow-up [14]. In a similar study limited to elderly patients, 31% of ultrasound findings went undetected during conventional physical examinations [15]. Another study conducted by German FPs designed for the early detection of renal cell carcinoma found that ultrasound examinations exclusively limited to the kidneys yielded a positive predictive value of 50% for positive findings and only 2% for equivocal findings, while identifying a rate of 12% of unexpected results [16]. On the contrary, a study conducted on 1962 patients and covering ten common clinical scenarios found that 63% of cases did not require additional diagnostic techniques, and only 5% were wrongly classified as negative [17].

Generally, we speak of POCUS when we refer to the ultrasound performed by FPs on the patients they treat. In Spain, some FPs have been performing ultrasounds for over 20 years. Initially, ultrasounds were conducted following the systematic exploration carried out by radiologists. FPs still follow this approach when performing ultrasounds, which is also taught to some clinicians. We refer to it as a 'comprehensive exam'. POCUS has developed over time as an ultrasound performed by clinicians to answer clinical questions and rule in or rule out the presence of certain pathologies in specific scenarios. This type of ultrasound is commonly referred to as a 'focused exam'.

During a comprehensive abdominal ultrasound, it is possible to uncover lesions in organs that do not exhibit symptoms, resulting in a diagnostic cascade of multiple tests. Despite this, the added concern for the patient remains a top priority. It should be noted, however, that clinical consequences of abnormal ultrasound findings occur rarely [18-20]. These may result in the use of other imaging methods that emit ionizing radiation or invasive procedures that offer no benefit to the patient's health and may have significant adverse effects.

Quantifying overdiagnosis may prompt a reassessment of ultrasound performance by clinicians. This can lead to more symptom-focused examinations like POCUS or more studies.

In fact, one systematic review on ultrasound in PC has determined that symptom-focused ultrasound scans at the point of care are linked to increased diagnostic accuracy, reduced overdiagnosis and underdiagnosis rates, and lower technical skill training requisites. However, the review also indicates that these results are

area-specific, and further research is necessary to substantiate the usefulness of diagnostic accuracy within the scope of FPs' duties. It highlights the insufficient quality of the research conducted and underscores the necessity for further studies. Additionally, it is important to determine the adequacy and quality of the training received by the FP, as well as to track the clinical progress of patients who undergo ultrasound by the FP [21].

Another review confirms the safety of POCUS use by FPs and indicates its positive impact on patient diagnosis. Nevertheless, the review highlights differences among populations and significant variability across clinical scenarios, suggesting that diagnostic accuracy must be assessed for each clinical entity and across different settings. There is a recommended need for PC studies, as the majority of ultrasound studies conducted by FPs originate from emergency settings [22].

This research project aims to provide evidence for all these questions.

The main objective of this study is to assess the diagnostic accuracy and validity of abdominal ultrasound performed by a FP in a PC environment. The patient's MR findings at one-year follow-up will be used as a reference test. Additionally, the study aims to determine the frequency with which FPs perform abdominal ultrasounds in different clinical scenarios, as well as the time spent in performing the technique and the identified ultrasound diagnosis. The diagnostic accuracy in each clinical scenario will be estimated, according to the type of ultrasound exam performed (focused or comprehensive), the professional's training, and the characteristics of the patient and the environment (rural or urban). We will examine the correlation between a FP's diagnostic precision and several contributing factors, including their ultrasound scanner type, training experience, and past ultrasound experience. Additionally, we will estimate the incidence of overdiagnosis and underdiagnosis.

## Methods

This is a prospective observational study of diagnostic test accuracy. The recommendations of the STARD statement (<https://www.equator-network.org/reporting-guidelines/stard/>) were adhered to. The study will take place at PC health centers located in different autonomous communities of Spain over a period of two years, with 12 months for patient recruitment and 12 months for MR review. The research includes patients over 18-years of age visited by their FP and who undergo an abdominal POCUS. All participants are required to sign an informed consent document prior to undergoing an ultrasound administered by their FP at the

health center; abide by the study protocol; and approve the consultation of their MR in a year. Recruitment of participants excludes pregnant women and those who have received an abdominal ultrasound from a radiologist in the past three months.

All FPs who participated in any training activities (including courses and scientific conferences developed by the Ultrasound Working Group of the Spanish Society of Family and Community Medicine) within the last ten years were invited to participate. They had to fulfill the following requirements: work at a PC center equipped with an ultrasound device, received at least 50 hours of theoretical and practical training in abdominal ultrasound, possess one year's experience in ultrasound, and had conducted at least 100 abdominal ultrasound examinations previously. The team of principal investigators thoroughly reviewed all prerequisites.

The study's sample size was calculated based on diagnostic tests studies with a sensitivity of 75% and a specificity of 90%. The researchers anticipated a prevalence of pathological findings of approximately 15% [23,24] and established a confidence level of 95% with a precision of 6%. The resulting size was 1334 participants, determined through the Epidat v 4.2 program. 100 sonographer FPs are included, each committed to recruiting between 20 and 50 patients for the study. The number of collaborators has been overestimated by 20%, resulting in a commensurate loss of collaborating physicians.

Demographic, ultrasound and technique variables, clinical variables, baseline test results, and variables associated with the investigating physician are all gathered and listed in Table 1.

Baseline variables will be obtained through patient interviews and ultrasound examinations administered by the FP. Data will be collected in both a physical data collection notebook and a web-based form, and assigned an anonymous identifier. Ultrasound images will be stored within the machine, and the results will be recorded in the patient's MR and the data collection form (DCF).

MRs will be reviewed 12 months after abdominal POCUS is conducted. The MR will be examined by an investigator from the research team, who is not the patient's regular physician, at the 12-month mark. Diagnostic findings consistent or inconsistent with the initial ultrasound diagnosis will be documented in both the patients' PC and hospital MR. The baseline variable "Findings in the MR at 12-month follow-up" will be recorded in the DCF. The study's actions are depicted in the flowchart (Figure 1).

### Diagnostic Procedure

Patients presenting with abdominal pathology at their FP's office and receiving an abdominal POCUS are offered the opportunity to participate in this study. All patients will receive information regarding the study's purpose and must provide informed consent per the study protocol. POCUS focused exams that are performed will adhere to the recommendations provided by the American Academy of Family Physicians and the American College of Emergency Physicians [25,26] as depicted in Figure 2.

For comprehensive POCUS, a complete examination of the abdomen will be conducted utilizing the traditional system of ultrasound views outlined by Professor Segura Cabral [27] (shown in Figure 3). The performance of the

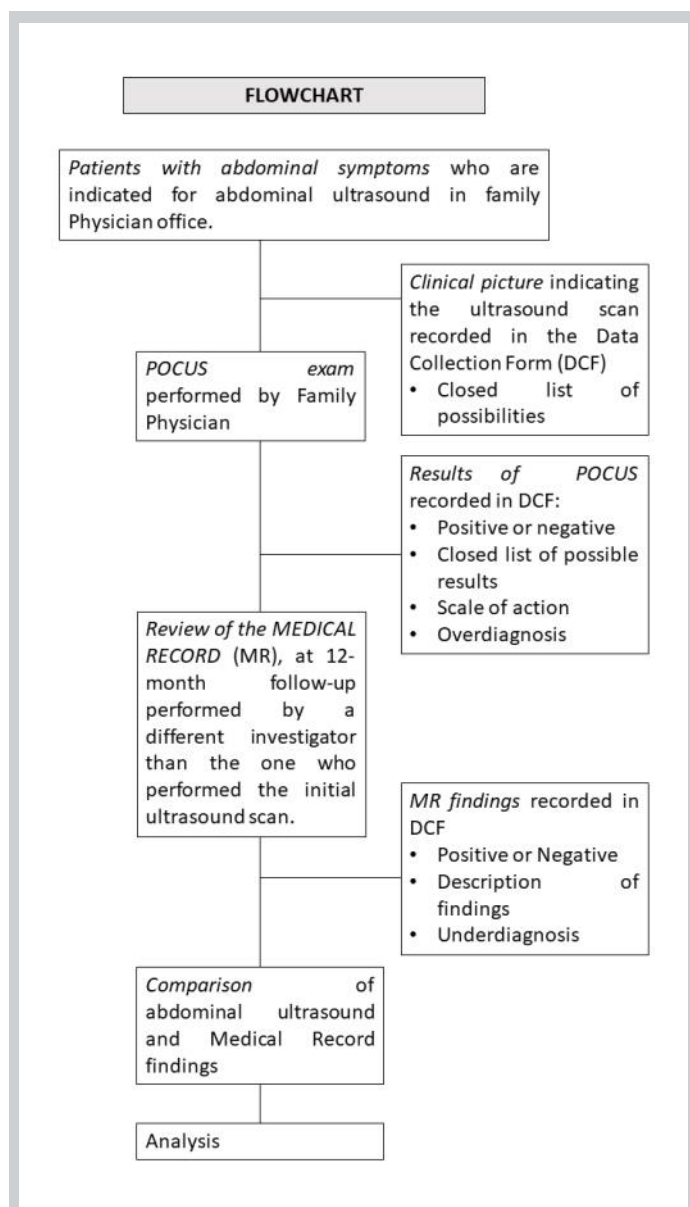


Figure 1. Flowchart depicting study protocol.

Table 1. Study protocol variables.

| <b>Sociodemographic Variables</b>   |  |
|---|--|
| <ul style="list-style-type: none"> <li>Age and gender</li> </ul>  |  |
| <b>Ultrasound Device and Ultrasound Technique</b>   |  |
| <ul style="list-style-type: none"> <li>Type of ultrasound machine, Time in minutes taken to perform POCUS, Type of POCUS exam (Focused or Comprehensive exam).</li> </ul>   |  |
| <b>Clinical Variables</b>   |  |
| <ul style="list-style-type: none"> <li>Clinical picture presented by the patient for abdominal ultrasonography (closed list of clinical pictures): Right upper quadrant abdominal pain, Dyspepsia, Hematuria, Palpable abdominal mass, Nephritic colic, Constitutional syndrome, Abnormal liver enzymes, Other analytical alterations suggesting abdominal pathology, Screening for Abdominal Aortic Aneurysm, Abdominal pain in another location, Abdominal trauma, Pelvic pain, Others.</li> </ul>  |  |
| <ul style="list-style-type: none"> <li>Abdominal ultrasound result (negative-normal vs positive-pathological findings)</li> </ul>   |  |
| <ul style="list-style-type: none"> <li>If positive, description of pathologic ultrasound findings (closed list): Abdominal Aortic Aneurysm, Aortic dissection, Aortic rupture, Dilated inferior vena cava, Pancreatic mass, Cholelithiasis, Cholecystitis, Common Bile Duct dilatation, Hepatomegaly, Choledocholithiasis, Vesicular polyposis, Enlarged gallbladder, Splenomegaly, Fatty liver, Ascites, Abdominal organ rupture, Hepatic space occupying lesion, Renal space occupying lesion, Renal cyst, Nephrolithiasis, Distal ureter dilatation, Hydronephrosis, Ureteral and bladder lithiasis, Bladder neoplasia, Prostatic volume, Distended bladder-acute urinary retention, Ureterocele, Bladder diverticulum, Struggling bladder, Urachal cyst, Acute appendicitis, Small bowel obstruction, Ectopic pregnancy, Uterine fibroids, Ovarian cyst, Ovarian mass, Others.</li> </ul> |  |
| Scale of action with respect to main pathologic finding   | <ol style="list-style-type: none"> <li>Requires referral to the emergency department and/or suspicion of malignancy</li> <li>Preferential referral required</li> <li>Requires normal referral or a complementary test</li> <li>Requires treatment in primary care</li> <li>Requires follow-up in primary care</li> </ol>   |
| Overdiagnosis (Yes or no)   | Presence of ultrasound findings unrelated to the current diagnostic process and requiring further exploration or intervention.   |
| <b>Outcomes</b>   |  |
| Pathologic findings in the medical record at 12-month follow-up:  | At the end of the 12-month follow-up period, the medical history will be considered positive when it shows the presence of pathological diagnostic findings (that required intervention, i.e. other diagnostic techniques or medical or surgical treatment or follow-up), which are related to the initial process and are susceptible to diagnosis by ultrasound. The absence of such findings will be considered negative. |
| Underdiagnosis  | Medical record reveals a clinical condition or diagnosis, detectable by ultrasound, that was not diagnosed in the initial ultrasound performed by their family physician and that justifies the initial picture.   |
| <b>Family Physician</b>   |  |
| Number of accredited hours of training in abdominal POCUS, Number of POCUS examinations previously performed, Number of years of experience performing POCUS, Rural or urban environment, Healthcare area and Spanish autonomous region   |  |

test yields a result that will be labeled normal or abnormal. The diagnostic impression will then be recorded in the DCF.

**Statistical Analysis**

The study will provide a description and estimation of patients' characteristics, physician involvement, clinical processes, and findings. Qualitative variables will be presented as percentages with a 95% confidence interval

(95% CI), while quantitative variables will be presented as a mean and standard deviation or median and IQR (interquartile range) if they do not follow a normal distribution. The characteristics of patients, ultrasound techniques and types, and physicians will be compared based on normal or pathological diagnosis. Continuous variables will be analyzed using the student's t-test for independent samples, while categorical variables will be analyzed using the chi-square test. Sensitivity, specificity, positive predictive value, negative predictive value, positive LR, and negative LR will be calculated, along with their corresponding 95% CIs. These calculations will be performed for all clinical scenarios, using FP ultrasound as index and the final diagnosis in medical history (MH) after one year of follow-up, as reference test. Additionally, the frequency of overdiagnosis and underdiagnosis will also be calculated, along with their corresponding 95% CIs. A multivariable logistic regression analysis will be utilized to identify the factors related to higher diagnostic accuracy.

**Discussion**

This study is, to the best of our knowledge, the only diagnostic accuracy study performed in PC that will prospectively use the patient's clinical course (including eventual diagnoses) as a reference test to evaluate abdominal POCUS. Other studies in our setting were also descriptive and identified scenarios where the test was frequently used; however, they did not assess its accuracy in a PC setting [28]. Furthermore, multiple concordance studies have been conducted with radiologists, but none have utilized as many investigators, or a large sample size as estimated in this study [2-5,29].

Although the diagnostic accuracy of various abdominal clinical scenarios has been studied in hospital settings, studies on this issue have not yet been conducted in PC. Thus, it is important to address the lack of evidence to support the proper use of this technique and to determine the optimal conditions for training, technology, and time use. Additionally, it is necessary to investigate whether the technique is being used in an optimal manner.

**Strengths**

It is important to note that the study will be conducted in the real-world setting of routine clinical practice, rather than simulated scenarios. The study will adhere to pragmatic principles and will maintain objectivity in its assessment. The purpose will be to evaluate the diagnostic abilities of PC physicians using POCUS, after receiving training from both Scientific Societies of Primary Care and Health Services of Autonomous Communities. This is a multicenter study with broad geographic representation, facilitating enhanced patient

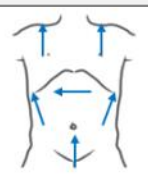
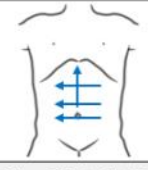

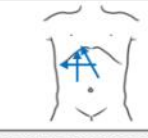
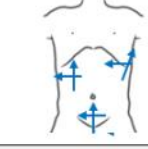
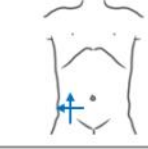

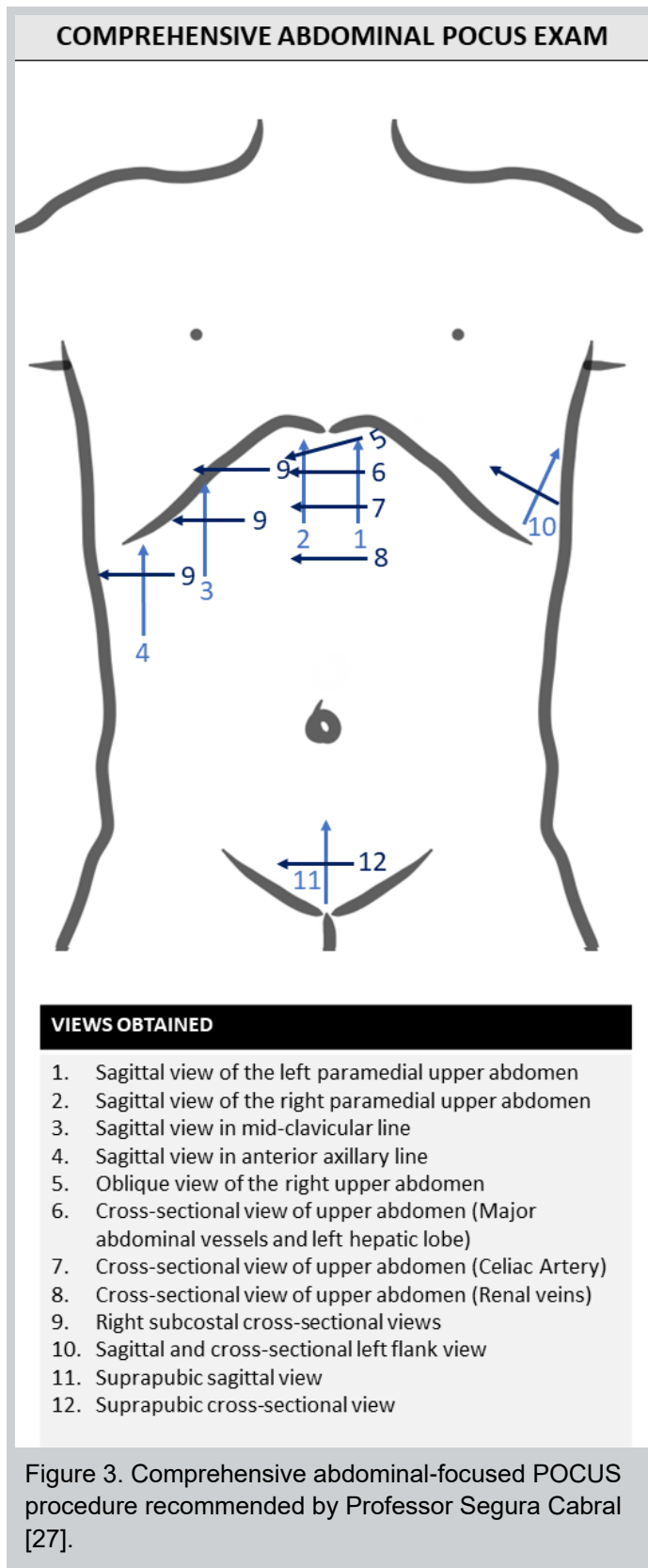
| POCUS ABDOMINAL (focused exam)  |   |
|---|---|
| E-FAST  | VIEWS   |
|    | Hepatorenal<br>Perisplenic<br>Suprapubic<br>Pericardial<br>R thorax for fluid<br>R thorax for lung sliding<br>L thorax for fluid<br>L thorax for lung sliding                 |
| FOCUSED ABDOMINAL AORTA   | VIEWS   |
|    | Proximal Transverse view<br>Distal Transverse view<br>Sagittal view<br>Celiac artery<br>Superior mesenteric artery<br>Bifurcation   |
| FOCUSED Non-Obstetric PELVIC ULTRASOUND   | VIEWS   |
|   | Transabdominal sagittal<br>Transabdominal transverse<br>Cul-de-sac (Douglas)<br>Left adnexa<br>Right adnexa<br>Hepatorenal space  |
| FOCUSED BILIARY   | VIEWS   |
|  | Gallbladder long axis<br>Gallbladder short axis<br>Common bile duct<br>Main lobar fissure<br>Portal vein  |
| FOCUSED RENAL/URINARY TRACT   | VIEWS   |
|  | Right kidney long axis<br>Right kidney short axis<br>Left kidney long axis (coronal)<br>Left kidney short axis<br>Transverse bladder<br>Sagittal bladder                      |
| FOCUSED BOWEL EXAMINATION   | VIEWS   |
|  | <b>Concerns for appendicitis:</b><br>Right lower quadrant<br>Appendix short axis<br>Appendix long axis<br>Blind end<br>Psoas  |
|  | <b>Concerns for bowel obstruction or intussusception:</b><br>Right upper quadrant<br>Left upper quadrant<br>Right lower quadrant<br>Left lower quadrant<br>Periumbilical area |

Figure 2. Abdominal-focused POCUS procedure recommended by the American Academy of Family Physicians and the American College of Emergency Physicians [25,26].



and professional participation from varied educational, occupational, and contextual backgrounds. The Ultrasound Working Group of the Spanish Society of Family and Community Medicine is leading this research and has vast experience in PC ultrasound education and practice. This is a reliable team that has done extensive

work in training numerous FPs in ultrasound and organizing ultrasound conferences and congresses. Additionally, they have participated in various research projects and ultrasound publications in the field of FM.

#### *Limitations*

Technology can introduce bias in the information. There are variations in ultrasound devices among different healthcare facilities, with each using unique devices acquired at specific times, leading to different performance levels. Diagnostic results may be influenced by different machines, so the data will indicate the type of ultrasound machine used. To ensure a blinded review of the reference test, MRs will be collected and evaluated by a different research team member, to minimize information biases. In order to minimize selection bias, it is important to consider the patients selected, as one researcher may have included significantly more cases than another. This could potentially skew the results towards those patients. To achieve balance in the number of patients per physician, each collaborator must obtain a minimum of 20 and a maximum of 50 cases. Additionally, every physician should extend an invitation to participate in the study to all patients who undergo an abdominal POCUS in their office. This will prevent the selection of patients with more severe pathologies or those that are easily diagnosed by ultrasound.

A follow-up period of 12 months has been established, which may overestimate the false-negative rate as new diagnoses may appear during this period that were not visible in the initial ultrasound. A 12-month follow-up period was established due to delays in accessing diagnostic tests and specialist visits within our healthcare system. Spain's healthcare system is publicly funded and universal, but due to high demand, waiting lists and delays for diagnostic tests and specialist consultations are common. This was considered during the study design, and a sufficient follow-up period was established to allow for the necessary diagnostic studies to be performed. The physician's clinical attitude will not be affected by the patient's participation in the study. The patient will undergo all necessary tests and referrals based on their clinical needs. To avoid time bias in acute pathologies related to the initial process, the MR will be reviewed 12 months after the ultrasound scan, taking into account any findings that occurred at one and three months. The variable MR has been defined precisely to only include positive MR findings that are related to the initial process and can be diagnosed by POCUS.

However, the development of the technique, access to training, and the availability of ultrasound devices varied among the regional healthcare services. The results will be categorized by autonomous communities and health areas.

### Potential Factors that May Predict Diagnostic Accuracy

To ensure homogeneity in the sample of collaborating FPs, those participating in the study must receive minimum accreditation for ultrasound training. We will gather data on the hours of abdominal ultrasound training to see if it impacts diagnostic accuracy. Additionally, we will collect information on the physician's prior experience, the number of exams performed before the study, and years of experience performing abdominal ultrasound. We understand that all these factors do influence a physician's ultrasound skill.

To minimize potential bias, we will provide objective definitions of MH outcomes. In reviewing the MH at the 12-month mark, false negatives can result from an information bias when there is no diagnosis of diseases with a prolonged chronic course, episodic course that does not reoccur during that year, or diagnostic delays exceeding one year (waiting lists, rare pathologies, etc.). It could be debated that ultrasound performed by a radiologist instead of a healthcare provider after one year should be the gold standard. However, we think that this would imply going out of the usual clinical practice. In many of these situations, specifically when performing a focused ultrasound scan (POCUS), a comprehensive ultrasound is not requested. Nevertheless, we believe that any significant pathology would have become apparent after one year of follow-up, indicating that there was not an underdiagnosis.

### Conclusion

The study aims to provide objective evidence on the diagnostic accuracy of abdominal ultrasound performed by family physicians in their typical work settings. Currently, the evidence base for ultrasound in Family Medicine is scarce, necessitating further research to determine its usefulness and assess its varied applications. It is essential to ascertain the suitability of the training, technological, time, and geographical conditions, and their correlation with the diagnostic potential of the method.

### Ethical Approval

The study has been approved by the Clinical Research Ethics Committee of Puerta de Hierro Majadahonda University Hospital (reference number 96.23) and the Primary Care Research Commission of Madrid Region (reference number 20230011). All patients will give written informed consent for use of their personal and clinical data for research purposes.

### Acknowledgements

We would like to express our gratitude to María Isabel del Cura González and Teresa Sanz Cuesta from the

Madrid Primary Care Research Unit for their valuable assistance during the design phase of this research project.

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# Effectiveness of a Brief Point of Care Ultrasound Course at a National Nephrology Conference

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## Abstract

The rising demand for point of care ultrasound (POCUS) instruction during nephrology fellowship has been limited due to a shortage of trained faculty and courses designed specifically for nephrologists. A hands-on POCUS pre-course was organized during the April 2023 National Kidney Foundation (NKF) Spring Clinical Meeting to address this challenge. The course consisted of pre-recorded lectures and a 4-hour hands-on workshop guided by multidisciplinary POCUS experts. The anonymous post-course survey received responses from 25 out of 39 participants, yielding a 64.1% response rate. On a scale of 0-10, confidence levels for acquiring kidney images rose from  $2.6 \pm 2.3$  (mean + SD) pre-workshop to  $7.8 \pm 1.5$  post-workshop ( $p < 0.001$ ). Similarly, a remarkable improvement in confidence for acquiring lung and cardiac images was seen as scores increased from  $1.8 \pm 2.4$  to  $7.7 \pm 1.5$  ( $p < 0.001$ ) and from  $1.5 \pm 2.2$  to  $7.2 \pm 1.3$  ( $p < 0.001$ ), respectively. Additionally, respondents reported a substantial improvement in their confidence to interpret kidney, lung, and cardiac POCUS images, with scores increasing from  $4.5 \pm 2.2$  to  $7.7 \pm 1.1$  ( $p < 0.001$ ),  $2.3 \pm 2.4$  to  $7.6 \pm 1.5$  ( $p < 0.001$ ), and  $2 \pm 2$  to  $7.3 \pm 1.5$  ( $p < 0.001$ ), respectively. Barriers to implementing POCUS use at institutions included a perceived lack of trained faculty, limited protected time for faculty, and insufficient support from division leadership. The NKF POCUS pre-course successfully improved participants' confidence in acquiring and interpreting basic POCUS images.

## Introduction

Point of care ultrasound (POCUS) refers to clinician-performed, focused ultrasound exams to answer specific clinical questions at the bedside that guide management [1]. Over the past 25 years, POCUS has emerged as a powerful tool to improve clinicians' diagnostic accuracy when evaluating patients in most specialties. In nephrology, POCUS is no longer confined to kidney ultrasound or procedural guidance but includes a broad range of applications, including assessment of volume status, cardiopulmonary disease, and venous thrombosis [2,3]. Most medical schools (78%) have integrated structured POCUS training into their preclinical and clinical curricula [4], and 61% of internal medicine residency programs had a POCUS curriculum in 2020 [5]. An increasing number of nephrology fellows are starting fellowship with POCUS skills that their supervising attending nephrologists may lack. As such, it is now imperative that practicing nephrologists and graduating fellows have a working knowledge of POCUS imaging. To

help bridge this training gap, a hands-on POCUS pre-course was conducted at the National Kidney Foundation (NKF) Spring Clinical Meeting in April 2023. The goal of the course was to introduce foundational knowledge and hands-on skills for nephrologists in-practice to perform basic POCUS exams pertinent to nephrology. Here we describe the course and summarize findings of a post-course survey that assessed course effectiveness.

## Materials and Methods

A set of 5 pre-recorded lectures lasting 15-20 minutes each was provided to learners as required pre-course work. This approach maximized time for hands-on scanning and expert-guided image review. Two identical 4-hour POCUS courses were offered on the same day to allow small group scanning sessions with 4 learners and 1 faculty per station; maximizing learner engagement and offering flexibility in attending the course (Figure 1). Six POCUS experts (2 nephrologists, 2 hospitalists, 1 nephrologist-intensivist, and 1 intensivist) served as

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DOI: <https://doi.org/10.24908/pocus.v9i1.16858>



faculty. The course began with an introductory lecture reinforcing the basics of image orientation and acquisition. Next, a short cardiac anatomy simulation using Heartworks® augmented reality simulator was used to demonstrate 3-dimensional cardiac anatomy and basic cardiac POCUS views. For hands-on practice, learners rotated through 5 scanning stations equipped with a portable ultrasound machine and live model. Each station was dedicated to teaching a specific POCUS application – one station for kidneys and bladder, one station for lungs and pleura, and three stations for cardiac views (parasternal, apical, and subcostal views). More time was allocated for cardiac POCUS since it is a crucial component of volume status assessment and acquiring proficiency can be challenging due to the complexity of cardiac anatomy. Learners practiced acquiring standard views on healthy models under the guidance of expert faculty and rotated through each station every 30 minutes. The workshop concluded with a 35-minute image review session showing common POCUS abnormalities relevant to nephrology. Following the conclusion of the meeting, an anonymous and voluntary post-course survey was distributed via email to collect feedback and evaluate the effectiveness of the course. No demographic data were collected, except for the participants' professional roles. Participants' confidence to perform and interpret POCUS applications taught in the course was evaluated on a 10-point Likert scale. Likewise, participants were requested to rate the perceived barriers to implement POCUS use at their institutions, utilizing a 10-point scale (0=no hindrance; 10=complete roadblock). Analyses were performed using GraphPad Prism version 10.0.1 for Windows, provided by GraphPad Software, San Diego, CA, USA

(www.graphpad.com). The confidence levels were reported using the mean and standard deviation, assuming a normal distribution of the data.

## Results

A total of 39 learners attended the course (16 in the morning; 23 in the afternoon) and 25 unique learners completed the post-course survey for a response rate of 64%. Among learners completing the post-course survey, 63% were practicing nephrologists, 23% were nephrology fellows, and 14% were advanced practice providers and internal medicine residents. Learners rated their level of confidence in acquiring and interpreting POCUS images on a 10-point Likert scale. Comparing pre- and post-course ratings, learners' confidence in acquiring renal images increased significantly from a mean of 2.6 ( $\pm$  2.3) pre-course to 7.8 ( $\pm$  1.5) post-course ( $p < 0.001$ ). Similarly, learner confidence in acquiring lung and cardiac images increased from 1.8 ( $\pm$  2.4) to 7.7 ( $\pm$  1.5) ( $p < 0.001$ ) and from 1.5 ( $\pm$  2.2) to 7.2 ( $\pm$  1.3) ( $p < 0.001$ ), respectively. With respect to confidence in image interpretation, learners reported a substantial improvement in interpreting kidney, lung, and cardiac POCUS images from 4.5 ( $\pm$  2.2) to 7.7 ( $\pm$  1.1) ( $p < 0.001$ ), 2.3 ( $\pm$  2.4) to 7.6 ( $\pm$  1.5) ( $p < 0.001$ ), and 2 ( $\pm$  2) to 7.3 ( $\pm$  1.5) ( $p < 0.001$ ), respectively (Figure 2). Regarding course duration, 81% of learners felt the duration was appropriate, while 15% would have preferred a longer course. Interestingly, all learners responded that the cardiac anatomy simulation improved their understanding of cardiac POCUS anatomy. The top 3 perceived barriers to implementing POCUS use at the learners' institutions (based on a subjective rating scale of 1-10), were lack of trained faculty (mean score of 7.5), lack of protected time

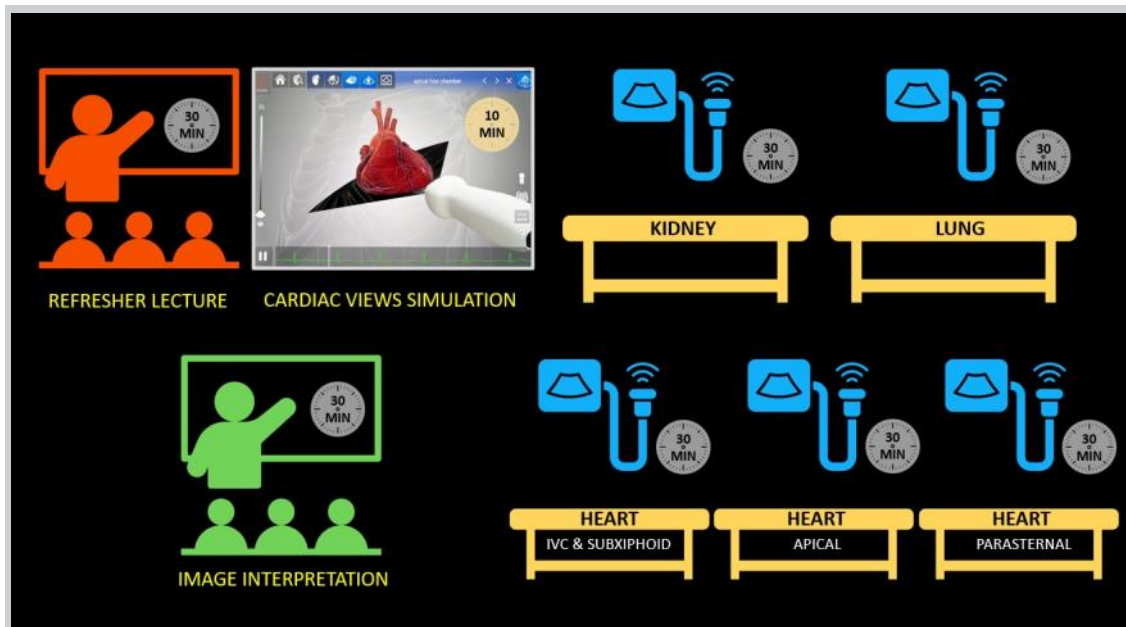
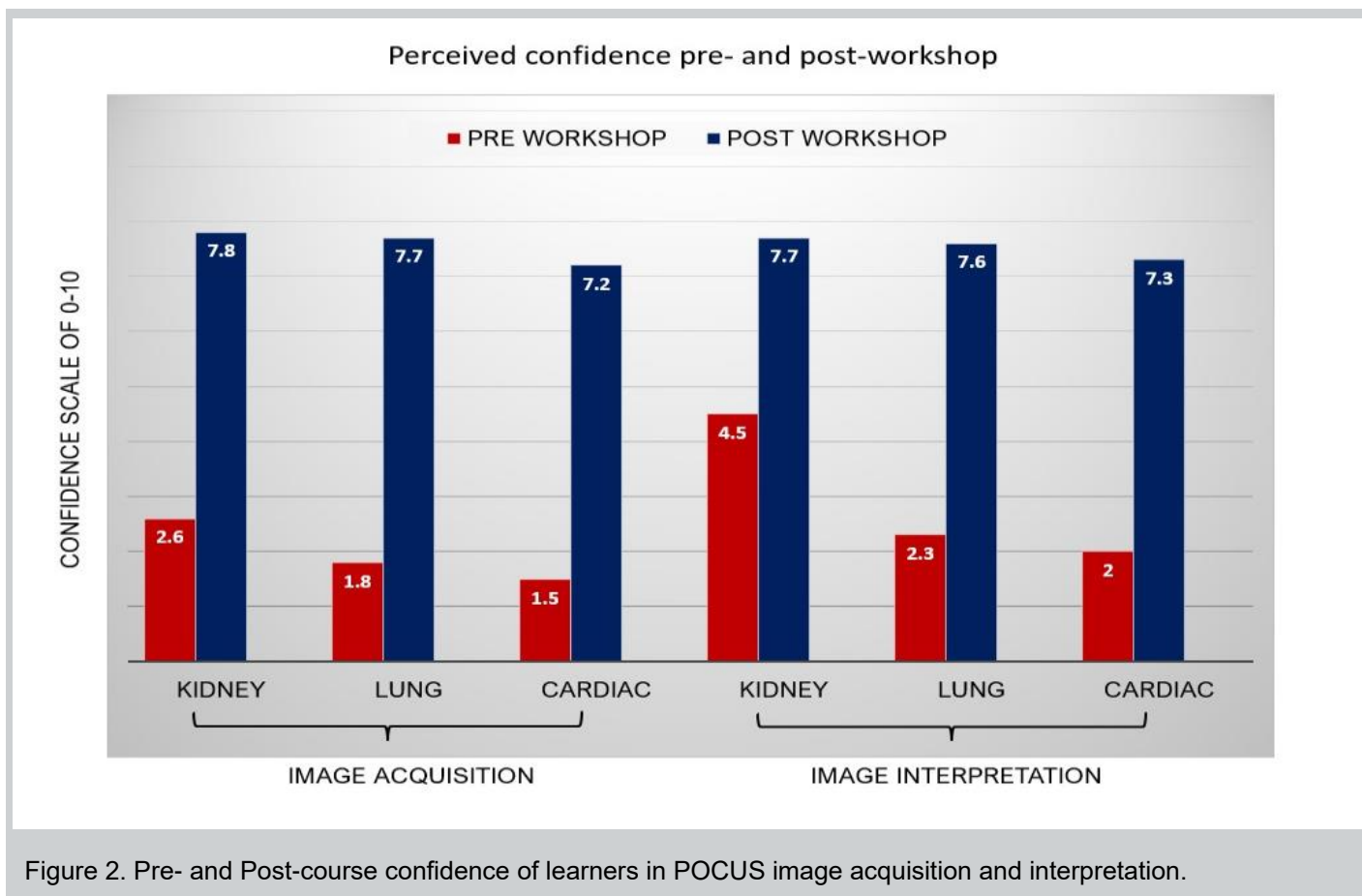


Figure 1. Nephrology Point of Care Ultrasound Workshop Curriculum. Two identical half-day courses were conducted. IVC, inferior vena cava.



for faculty (7.2), and lack of support from their division leadership (6.8).

### Discussion

The spring 2023 NKF POCUS pre-course was successful at improving the confidence of nephrology attending physicians and fellows in acquiring and interpreting common POCUS views relevant to nephrology. Although the substantial boost in learner confidence is encouraging, it may be influenced by their excitement to learn new skills. This increased confidence does not automatically translate into competency. Achieving competence requires structured, longitudinal practice, and honing skills acquired during workshops like this can serve as a starting point. In fact, studies have consistently demonstrated that confident learners may not necessarily be competent, especially in the absence of continued supervised practice [6, 7]. As the shortage of qualified nephrology faculty poses a significant obstacle to widespread POCUS adoption [8], nephrology professional societies should take a leading role to deliver sustained and methodical POCUS training to interested nephrologists. Notably, all learners said they would (89%) or may (11%) pursue a longitudinal POCUS training program if NKF offered such a program. Furthermore, publication of specialty-specific guidelines by respected organizations delineating the scope of

practice, training requirements, and competency standards for nephrologists would garner institutional support and help standardize practice. Without such initiatives, an increasing disparity between the desire to incorporate POCUS into practice and availability of POCUS-trained nephrology attending physicians may lead to POCUS use that lacks quality and standards.

### Conflict-of-Interest Statement

The authors declare no potential conflicts of interest.

### Funding Statement

AK reports research funding from KidneyCure and the American Society of Nephrology's William and Sandra Bennett Clinical Scholars Grant. NS reports receiving grant funding from the Department of Veterans Affairs Quality Enhancement Research Initiative (QUERI) Partnered Evaluation Initiative (150 HX002263-01A1) and National Center for Patient Safety. The contents of this publication do not represent the views of the US Department of Veterans Affairs or the US Government. RM is supported by grant K23HL150236. RM owns stock in Abbvie and has received consultation fees/honoraria from AstraZeneca and is on the Speaker's Bureau for AstraZeneca.

## Ethics Approval

This study falls outside the scope of the institutional review board. The results have been shared with the meeting/course organizers and approved for publication.

## Data Availability Statement

Available data is furnished in the manuscript. Further enquiries can be directed to the corresponding author.

## Author Contributions

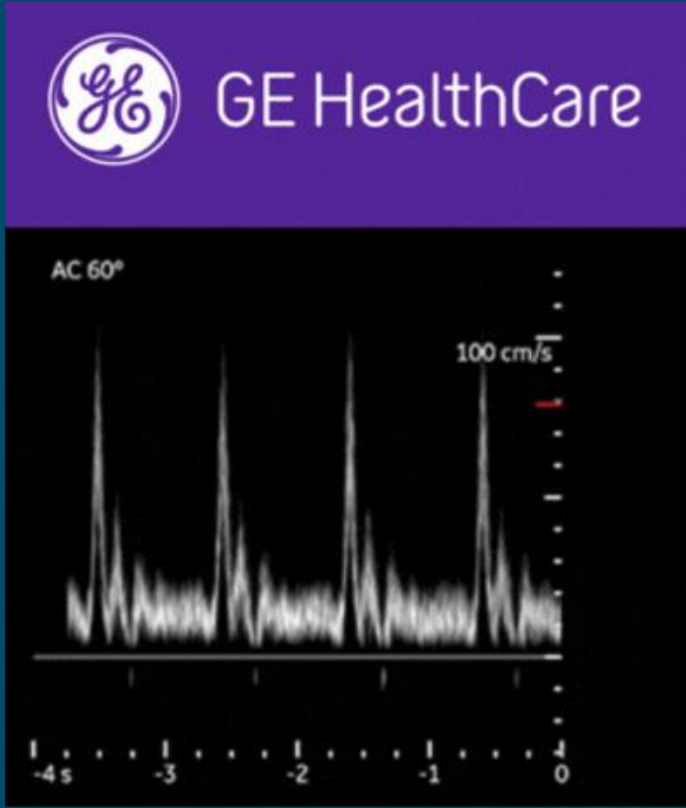
All authors contributed to drafting the manuscript and organization of the course. AK served as course director. All authors have seen and approved the final version of the manuscript.

## Acknowledgements


We thank Jordan Cannon, Sr. Director, Professional Programs & Member Engagement, NKF for the help and support in organizing this workshop. We are grateful to all the course faculty for sharing their expertise.

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# Emergency Physician Performed Ultrasound-Guided Abdominal Paracentesis: A Retrospective Analysis

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## Abstract

**Background:** Emergency physicians commonly perform ultrasound-assisted abdominal paracentesis, using point of care ultrasound (POCUS) to identify ascites and select a site for needle insertion. However, ultrasound-guided paracentesis has the benefit of real-time needle visualization during the entire procedure. Our objective was to characterize the performance of emergency physician-performed ultrasound-guided paracentesis using POCUS, their ability to achieve good in-plane needle visualization, and factors associated with procedural success. **Methods:** A POCUS database was retrospectively reviewed for examinations where abdominal paracentesis was performed by an emergency physician at two academic urban emergency departments over a six-year period. Medical records were reviewed for demographics, presenting history, complications, and hospital course. Descriptive statistics were used to summarize the data. **Results:** 131 patients were included in the final analysis. The success rate for ultrasound-guided paracentesis was 97.7% (84/86 [95% CI: 92-100%]) compared to 95.6% (43/45 [95% CI: 85-99%]) for ultrasound-assisted paracentesis ( $p=0.503$ ). 58% (50/86) demonstrated good in-plane needle visualization; 17% (15/86) had partial or out-of-plane visualization; and 24% (21/86) did not demonstrate needle visibility on their saved POCUS images. All four procedural failures were performed by first- or second-year residents using a curvilinear transducer, while all procedures using a linear transducer were successful. The most common complications were ascites leak, infection at the site, and minor bleeding. **Conclusions:** Emergency physicians with training in real-time needle guidance with ultrasound were able to use POCUS to perform ultrasound-guided paracentesis in the emergency department with a high success rate and no fatal complications. Based on our experience, we recommend performing ultrasound-guided paracentesis using a linear transducer, with attention to identifying vessels near the procedure site and maintaining sterile technique.

## Background

Diagnostic abdominal paracentesis is an essential emergency department (ED) procedure. Emergency physicians commonly employ ultrasound-assisted paracentesis, in which point of care ultrasound (POCUS) is used to identify ascites and mark an ideal location for needle entry [1]. Ultrasound-assisted paracentesis has been shown to be more successful and result in fewer complications than a landmark-based approach, but requires an adequately-sized volume of ascites to be performed safely [1-5].

For smaller volumes of ascites, ultrasound-guided paracentesis, in which ultrasound is used for real-time needle visualization during the entire procedure, may be utilized [4]. Ultrasound-guided paracentesis has been shown to be successful with minimal complications when performed by radiologists [6]. However, waiting for interventional radiology to perform paracentesis is

associated with delays in care [7]. Emergency physicians already use real-time ultrasound needle guidance for other emergent procedures, such as vascular access [8]. To our knowledge, the ability of emergency physicians to use POCUS for real-time needle guidance during paracentesis has not been previously studied.

The objective of this study was to evaluate (1) the success and complication rates of ultrasound-guided paracentesis compared to ultrasound-assisted paracentesis in the ED, (2) the ability of emergency physicians to achieve real-time in-plane POCUS needle guidance, and (3) the procedure and patient-related factors associated with success.

## Methods

### Study Design/Study Setting

A retrospective review of ED patients who received paracentesis using ultrasound in the ED at two academic

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DOI: <https://doi.org/10.24908/pocus.v9i1.16668>

urban hospitals with a total annual census of 125,000 between July 2014 and October 2021 was performed. These hospitals support two ACGME (Accreditation Council for Graduate Medical Education) emergency medicine residency programs – one combined emergency medicine and pediatrics residency, and one emergency ultrasound fellowship that operates at both hospitals.

Emergency medicine residents typically have minimal prior ultrasound experience at the beginning of their residency training. All emergency medicine residents receive real-time needle guidance training for performing procedures as part of their internal orientation, led by residency leadership. Additionally, during the ultrasound orientation day, emergency medicine residents participate in didactic and hands-on training sessions on needle guidance using phantoms. All emergency medicine first year emergency medicine residents undergo a two-week emergency ultrasound rotation, gaining both didactic instruction and supervised scanning experience in the ED. This includes specific training on real-time needle guidance for procedures. They are required to review materials on ultrasound-guided procedures and take quizzes as part of the evaluation process. They also receive direct instruction on needle guidance while performing procedures in the ED during this two-week rotation. Furthermore, residents attend recurring didactic sessions, with at least three sessions annually focused on performing ultrasound-guided procedures, such as paracentesis. Finally, they participate in hands-on training in various ultrasound-guided procedures that require real-time needle guidance, offered four times a year during simulation training sessions.

Multiple ultrasound systems were available for use in the ED, including Mindray M9 (Shen Zhen, China), Philips CX50 (Amsterdam, The Netherlands), Zonare ZS3 (Zonare Medical Systems, Mountain View, California), and Philips Sparq (Philips Healthcare, Andover, Maryland). All systems are equipped with a curvilinear and a high frequency linear transducer. All POCUS images acquired in the ED are archived in the web-based middle-ware Q-path (Q-path, Telexy Healthcare, BC, Canada) and undergo quality assurance by an emergency ultrasound fellow or faculty.

### *Study Protocol*

The Q-path ultrasound image archiving system (Telexy Healthcare, Maple Ridge, BC, Canada) was queried for eligible patients who underwent abdominal paracentesis using POCUS in the ED. Patients were excluded for several reasons. These include if there

was no corresponding documentation available for the procedure in the electronic medical record; the procedure was not performed by an ED provider; the procedure was not performed due to minimal or no accessible fluid pocket, or patient refusal as documented by the performing physician; the examination was a duplicate from the same procedure; or the Q-path record was incorrectly labeled as a paracentesis.

First, one chart reviewer performed electronic medical record review and data abstraction using a standardized data extraction form via REDCap [9], including patient demographic characteristics, relevant labs, documented success of the procedure, number of attempts, volume of fluid aspirated, disposition, and admitting or discharge diagnosis. The discharge summary (if admitted) or ED document (if discharged) were reviewed. Second, ultrasound images in the Q-path database were reviewed by two emergency ultrasound fellowship-trained physicians to determine the level of training of the performing physician, type of transducer utilized, depth of the fluid pocket relative to peritoneum based on on-screen depth ruler, the technique attempted (ultrasound-guided versus assisted, as documented in the Q-path procedure note), identification of inferior epigastric vessels (considered attempted if a Doppler box was used, and visualized if there was Doppler captured pulsatile flow in the expected location), and whether in-plane or out-of-plane visualization was achieved. The primary author of the procedural documentation was assumed to be the performing provider. However, because all residents are supervised by an attending physician in the ED, the supervising physician could have aided in some cases. The reviewers independently rated image quality on a Likert scale from 1 (uninterpretable images) to 5 (excellent) with 3 (minimum criteria for diagnosis) as a median. Depth measurements and quality ratings were averaged between reviewers. Statistical analysis was performed using SPSS (IBM SPSS Statistics for Macintosh, Version 28. Armonk, NY: IBM Corp). Continuous data are presented as means, and dichotomous data are presented as percent frequencies of occurrence with 95% confidence intervals (CIs). The statistical level of significance used in all analyses was 0.05. This study was approved by the Institutional Review Board.

### **Results**

A total of 131 patients who had abdominal paracentesis performed in the ED using POCUS were included in the final analysis. Thirty-five patients were excluded. Patient and procedure characteristics are shown in Table 1.

*Table 1. Comparison of patient and procedure characteristics between patients undergoing ultrasound-assisted and ultrasound-guided paracentesis in the emergency department using point of care ultrasound.*

| Characteristics                     | Ultrasound-Assisted (n=45) | Ultrasound-Guided (n=86) | p-value |
|-------------------------------------|----------------------------|--------------------------|---------|
| Age, years (SD)                     | 54.5 (±12.1)               | 55.1 (±11.6)             | 0.789   |
| <b>Sex</b>                          |                            |                          | 0.657   |
| Female                              | 18 (40%)                   | 31 (36%)                 |         |
| Male                                | 27 (60%)                   | 55 (64%)                 |         |
| Body Mass Index                     | 27.1 (±6.0)                | 27.8 (±6.4)              | 0.653   |
| <b>Labs</b>                         |                            |                          |         |
| Hemoglobin (SD)                     | 10.8 (±2.1)                | 10.5 (±2.4)              | 0.478   |
| Platelets (SD)                      | 182.3 (±130.2)             | 169.7 (±103.7)           | 0.556   |
| International Normalized Ratio (SD) | 1.6 (±0.5)                 | 1.8 (±0.7)               | 0.131   |
| <b>Ultrasound Data</b>              |                            |                          |         |
| Average Skin Thickness, cm (SD)     | 1.8 (±0.7)                 | 1.7 (±0.7)               | 0.448   |
| Average Ascites Depth, cm (SD)      | 5.6 (±2.1)                 | 4.9 (2.6)                | 0.168   |
| Volume Aspirated, mL (SD)           | 2306 (±2375)               | 1928 (±2313)             | 0.388   |
| Procedure Intent                    |                            |                          | 0.470   |
| Diagnostic                          | 17 (37.8%)                 | 41 (47.7%)               |         |
| Therapeutic                         | 5 (11.1%)                  | 4 (4.7%)                 |         |
| Both                                | 22 (48.9%)                 | 39 (45.3%)               |         |
| Procedure Location                  |                            |                          | 0.238   |
| Right Lower Quadrant                | 30 (66.7%)                 | 63 (73.3%)               |         |
| Midline                             | 1 (2.2%)                   | 0 (0%)                   |         |
| Left Lower Quadrant                 | 12 (26.7%)                 | 15 (17.4%)               |         |
| Diagnosis                           |                            |                          | 0.322   |
| Uncomplicated Ascites               | 31 (68.9%)                 | 66 (76.7%)               |         |
| Spontaneous Bacterial Peritonitis   | 5 (11.1%)                  | 11 (12.8%)               |         |
| Unknown/Other                       | 9 (20.0%)                  | 9 (10.5%)                |         |

There were no significant differences in triage vitals or the rate of hospital admission (68.9 vs. 66.3%) between ultrasound-assisted and ultrasound-guided groups. The observed success rate for ultrasound-guided paracentesis was 97.7% (84/86 [95%CI: 92-100%]) compared to 95.6% (43/45 [95%CI: 85-99%]) for ultrasound-assisted paracentesis (p=0.503); procedural outcomes are summarized in Table 2. The depth of ascites fluid was not significantly smaller for failures versus successes (6.1±2.4 vs 5.1±2.5 cm, p=0.45).

Conservatively, including complications theoretically attributable to paracentesis, the proportion of patients experiencing complications was 10.5% (9/86) with ultrasound-guided paracentesis and 4.4% (2/45) with ultrasound-assisted paracentesis (p=0.238). The complications in the ultrasound-assisted patients were minor. One patient reported persistent pain at the paracentesis site and one patient had minor superficial bleeding that resolved with direct pressure. The complications in the ultrasound-guided patients included five patients with leaking ascites and one patient with minor superficial bleeding that resolved with a pressure dressing. One patient developed an abdominal wall hematoma that required two red blood cell transfusions. It was unclear if this was secondary to the ED paracentesis or the interventional radiology-performed paracentesis shortly thereafter and was not attributed to an inferior epigastric vessel injury. Two patients developed abdominal wall cellulitis, including one that required intravenous antibiotics and one that required incision and drainage of an associated abscess followed by operative surgical debridement of the abdominal wall. Another patient developed Staphylococcus epidermidis bacteremia which was included as a possible complication due to unknown source.

For real time ultrasound-guided paracentesis, 58% (50/86) demonstrated good in-plane needle visualization (needle tip and shaft fully seen) and 17% (15/86) had partial or out-of-plane visualization. Twenty four percent (21/86) did not demonstrate needle visibility on their saved POCUS images despite documenting use of real-time guidance. The average image quality was rated as 3.5 (SD±0.5) in the ultrasound-assisted group compared to 3.6 (SD±0.8) in the ultrasound-guided group (p=0.292). There was moderate or better agreement between the two raters with respect to image quality (ICC=0.62 [95% CI: 0.47-0.73]), measurement of ascites depth (ICC=0.79 [95%CI: 0.69-0.85]), and measurement of skin thickness (ICC=0.82 [95%CI: 0.74-0.87]).

The overall success rate was 97.6% (40/41) for first year residents, 91.4% (32/35) for second year residents, and 100% (55/55) for third-fifth year residents, fellows, and

*Table 2. Comparison of outcomes between patients undergoing ultrasound-assisted and ultrasound-guided paracentesis in the emergency department using point of care ultrasound.*

| Outcome                              | Ultrasound-Assisted (n=45) | Ultrasound-Guided (n=86) | p-value |
|--------------------------------------|----------------------------|--------------------------|---------|
| Procedure Successful (%)             | 43 (95.6)                  | 84 (97.7)                | 0.503   |
| Inferior Epigastric Vessels (%)      |                            |                          | 0.015   |
| Visualized                           | 0 (0)                      | 7 (8.1)                  |         |
| Attempted                            | 4 (9.8)                    | 19 (22.1)                |         |
| Not Shown                            | 41 (90.2)                  | 60 (69.8)                |         |
| <b>Complications (%)<sup>a</sup></b> |                            |                          |         |
| Severe Pain                          | 1 (2.2)                    | 0                        | 0.165   |
| Minor Bleeding                       | 1 (2.2)                    | 1 (1.2)                  | 0.639   |
| Major Bleeding                       | 0                          | 1 (1.2)                  | 0.468   |
| Infection                            | 0                          | 3 (3.5)                  | 0.205   |
| Ascites Leak                         | 0                          | 5 (5.8)                  | 0.099   |
| Death                                | 0                          | 0                        | -       |

a = One patient in the ultrasound-guided group had both ascites leak and infection.

faculty. All four unsuccessful procedures occurred while using a curvilinear transducer (4/87), and there were no unsuccessful procedures (0/44) using a linear transducer ( $p=0.149$ ). Patients had a higher average BMI in the curvilinear group than the linear group ( $28.6\pm 6.3$  vs.  $24.9\pm 5.3$ ,  $p=0.017$ ).

## Discussion

We found that emergency medicine physicians were highly successful at performing ultrasound-guided paracentesis in the ED using POCUS. The success rate for ultrasound-assisted paracentesis (96%) was similar to a prior randomized control trial of ultrasound-assisted paracentesis including emergency medicine residents (95%) [1]. To our knowledge, the current study is the first to report success rates for emergency medicine physicians performing ultrasound-guided paracentesis (98%).

The types of complications we observed for ultrasound-guided paracentesis – such as bleeding, infection, and

ascites leak – were similar to prior studies of paracentesis performed outside of the ED. Abdominal wall infection occurred in 2.3% (2/86) of observed patients. A prior study of inpatient paracentesis using ultrasound found 0.41% (3/723) had infectious complications, but they did not differentiate between ultrasound-assisted and ultrasound-guided procedures, and a similar percentage of infectious complications (2.4%, 14/574) were observed with no use of ultrasound at all [3]. After receiving both an ED-performed and interventional radiology-performed paracentesis, one patient (1.2%) required red blood cell (RBC) transfusion; a prior retrospective study of 3,116 ultrasound-guided paracenteses performed by radiologists observed hemorrhage requiring RBC's or angiogram in 0.19% [6]. The most common complication was ascites leak (5.8%, 5/86), similar to the 5.0% leak rate reported in a prospective study mostly without using ultrasound [10]. We agree that performing the recommended “z-track” technique (where the non-dominant hand is used to put tension on the skin during puncture to decrease post-procedure leaking) might be more difficult when that hand is also holding the ultrasound probe [4,8]. However, many of the complications we observed seem unlikely to be directly attributable to the use of real-time ultrasound guidance, and may instead be associated with patient factors like a smaller ascites volume. The average ascites sampling area was numerically smaller for patients who had real-time guidance, although not statistically different in size. It is possible that real-time guidance in these patients was still safer than it would have been if ultrasound-assisted paracentesis had been performed due to unmeasured patient-level factors. Future prospective study may be needed to identify factors contributing to the demonstrated complications.

The number of residents who achieved good in-plane needle visualization on their saved clips despite attempting an ultrasound-guided technique was low (58%). It is uncertain to what degree this was secondary to lack of provider skill versus non-procedural factors, such as timing of image capture by an assistant, but was similar to the 51% of residents achieving good needle visualization in a study of ultrasound-guided arthrocentesis [11]. Overall, in 75% of cases real-time needle visualization (complete and partial) was demonstrated. However, retrospective review of ultrasound images has limitations for determining residents' ability to achieve good in-plane needle visualization with real-time ultrasound-guided procedures. Future research could include prospective evaluation of needle-guidance quality to identify specific targets for interventions to improve needle visualization during ultrasound-guided procedures, better quantify the

learning curve of this important skill, and investigate ways to further decrease complications.

The only unsuccessful procedures in our study were performed by first and second year residents, all using a curvilinear probe. The higher success rate for third year residents and above is similar to that of ultrasound-guided arthrocentesis in the ED, suggesting a learning curve [11]. Previously, the use of a linear transducer has been suggested for thin patients and phased-array for larger patients [4]. However, real-time needle tracking is easier with a linear transducer since the area of interest (ascites) is superficial, generally within 5 cm. A linear transducer emits only parallel ultrasound beams and allows for the same resolution in the near-field and the far-field, making it ideal for needle tracking as the needle is advanced from the skin into the abdomen. We recommend using a curvilinear transducer for confirming the presence of ascites and choosing the ideal location to perform the procedure, then switching to linear array transducer to perform the procedure. The linear array transducer provides the added benefit that it can be used to visualize the inferior epigastric artery (IEA) prior to needle insertion, as damage to the IEA can cause significant morbidity and mortality [12,13].

### Limitations

This study has several inherent limitations due to its retrospective nature. First, only cases where ultrasound images were saved were included. While it is standard practice at our institution to save all images used for patient care, some physicians may have chosen not to perform paracentesis on patients who they felt were likely to be too technically challenging based on initial examination without saving any images, spuriously improving success rates due to selection bias. Additionally, physicians with higher skill levels could have been more likely to save images. There may have been patient-specific factors which led a physician to choose a particular approach where the alternate may have been less successful. However, a wide range of ascites fluid pocket sizes, body mass index (BMI), and skin thickness were included. Finally, while not all data collectors were blinded to the study hypothesis, we attempted to minimize the bias in retrospective data collection by using a standardized abstraction form.

### Conclusions

Emergency medicine physicians with training in real-time needle guidance with ultrasound were able to use POCUS to perform ultrasound-guided paracentesis in the ED with a high rate of success, similar to the success rates observed for ultrasound-assisted paracentesis. Improving in-plane needle visualization remains an educational goal. Based on our experience, we

recommend performing ultrasound-guided paracentesis using a linear transducer, with attention to identifying vasculature near the procedure site and maintaining sterile technique.

### Disclosures

The authors disclose the following actual or potential conflicts of interest within the last 36 months: BW, JD, OR have nothing to disclose; SA, funding from the US NIH and Department of Defense, Springer Book Royalties, Consulting Fees from GE and Exo Ultrasound, Honoraria from the American Society of Regional Anesthesia and Pain Medicine, and board membership to the American Institute of Ultrasound in Medicine.

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# Trends in Point of Care Ultrasound Familiarity Among Undergraduate Medical Clerkship Educators

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## Abstract

**Objectives:** Despite growing use of point of care ultrasound (POCUS), there remains a paucity of data about familiarity with POCUS among educators who dictate curricular content in undergraduate medical education. This paper aims to longitudinally characterize the level of comfort and frequency of POCUS use among faculty involved in undergraduate clerkship education. **Methods:** A web-based cross-sectional survey assessing comfort, frequency of use, and awareness of indications for POCUS among faculty involved in Internal Medicine, Family Medicine, and Surgery undergraduate clerkship education in a single urban academic medical center in 2016 and again in 2022. **Results:** A total of 45 responses from 2016 and 30 responses from 2022 are included. The percentage of faculty “not comfortable” with performing POCUS decreased from 78% to 46%, although the overall change in comfort was not statistically significant. Comfort interpreting POCUS images, frequency of POCUS use, and familiarity with the clinical applications of POCUS all improved. Faculty identified multiple barriers to more frequent POCUS use. **Conclusions:** Over a six-year period at one urban, academic medical center, comfort with POCUS and frequency of use have increased slightly but remain low among core faculty responsible for clerkship education. There are still large gaps in knowledge and very few faculty regularly use POCUS, which can be attributed to multiple different barriers.

## Introduction

Point of care ultrasound (POCUS) instruction in undergraduate medical education is widespread but variable. In a 2019 survey, 73% of United States accredited medical schools indicated having a POCUS curriculum, 84% of which were mandatory [1]. POCUS was primarily taught by Emergency Medicine physicians and was often integrated into specific basic science or clinical skills courses, with 35% of instruction occurring on clinical rotations.

As noted in a recent international consensus statement [2], an ideal POCUS curriculum can enhance the learning of clinical sciences through the integration of POCUS into clinical problem solving and through the care of patients at their point of care. Yet, the rapid inclusion of POCUS into undergraduate medical education is challenged because medical students' knowledge on this subject may exceed that of supervising physicians who did not

receive this training. Lack of attending physician awareness or comfort with POCUS can create a barrier for medical students and resident trainees who wish to use or expand their skill set. This knowledge deficit may be particularly impactful when the untrained supervisor is responsible for establishing learning goals and experiences for trainees.

The increased utilization of POCUS has been recognized, [3–6] especially in Emergency Medicine [7]. Nevertheless, there is not enough investigation on the level of experience with POCUS among educators of medical students and how this has changed over time. The aim of this paper is to describe the level of comfort with POCUS, frequency of POCUS use, and knowledge of indications for POCUS among faculty involved in the undergraduate clerkship education at a single urban academic medical center using surveys from both 2016 and 2022.

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DOI: <https://doi.org/10.24908/pocus.v9i1.16678>

## Materials and Methods

### *Study Design*

We conducted a web-based cross-sectional survey assessing comfort, frequency of use, and awareness of indications for POCUS among faculty involved in undergraduate clerkship education in a single urban academic medical center in both 2016 and in 2022. The University of Pennsylvania Institutional Review Board (IRB) exempted the study protocol from full IRB review in both iterations.

### *Population and Setting*

The target survey population included faculty who were responsible for the curriculum or clinical teaching on medical student clerkship rotations. These included clerkship directors, clinical site directors, and core clinical preceptors. In 2016, this survey was distributed to faculty involved in the Internal Medicine, Family Medicine, General Surgery, Emergency Medicine, and Pediatric Emergency Medicine clerkships, as identified by the School of Medicine's Curriculum Office. In 2022, a repeat survey was distributed to faculty in similar positions, although the distribution method differed. In 2016, invitations were distributed through a dean's email distribution list for core faculty, while in 2022, due to a change in medical school leadership, invitations were distributed directly by clerkship directors to faculty in specified roles. While clinical educators from Emergency Medicine and Pediatric Emergency Medicine participated in the 2016, very few responses were received from these specialties in 2022; therefore, this paper reports results from only Internal Medicine, Family Medicine, and Surgery. Subset analyses were also performed for primary care specialties (Internal Medicine and Family Medicine) and paired responses across the two timepoints.

This set of roles was chosen because these educators dictate the curricular content, clinical experiences, and educational priorities for medical students during their core rotations of the clerkship year. In this paper we analyze responses from faculty focusing on the trends of change between two different time periods.

### *Survey Content and Administration*

The survey examined respondents' demographics, comfort with acquiring and interpreting POCUS images, personal frequency of POCUS use, and knowledge of possible indications for POCUS. Comfort was assessed on a four-point scale including "not comfortable," "somewhat comfortable," "moderately comfortable," "extremely comfortable." To assess knowledge regarding the role of POCUS, respondents were presented with brief clinical vignettes and explicit

suspected diagnoses. They were then asked whether POCUS could be used by a trained provider in a theoretical diagnostic evaluation. Scenarios included 12 possible diagnoses for which POCUS is generally considered helpful in the diagnostic workup, as well as three diagnoses for which POCUS is not commonly used (stroke, urinary tract infection, and acute otitis media). Vignettes included a range of pediatric, adult, medical, and surgical pathologies. They were developed by POCUS content experts and reflected both common and uncommon POCUS applications, falling within published guidelines regarding core emergency medicine POCUS applications [8]. These survey questions were pilot tested among emergency medicine faculty members prior to distribution.

The survey content was designed to assess the respondent's knowledge regarding the utility of POCUS exams for commonly faced clinical problems, regardless of the ability of the respondents themselves to perform or interpret the exam. This survey design was able to assess general knowledge regarding POCUS that experts expect from medical students' educators.

The survey was conducted through Research Electronic Data Capture (REDCap®, Nashville, TN), a secure web application for building and managing online surveys and databases. Respondents were sent an invitation to participate via email, with two subsequent email reminders. In the first iteration these were distributed between December 2015 and February 2016, and were sent by the Senior Vice Dean for Education. In the second iteration, invitations were sent between April and May 2022, and were distributed by the clerkship director for each respective specialty. Participants were asked to enter a semi-unique identifying code consisting of the first three letters of their birth city and the two digits of their birthday, which allowed for anonymized responses that could be linked across time points. For presenting the results throughout the manuscript, we refer to the first timepoint as 2016 and the second timepoint as 2022.

### *Statistical Analysis*

Descriptive and contingency statistical analyses were performed. Results are presented in frequencies. Parametric variables are presented as means  $\pm$  standard deviation. Non-parametric variables are presented in median and interquartile ranges (IQR). Two-tail Fisher's exact test was used to examine for contingency for trends of variables between the study timepoints. Two-tail Student's t-Test was used to examine for difference in means for continuous variables.

In testing for knowledge regarding the role of POCUS in specific clinical diagnoses, we combined ratings of

“never” and “sometimes” together as responses reflective of no or minimal role for POCUS. We combined ratings of “often” and “always” together as responses reflective of a role for POCUS.

## Results

### Characteristics of Study Participants

In 2016, a total of 88 of 192 surveys were completed (46% response rate). Of those completed, 45 were included in the analysis, and came from Internal Medicine (22, 48.8%), Family Medicine (16, 35.6%), or Surgery (7, 15.6%). The median length of years after residency for the 2016 clinical educators cohort was 21 years (IQR 10–31). Educational roles included 9 (20.0%) clerkship directors, 15 (33.3%) site directors, 38 (84.4%) clinical educators in the ward, clinic, or operating room, and 16 (35.6%) didactic educators.

In 2022 a total of 30 of 97 surveys were completed (31% response rate), of which 28 came from either Internal Medicine (8, 28.6%), Family Medicine (14, 50.0%), or Surgery (6, 21.4%). The median length of years after residency for the 2022 clinical educators cohort was 15 years (IQR 5–25). Participants included 5 (17.9%) clerkship directors, 10 (35.7%) site directors, 23 (82.1%) clinical educators in the ward, clinic, or operating room, and 10 (35.7%) didactic educators. Years since training and current educational roles are summarized in Table 1.

**Table 1. Demographics of clerkship faculty survey respondents: 2016 and 2022 cohorts.**

| Variables   | 2016 Respondents (n = 45) | 2022 Respondents (n=28) |
|---|---------------------------|-------------------------|
| Specialty, n (%)                                      |                           |                         |
| • Internal medicine                                   | 22 (48.8)                 | 8 (28.6)                |
| • Surgery   | 7 (15.6)                  | 6 (21.4)                |
| • Family medicine                                     | 16 (35.6)                 | 14 (50)                 |
| Educational Role, n (%)                               |                           |                         |
| • Clerkship director                                  | 9 (20)                    | 5 (17.9)                |
| • Site director                                       | 15 (33.3)                 | 10 (35.7)               |
| • Clinical teaching                                   | 38 (84.4)                 | 23 (82.1)               |
| • Didactic teaching                                   | 16 (35.6)                 | 10 (35.7)               |
| Years since completing residency, years, median (IQR) | 21 (10–31)                | 15 (5–25)               |

IQR = Interquartile ranges

### Comfort and Frequency of POCUS Use

Respondents were asked how comfortable they were performing POCUS examinations, as well as interpreting the POCUS images performed either by themselves or another individual (Table 2). Comfort performing POCUS improved from 2016 to 2022, although this was not statistically significant ( $p=0.053$ ). Those who responded that they were not comfortable performing POCUS decreased from 77.8% to 46.4%. Moreover, those who responded that they were moderately or extremely comfortable performing POCUS increased from 11.1% and 2.2% in 2016 to 28.6% and 7.1% in 2022, respectively.

Regarding interpretation of POCUS, those who were not comfortable interpreting scans decreased from 75.6% in 2016 to 46.4% in 2022. Additionally, those who were moderately comfortable interpreting scans increased from 8.9% in 2016 to 25% in 2022, and those who were extremely comfortable interpreting scans increased from 0% in 2016 to 7.1% in 2022 ( $p=0.032$ ). Those who used POCUS several times a month increased from 6.7% in 2016 to 14.3% in 2022, and those who used POCUS several times a week increased from 2.2% to 10.7% ( $p=0.004$ ).

### Knowledge

Knowledge about the utility of POCUS in the diagnostic evaluation varied significantly by condition. Respondents were more familiar with POCUS use in conditions such as cardiac tamponade, gallstones, and ectopic pregnancy, and less aware of the role of POCUS in conditions such as elevated intracranial pressure and pyloric stenosis (Figure 1).

Overall, for positive indications, those who correctly rated a role for POCUS as “often” or “always” increased in average from 40.9% in 2016 to 59.8% in 2022. For the negative indications, those who rated a role for POCUS as “rare” or “sometimes” slightly decreased from 98.5% to 95.2%. We noted significant improvement in identifying the role of POCUS in diagnosis of pulmonary edema and pneumothorax. In 2016, only 8.9% of respondents thought there was “often” or “always” a role for POCUS in diagnosing pulmonary edema, versus 75% of respondents with similar opinions in the 2022 cohort ( $p<0.0001$ ). Additionally, in 2016, 22.2% of respondents thought there was “often” or “always” a role for POCUS in diagnosing pneumothorax, versus 67.9% of respondents with similar opinions in the 2022 cohort ( $p=0.0002$ ). The knowledge of the role of POCUS in diagnosing increased intracranial pressure (ICP) remained very limited with greater than 95% of respondents indicating the role of using POCUS for this diagnosis as “never” or “sometimes.”. Responses to

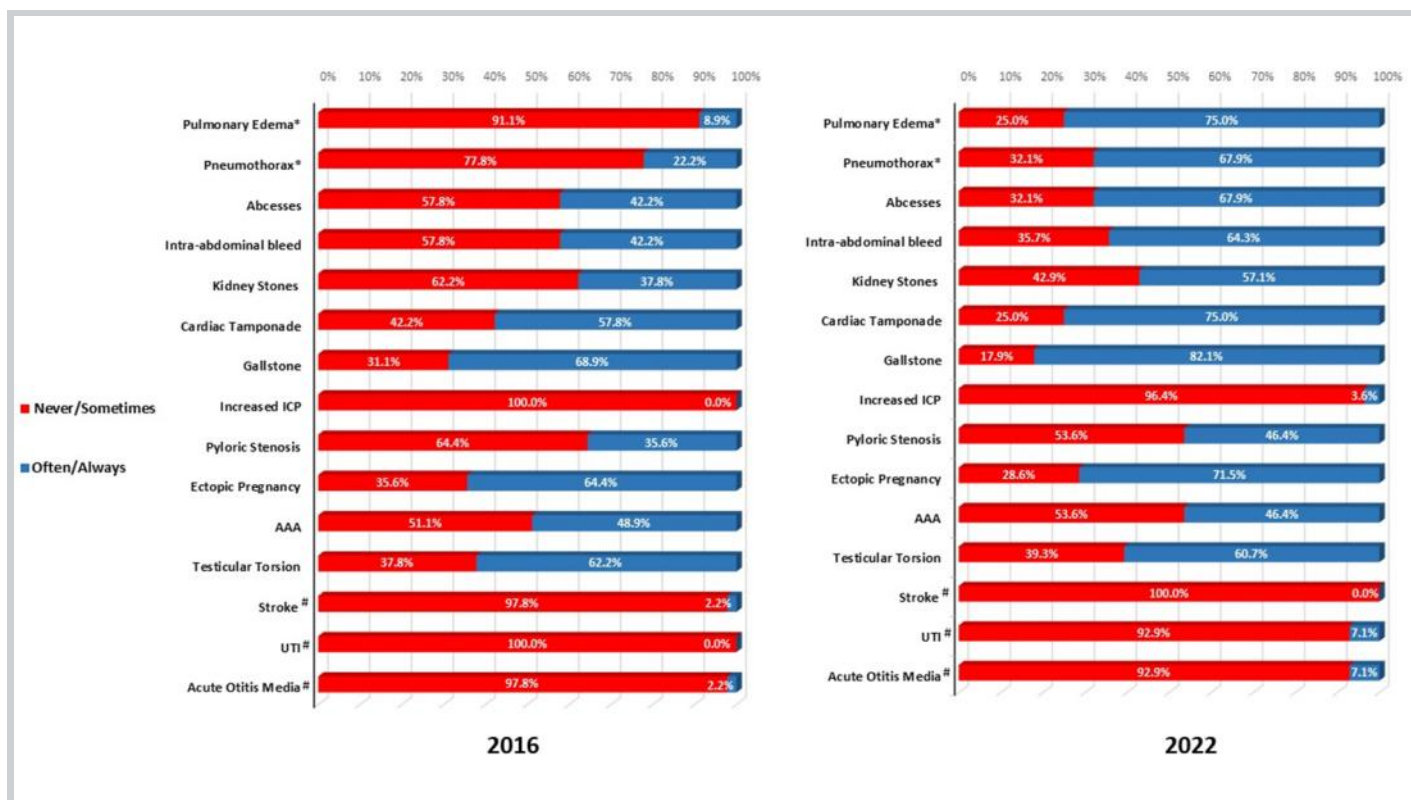


Figure 1. Knowledge of appropriate and inappropriate indications for POCUS, scored as the frequency with which respondents believe a clinician can use POCUS to evaluate symptoms.

\* = Significant  $p$ -value; # = False indication; ICP = Intracranial pressure; AAA = Abdominal aortic aneurysm; UTI = Urinary tract infection

false indications of POCUS (stroke, urinary tract infection, and acute otitis media) showed that clinical educators are aware of the lack of a role for POCUS in diagnosing of these conditions. More than 95% of respondents rated role of using POCUS for negative indications as “never” or “sometimes” in both study timepoints.

#### Paired Responses

Seven paired responses were identified through the clinical educator’s semi-unique identifier, specialty, and years since residency. Six clinical educators (85.7%) had clinical teaching roles in 2016 that they all continued to perform in 2022, and the remaining clinical educator took on a clinical teaching role in 2022. Only one clinical educator was a clerkship director in 2016 and continued to have this role in 2022. One of the clinical educators was a site director in 2016 and did not continue to have this role in 2022. The majority of clinical educators did not teach didactics in either timepoint (5 and 4 clinical educators in 2016 and 2022, respectively).

In these paired responses, comfort level using or interpreting POCUS remained unchanged ( $p=0.543$  and

$p=0.472$ , respectively). Similarly, frequency of using POCUS remained the same ( $p=0.548$ ).

#### Barriers to more frequent use of POCUS

In 2022, one additional question set was included in the survey which aimed to interrogate clinical educator perspectives on specific needs to allow more frequent POCUS use (Table 3). Real-time supervision and continuing medical education (CME) were the most highly rated needs, with an average of  $6.6 \pm 3.2$  and  $6.0 \pm 3.5$  points on a scale of 0 to 10, respectively. However, all other needs were highly rated, including access to handheld ultrasound ( $5.0 \pm 3.9$ ), access to imaging archive system ( $5.0 \pm 3.7$ ), and protected time ( $4.8 \pm 3.4$ ).

#### Utility of POCUS in Primary Care Specialties

A subset analysis for primary care specialties (Internal Medicine and Family Medicine) revealed no differences in comfort performing POCUS ratings between 2016 and 2022 ( $p=0.123$ ). Around 3 in 4 (78%) clinical educators in 2016 and 1 in 2 (50%) clinical educators in 2022 were not comfortable performing POCUS. Only 2.6% in 2016 and 4.5% in 2022 were extremely comfortable

performing POCUS. Despite this finding, frequency of POCUS use improved between the study timepoints. Those who never used POCUS decreased from 73.7% in 2016 to 36.6% in 2022; those who performed POCUS several times a month increased from 7.9% in 2016 to 18.2% in 2022; and those who performed POCUS several times a week increased from 2.6% in 2016 to 9.1% in 2022 ( $p=0.042$ ).

Primary care specialists rated comfort in interpreting POCUS slightly better in 2022 compared to 2016, although this was not statistically significant ( $p=0.094$ ). While around 3 in 4 (77.8%) were not comfortable interpreting POCUS, and 1 in 10 (10.5%) were somewhat and moderately comfortable interpreting POCUS in 2016, no clinical educator rated their comfort level interpreting POCUS as extremely comfortable. In 2022, 1 in 2 clinical educators (50.0%) were not comfortable interpreting POCUS, while (18.2%) and (27.3%) were somewhat and moderately comfortable interpreting POCUS, respectively. Only one clinical educator rated their comfort level interpreting POCUS as extremely comfortable in 2022.

## Discussion

Multiple surveys have interrogated the extent of POCUS use and education in medical training programs, but this survey represents a unique focus on medical student clerkship-level educators over a multi-year period.

Although the overall distribution in level of comfort did not change in a statistically significant way from 2016 to 2022, we noted a reduction in educators who are

uncomfortable performing POCUS by 31.4%. Many educators gained some level of comfort with POCUS, but ultimately almost none had become “extremely comfortable” performing their own ultrasound exam. In fact, more educators described their comfort level as “somewhat” or “moderately comfortable.” Comfort level interpreting POCUS did change significantly from 2016 to 2022, suggesting that educators may have had more exposure to cognitive concepts of POCUS, with an ability to interpret basic images, even if they had not benefitted from hands-on scanning experience. Finally, the frequency of use of POCUS has significantly increased. Overall, the trends noted are indicative of growing use of POCUS with perhaps gradual improvement in comfort level performing it.

A subset analysis of responses by primary care providers alone, excluding the surgical educators, showed a more muted increase in comfort and frequency of POCUS use than the overall trends. Though the absolute numbers of surgical educators were small, this hypothesis-generating observation could suggest that increasing frequency of POCUS use might be driven in part by increasing use of POCUS in surgical and perioperative services [9].

There was noticeable discrepancies in awareness of POCUS utility for diagnostic evaluation of various clinical scenarios. Our findings indicated higher awareness for POCUS in commonly managed medical problems such as pneumothorax and pulmonary edema. For instance, the role of POCUS in pulmonary edema has been frequently discussed in recent literature resulting in

*Table 2. Comfort in performing and interpreting POCUS images and personal frequency of POCUS use in 2016 and 2022 cohorts.*

| Variables, n (%)   | Likert Scale           |   |  |  | P-Value |
|--|------------------------|---|--|--|---------|
|  | Not comfortable        | Somewhat comfortable                            | Moderately comfortable                             | Extremely comfortable                              |         |
| Comfort performing POCUS:<br>• 2016 (n=45)<br>• 2022 (n=28)          | 35 (77.8)<br>13 (46.4) | 4 (8.9)<br>5 (17.9)                             | 5 (11.1)<br>8 (28.6)                               | 1 (2.2)<br>2 (7.1)                                 | 0.053   |
| Comfort interpreting POCUS images:<br>• 2016 (n=45)<br>• 2022 (n=28) | 34 (75.6)<br>13 (46.4) | 7 (15.6)<br>6 (21.4)                            | 4 (8.9)<br>7 (25)                                  | 0 (0)<br>2 (7.1)                                   | 0.032   |
|  | <b>Never</b>           | <b>Rarely</b><br><i>Once or twice per month</i> | <b>Sometimes</b><br><i>several times per month</i> | <b>Frequently</b><br><i>several times per week</i> |         |
| Frequency of use of POCUS:<br>• 2016 (n=45)<br>• 2022 (n=28)         | 35 (77.8)<br>10 (35.7) | 6 (13.3)<br>11 (39.3)                           | 3 (6.7)<br>4 (14.3)                                | 1 (2.2)<br>3 (10.7)                                | 0.004   |

POCUS = Point of care ultrasound.

Table 3. Barriers to more frequent use of POCUS.

| Questions<br>Mean $\pm$ SD  | 2022 Respondents<br>(n = 28) |
|---|------------------------------|
| <i>How much more likely would you be to perform POCUS yourself if you had access to:</i>          |                              |
| • A handheld or easily accessible cart-based ultrasound device                                    | 5.0 $\pm$ 3.9                |
| • A day/weekend CME-eligible workshop on basic ultrasound skills                                  | 6.0 $\pm$ 3.5                |
| • Real-time expert supervision to assist with acquiring and interpreting images                   | 6.6 $\pm$ 3.2                |
| • An image archive system for delayed expert review, feedback, and assistance with interpretation | 5.0 $\pm$ 3.7                |
| • Protected time and/or longer visits to incorporate ultrasound                                   | 4.8 $\pm$ 3.4                |

\*On a scale of 0 to 10

increased awareness [10–12]. Although there is Emergency Medicine literature regarding the use of optic nerve sheath diameter to detect findings of increased intracranial pressure [13], this is a less common indication outside of the Emergency Medicine setting and there was relatively lower awareness of the role of POCUS in this application. These trends might suggest that educators tend to focus on more frequently performed ultrasounds. Moreover, it may suggest that certain ultrasound exams are more commonly taught due to the seriousness of the illness or the feasibility of teaching the topic.

Thus, while educational programs should aim to cover a wider range of POCUS uses, the utilization of the modality may continue to vary with exposure, knowledge and experience.

Though the number of paired responses is limited, this subgroup did not appear to have significant changes in ultrasound comfort, frequency of use, or knowledge over the captured six-year period. Rather, the global changes in ultrasound use are possibly driven by hiring and promoting junior faculty who received more POCUS instruction in their own training. Multiple surveys have captured the changing landscape of ultrasound curricula in undergraduate and graduate medical education [14–18]. For example, in one 2012 national survey, 62% of responding medical schools reported integrating ultrasound training into their curricula, and only 19% responded that it was a priority at their institution [14]. It is plausible that clerkship educators who trained in this environment would not feel comfortable with POCUS use and that hiring new faculty would more effectively

change this dynamic than training these established faculty through continuing medical education. More rapid uptake of this new technology has almost certainly been aided by concurrent improvements in machine portability, integration with electronic health records, and a growing evidence base supporting its use.

To inform future POCUS initiatives, we surveyed respondents about barriers to more frequent POCUS use, drawing from discussions with POCUS experts and other studies on POCUS use and including portable equipment availability, further training, real-time support for image acquisition and interpretation, delayed support for image interpretation, and supported clinical time. These were all frequently cited, and highlighted that barriers to more widespread POCUS use are multifactorial. Device access, training, support during image acquisition and interpretation, and thoughtful scheduling should all be considered in any structured intervention. Simply purchasing a handheld ultrasound or funding faculty attendance at a one-time POCUS training course cannot reasonably be expected to meaningfully change future ultrasound use.

#### Limitations

This study may be limited by response rates of 46% and 31% and an overall low sample size that would be underpowered to detect subtle changes over time. However, the collected responses do capture the faculty who have a significant impact on medical student education and curricula. Among the seven internal medicine faculty responses in 2022, for example, were the one clerkship director and five other site directors. These six faculty have an outsized impact on the educational content and curricular objectives for medical students in this clerkship.

It is possible that a selection bias exists, and respondents were more likely to be enthusiastic about POCUS than non-responders. These results may therefore overestimate POCUS use and knowledge among the broader population of educators at our institution and may not be generalizable to other training environments where the medical school POCUS curriculum is more or less developed. As these biases would presumably affect both time points, the temporal trend is nevertheless instructive.

Self-reported comfort and this assessment of knowledge through POCUS indications may also not reflect individual clinical practice or POCUS competence. Adult outpatient internal medicine clinical educators may never encounter pediatric conditions such as pyloric stenosis, or emergent conditions such as tamponade. These specific diagnoses formed a small portion of the overall content assessed.

## Conclusions

We have shown that over a six-year period at one urban, academic medical center, comfort with POCUS and frequency of use have increased slightly but remain low among core faculty responsible for medical student clerkship education. There are still large gaps in knowledge and very few faculty regularly use POCUS, which can be attributed to a variety of barriers including device access, training, and expert support. Future initiatives for POCUS in undergraduate medical education should take these factors into account to better support the educators who are designing and delivering curricula.

## Conflict of Interests

Authors declare no conflict of interests relevant to this work.

## Funding

None.

## Authorship Statement

NS, WC, CB, and NP contributed to the conception and design of the research. NS contributed to the acquisition of data. FS, NS, and MME contributed to analysis of data. NS, MME, and NP contributed to interpretation of data. MME and NS drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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# Radiology Imaging Adds Time and Diagnostic Uncertainty when Point of Care Ultrasound Demonstrates Cholecystitis

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## Abstract

**Background:** Point of care ultrasound (POCUS) is specific for acute cholecystitis (AC), but surgeons request radiology imaging (RI) prior to admitting patients with POCUS-diagnosed AC. **Objectives:** We sought to determine the test characteristics of POCUS for AC when performed and billed by credentialed emergency physicians (EPs), the accuracy rate of RI when performed after POCUS, and the time added when RI is requested after POCUS demonstrates AC. **Methods:** We performed a dual-site retrospective cohort study of admitted adult ED patients who had received biliary POCUS from November 1, 2020 to April 30, 2022. Patients with previously diagnosed AC, liver failure, ascites, hepatobiliary cancer, or cholecystectomy were excluded. Descriptive statistics and 95% confidence intervals for point estimates were calculated. Medians were compared using a Wilcoxon signed-rank test. Test characteristics of POCUS for AC were calculated using inpatient intervention for AC as the reference standard. **Results:** Of 473 screened patients, 143 were included for analysis: 80 (56%) had AC according to our reference standard. POCUS was positive for AC in 46 patients: 44 true positives and two false positives, yielding a positive likelihood ratio of 17.3 (95%CI 4.4-69.0) for AC. The accuracy rate of RI after positive POCUS for AC was 39.0%. Median time from ED arrival to POCUS and ED arrival to RI were 115 (IQR 64, 207) and 313.5 (IQR 224, 541) minutes, respectively;  $p < 0.01$ . **Conclusion:** RI after positive POCUS performed by credentialed EPs takes additional time and may increase diagnostic uncertainty.

## Background

Acute cholecystitis (AC) accounts for up to 25% of hospital surgery admissions and is associated with a mortality rate of 0.8% [1,2]. While consensus guidelines allow for diagnosis of suspected AC based on physical exam and laboratory findings, definitive diagnosis requires imaging findings consistent with AC [3]. Radiology imaging (RI) modalities frequently used in the evaluation of AC include ultrasound, computed tomography (CT) and hepatobiliary iminodiacetic acid (HIDA) scan. Ultrasound and CT have comparable sensitivity and specificity, whereas HIDA has been shown to outperform these modalities but is more expensive and time-consuming [4-6]. Given the favorable test characteristics of multiple potential imaging modalities that can be used to diagnose AC, a positive finding in one imaging test need not necessarily be confirmed by

another imaging test.

Ultrasound is considered the most appropriate initial imaging modality for a patient with suspected biliary pathology, per radiology society guidelines [7]. Point of care ultrasound (POCUS) has demonstrated similar sensitivity and specificity for AC when compared with ultrasound performed by the Radiology Department (RADUS) [8,9]. Despite this, most surgeons still request additional RI modalities, such as RADUS and CT, to confirm AC before admitting the patient to their service. These requests may be related to surgeon attitudes and perspectives regarding the accuracy of POCUS, personal unfamiliarity with POCUS, and long-established practice patterns [10-12].

POCUS diagnosis of AC by emergency physicians (EPs) has been shown to decrease ED length-of-stay [13]. The

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DOI: <https://doi.org/10.24908/pocus.v9i1.16596>



addition of any RI modality after POCUS in the evaluation of AC results in an increased length of stay [14]. This added time is clinically significant; delayed cholecystectomy has been associated with increased complications, mortality and costs [15]. Disagreement between POCUS and subsequent imaging may paradoxically increase diagnostic uncertainty for AC.

This study has three aims: first, to determine the test characteristics of POCUS for AC when performed and billed by credentialed attendings in two ED settings; second, to determine the accuracy rate of RI following a positive POCUS using inpatient intervention for AC as the reference standard; and third, to determine the time added when subsequent RI is requested after POCUS demonstrates AC. We hypothesized that POCUS performed by credentialed EPs is accurate when positive for AC, and that the accuracy of POCUS is greater than that of subsequent RI for evaluation of AC in this setting. Describing the value or lack thereof of subsequent imaging after a positive POCUS and quantifying the associated potential time delay may lead to improved clinical practice and more efficient hospital admissions processes.

## Methods

This was a dual-site retrospective cohort study at two hospitals of all patients presenting to the ED who received a biliary POCUS examination by a credentialed EP during their ED visit. The study data was collected over an 18-month period, from November 1, 2020 to April 30, 2022. Institutional Review Board (IRB) approval was obtained from the study institutions. The study was deemed exempt and consent was waived.

### *Study Setting and Population*

Study data was obtained from two sites. The first is a community hospital designated Level III Trauma Center in a suburban area, with 38,000 annual ED visits and a ten percent admission rate. It is the primary site of a four-year university-based medical school and a community site for an emergency medicine residency program. The hospital has four credentialed biliary ultrasound attendings and two Sonosite X-porte (FUJIFILM Sonosite, Inc, Bothell, WA) ultrasound machines. The second is an urban Level I Trauma Center with approximately 120,000 annual ED visits and a 30 percent admission rate. It is the primary clinical site for an emergency medicine residency and has six credentialed biliary ultrasound attendings and six ultrasound machines: three Sonosite X-Porte, Sonosite M-Turbo (FUJIFILM Sonosite, Inc, Bothell, WA), Mindray M-9 (Mindray, Shenzhen, China) and Philips Sparq (Philips Healthcare, Andover, MA).

### *Patient Selection*

All admitted patients 18-years-old who had a biliary POCUS examination performed and billed at either hospital during the study period were included. Biliary POCUS examinations may be conducted in both sites for diagnostic or educational purposes. For a scan to be billed, it must be a diagnostic scan performed by a credentialed EP with saved images and an accompanying interpretation. It is the policy at our institutions that when working with residents, credentialed EPs supervise the acquisition and interpretation of POCUS scans acquired by residents. Attendings then attest to these when they document and sign the POCUS interpretation. Credentialed EPs are attending-level physicians designated by the ED ultrasound director according to American College of Emergency Physicians (ACEP) Guidelines [16]. Patients with liver failure, ascites, or hepatobiliary cancer were excluded due to the effect these diagnoses can have on the gallbladder that may complicate diagnosis. Patients with prior partial or complete cholecystectomy, patients sent to the ED with known cholecystitis, and patients who left against medical advice before their active biliary workup was complete, were also excluded. If patients meeting inclusion criteria had repeat ED visits during the study period, only the most recent visit was included.

### *Data Collection*

Using an automated electronic medical record (EMR) report, a list of all patients who received a billed biliary POCUS examination in the ED during the study period was used as the basis for the chart review. Patients discharged from the ED were removed, exclusion criteria were applied, and a structured chart abstraction was performed by four independent investigators following a one-hour educational session on a specific systematic approach to collecting data variables from the EMR. There was a prespecified random 10% overlap of charts reviewed to ensure consistency and accuracy in data abstraction amongst the four investigators.

The time stamp of the first radiology report was used as the RI interpretation time. The acquisition time of the last POCUS image acquired was used as the POCUS interpretation time, since the physician performing POCUS interprets obtained images simultaneously [17].

POCUS was positive for AC if there was both an obstructing stone in the gallbladder neck and a positive sonographic Murphy's sign (SM), as these findings are the minimum criteria for AC at the two study sites and have been shown to be sensitive and specific in ultrasound-guided diagnosis of AC [18,19]. Sludge was considered equivalent to stone(s), and the cystic duct was considered contiguous with the neck given both

appear similarly on ultrasound. Investigators abstracted the presence of gallstones, SM, wall thickening, and pericholecystic fluid according to POCUS procedure documentation from the EMR. The standard POCUS interpretation documentation did not require the physician to indicate the location of gallstones when present. For this reason, two credentialed EPs with ultrasound fellowship training blinded to chart variables and patient outcomes independently reviewed the POCUS images of patients with documentation of both SM and stones present. Next, they came to a consensus on whether any of the stones present were in the neck to identify cases of sonographic AC in our study population. RI was positive for AC if the first radiology report included any mention of concern, suspicion for, or findings consistent with AC. Patients with cholelithiasis but no mention of cholecystitis were considered negative for AC on RI. We only considered the first RI modality performed if there was more than one.

The reference standard for AC diagnosis was defined as active intervention targeted at AC during the hospital admission associated with the ED visit. Specifically, this was cholecystectomy demonstrating cholecystitis on the pathology report, percutaneous cholecystostomy tube placement, or inpatient intravenous antibiotic therapy targeted towards pathogens suspected to cause AC with

delayed cholecystectomy demonstrating cholecystitis on the pathology report. Patients who did not receive any of these interventions during the admission that followed the initial ED presentation were considered to not have AC by our reference standard.

*Measuring Outcomes and Data Analysis*

We used Microsoft Excel (Microsoft Corp) and MedCalc Statistical Software version 19.7.4 (MedCalc Software LTd, Ostend, Belgium; <https://www.medcalc.org>; 2022) for descriptive statistics and statistical calculations. Sensitivity, specificity, and positive and negative likelihood ratios of POCUS for cholecystitis (dichotomized to present or absent) were calculated, using inpatient intervention as defined above as the reference standard. An accuracy rate for RI following positive POCUS was calculated by dividing the true positive RI by the total number of RI examinations. Medians were compared using a Wilcoxon signed-rank test.

**Results**

Overall, 473 patients across both sites underwent biliary POCUS billed by a credentialed attending in the ED, 170 patients from the community hospital and 303 patients from the urban trauma center. Two patients (both from the community hospital) had recurrent ED visits during

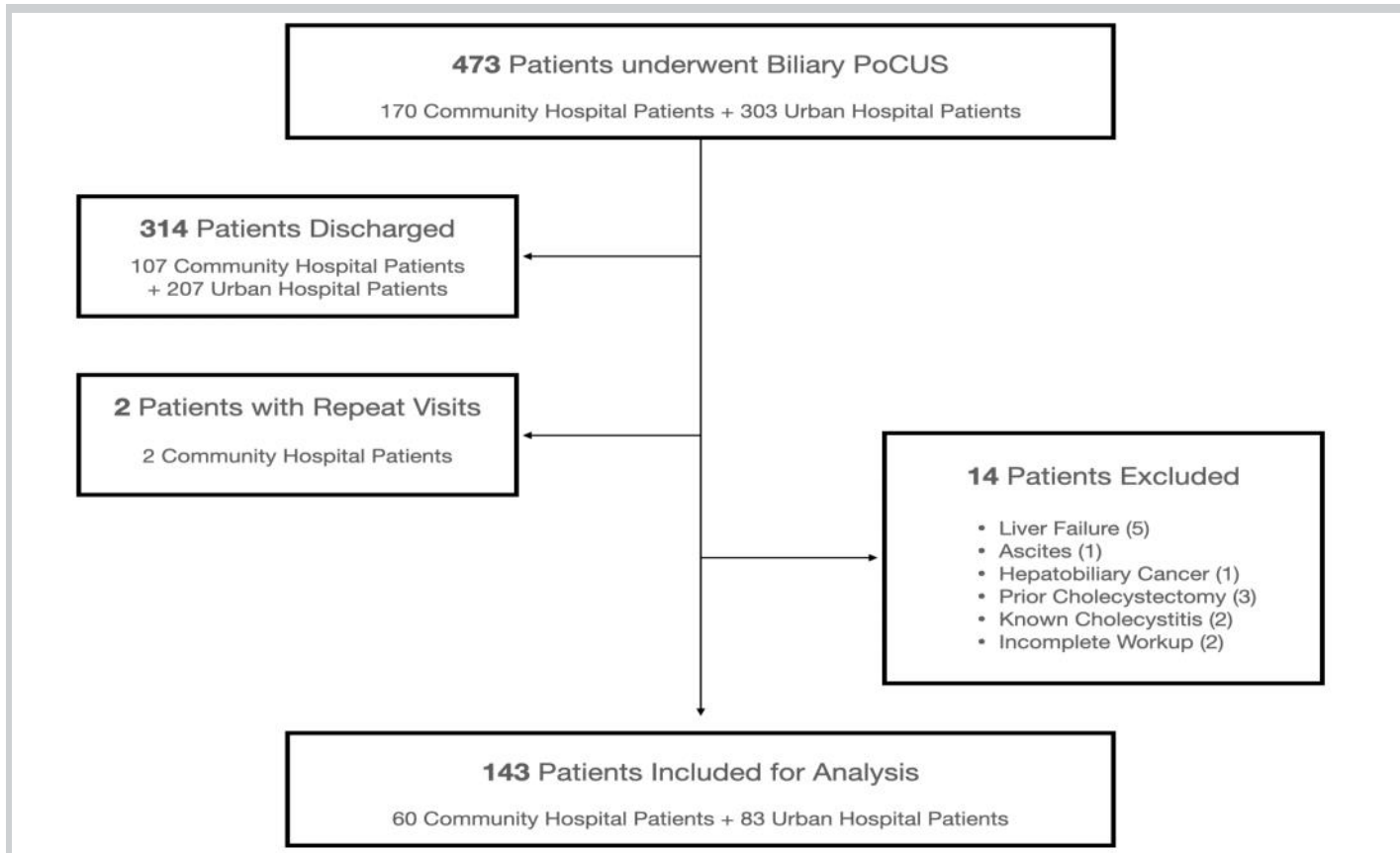


Figure 1. Patient flow chart. POCUS = point of care ultrasound

the study period where only the most recent visit for each was included. Three-hundred-fourteen patients were discharged from their ED visits and 14 patients met exclusion criteria, leaving 143 patients for analysis (Figure 1). There was 100% agreement across all investigators for overlapping data.

Table 1 summarizes patient demographics. Of the 143 patients, 80 (56%) had AC according to our reference standard: 69 had immediate cholecystectomy with subsequent pathology demonstrating cholecystitis, 7 had percutaneous cholecystostomy tube placement, and 4 received intravenous antibiotics with delayed cholecystectomy demonstrating cholecystitis. Of the 143 POCUS examinations, 62 had a positive SM, of which 57 had gallstones, and among those, 46 had a stone in the neck of the gallbladder. Among these 46 patients with positive POCUS for AC, two were falsely positive. POCUS had a specificity of 96.8% (95% CI 89.0-99.6) and positive likelihood ratio of 17.3 (95% CI 4.4-68.7) for AC. Table 2 summarizes POCUS test characteristics.

Additional radiologic imaging (RI) was performed after POCUS in the ED for 122 of the total 143 patients (46 at the community hospital and 76 at the urban trauma center). Forty-five patients had subsequent CT scans, 76 patients had subsequent RADUS, and one patient had an MRI.

Among the 46 positive POCUS examinations, 41 had subsequent RI (8 CT, 33 RADUS). Of these 41 patients, 25 were falsely negative for AC according to our reference standard, yielding an accuracy rate of 39.0% (95% CI 24.2-55.5). Figure 2 summarizes the sequence

of events from positive POCUS to subsequent RI and AC intervention.

Two patients had a false positive POCUS examination for AC according to our reference standard, with a subsequent true negative RADUS examination. The first patient presented with sepsis and transaminitis, and her blood cultures grew extended-spectrum beta-lactamase-producing *Escherichia coli*. A magnetic resonance cholangiopancreatography study showed gallstones and gallbladder distension without ductal dilatation or choledocholithiasis. Repeat blood cultures were negative, and she was discharged on antibiotics. Her bacteremia was thought to be due to transient choledocholithiasis. The second patient presented in septic shock with diffuse abdominal pain. POCUS demonstrated a gallstone in the neck of the gallbladder with wall edema. CT revealed diffuse pneumoperitoneum of unclear origin with diffuse mesenteric edema and intra-abdominal free fluid, as well as a distended gallbladder with pericholecystic fluid and wall thickening, but no pneumobilia to suggest biliary source for pneumoperitoneum. She underwent exploratory laparotomy, sigmoid colectomy, colostomy creation and umbilical herniorrhaphy. She was discharged with a diagnosis of pneumoperitoneum of unknown etiology.

The median time from ED arrival to POCUS and ED arrival to subsequent RI for all patients who received both a POCUS and RI ( $n = 122$ ) was 115 (IQR 64, 207) minutes and 314 (IQR 224, 541) minutes respectively ( $p < 0.01$  for the difference). Among patients with AC on

Table 1. Patient Demographics According to Hospital Site.

|                                 | Hospital X* (N=60) | Hospital Y (N=83) | Total (N=143) | Significance p-value |
|---------------------------------|--------------------|-------------------|---------------|----------------------|
| Age – yr.                       | 57.3               | 51.9              | 54.2          | 0.100                |
| Female Sex - %                  | 60.0               | 78.3              | 70.6          | 0.025                |
| <b>Race/Ethnicity – no. (%)</b> |                    |                   |               | †                    |
| Asian                           | 4 (6.7)            | 3 (3.6)           | 7 (4.9)       | 0.453                |
| Black                           | 5 (8.3)            | 8 (9.6)           | 13 (9.1)      | 1.00                 |
| Hispanic                        | 6 (10)             | 31 (37.3)         | 37 (25.9)     | <0.001               |
| White                           | 44 (73.3)          | 36 (43.4)         | 80 (55.9)     | <0.001               |
| Other                           | 1 (1.7)            | 5 (6.0)           | 6 (4.2)       | 0.401                |
| Acute Cholecystitis – no. (%)   | 28 (46.7)          | 52 (62.7)         | 80 (55.9)     | 0.063                |

†Race and ethnicity were obtained from the medical record registration information.

\*Hospital X refers to the community hospital; Hospital Y refers to the urban Level 1 trauma center.

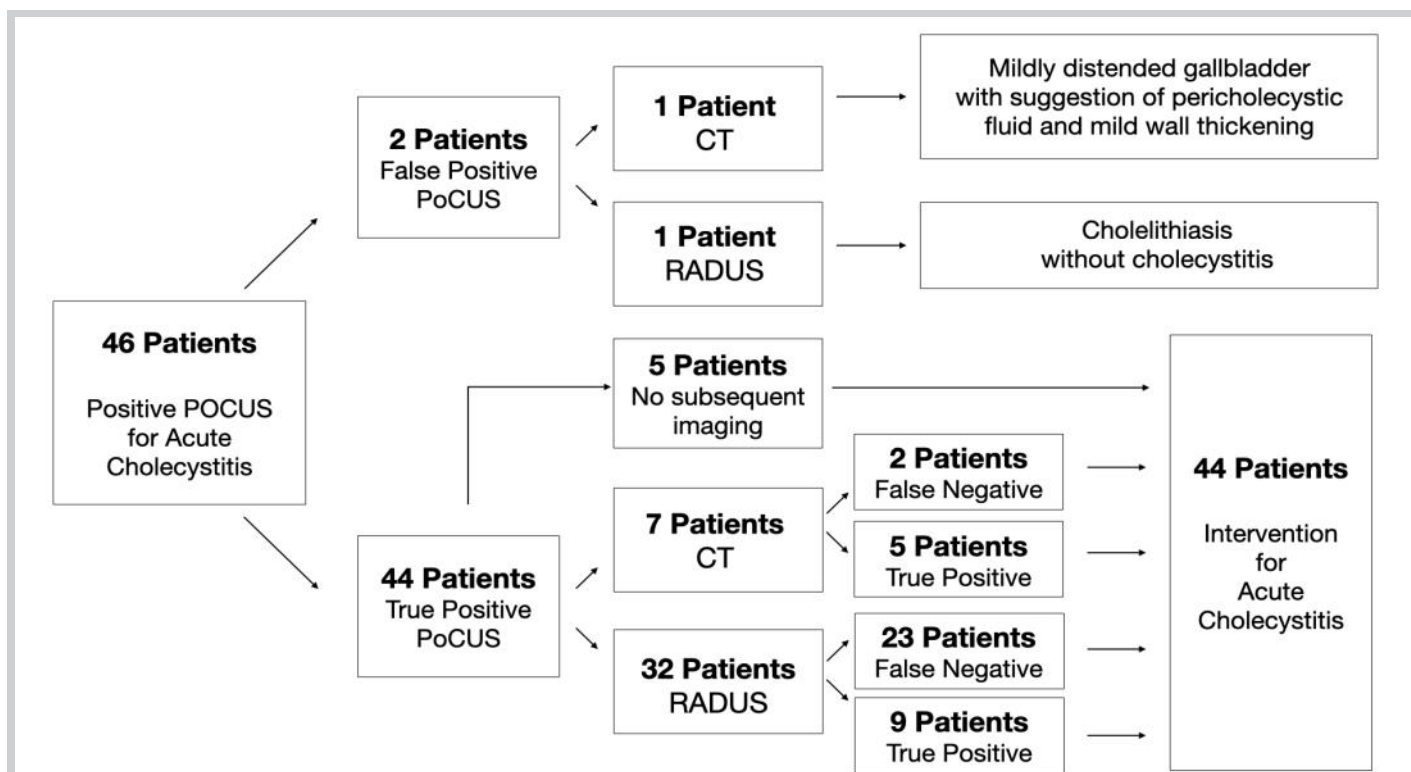


Figure 2. Visual summary of subsequent imaging and intervention among patients with positive biliary point of care ultrasound. POCUS, point of care ultrasound; RADUS, Radiology-performed ultrasound; CT, computed tomography

POCUS (n = 46), median time from ED arrival to POCUS and ED arrival to subsequent RI was 107 (IQR 53, 183) minutes and 313 (IQR 227, 471) minutes respectively ( $p < 0.01$ ). The RI result was available after the POCUS result in this group of patients following a median interval of 175 (112, 358) minutes, or 2.9 hours.

Regardless of the RI result (i.e., true positive or false negative), the median ED length of stay, hospital length of stay, and time to cholecystectomy were not significantly different among the patients who had a positive POCUS and subsequent RI ( $p = 0.34$ ,  $p = 0.45$ , and  $p = 0.20$ , respectively).

### Discussion

Our results demonstrate that RI not only adds hours to the ED workup, but also adds diagnostic uncertainty in the setting of a positive POCUS examination for AC. Prior studies of POCUS for AC have reported test characteristics of POCUS, time added by subsequent RI, and agreement between POCUS and subsequent RI. To our knowledge, none have focused on the utility of additional RI after POCUS demonstrates cholecystitis, using inpatient hospital intervention and pathology reports as the reference standard for AC. Our patients with a positive POCUS for AC overwhelmingly had AC-

directed inpatient management even with negative subsequent RI. These results suggest that subsequent RI is of limited utility in the case of a positive POCUS for AC.

Our results compare favorably with recent literature. For example, Zitek et al., Evans et al., and Hilsden et al. found a similarly high specificity of POCUS for AC using a less robust reference standard when performed by novice to experienced physicians; whereas our result was for POCUS performed and billed by credentialed providers using AC inpatient intervention [14,20,21]. Since credentialed attendings, not learners, are the ones making clinical decisions using POCUS, their results are most relevant to patient care and clinical decision making.

Hilsden et al. and Evans et al. reported time added by performing additional imaging. Our results confirmed this finding and suggested that this added time is even more substantial when POCUS is performed by credentialed physicians [14,21]. In our study, the time added by ordering additional RI after positive POCUS was 41% higher than that of these studies.

Although there are multiple findings that can be seen on POCUS in the setting of AC, there is notable variability

*Table 2. Test Characteristics for Point of Care Ultrasound in the Diagnosis of Cholecystitis*

| Test Characteristic       | Value (N = 143)* | 95% Confidence Interval |
|---------------------------|------------------|-------------------------|
| Sensitivity               | 55.0%            | 43.5-66.2%              |
| Specificity               | 96.8%            | 89.0-99.6%              |
| Positive Likelihood Ratio | 17.3             | 4.4-68.7                |
| Negative Likelihood Ratio | 0.46             | 0.36-0.59               |
| Positive Predictive Value | 55.9%            | 47.4-64.2%              |
| Negative Predictive Value | 62.9%            | 57.0-68.4%              |
| Accuracy                  | 73.4%            | 65.4-80.5%              |

\*Based on 44 true positives, 2 false positives, 36 false negatives, and 61 true negatives

regarding the minimum criteria to define AC on POCUS. The presence of an objective finding (obstructing stone in the neck of the gallbladder) plus a local sign of inflammation (SM) as used in this study meet criteria for AC according to validated guidelines and also carry a high positive predictive value for AC [3,18,19]. While comparable to recent studies where POCUS was considered positive for AC based on documented interpretation alone, without review of specific imaging findings [9,20,21], our specificity was greater than that reported by a study from over a decade ago with similar, but less stringent, criteria for AC (gallstones plus either gallbladder wall thickening, pericholecystic fluid, or SM) [8]. The improvement of published test characteristics of POCUS over time can likely be attributed to increased POCUS utilization, more strict training milestones and quality standards for credentialed EPs, and advancements in ultrasound technology.

We were surprised at the high false negative rate of RI for AC, particularly of RADUS, given that most clinicians use RADUS as a gold standard for diagnosis. While this finding was likely much higher in our sample of patients with positive POCUS for AC than it would be among the general population, it may explain why so many imaging studies are ordered to diagnose AC: imaging in isolation is not ideal for AC diagnosis [20]. An inherent difference between POCUS and RI is the degree of separation between the physician and the patient. With POCUS, there is no separation of physician from the patient, allowing real time correlation of findings (including a

positive SM when present) with patient presentation. However, there are many degrees of separation between the physician and patient with RI, making it more difficult to correlate imaging findings with the clinical picture. This can lead to diagnostic uncertainty, especially among cases of early cholecystitis, where there are not yet wall changes or pericholecystic fluid [22]. This suggests that when POCUS is positive, particularly with the specific criteria used in this study, additional RI does not add clarity to a diagnosis and instead may add ambiguity and complicate disposition decisions. Despite additional RI often disagreeing with a positive POCUS, patients in our sample eventually had AC-directed inpatient management without any significant difference in ED length of stay, hospital length of stay, or time to cholecystectomy. This was true regardless of the findings of subsequent RI. We believe this could have been because the patients with a positive POCUS for AC had other evident signs that may have convinced admitting providers to treat for AC. It may have been that the surgeons making the decision to take these patients to the operating room relied on patient history, serial examinations, symptomatic response to oral intake, and laboratory results rather than additional RI alone, even if that RI was negative for AC. It is possible that additional imaging was requested and performed for operative planning more so than to diagnose AC [23]. Because it was not an aim of our study to look at the rationale for definitive AC management, much of this is left to speculation. Regardless, the fact that subsequent RI did not affect the time nor the rate of AC management further questions its utility. For these reasons, we feel additional RI should be reserved for cases where initial imaging results are negative or equivocal and clinical suspicion remains high.

From the perspective of an EP, the goal of care for every patient with AC is timely intervention and prompt disposition to an admitting service. Though there are many variables in ED length of stay, additional RI adds time and uncertainty to diagnosis. The use of POCUS in identifying AC quickly and accurately has the potential to expedite the admission process and prevent delays in intervention that may impact patient outcomes.

#### *Limitations*

There are several limitations in this study. Because it is a retrospective chart review, the findings are based only on what is documented in the chart. As such, it is difficult to ascertain with certainty the precise clinical picture, all the findings made by the EP, and the extent and nature of discussions between the EP and the consultants. We attempted to keep the POCUS definition objective by

conducting an independent review for gallstone location to determine the presence of a stone in the neck, however, we were reliant on the chart for the presence of stones and SM. Our POCUS definition was not intended to detect acalculous cholecystitis, given its rare occurrence, tendency to affect patients with critical illness, and often requirement for additional imaging.

The design of this study is based on ultrasound imaging, without accounting for the myriad of other factors that may impact a clinician's decision to delay intervention or surgical admission.

Although two sites were included, both are in the same state and region, so results may not be generalizable to other states, regions, or settings. Furthermore, there may have been variability in the time intervals studied according to site. If there were longer ED lengths of stay at the urban trauma center, for example, this may have obscured a difference in length of stay due to the relative contribution of each site, even though we utilized medians with IQRs to mitigate this.

We did not compare ED length of stay when POCUS was performed alone versus when additional RI were performed, given POCUS was not generally considered diagnostic outside of the ED at our institutions. Too few patients had POCUS alone to adequately power this comparison. We did not include patients diagnosed with AC who did not receive POCUS and did not focus on patients who were diagnosed with AC with an initial negative POCUS. We directed our analysis on the utility of additional RI in the setting of a positive POCUS for AC, which is a clinical scenario where the burden of disposition should not hinge on further, unnecessary testing to diagnose AC. Future prospective studies are needed to look at time and costs saved when POCUS is performed alone, as well as the rate of potential surgical complications that might result from delays to admission among patients with AC.

## Conclusions

POCUS performed and billed by ultrasound-credentialed attendings in the ED is specific and carries a high likelihood ratio for AC. RI after POCUS in this setting may detract from true positive results, takes additional time, and may not be required on a routine basis; rather, it should be reserved for complicated presentations or inconclusive POCUS studies. Further research is needed to determine which patients would benefit from RI after POCUS.

## Disclosures

*Acknowledgements:* The authors would like to thank

Jonah Haber MS for his contributions to an earlier version of this work; João Delgado MD for his assistance in reviewing and editing the manuscript; and James Grady PhD for his statistical assistance.

*Funding:* None

*Other disclosures/ Conflicts of interest:* None

*Ethical approval:* This study was approved by the University of Connecticut Health Center Institutional Review Board (study number 22X-277-1, approved on May 4, 2022) and Hartford Healthcare Institutional Review Board (study number D-HHC-2022-0119, approved on May 18, 2022).

*Disclaimers:* None

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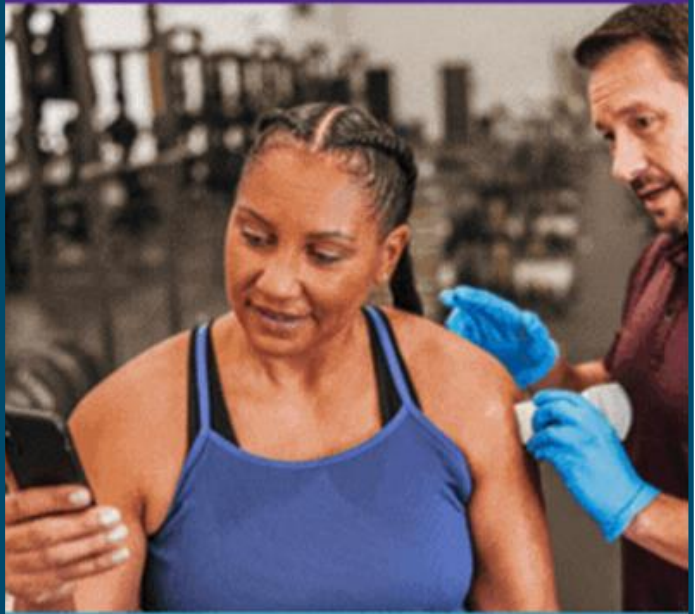
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# Best Practices for Point of Care Ultrasound: An Interdisciplinary Expert Consensus

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## Abstract

Despite the growing use of point of care ultrasound (POCUS) in contemporary medical practice and the existence of clinical guidelines addressing its specific applications, there remains a lack of standardization and agreement on optimal practices for several areas of POCUS use. The Society of Point of Care Ultrasound (SPOCUS) formed a working group in 2022 to establish a set of recommended best practices for POCUS, applicable to clinicians regardless of their training, specialty, resource setting, or scope of practice. Using a three-round modified Delphi process, a multi-disciplinary panel of 22 POCUS experts based in the United States reached consensus on 57 statements in domains including: (1) The definition and clinical role of POCUS; (2) Training pathways; (3) Credentialing; (4) Cleaning and maintenance of POCUS devices; (5) Consent and education; (6) Security, storage, and sharing of POCUS studies; (7) Uploading, archiving, and reviewing POCUS studies; and (8) Documenting POCUS studies. The consensus statements are provided here. While not intended to establish a standard of care or supersede more targeted guidelines, this document may serve as a useful baseline to guide clinicians, leaders, and systems considering initiation or enhancement of POCUS programs.

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DOI: <https://doi.org/10.24908/pocus.v9i1.17240>



## Introduction

Ultrasound is now widely used by clinicians as a real-time bedside diagnostic and monitoring tool, a practice often denoted as point of care ultrasound (POCUS). By virtue of its portability, relatively low cost, and broad applicability for a variety of clinical indications, POCUS use has grown in a grass-roots pattern; different centers and even individual clinicians have implemented ultrasound using diverse workflows and practice patterns, often in the absence of well-defined standards.

Professional groups have released guidance on POCUS use in the form of guidelines, expert consensus statements, or practice recommendations, particularly from specialties with high levels of POCUS uptake, such as emergency medicine and critical care [1–12]. However, most guidelines have focused on evidence-based recommendations for the specific clinical uses of POCUS common to their specialty setting. Less effort has been made to establish best practices for POCUS as a generalizable imaging modality, as dictated by the intrinsic characteristics of the tool itself rather than its use-cases for certain subsets of users. Moreover, for many practical questions surrounding POCUS administration and workflows, data are limited. Good practices are instead defined by the subjective perception of a POCUS workflow that is efficient, safe, and ethical for clinicians, learners, and patients. Such questions may be best addressed via expert consensus.

## Methods

With the goal of establishing a set of POCUS best practices with broad applicability, the Society of Point of Care Ultrasound (SPOCUS) formed a multi-disciplinary working group in 2022 (BO, RB, LC, PD, RD, SF, CL).

Between November 2022 and May 2023, the working group drafted a preliminary set of statements related to POCUS use, focusing the content in areas of perceived practice variation, common workflow questions, and a review of existing literature and practice guidelines. As the content focused on areas with limited evidence, the supporting literature review was informal and not structured.

After establishing the initial statement set, a larger panel of POCUS experts was recruited via email (Table 1 for brief panel composition; full member details in Appendix A). Acknowledging that best practices may be specific to country of practice, all experts were based in the United States. All were highly experienced in the clinical use of POCUS; the majority were providers of POCUS training and education; and most held administrative positions in POCUS programs. Otherwise, the panel composition was selected to include diversity of both specialty and

Table 1. Expert panel composition

|  |
|--|
| <b>Anesthesiology and Critical Care</b>  |
| Aliaksei Pustavoitau, MD, MHS, FCCM  |
| <b>Emergency Medicine</b>  |
| Andrew Goldsmith, MD, MBA<br>Meghan Kelly Herbst, MD, FACEP<br>Viveta Lobo, MD, FACEP  |
| <b>Emergency and Prehospital Medicine</b>  |
| Carl William Lange, IV, MSBS, EM-CAQ, PA-C   |
| <b>Emergency and Internal Medicine</b>   |
| Jason T Nomura, MD, FACEP, FAAEM, FACP, FAHA   |
| <b>Cardiology</b>  |
| James N. Kirkpatrick, MD, FASE, FACC<br>Mourad H Senussi, MD, MS<br>Vincent L. Sorrell, MD, FACP (honorary), FACC, FASE, FSCCT, FSCMR                                  |
| <b>Critical Care and Pulmonology</b>   |
| Cameron Baston, MD, MSCE, FACP<br>Steven Fox, MD<br>Frances Mae West, MD, MS, FACP   |
| <b>Critical Care Medicine</b>  |
| Robert Baeten, PA-C, FCCP<br>Leon Chen, DNP, AGACNP-BC, FCCP, FAANP, FCCM<br>Siddharth Dugar, MD, FCCM, FASE, FCCP<br>Michael J. Lanspa, MD<br>Brandon Oto, PA-C, FCCM |
| <b>Family Medicine</b>   |
| Paul Bornemann, MD, RMSK, RPVI<br>Puja Dalal, MD, FAAFP  |
| <b>Internal Medicine and Pediatrics</b>  |
| Ria Dancel, MD, FACP, SFHM, FAAP   |
| <b>Nephrology</b>  |
| Abhilash Koratala, MD, FASN  |
| <b>Neurology and Neurocritical Care</b>  |
| Aarti Sarwal, MD, FNCS, FAAN, FCCM, FASN, RPNI   |

See Appendix A for details on panel member affiliations, training, and background; Two members who did not complete the consensus process are not listed

practice setting. Specialties represented included emergency and prehospital medicine, critical care and pulmonology, internal medicine and pediatrics, family medicine, neurology, cardiology, anesthesiology, and nephrology; their practice settings included both community and academic institutions, as well as both inpatient and outpatient environments. The panel's clinical background included both physicians and non-physicians (nurse practitioners and physician assistants) with a variety of generalized, specialized, and practical training in clinical ultrasound; their areas of expertise spanned echocardiography, lung and abdominal ultrasound, neurosonography, transesophageal echocardiography, and other modalities.

The statements were offered to the full panel for voting between June 2023 and November 2023. The format was three iterative voting rounds using a modified Delphi format [13–17]. The first round was exploratory, with the primary goal of developing the themes and crafting semi-final statements. The second round attempted to reach consensus on as many statements as possible. A third round was considered optional, with the purpose of finalizing any statements with lingering concerns. For each statement, consensus was sought either to accept (agree with) or reject (disagree with) its content as written.

The survey was performed using a web-based platform (SurveyMonkey), and required panelists to express agreement with each statement on a five-point Likert scale from *Strongly Disagree* to *Strongly Agree*. A sixth option, *This topic is outside my expertise*, was allowed in case a panelist was unfamiliar with a specialized topic. Qualitative feedback was also permitted via free text, and respondents were encouraged to offer input on how a statement could be improved, particularly if they voted to reject it. No live meetings occurred, and direct collaboration between panel members was not facilitated.

After each round of voting, responses were tabulated. Votes for *This topic is outside my expertise* were omitted from the denominator for that statement. Out of the remainder, a statement was considered a candidate for acceptance if the votes in agreement (*Agree* + *Strongly Agree*) were  $\geq 75\%$  of the total; a statement was a candidate for rejection if the votes in disagreement (*Disagree* + *Strongly Disagree*) were  $\geq 75\%$  of the total. The consensus thresholds were defined before the start of voting. Accepted or rejected statements were removed from further voting.

Statements not meeting the consensus criteria were either modified in response to feedback, combined with other statements, or dropped if they appeared redundant or unlikely to achieve consensus. Reintroduced

statements included a summary of results of the prior round of voting, including both the vote counts and the qualitative feedback, both de-identified. Statements could also be reintroduced despite reaching consensus if the qualitative feedback voiced important concerns or the potential for further improvement.

The consensus statements were compiled and reviewed by the panel for final approval. Panelists were advised that the final document was the product of the majority consensus, and need not reflect their individual opinion in all respects.

## Results

Panel invitations were extended to 37 experts, and were accepted by 17, creating an initial voting panel of 24 when combined with the seven-person working group (Figure 1).

94 statements were offered in the first voting round, 30 statements in the second, and 8 statements in the third. Of the initial 24 panel members, 23 completed all three voting rounds with 100% responses, while one member dropped out during the second round. A second member completed voting but requested to be omitted from the final consensus statement due to disagreement with one of the accepted statements (see the discussion of *Uploading, Archiving, and Review*, below). Votes from the two dropout members were included in the data analysis with their permission.

After the three rounds, 57 statements achieved consensus by the panel, with 52 statements accepted and 5 rejected. The consensus statements are shown in Tables 2–12. (Full tabulation of voting results can be found in Appendix B.)

## Definitions

These statements (Table 2) define the terminology used in later statements.

They define a practical definition of POCUS (#1), establish a distinction between POCUS studies performed for clinical purposes and those performed solely for training (#2), and also establish that some studies are non-invasive while others are more invasive in nature (#3); these distinctions are pertinent in later sections (see *Credentialing* and *Consent and Education*). The concept of trainees was introduced (#4) separately; this separate distinction allowed study types to be labeled as educational irrespective of the individual performing them, since learners and fully-trained practitioners might perform both clinically-indicated and educational scans. The label “learner” was selected for trainees to be agnostic as to clinical level, since clinicians may learn POCUS at any stage of their training.

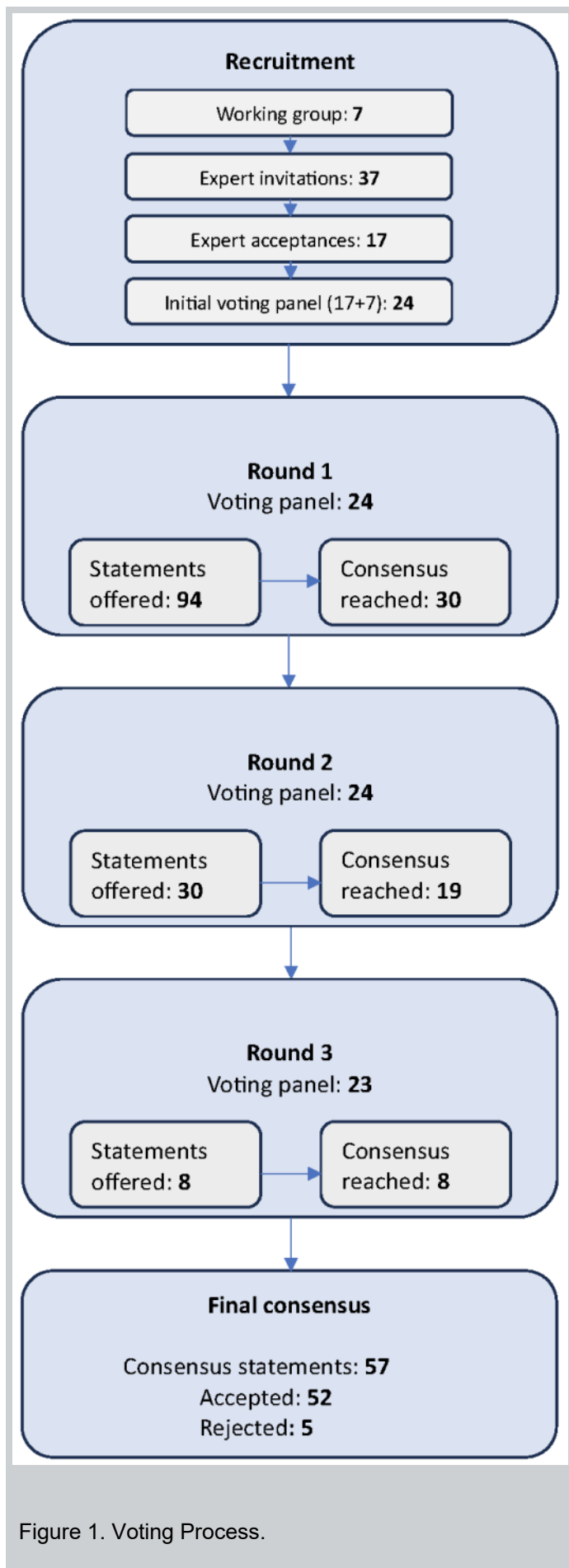


Figure 1. Voting Process.

Table 2. Accepted statements (Definitions)

| # | Accepted statement   | Accepted by |
|---|--|-------------|
| 1 | <p><b>Point of care ultrasound (POCUS):</b> Ultrasound examination performed at the point of care, interpreted and integrated into the clinical context by the treating team.</p> <p>POCUS typically differs from non-POCUS ultrasound by its more targeted scope focused on answering specific clinical questions, and by its real-time acquisition—in most cases with simultaneous interpretation—by the clinical team. POCUS may also be used to identify the need for procedures or interventions, assist in their execution, and confirm their success or identify resulting complications.</p> | 91.6%       |
| 2 | <p><b>Clinically-indicated study:</b> A POCUS study performed with the intent of assisting clinical decision-making, such as diagnosis, prognostication, or treatment. Ultrasound used for procedural guidance is included in this category.</p> <p><b>Educational study:</b> A POCUS study performed primarily for education of the self or others, such as practice in image acquisition or demonstration for learners, rather than for a specific clinical indication.</p>  | 83.3%       |
| 3 | <p><b>Non-invasive study:</b> POCUS examination using surface probes.</p> <p><b>Invasive study:</b> POCUS examination using invasive transducers, such as transesophageal, transvaginal, or transrectal studies.</p>   | 83.3%       |
| 4 | <p><b>Learner:</b> A clinician not qualified to independently perform and interpret a given modality, technique, or clinical application of POCUS.</p>   | 83.3%       |

These statements were generally uncontroversial, although panelists highlighted that the concept of an “educational” examination (while widely used by both POCUS learners and educators) is relatively unique to POCUS and largely not found in other imaging domains. They also cautioned that these simplified definitions of “invasiveness” may miss distinctions relevant for some applications (see *Cleaning and Maintenance*).

*Role of POCUS*

The single statement in this section (Table 3) establishes the distinction between POCUS and other ultrasound techniques. Initial versions emphasized that POCUS exams are usually more focused than other ultrasound studies and do not serve to replace them. However, a significant number of respondents noted this is not always true; in certain contexts, POCUS exams (particularly when supported by an adequate infrastructure; see *Documentation* as well as *Study*

Table 3. Accepted statements (Role of POCUS)

| # | Accepted statement  | Accepted by |
|---|---|-------------|
| 5 | Although their diagnostic roles may overlap, POCUS studies are distinct from imaging studies performed through other workflows, including ultrasound examinations of the same anatomic region. POCUS studies tend to yield more immediate data than other studies, and are more easily repeated to assess for changes over time, but in most cases are not as detailed and comprehensive; therefore, depending on the clinical context, a successful POCUS examination may or may not replace the need for other imaging. | 87.5%       |

uploading, archival, and review) may be sufficient to preclude the need for other testing. Many respondents also highlighted the repeatability of POCUS, which enables it to serve a greater role in monitoring than other ultrasound tests.

#### Training pathways

These statements (Table 4) address the means by which

clinicians, either during or after their foundational training, can develop competence using POCUS. This section was limited by generalizability (#6), as POCUS training is often heavily molded by its context, such as when occurring during undergraduate education, initial clinical training, residency programs, on-job training, or via self-directed learning [18–22].

Table 4. Accepted statements (Training pathways)

| #  | Accepted statement  | Accepted by |
|----|---|-------------|
| 6  | Multiple different approaches to POCUS training exist, often varying by medical background and specialty. Although it may be more feasible for specific populations of learners, it is difficult to describe a generalized model for POCUS training that includes every acceptable pathway to competence and acknowledges the many distinct applications and clinical environments of POCUS use.  | 87.5%       |
| 7  | For some clinicians and circumstances, informal training or self-directed learning may play a significant role and yield successful results, though expert tutelage and structured practice will generally accelerate skill acquisition. However, verification of skills via a supervisory or quality assurance process is essential for such clinicians, to ensure their knowledge base and practice pattern meets locally accepted standards.   | 83.3%       |
| 8  | We recommend consulting specialty-specific resources and guidelines for recommendations addressing POCUS education within a given training context.   | 87.5%       |
| 9  | We suggest the following basic framework, which can be flexibly applied to most situations. In general, initial POCUS training should include three elements:<br><b>1. Didactic training</b><br><b>2. Hands-on practice</b><br><b>3. Monitored usage</b>  | 83.4%       |
| 10 | <b>Didactic training</b> will generally include education on the principles of ultrasound physics, probe selection, image optimization, artifact recognition, standard views, and the appearance of normal anatomy and important pathology.   | 91.7%       |
| 11 | This component of learning is amenable to flexible approaches to instruction, including classroom education, bedside teaching, textbook or online training, “flipped” classroom models, or other formats.   | 100%        |
| 12 | <b>Hands-on practice</b> involves learners performing POCUS under direct supervision. This can initially involve practice using ultrasound models, volunteers, cadavers, or high-fidelity simulators, and eventually transition to practice on live, consenting patients under supervision. Immediate feedback by experts should be provided during this stage to guide both image acquisition and interpretation. As live patients are introduced, the clinical integration of POCUS should be embedded into the training process.   | 100%        |
| 13 | <b>Monitored usage</b> involves clinicians applying POCUS to actual patients in the absence of real-time supervision, but with ongoing monitoring in a more sporadic or asynchronous manner. This is usually performed by expert review of archived images, although expert review in real time (in-person or virtual) is sometimes possible.<br><br>Monitored usage can be implemented to varying degrees depending on local policy and the needs of the system. It can be utilized as a late stage of training or “transition to practice,” wherein POCUS users are considered competent to acquire and interpret images without direct supervision, but still benefit from expert feedback on technical quality or clinical interpretation.<br><br>After a clinician acquires independent competence with a given study type, as determined by local standards, clinicians may use POCUS within their established skillset without monitoring. However, institutions may choose to continue expert review of either some or all studies performed by credentialed clinicians for purposes of quality assurance or for ongoing education. | 91.3%       |

Given these limitations, the panel limited their recommendations to broad themes, deferring to other appropriate guidelines to address specific groups (#8–13). The role of informal or self-directed learning in POCUS was controversial (#7). Here, many of the panel acknowledged its prevalence in POCUS, but urged caution given its pitfalls, such as the potential for unrecognized errors; the panel emphasized the importance of adequate quality assurance processes.

Significant debate also occurred around the concept of “monitored usage” (#13), a phase of training which was felt to overlap significantly with later stages of “hands on practice” and with quality assurance during independent practice. Due to this it was unclear to some of the panel whether such a stage is needed. The final accepted statement emphasizes the flexible applicability of the concept.

### *Credentialing*

This section (Tables 5 and 6) addresses institutional credentialing and privileges for POCUS-performing clinicians.

There was agreement that any credentialing system

should be carefully structured to serve the specific system (#14, #15), and should generally be formed by standards and experts specific to the given specialty and setting (#16). No consensus was reached on the optimal approach in systems without sufficient infrastructure to perform institutional credentialing, such as independent practice or austere environments.

A variety of standardized external certifications or examinations intended to demonstrate POCUS competency now exist, generally fee-based and offered by professional societies or commercial enterprises. For example, the National Board of Echocardiography offers specialty ultrasound certifications (such as the “CCEeXAM” in critical care echocardiography), which are undertaken by some clinicians to demonstrate particular expertise in that domain; the process is associated with fees and is not available to non-physicians [23]. The panel rejected such external certifications as a standard requirement of POCUS credentialing (#17), believing them unnecessary if competence can be assessed through local methods. However, the majority did feel that certification programs could sometimes have a role in credentialing when thoughtfully or selectively applied (#18).

*Table 5. Accepted statements (Credentialing)*

| #  | Accepted statement   | Accepted by |
|----|--|-------------|
| 14 | Processes for ensuring competence among clinicians performing POCUS should be tailored to the practice environment, including the medical specialty and available resources. Although approaches vary, most should involve some combination of a required volume of experience (including both a minimum total number of examinations performed, and minimum pathology encountered), evaluation by a qualified supervisor, and potentially other forms of evaluation such as didactic testing.   | 87.5%       |
| 15 | Given the heterogeneity of ultrasound applications, it may be difficult to establish privileges for performing POCUS studies that effectively describe the skillsets involved. Few clinicians have competence with every possible application of POCUS, but attempts to define privileges more narrowly (e.g. echocardiography versus abdominal ultrasound) may still lack sufficient breadth and detail to be meaningful for individual clinicians.<br><br>In general, local privileging strategies for POCUS should be thoughtfully structured to promote safety without creating arbitrary restrictions on practice. More specific privileging for studies with increased risk, such as invasive studies, is usually appropriate. More granular assessments of POCUS skill (e.g. competence examining specific anatomy or using specific modalities) may sometimes be better performed through other pathways, such as departmental supervisory and mentoring structures. | 81.8%       |
| 16 | Local standards and methods for establishing POCUS competence should be determined by experts in the specialty and practice environment in which it is being used; standards appropriate for one clinical setting may not apply in another.  | 87.5%       |
| 18 | In some local credentialing processes, external courses, certifications, or examinations intended to demonstrate a baseline of POCUS training may play a useful role. However, as a broad approach to verifying competence, such standardized tools should neither be considered mandatory (as they may be superfluous for some clinicians to achieve and demonstrate competence), nor necessarily sufficient (in the absence of other training). Without tailoring for the local environment, we do not recommend the general requirement for clinicians to satisfy external standards before credentialing for POCUS use.  | 82.4%       |
| 19 | Achieving POCUS competency requires experience with its use. In most cases, a sound credentialing standard should therefore require clinicians to perform a pre-defined number of studies prior to allowing unsupervised practice. However, as skill develops non-linearly and at different rates in different clinicians, it is reasonable to establish this minimum threshold at a relatively low number, and it must be combined with a qualitative evaluation of competency that assesses actual knowledge base and practical skills.  | 87.5%       |

Table 6. Rejected statements (Credentialing)

| #  | Rejected statement   | Rejected by |
|----|--|-------------|
| 17 | External courses, certifications, or examinations intended to demonstrate a baseline of POCUS training should be a requirement of local credentialing processes. | 79.1%       |

The panel noted that ultrasound training occurring during foundational clinical programs might be considered “external,” but was not the intention of this statement. For example, clinical ultrasound is a mandatory element of modern emergency medicine residencies [9], and the American College of Emergency Physicians (ACEP) has issued a policy statement asserting that external certification has no role for residency-trained emergency physicians [24].

The American Medical Association’s resolution H-230.960 states that hospital requirements for POCUS credentialing for physicians should be guided by standards defined by that specialty, such as the well-

established ACEP recommendations (which suggests emergency physicians undertake 25–50 quality-reviewed ultrasound studies in each application prior to independent practice) [9,25]. Mirroring this, the expert panel was unable to recommend any specific criteria applicable across both specialty type and resource setting (#14, #19). It was noted that the challenges to POCUS credentialing mean that supervising it through other pathways, such as internal departmental processes, may sometimes be more effective (#15).

#### Cleaning and Maintenance

This section (Table 7) addresses maintenance of POCUS equipment in a safe and functional state.

There was difficulty in reaching consensus on standards of device disinfection, partly driven by inconsistencies in the existing recommendations issued by the Center for Disease Control, the American Institute of Ultrasound in Medicine, and an intersocietal position statement issued jointly by 20+ professional clinical groups [26–29]. Guidelines have inconsistently applied the concept of “intermediate level disinfection” (a category between low-

Table 7. Accepted statements (Cleaning and Maintenance)

| #  | Accepted statement   | Accepted by |
|----|--|-------------|
| 20 | Procedures for cleaning and maintenance of POCUS devices should generally adhere to manufacturer recommendations, as well as pertinent federal, state, and institutional policies. Consideration should be made of the type of exposure, the level of disinfection required based on clinical application, and manufacturer guidelines for the specific equipment. We suggest the following general recommendations which will apply in most circumstances.  | 95.8%       |
| 21 | Between patient encounters, non-invasive transducers should be cleaned of gross contaminants, then disinfected using an approved agent. Transducers that may contact non-intact skin or bodily fluids, such as during percutaneous procedures, should first be covered with a transducer cover (sterile or clean as determined by the standards of the procedure); disinfection must be performed regardless of the use of a transducer cover.<br><br>Transducers that will contact mucous membranes (e.g. during transesophageal or transvaginal studies), enter body cavities or the bloodstream, or be used in surgical procedures should be processed in accordance with local policy. | 95.7%       |
| 22 | Secondary components of the ultrasound device with the potential for surface contamination, such as cables, control panels, displays, and storage bins, should be disinfected after each patient encounter.  | 87.5%       |
| 23 | During patient encounters involving exposure to highly contagious aerosolized droplets or airborne particles, the use of barrier devices (e.g. drapes or covers) to cover portions of the ultrasound device should be considered; this measure does not replace the need for appropriate decontamination, but may serve as an adjunct by limiting exposure of secondary device surfaces.   | 91.3%       |
| 24 | Transducers with visible cracks or penetrating surface defects cannot be adequately cleaned, and should not be used for patient examination until repaired or replaced.  | 91.3%       |
| 25 | Such damaged transducers may be used in exigent or resource-limited circumstances if completely covered by a non-porous transducer cover.  | 85.0%       |
| 26 | Spare supplies stored on POCUS machines, such as gloves, catheters, and containers of gel may become contaminated during patient encounters. Even when individually packaged, their exterior surfaces are difficult or unlikely to be disinfected between patients. While sometimes unavoidable, the storage of supplies on POCUS devices should be limited when possible, and care should be taken to avoid their contamination. Disposables such as single-use gel packets should be discarded after each patient encounter.   | 91.6%       |

level and high-level disinfection not found in all standards) and offer mixed guidance on the disinfection of transducers used for percutaneous procedures such as vascular access (i.e. low- vs high-level disinfection), as well as whether such processing should occur before or after the procedure. Given the high stakes involved in device disinfection, the panel elected to avoid specific recommendations, instead merely reinforcing the importance of following applicable standards, regulations, and manufacturer recommendations (#20).

To address common clinical pitfalls, the panel did emphasize that transducers should be cleaned between patient encounters (#21), as should other components of POCUS devices that become contaminated (#22). The majority favored protecting probes with non-porous covers prior to percutaneous procedures (#21), in contrast with placing a dressing over the transducer face or using disinfection alone. They recommended limiting extra supplies carried on POCUS machines (#26), a common practice that creates inevitable challenges to decontamination, although they acknowledged this was not always practical. A recommendation was made to consider covering portions of the POCUS device with a protective barrier (#23) during encounters with highly contagious airborne or aerosol particles. This method emerged largely during the COVID-19 pandemic; however, the panel acknowledged this practice is lacking

in evidence, is not mandatory, and is not sufficient to replace other decontamination measures.

Transducers in heavy use may become damaged, such as by cracks or chips in the case material, and often remain in use despite these defects. The panel recommended against such use (#24), primarily due to the increased barriers to adequate disinfection. However, they acknowledged that using such devices might be necessary in some cases, and allowed this if the transducer is covered to protect the defect (#25).

### *Consent and Education*

This section (Table 8) focuses on the role of patient consent for POCUS studies, and the overlapping topic of POCUS performed for practice or education.

The panel agreed that POCUS studies may be observed by learners if patients allow (#27), and that learners may perform non-invasive studies if adequately supervised (#28). Despite this agreement, the panel was highly divided on the role of learners in invasive studies. While accepting that appropriately-supervised learners may be involved in performing invasive studies, such as transesophageal or transvaginal ultrasound, the majority felt that patient consent was needed for this (#29).

Some respondents felt that non-indicated invasive studies should never be performed for educational reasons alone, but the majority acknowledged that rare

*Table 8. Accepted statements (Consent and Education)*

| #  | Accepted statement   | Accepted by |
|----|--|-------------|
| 27 | Learners may observe the performance of any POCUS study if the patient or surrogate decision-maker does not object.  | 100%        |
| 28 | Non-invasive studies, either clinically-indicated or educational, may be performed by learners if appropriately supervised.  | 100%        |
| 29 | Consent should be obtained for learner participation in clinically-indicated invasive studies.<br>Outside of uncommon situations, such as educational models, invasive studies should not be performed purely for educational purposes. Explicit consent must be obtained and documented for invasive educational studies.   | 82.6%       |
| 30 | In order to avoid discovering ultrasound findings of unclear significance, educational studies should not be performed by learners without either:<br>1. The presence or immediate availability of an expert to validate their findings in real time<br>2. Other definitive imaging already depicting the area of interest<br>or<br>3. A quality assurance process that includes archival and timely expert review of all educational studies. | 83.3%       |
| 31 | If pathology is identified during an educational study which was not already diagnosed by other means (e.g. prior imaging), expert guidance should be obtained, the primary clinical team informed, and confirmatory imaging considered.   | 100%        |
| 32 | Learners performing POCUS prior to achieving independent competence should not incorporate their findings into medical decision-making prior to expert review.   | 87%         |

exceptions might exist, such as certain didactic situations (e.g. models volunteering for training programs). They agreed that explicitly documented consent must be obtained for these unusual situations (#29).

The panel was unable to agree on the role of consent for non-invasive educational studies, agreeing that they should not be performed on actively dissenting individuals, but acknowledging that non-invasive exams are commonly performed on comatose or sedated patients for practice or teaching. Some experts raised doubts about the ethical basis of this practice, while others wondered whether its acceptability depended on whether it fell under umbrella consents for educational activities in teaching facilities. In the end, no consensus could be reached. Because of this, it was suggested that

the topic could be more fully explored in another venue, such as an ethics panel that included patient representatives.

There was clear agreement that learners should not act on POCUS findings unless their findings were first reviewed by an expert (#32). Indeed, the majority felt that learners should generally not perform educational studies without either real-time expert supervision, the availability of timely expert review, or other imaging available to correlate their findings (#30).

*Security, storage, and sharing*

This section (Tables 9 and 10) addresses how POCUS exams are stored, as well as non-clinical sharing of images.

*Table 9. Accepted statements (Security, Storage, and Sharing)*

| #  | Accepted statement  | Accepted by |
|----|---|-------------|
| 33 | Clips or images from POCUS studies, whether clinically indicated or acquired for training purposes, are frequently reproduced for teaching. This may include classroom use, lectures in a clinical setting, or digital reproduction on websites, podcasts, or social media.   | 86.9%       |
| 35 | Images should not be stored, reproduced, shared, or utilized in any form outside the secured medical infrastructure without de-identification. This process should include redaction of the patient’s name, identifier numbers, and date of birth.  | 87.0%       |
| 36 | Combined with other clinical context, time stamps that include the date of image acquisition may be sufficient to identify the source patient, and should be redacted along with other patient identifiers.   | 82.6%       |
| 37 | Depictions of rare pathology require additional efforts at obfuscation to prevent identification of the source patient. This may include “fictionalizing” the clinical context not directly relevant to the teaching point, such as gender, age, or secondary clinical features. It may also include delaying usage to establish temporal distance between the case and the reproduction.   | 95.6%       |
| 38 | When reproduced in public forums such as social media, POCUS cases may be viewed by the public, and should be described using respectful and professional language. Caution should be exercised when clinicians depict cases using humorous or glamorizing language, and derogatory commentary should never be used.  | 87.0%       |
| 39 | POCUS studies associated with patient identifiers may be retained in local storage on the device, but represent protected healthcare information, and measures must therefore be taken to protect their security. At minimum, this should include limiting physical access to the device, e.g. in locked units or storage areas. In some cases, particularly when physical access cannot be completely restricted (e.g. if patients or visitors may have access), password protection of the device is recommended. Periodically deleting unneeded archives from device storage should be considered as an adjunct to these measures. In settings where neither physical access nor password protection can be adequately achieved, a policy of deleting patient information following each use (after any appropriate archival has been performed) should be considered. We do not recommend long-term archival on local devices without a minimum of password protection.       | 92.2%       |
| 40 | Personal POCUS devices maintained outside the medical infrastructure may be especially vulnerable to privacy violations. Patient identifiers should not be stored on such devices if they have not been secured in a manner that satisfies federal, state, and local security standards for protected health information, such as password protection and/or the ability to remotely erase stored images in the event of loss or theft. This standard also applies to other devices that may interface with and store footage from portable POCUS transducers, such as mobile phones or portable computers. Remote file storage (i.e. uploading to cloud-based databases) should not occur unless it meets the same standards, which may also apply to the process of electronic transmission, the storage method and permissible usage of the stored files by the parent company, and the security of other downstream devices that may access the stored files after uploading. | 100%        |



**Table 10. Rejected statements (Security, Storage, and Sharing)**

| #  | Rejected statement  | Rejected by |
|----|---|-------------|
| 34 | Regardless of de-identification, POCUS studies obtained during patient care should never be reproduced in public forums (such as the internet or social media) without patient consent. | 79.2%       |

The panel acknowledged that POCUS images or clips are often reused outside the clinical context, such as for classroom education or even posts on social media (#33) [30]. However, they emphasized that such reproduction should only occur after scrupulous eradication of patient identifiers (#35), which in some cases might include redacting the date of acquisition (#36). When especially rare pathology is depicted, deidentification might require even greater efforts at obscuring the source (#37). They also highlighted the importance of using professional

language (#38) when POCUS cases were discussed in public media [31–35]. Despite these cautions, they rejected the idea that properly-anonymized clinical POCUS images should never be reproduced or discussed in public, or that such use always requires patient consent (#34).

The panel noted that studies saved on local device storage present a potential for privacy violations. They suggested that this risk can be mitigated through various methods, including password protection, limiting physical access to devices, or periodic deletion of stored studies (#39). Given the practical and logistical barriers to each of these methods, respondents were reluctant to mandate any of them (for example, recognizing that POCUS machines in busy clinical areas cannot always be stored in locked rooms), but did recommend considering periodic deletion of patient information when device access could not be completely restricted.

Particular caution was urged when personal POCUS devices are independently purchased and used by clinicians (#40). The panel universally agreed that patient

**Table 11. Accepted statements (Uploading, Archival, and Review)**

| #  | Accepted statement  | Accepted by |
|----|---|-------------|
| 42 | When resources permit, systems should develop infrastructures for the uploading, archival, and shared viewing of POCUS images.  | 95.7%       |
| 43 | In systems lacking the infrastructure for image uploading, local approaches to image storage should be considered, such as long-term storage on the ultrasound device, archival on local hard drives, or retaining printed hardcopies, although these methods impede the ability of other clinicians to review the findings. Any storage method must offer sufficient privacy and security for storage of healthcare information.   | 91.3%       |
| 44 | When achievable, uploaded POCUS studies should be accessible by the entire treatment team.  | 95.6%       |
| 45 | Training, credentialing, and quality assurance are best served when educational studies are saved for review. Depending on local infrastructure, this can be served by uploading them to a separate system which is dedicated to educational imaging and distinct from the clinical record, or by other archival systems such as local storage (e.g. on local discs or plug-in devices). Any method of archival must adhere to local standards of privacy and security.   | 91.3%       |
| 46 | Educational studies should not be uploaded to imaging archives intended for patient care.   | 82.6%       |
| 47 | Learners performing POCUS prior to achieving independent competence should have all studies reviewed by an expert.  | 86.9%       |
| 48 | If review of a study is warranted in a system without the capacity for formal image uploading, it may be achieved using ad hoc methods (such as digitally sharing photographs of device screens), as long as such methods conform to local standards of privacy and security.   | 78.2%       |
| 49 | Image review should be performed by experts in that type of study.  | 86.9%       |
| 50 | Whenever resources permit, systems should develop infrastructures and workflows that involve expert review of POCUS studies. Although universal review of all studies may be ideal, review of a selected portion is acceptable, with the fraction determined locally.<br><br>A process of review is always preferable to no review, and should be established whenever possible. However, in low-resource environments where expert review is not feasible, POCUS use by qualified clinicians should not necessarily be prohibited. | 87.0%       |

*Table 12. Rejected statements (Uploading, Archival, and Review)*

| #  | Rejected statement  | Rejected by |
|----|---|-------------|
| 41 | In systems of care lacking an infrastructure for uploading and archival of images, clinicians should not perform POCUS. | 82.6%       |

information should not be stored on such devices unless they meet the same regulatory and privacy standards as other clinical devices. They also noted that such personal devices often interface with phones or tablets, or upload to cloud-based storage, and each step of this process must also adhere to the same security standards.

*Uploading, Archival, and Review*

This section (Tables 11 and 12) addresses how and when POCUS exams should be saved and reviewed by others.

The panel overwhelmingly agreed that all clinical groups should pursue the infrastructure (e.g. necessary hardware, software, and support) to allow POCUS studies to be saved to the medical record (#42). A method of archival that is readily accessible, such as uploading to a digital radiology system, was heavily preferred (#44); however, in the absence of such infrastructure, it was considered acceptable to save studies using other means, such as printed hardcopies or local storage on the device (#43).

This topic was controversial. In the end, the panel fell just short of mandating that archival must occur universally, allowing the caveat “when resources permit” for niche circumstances or austere environments. They rejected the statement that systems without archival capability

should simply not perform POCUS (#41), but repeatedly emphasized that some form of archival is always desirable. (The single expert who dropped out of the consensus process after completion of voting did so due to declining to endorse a recommendation that did not mandate study archival).

The panel agreed that educational studies should generally be saved in some form (#45), but should not be entered into the general medical record; some respondents felt this might be acceptable if educational studies were clearly flagged or labeled as being non-clinical in nature, but the majority believed this created undesirable confusion in the medical record (#46). They agreed that learners should have all studies reviewed by experts in that type of exam (#47, #49), even if this requires informal methods (such as handheld videos of the device display), as long as such methods adhere to privacy standards (#48).

Unlike for educational studies, the panel had more difficulty agreeing on a requirement for expert review of studies performed by credentialed clinicians. Nearly all of the respondents supported a process of review and quality assurance, but there was little consensus on how universally this should occur. Some believed that an expert review process is mandatory and should be achievable in all systems even if it requires flexible approaches. Others felt that exceptions might exist in low-infrastructure settings. In the end, a consensus majority recommended expert review to whatever extent possible, but accepted that systems lacking such resources should not necessarily forbid POCUS use (#50).

The panel was unable to reach consensus on whether expert review constituted a billable clinical service. They felt this was too dependent on regulatory considerations and individual variables.

*Table 13. Accepted statements (Documentation)*

| #  | Accepted statement   | Accepted by |
|----|--|-------------|
| 51 | The acquisition and interpretation of clinically indicated studies should be documented in the medical record.   | 95.7%       |
| 53 | POCUS documentation should, at minimum, include a description of the study performed, its indication, the findings, and the resulting clinical impression.   | 91.2%       |
| 54 | If a clinically indicated study is attempted, but is inadequate to answer the clinical question(s) for technical reasons, the attempt should be documented.  | 95.6%       |
| 55 | If image interpretation is performed by a clinician who did not perform the study, such as a consultant or telemedicine provider, the interpreting clinician should document their interpretation in the medical record. | 100%        |
| 56 | The acquisition and interpretation of POCUS studies is best documented using standardized note templates.  | 82.6%       |

Table 14. Rejected statements (Documentation)

| #  | Rejected statement   | Rejected by |
|----|--|-------------|
| 52 | The acquisition and interpretation of educational studies should be documented in the medical record.  | 82.5%       |
| 57 | Some POCUS studies serve a purpose more analogous to physical examination than to radiographic studies. Such POCUS applications need not be formally documented. | 82.6%       |

### Documentation

This section addresses appropriate documentation of POCUS studies (Tables 13 and 14).

There was universal agreement that the acquisition and interpretation of clinically-indicated studies should be documented in the medical record (#51). This should occur even when the interpretation is performed by a separate individual (#55), as may sometimes happen when consultants or remote clinicians are involved in care. Although somewhat receptive to the idea that certain POCUS applications play a role similar to the physical examination, the panel nevertheless rejected the idea that such studies are exempt from requiring documentation (#57).

The majority supported the use of relatively standardized methods of documentation (#53, #56). Notably, the panel also recommended documenting attempts at clinically-indicated POCUS exams even when they were technically inadequate (#54).

As with archival (see *Uploading, archival, and review*), the panel rejected the idea that purely educational studies should be documented in the general medical record (#52), preferring that the record of educational and learning POCUS should remain separate from clinical documentation.

### Discussion

This consensus statement is the first known attempt to establish a universal foundation of best practices underpinning POCUS implementation.

It benefits from the diversity of the expert panel as well as the rigorous process of consensus. Although no group of experts can represent the perspective of every practicing clinician, our panel included a broad cross-section of medical specialties, including those with less established footing in POCUS, such as family medicine, neurology, and nephrology. It also included representation from non-physician practitioners, such as physician assistants and nurse practitioners, helping to

establish a more general consensus than position statements issued by professional groups with narrower constituencies. Overall, it may serve as a step towards reducing the practice variation that currently exists in the domains addressed, bringing the many disparate implementations of POCUS towards a more unified, consistent standard.

The primary limitations of this document derive from its nature. Regardless of the rigor and diversity of the consensus process, it remains merely an expert consensus, not the direct product of robust evidence. Indeed, many of the topics addressed, such as workflows around documentation and image review, likely have no objectively correct answer.

Additionally, while the final consensus statements were accepted or rejected by  $\geq 75\%$  of the panel, only 12% reached 100% agreement in either direction, implying a lack of universal consensus. The final recommendations can therefore be viewed as a majority opinion, but not one free of controversy.

While diverse, the panel also lacked representation from every potential sub-domain of clinical practice—and even when present, minority perspectives (though potentially valid for certain practice settings) may have been overcome and nullified by the majority vote. No members of non-advanced-practice nursing or active military service were included, nor was there any involvement from patient representatives. The inclusion of these groups could have meaningfully broadened the basis of consensus. Finally, the panel was entirely based in the US and the recommendations were targeted to that setting; international differences in practice were not addressed.

By aiming to describe practices relevant to all users of POCUS, this statement is also limited by the constraints of generalizability. More targeted recommendations may be possible for more specific groups, such as those with shared training (e.g. a background of emergency medicine residency or critical care fellowship), similar practice setting (e.g. hospital wards, outpatient clinics, or the operating room), or consistent needs (e.g. procedural guidance for vascular access or prehospital diagnosis of pneumothorax).

Given the limitations described, this document should not be viewed as a normative guideline describing a standard of care. While the statements included were believed to depict reasonable best practices within the current environment of POCUS in the United States, alternative practices may be appropriate for specific settings or in response to specific needs. The local context, as well as more targeted recommendations or data (where available), must be considered.

Further efforts in this space should consider developing the themes addressed in greater detail, with the ultimate goal of establishing a set of universally-accepted practices that are applicable to POCUS users in every environment. Such a standard should be tested for relevance and appropriateness across multiple specialty settings, and some aspects could potentially be expanded to apply to international clinicians. As stringent criteria can easily be created for high-resource centers that would preclude POCUS use in more austere settings, a universal standard might involve a spectrum of recommendations ranging from optimal practice (appropriate in ideal settings) to minimum acceptable standards (below which POCUS should not be performed).

### Patient Consent Statement

No patients are described in this manuscript.

### Disclosures

AG has received grants from NIH and consulting fees from Butterfly Network and Ultrasight. AK has received research funding from KidneyCure and the American Society of Nephrology. JK is the chair of the American Society of Echocardiography's Scientific Statement Writing Group on Nomenclature of cardiac POCUS, and a member of the Critical Care Echocardiography Council Leadership Group.

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# The Application of Point of Care Ultrasound to Screen for Pulmonary Hypertension: A Narrative Review

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## Abstract

**Background:** Pulmonary Hypertension (PH) is a condition with several cardiopulmonary etiologies that has the potential of progressing to right heart failure without proper intervention. After a history, physical exam, and investigations, cases of suspected PH typically undergo imaging via a transthoracic echocardiogram (TTE). This is a resource-intensive procedure that is less accessible in remote communities. However, point of care ultrasound (POCUS), a portable ultrasound administered at the bedside, has potential to aid in the diagnostic process of PH. **Methods:** The MEDLINE, Embase, and CENTRAL databases were searched to screen the intersection of POCUS and PH. Studies involved adult patients, and only English articles were accepted. Reviews, case reports, unfinished research, and conference abstracts were excluded. Our aim was to identify primary studies that correlated POCUS scan results and additional clinical findings related to PH. **Results:** Nine studies were included after our search. In these studies, POCUS was effective in identifying dilatation of inferior vena cava (IVC); internal jugular vein (IJV); and hepatic, portal, and intrarenal veins in patients with PH. The presence of pericardial effusion, pleural effusion, or b-lines on POCUS are also associated with PH. **Conclusions:** This review suggests important potential for the use of POCUS in the initial screening of PH. IVC and basic cardiopulmonary POCUS exams are key for PH screening in patients with dyspnea. Right-heart dilatation can be visualized, and peripheral veins may be scanned based on clinical suspicion. POCUS offers screening as an extension of a physical exam, with direct visualization of cardiac morphology. However, more studies are required to develop a statistically validated POCUS exam for PH diagnosis. More studies should also be conducted at the primary-care level to evaluate the value of screening using POCUS for PH in less-differentiated patients.

## Introduction

Pulmonary hypertension (PH) is a severe condition arising from increased pulmonary vascular resistance with complications including right heart (RH) failure and hypoxia [1]. Pulmonary Arterial Hypertension (PAH), also known as primary PH, has no other cardiopulmonary etiology, and its 3-year mortality can be as high as 21% [2]. Therefore, early screening and detection is an important component of PH management.

There are five types of PH, labeled groups 1-5 by the World Health Organization (WHO) [3,4] as follows: PAH, PH due to left heart disease, PH due to hypoxia and lung disease, chronic thromboembolic pulmonary hypertension (CTEPH), and PH with unclear or multifactorial mechanisms, respectively. Group 2 PH comprises 68% of PH cases, as reported by Brown et al.

[5]. Group 5 is the second most common, making up 15%. Group 3 forms 9% and Groups 1 and 4 account for 3% and 2%, respectively [4,5]. Within PAH, there are several subtypes which include idiopathic, heritable conditions associated with PAH such as connective tissue diseases, human immunodeficiency virus infection, portal hypertension, congenital heart disease, schistosomiasis, PAH associated with drugs and toxins, PAH with features of venous/capillary involvement, and persistent PH of the newborn. Though relatively rare, PH is increasing in incidence around the world and becoming a greater healthcare burden [4,6].

The diagnosis of PH begins with a clinical suspicion, often in patients with dyspnea, reduced exercise tolerance, fatigue, edema, chest pain, and syncope or near-syncope [7]. Following clinical suspicion, a thorough cardiac and abdominal physical exam is

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DOI: <https://doi.org/10.24908/pocus.v9i1.17494>

indicated. After an electrocardiogram and bloodwork, the next step in the workup is typically a trans-thoracic echocardiogram (TTE) [8,9]. Access to echocardiography can pose a barrier to rapid early diagnosis, depending on resource availability such as requiring specialized personnel and equipment [10–12]. Furthermore, echocardiography may be less accessible in some remote communities since these facilities are typically situated in urban centers [13].

However, with the advent of point of care ultrasound (POCUS), ultrasound scans are now employed at the bedside. Images may be obtained quickly and cheaply, allowing for efficient examination and extension of the physical examination that may point to etiologies such as PH contributing to patient symptoms.

Currently, PH is often missed, especially in younger patients using existing bedside approaches to history and physical examination [5]. Even in secondary PH, there is still the risk of RH failure in addition to the primary disease. The increased efficiency of a cardiopulmonary POCUS exam could motivate a broader differential diagnosis that includes PH. Relevant cardiovascular images that apply to PH are shown in Figure 1. This article reviews the potential for POCUS to aid in the diagnostic process of PH and discuss its implications.

## Methods

We conducted a literature review using the MEDLINE, Embase, and CENTRAL databases, capturing the intersection of POCUS and PH using these terms, their synonyms, and relevant subject headings. The full search criteria are shown in the Supplementary Material. Only English studies involving adult patients were included. Conference abstracts, reviews, unfinished research, and case studies were excluded. After title and abstracts were screened, included articles underwent full

-text screening. Data from relevant articles were extracted. One reviewer [D.K.] performed the entire screening and extraction.

## Results

We found nine studies that correlate POCUS findings with PH-related clinical features. The PRISMA diagram is displayed in Figure 2. The results are summarized in Table 1.

Samant et al. [14] qualitatively estimated the right atrial pressure (RAP) using POCUS by measuring IVC size and collapsibility. PH patients (60% Group I) were then stratified into normal, intermediate, and high eRAP. BNP values (in pg/ml) were 70 (95% Confidence interval [CI] 39–120), 166 (CI 80–341), 236 (CI 111–503), respectively. Differences of normal vs intermediate and normal vs high eRAP groups were both significant at  $p < 0.01$ .

Avriel et al. [15] studied the effect of POCUS in a PAH clinic. 36 patients were randomized 1:1 to either receive an additional POCUS assessment or not. The number of changes to patients' management was recorded. Cardiac, pulmonary, and IVC POCUS exams were performed. There were 48 management changes in the POCUS group and 18 in the control group ( $p < 0.001$ ).

Torres-Arrese et al. [16] used POCUS to scan acute heart failure patients' lungs and their hepatic, portal, intrarenal, and femoral veins, both on admission and discharge. The congestion values of the hepatic, portal, and intrarenal veins were used to calculate a Venous Excess Ultrasound Score (VExUS), estimating the congestion in the venous system [17]. In paired analysis for patients' results on admission and discharge, the researchers found that the score significantly correlated with the EVEREST score, a validated clinical scoring for congestion [18], with a correlation of 0.532 ( $p = 0.004$ ).

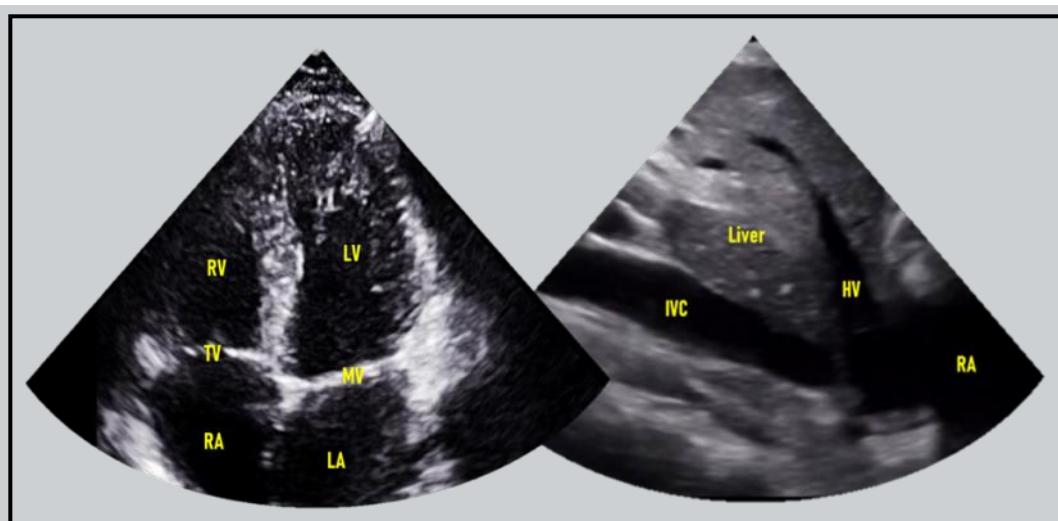


Figure 1. Images of normal cardiac and subcostal views obtainable using a point of care ultrasound (POCUS) examination. The following heart and abdominal structures are labeled: Right and left ventricles (RV, LV), tricuspid and mitral valves (TV, MV), right and left atria (RA, LA), inferior vena cava (IVC), liver, and hepatic vein (HV).

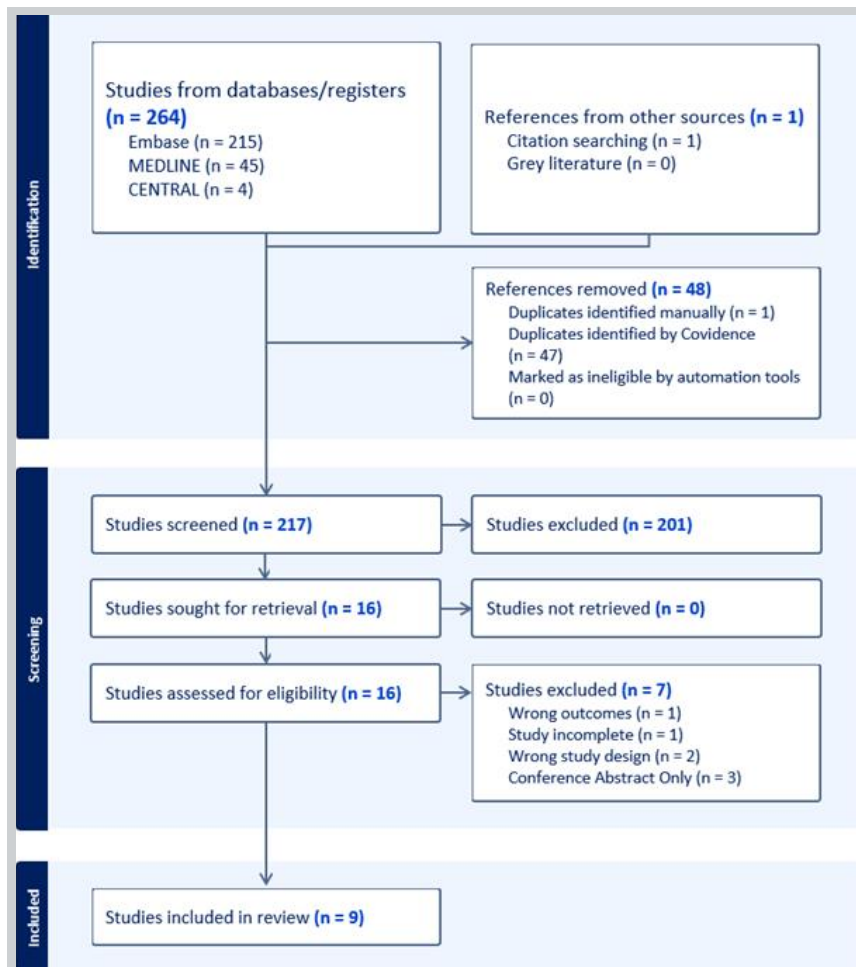


Figure 2. The PRISMA diagram of the resulting literature search. Nine studies were included in this review.

The VEXUS also correlated with a decrease in NT-proBNP, with a correlation of  $-0.411$  ( $p = 0.024$ ).

Dayioglu et al. [19] employed POCUS to measure the following cardiopulmonary parameters, comparing them to conventional ultrasound: fractionated area change; IVC collapsibility/distensibility; LV/RV end-diastolic and IVC diameter; LV/RV diastolic and systolic centricity index; right atrium area; pulmonary artery diameter. None of these parameters were significantly different from conventional handheld ultrasound. Overall, POCUS was 68% accurate for detecting PH with 88% negative predictive value.

Kurnik et al. [20] analyzed POCUS performed on admission to ICU in patients >70 years-old with COVID-19 pneumonia. Pulmonary artery systolic pressure (PASP) was significantly higher in non-survivors compared to survivors (40.4 vs 32.5 mmHg,  $p = 0.024$ ). Furthermore, a greater percentage of non-survivors had diffuse lung b-lines compared to survivors (59% vs 33%,  $p = 0.005$ ).

Elzeneini et al. [21] compared POCUS RAP, estimated from the IVC scan, to that determined by RHC. They found a correlation of 0.80,  $P < .001$ , and that POCUS was

76-92% accurate overall.

Chopra et al. [22] found that in PH patients, pericardial effusion was 89% predictive of systemic venous hypertension (RAP > 10mmHg at rest), while pleural effusion had only a 67% positive predictive value for pulmonary venous hypertension (pulmonary artery wedge pressure > 15mmHg). Both effusions were found using POCUS.

Parikh et al. [23] used POCUS to measure the internal jugular vein (IJV) in patients undergoing RHC for PH. The following were measured: IJV diameter at rest, during respiratory variation, and during manual compression. The collapsibility indices were calculated during respiration and during manual compression. The measured RAP correlated significantly with the IJV diameter ( $r=0.26$ ,  $p=0.029$ ). Furthermore, the compression collapsibility index correlated significantly with mRAP ( $r=-0.43$ ,  $p=0.0002$ ), pulmonary artery occlusion pressure also obtained from an RHC ( $r=-0.35$ ,  $p<0.0027$ ), and BNP levels ( $r=-0.31$ ,  $p=0.015$ ).

Simon et al. [24] studied patients undergoing RHC, but not necessarily for suspected PH. The right IJV cross-sectional area (CSA) with and without the Valsalva maneuver was measured using POCUS. Patients were



*Table 1. Results of the review. Five primary studies evaluating point of care ultrasound (POCUS) were found relevant to pulmonary hypertension (PH). The number of patients (n), patient population, and clinical findings are also summarized.*

| Study ID           | n   | Population                                    | POCUS Technique   | Measured using POCUS   | Correlated significantly with  | Ref  |
|--------------------|-----|---|---|--|--|------|
| Samant 2022        | 90  | PH, 60% Group I                               | IVC - Subcostal view  | RAP - IVC diameter and collapsibility  | BNP levels   | [14] |
| Avriel 2023        | 36  | PAH (Group I)                                 | PLAX, PSAX, A(5,4,2)C, SC, IVC. Lung congestion, b-lines, pneumothorax, atelectasis, pleural effusion, consolidations | Use of cardiopulmonary exams, IVC diameter                                     | Management changes, attributed to POCUS use                                  | [15] |
| Torres-Arrese 2022 | 30  | PH in Acute Heart Failure (Group II PH)       | Peripheral venous scan  | Hepatic, portal, and intrarenal vein congestion, combined into the VExUS score | NT-proBNP and EVEREST grading score  | [16] |
| Dayioglu 2024      | 46  | Cardiopulmonary problems, at high risk for PH | PLAX, PSAX, A4C, A4CRV, SC, IVC, RA using B mode  | Cardiopulmonary measurements   | The same on conventional ultrasound; no significant differences between them | [19] |
| Kurnik 2023        | 117 | Age >70 in ICU for COVID-19 pneumonia         | Lung exam with 8 areas + cardiac exam.  | PASP and presence of pleural b-lines   | Death  | [20] |
| Elzeneini 2022     | 50  | PH patients undergoing RHC                    | IVC - Subcostal view in sagittal plane  | RAP - IVC diameter and collapsibility  | RAP using RHC  | [21] |
| Chopra 2021        | 32  | PH patients undergoing RHC                    | PLAX, PSAX, A4C, SC4C, abdomen/thorax   | Presence of pleural effusion and pericardial effusion                          | Systemic and pulmonary venous hypertension from RHC                          | [22] |
| Parikh 2019        | 71  | PH patients undergoing RHC                    | Linear probe, with and without compression. Color doppler implemented   | IJV diameter   | RAP using RHC  | [23] |
| Simon 2010         | 67  | Patients undergoing RHC                       | Head turned left, supine. Probe at right sternocleidomastoid  | Right IJV cross-sectional area with and without valsalva                       | RAP using RHC  | [24] |

POCUS = point of care ultrasound; PH = pulmonary hypertension; PAH = pulmonary arterial hypertension; RHC = right heart catheterization; BNP = b-type natriuretic peptide; NT = N-terminal; PLAX = parasternal long axis; PSAX = parasternal short axis; A\_C = apical \_-chamber; SC4C = subcostal 4-chamber; PASP = pulmonary artery systolic pressure; RAP = right atrial pressure; VExUS = Venous Excess Ultrasound; EVEREST = Efficacy of Vasopressin Antagonism in Heart Failure: Outcome Study with Tolvaptan

grouped as normal and elevated mRAPs. The Valsalva maneuver increased IJV CSA by a median of 35% (IQR 19%-79%) in normal mRAP patients, and 5% in high mRAP patients (IQR 3%-14%). They reported that a >17% increase in right IJV CSA with Valsalva can predict elevated RAP with a sensitivity and specificity of 90% and 74%, respectively.

## Discussion

POCUS is an inexpensive, fast, and accessible tool that is increasingly prevalent in outpatient settings. POCUS examinations have the potential to be used as a screening tool for PH. The POCUS exams used to screen for PH are: parasternal long axis (PLAX), parasternal short axis (PSAX), apical 4-chamber (A4C), and subcostal 4-chamber (S4C), subcostal for the IVC

and estimating RAP, and B-mode pulmonary views of each lobe. These techniques are derived from ultrasound guidelines and are standard across included studies [25–27]. The full cardiopulmonary POCUS exam and veins encompassing the IVC and peripheral veins are all reasonable in the screening of PH, as outlined below.

The IVC diameter and collapsibility arising from the subcostal view has been the most used and validated estimate of the RAP among the studies, and it should be the preferred screening method for PH on POCUS.

The cardiac exam uses standard visualizations PLAX, PSAX, A4C, and S4C. The goal is to identify pericardial effusion, RH dilatation, tricuspid regurgitation, and rule out other cardiac etiologies such as left heart or valvular diseases. RH dilatation was not thoroughly investigated in the studies included, as it arises later in the disease process of PH [28,29]. Meanwhile, tricuspid regurgitation is a complication of RH dilatation and can also be viewed on POCUS [30,31].

The pulmonary exam employs B-mode investigating each lobe, and visualizes the presence of b-lines and pleural effusion. These are associated with PH based on our results. In addition, the pulmonary exam scans for signs of pulmonary decompensation while ruling out other pulmonary causes of the presentation.

The IJV may be useful to obtain RAP. However, the IVC has been more thoroughly studied in the studies we reviewed. Other peripheral veins such as the hepatic, portal, and intrarenal veins are also effective proxies for the RAP. However, they are distal to the IVC and should only be examined under exceptional circumstances or with complaints such as peripheral swelling.

Table 2. Summary of POCUS exam for PH screening, illustrating techniques used and the exam’s objectives.

| POCUS Exam              | POCUS technique (s) used                       | Exam objective(s)  |
|-------------------------|--|--|
| Inferior Vena Cava      | Subcostal                                      | Diameter and collapsibility to estimate RAP                            |
| Cardiac Exam            | PLAX, PSAX, A4C, SC4C                          | Pericardial effusion, RH dilatation, rule out other cardiac etiologies |
| Pulmonary Exam          | B-mode exam of each lobe                       | B-lines, pneumothorax, atelectasis, pleural effusion, consolidations   |
| Internal jugular vein*  | Longitudinal and cross-sectional visualization | Internal jugular vein diameter   |
| Peripheral Venous Scan* | Longitudinal and cross-sectional visualization | Hepatic, portal, and intrarenal vein diameter                          |

\*Only need to be performed for unclear findings or clinical suspicion of peripheral decompensation. PLAX = parasternal long axis; PSAX = parasternal short axis; A4C = apical 4-chamber; SC4C = subcostal 4-chamber; RAP = right atrial pressure; RH = right heart.

A summary of the POCUS exam for PH screening is outlined in Table 2. The screening role of POCUS in the diagnostic algorithm of PH is outlined in Figure 3. Select abnormal POCUS findings are pictured in Figure 4.

There are several limitations of this study. First, while RHC is the gold-standard for the diagnosis of PH, it is utilized less due to its invasiveness. Therefore, other

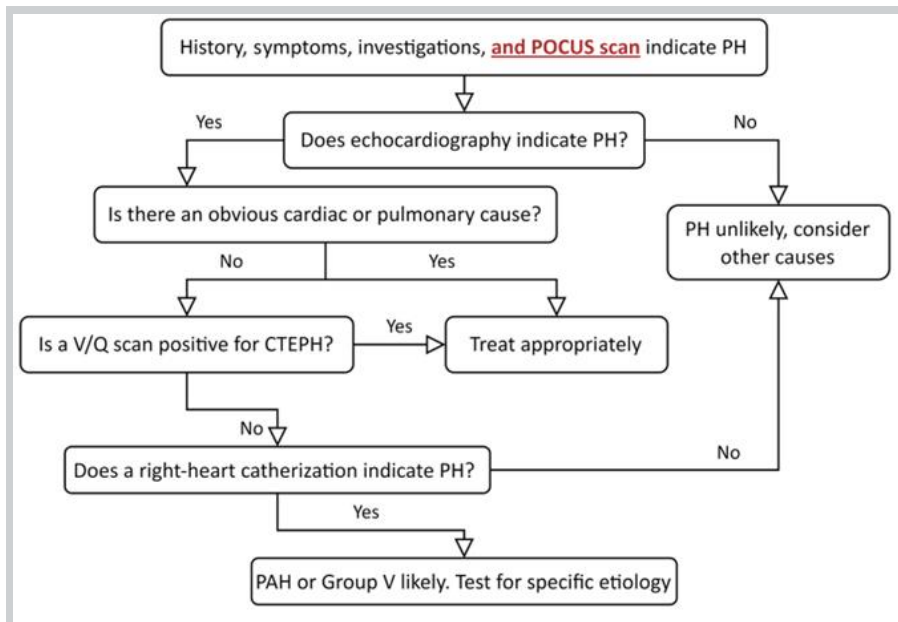


Figure 3. The proposed addition of point of care ultrasound (POCUS) to the initial screening for pulmonary hypertension (PH). Echocardiography, a ventilation/perfusion (V/Q) scan, and a gold-standard right-heart catheterization (RHC) are still required to progress in the diagnosis as needed should the PH probability be high. CTEPH = Chronic thromboembolic pulmonary hypertension.

clinical findings indicative of PH such as lab values and clinical scores were also used. This makes it difficult to isolate the effect of the PH itself in a patient complicated by other cardiopulmonary disease unless the focus was only on patients with PAH. Another limitation was the heterogeneity and overall low number of studies in this field. The studies are unable to be amalgamated due to differences in patient population, group of PH, experimental design, regions investigated by POCUS, and outcomes examined.

Therefore, the goal for the future is to produce a fast and clinically validated screening exam utilizing current standards. This screening exam would be intended for patients in the primary care setting who present with dyspnea and other PH-related symptoms, and would ultimately serve as an extension of the physical exam. To that end, more studies are required in this field, to determine exact measurements, their cutoffs for severity, and their relative weights of consideration. These studies should be replicated to allow for the creation of more

statistically robust POCUS exams for PH.

In addition, more studies should be conducted in a primary care setting. None of the studies reviewed focus on undifferentiated patients presenting with dyspnea and how POCUS can help screen them for PH. These studies would be more similar to their proposed use in the context of PH. While the studies that were reviewed illustrated the ability for POCUS to estimate severity in cohorts of PH patients, undifferentiated patients at an earlier stage of disease may present with less discernible findings. Other presentations and differential diagnoses in a primary care setting may also add complexity to the protocols outlined in these studies.

Nonetheless, POCUS should still be used today to help screen for PH where indicated. Even though the absence of positive findings on POCUS cannot rule out PH, the presence of findings can further the probability of PH and the acute risk to the patient. This information can be used to triage limited space and resources in the echocardiography lab, and to communicate the urgency

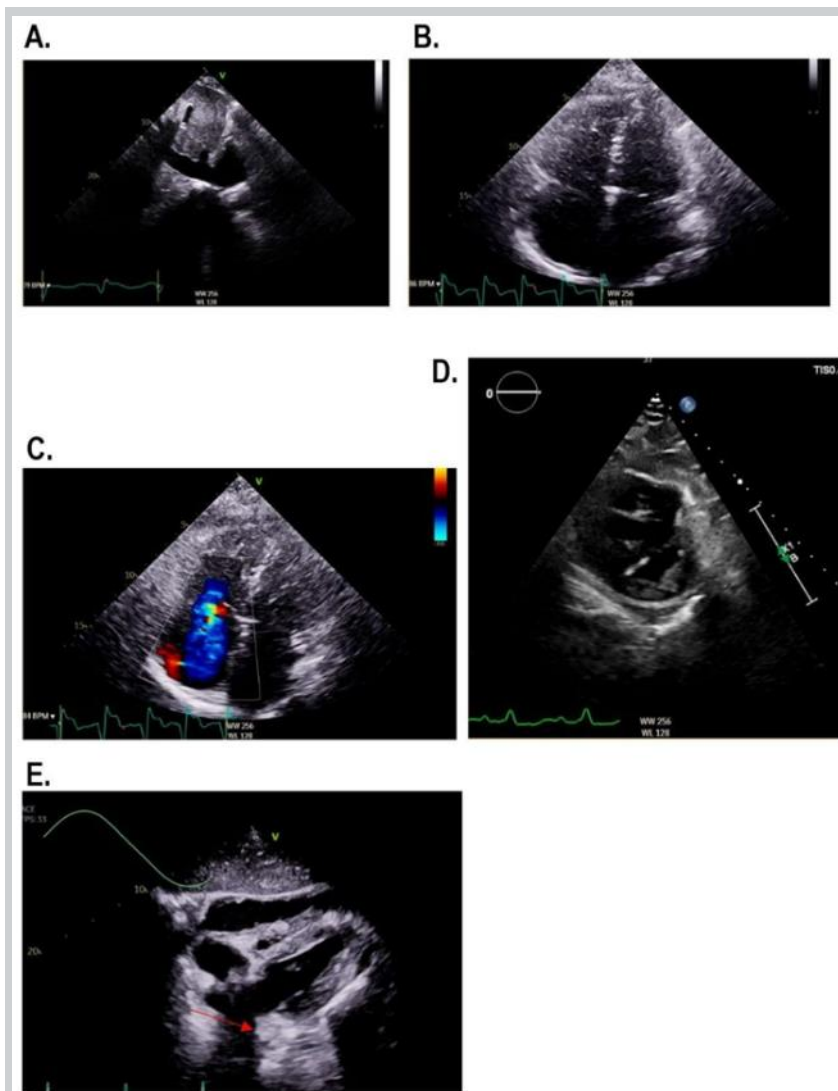


Figure 4. Abnormal point of care ultrasound (POCUS) scans of patients with PH. A) Inferior Vena Cava (IVC) Dilatation. B) Right Ventricle (RV) Dilatation. C) Severe Tricuspid Regurgitation. D) Dilated RV in the parasternal short axis. The D-shaped septum is indicative of RV pressure overload. E) Pericardial effusion.

of such a procedure. This information would still be of great importance in rural and remote communities, where transportation to an echocardiography lab may be less accessible.

## Conclusion

POCUS can supplement the physical exam during the screening for PH. Compared to echocardiography, POCUS is also more accessible in outpatient and rural/remote areas. We find that POCUS for PH should primarily involve the IVC. A cardiac and pulmonary exam are also indicated to look for RH dilatation, pleural and pericardial effusions, b-lines, and other cardiopulmonary comorbidities. Other peripheral veins such as the IJV, hepatic, portal, and intrarenal veins may be assessed if clinical suspicion is present for peripheral vascular decompensation. Basic cardiopulmonary POCUS techniques are standard across studies we reviewed, but a standardized and validated POCUS exam for PH still needs to be developed. To that end, more studies are required in both PH and primary care populations. The use of POCUS to screen for PH is still in its infancy, and this article provides a foundation on which future research can build. Nevertheless, POCUS can still serve an important role in triaging, maximizing limited echocardiographic resources, and more accurately estimating a patient's urgency in rural and remote areas.

## Disclosures

None.

## Acknowledgements

Thank you to the Cardiovascular Imaging Network at Queen's (CINQ) for the supportive environment. A special thanks is given to Kim Mitchell for her revision of this manuscript.

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# Point of Care Ultrasound for Diagnosis and Management in Heart Failure: A Targeted Literature Review

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## Abstract

**Background:** Cardiac point of care ultrasound (POCUS) has shown increasing utility as a tool for diagnosing and managing heart failure (HF). Within cardiology, intravascular volume assessment leveraging visualization of the inferior vena cava (IVC) is a central aspect of care, as IVC size correlates with central venous pressure. This targeted literature review aimed to examine the existing literature assessing the use of POCUS in diagnosis and management of HF patients utilizing POCUS-based IVC measurement either alone or in combination with secondary methods.

**Methods:** A targeted PubMed and Ovid database search up until August 28, 2023 using a keyword search was completed. Studies that did not include IVC assessment with POCUS in HF were excluded. **Results:** The initial search using both PubMed and Ovid resulted in 370 journal publications. After exclusion criteria were used 15 studies were included in the review. Studies were grouped into three categories: 1) how well POCUS was able to identify HF, 2) whether POCUS-based findings correlated with other measures evaluating HF and was able to predict the effect of diuretic administration, and 3) whether POCUS-based findings served as a good prognostic indicator. The 5 studies that evaluated HF identification with POCUS found that both diagnostic sensitivity and specificity may reach 90%-100% when IVC measurement was coupled with a lung ultrasound assessing the presence of B-lines or pleural effusion. Five studies assessing POCUS findings correlating with other HF measures and diuretic effect found that IVC diameter changed significantly with diuretic administration ( $p < 0.05$ ). All 6 studies assessing POCUS as a predictor of long-term mortality or hospital readmission found measures that achieved statistical significance with  $p < 0.05$ .

**Conclusions:** Including POCUS as standard-of-care – both as a diagnostic tool in the emergency department and a management tool in in-patient and out-patient facilities – may improve the treatment of HF.

## Introduction

Heart failure (HF) is a growing worldwide epidemic, affecting about 1-2% of the worldwide population and 2.5% of the US population [1]. The mortality rate for patients diagnosed with HF is approximately 30% after 1 year following diagnosis and 45-65% after 5 years [2]. As such, there is a pressing need to refine protocols for the management of HF, particularly in regard to its diagnosis and longitudinal management.

While traditional cart-based echocardiography is well-recognized as a critical adjunct to HF management, cardiac point of care ultrasound (POCUS) is an emerging imaging modality that can provide similar qualitative and quantitative imaging of the heart, lungs, and vasculature

at the bedside. Commercially available hand-carried ultrasound devices have been marketed for over 10 years [3], and POCUS with hand-carried ultrasound devices is currently applied in acute care settings for diagnosis of specific disease states like cardiac arrest, pneumothorax, pericardial effusion, and free intra-abdominal fluid in trauma or surgery patients [4,5].

A particularly important application of POCUS is in patients with HF. Intravascular volume status can be measured by visualizing and measuring the inferior vena cava (IVC) diameter, as well as the IVC collapsibility index (IVC-CI) which is calculated using  $(IVC_{max} - IVC_{min}) / IVC_{max}$ . An increase in the IVC diameter as well as a reduction in the IVC-CI indicate intravascular volume

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DOI: <https://doi.org/10.24908/pocus.v9i1.16795>

overload, which is associated with cardiac dysfunction and is characteristic of HF. Furthermore, central venous pressure (CVP), which increases with impairment of right ventricular functioning, is positively correlated with IVC diameter and negatively correlated with IVC-CI [6]. Possible applications of POCUS include diagnosing HF in the ED for patients presenting with dyspnea, predicting readmission and mortality outcomes for patients with HF, and serving as a more accurate management tool than brain natriuretic peptide (proBNP) levels [7] or physical assessment of volume status. While multiple studies have evaluated the benefit of utilizing POCUS in both the diagnostic and management protocols for patients with acute decompensated heart failure (ADHF), these studies have not been systematically compared and analyzed. We provide a comprehensive review of the potential of POCUS, particularly as it is used to measure IVC, for both the hospital and outpatient settings.

## Methods

We performed a targeted literature search in PubMed and Ovid (MEDLINE and Embase) with the search term “point of care ultrasound” of “hospitalized heart failure inferior vena cava” or “point of care ultrasound” of “heart failure inferior vena cava” to identify studies that evaluated the use of POCUS, particularly with IVC measurement as a benchmark, as a diagnostic and management tool for patients hospitalized with HF. Observational cohort studies and randomized controlled studies that included adults that assessed HF, used POCUS, included a measurement of the IVC as part of their methodology, and were published in English were included in our review. The studies were grouped in terms of similar research questions and methods of analysis (Supplement). For each study, we collected data on study design, patient population, and major findings. Major findings included the correlation between POCUS measurements focusing on IVC diameter and other measurement tools, as well as the ability of POCUS to diagnose HF and predict readmission or mortality. Excluded from the review were studies that did not relate to diagnosing or managing HF, studies that did not include IVC measurement, case series, and case studies.

## Results

The initial literature review with the combined databases resulted in a total of 370 journal articles. Of these, five studies were excluded because they did not assess IVC diameter; four studies focused only on lung ultrasound (US) and one study focused only on jugular vein ultrasound. Additionally, three studies were deemed outside the scope of the research objective (identifying the use of POCUS in managing HF), including one study

that investigated physician training methods for POCUS and two that analyzed the use of POCUS for managing septic shock. Five case studies and one pilot study were excluded. The remaining 337 did not encompass all of the key terms included in the search query (i.e. not including either POCUS or HF in the body of the publication), thereby making their objectives and methodology out of the scope of this review. The remaining 15 studies all assessed POCUS as a diagnostic or maintenance tool for patients with HF and included IVC measurements as part of their criteria to some capacity (Figure 1).

### *POCUS for the Diagnosis of Heart Failure*

Of the 15 studies, five assessed the diagnostic capacity of POCUS for patients presenting with acute dyspnea (AD) in the emergency department (ED), compared with the clinical gold standard for HF diagnosis defined by abnormal chest x-ray, blood tests (such as proBNP), ECG, and clinical history (Table 1). Each of these studies calculated sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (+LR), negative likelihood ratio (-LR), and accuracy. Additionally, these studies assessed the diagnostic capability of various combinations of measurement parameters determined using POCUS. These included IVC and IVC-CI, lung US measures such as B-line count (BLC) and B-zones (BBPC), left ventricular ejection fraction (LVEF), and abnormal or dilated cardiac chamber geometry. The presence of B-lines in the thorax – and, if in multiple thoracic zones, B-zones – indicates edema and left ventricular dysfunction i.e. reduced ejection fraction) [8]. All studies showed similar measurement methods as well as diagnostic cut-off points.

Table 1 shows that the specificity of several measures and their combinations was increased relative to their sensitivity. Miller et al. have demonstrated that as the cut-off for IVC-CI increases, the sensitivity of this measure increases while its specificity decreases. However, the particularly high +LR of 12.3 for an IVC-CI cut-off <10% suggests a potentially optimal cutoff for HF [9]. Throughout all the studies, the highest seen sensitivity, specificity, PPV, and NPV were generally any combination of IVC-CI, LVEF, and lung US measures of BLC and bilateral B-pattern count (BBPC). Carlino et al. showed that any combination of the presence of bilateral ischemia (IS) (defined as  $\geq 3$  BLC), pleural effusion (PE) (defined as hypoechoic space between the two pleural walls), or a dilated left atria outperformed traditional diagnostic tools such as pro-BNP or chest x-ray in sensitivity, specificity, and accuracy [10].

Overall, the results show higher sensitivity and specificity

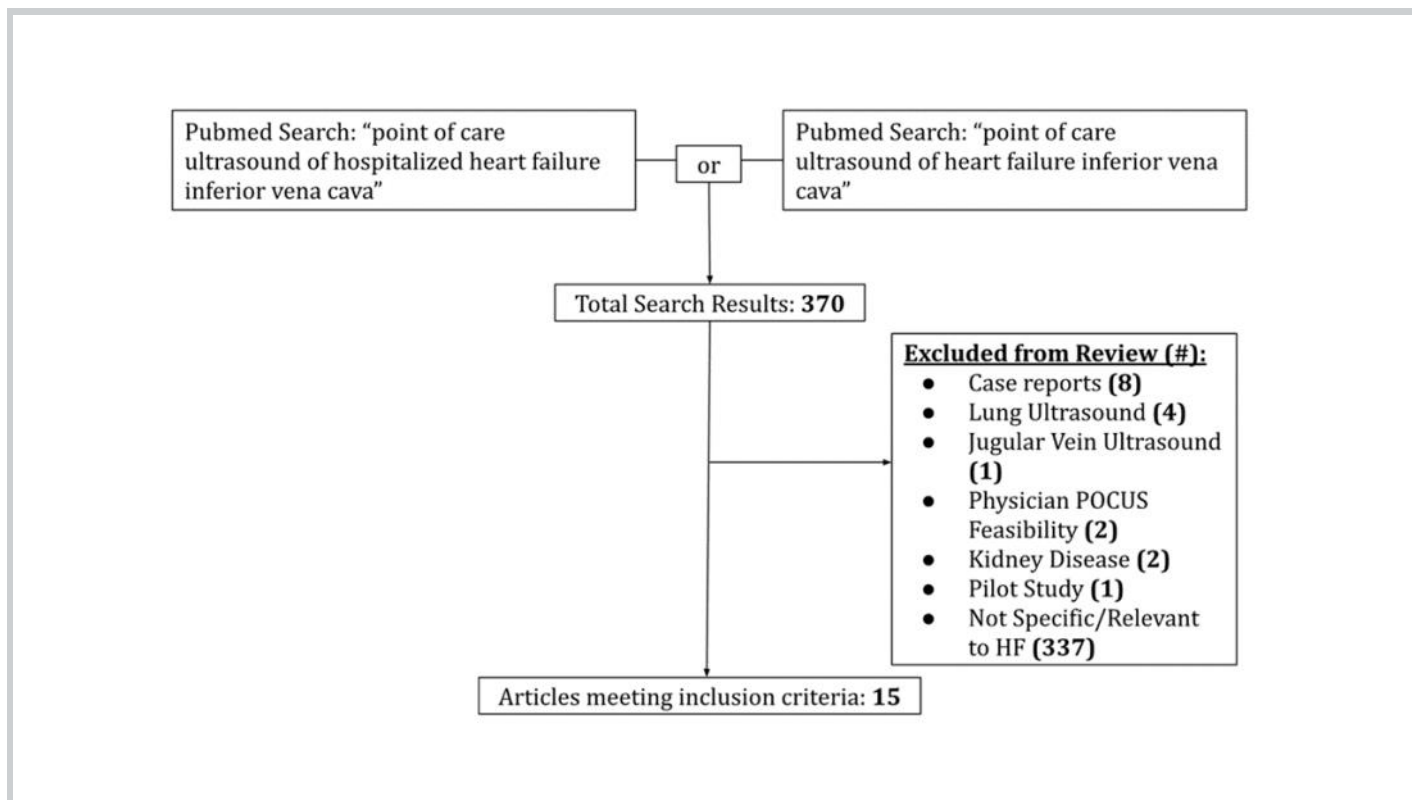


Figure 1. Search criteria figure. Results from targeted PubMed literature search using search terms “point of care ultrasound” of “hospitalized heart failure inferior vena cava” or “point of care ultrasound” of “heart failure inferior vena cava”

in the diagnosis of HF with the use of POCUS compared to standard of care, specifically when combining cardiac, vascular, and lung US protocols and when utilizing conventional cut-off values for each parameter. The studies collectively showed that the specificity of POCUS was greater than its sensitivity, except for the caval-aortic ratio [9]. The data indicates that the diagnostic power of POCUS is maximized upon the combination of IVC, LVEF, BLC, and BBPC, effectively utilizing both cardiac and lung radiography.

#### *POCUS for the Management of Heart Failure*

Ten studies evaluated the utilization of POCUS for the management of known HF patients (Table 2). Five of these studies compared the parameters measured with POCUS, primarily IVC measurement, with other variables using Spearman or Pearson tests. These reference variables included clinical assessment of volume status change (based on the resolution of peripheral edema) following administration or adjustment of diuretic dose as well as comparison to volume status determined from physical examination and reference echocardiography measurements. While most studies assessed the correlation between POCUS and the reference variables, Tchernodrinski et al. and Hacialioğulları et al. assessed the change in IVC diameter relative to baseline at various

time points following diuretic administration [14,15]. The reliability of POCUS as a tool compared to other methods of assessing volume status was tested by Nixon et al. and Dalen et al. Nixon et al. found a significant correlation between physical volume assessment and POCUS IVC<sub>d</sub> measurements [13], and Dalen et al. found a significant correlation between POCUS and baseline echocardiography measurements of IVC<sub>max</sub>, IVC<sub>min</sub>, and determination of PE [16].

Tchernodrinski et al. and Hacialioğulları et al. both assessed the ability of POCUS to identify a sonographic change in volume status of patients with HF following intravenous diuretic administration, with Tchernodrinski et al. identifying a significant change in IVC<sub>max</sub> both 1-2 hours and 3-4 hours following the treatment [14]. Hacialioğulları et al. found similar results 3 hours following treatment not only for IVC<sub>min</sub>, IVC<sub>max</sub>, and IVC-Cl, but also for the presence of B-lines in both right and left lung zones [15]. During both the initial visit and follow-up, Gundersen et al. observed a correlation between POCUS-determined volume status (hypovolemic, hypovolemic, or euvolemic) and the alteration of diuretic dose, and a weak correlation between IVC<sub>max</sub>, IVC-Cl, or the presence of PE and diuretic dosing (all p-values <0.05). Overall, these ultrasound parameters strongly correlated with nurse-assessed physical volume status



Table 1. Sensitivity, specificity, and other associated diagnostic statistics of various POCUS parameters used to diagnose patients with HF [9-13]. Number of patients included in each study included in parentheses.

| Study (# of patients) | Diagnostic Parameter     | Cut-point   | Sensitivity (95%CI) | Specificity (95% CI) | Positive Predictive Value (PPV) | Negative Predictive Value (NPV) | +LR           | -LR  | Accuracy |
|-----------------------|--------------------------|-------------|---------------------|----------------------|---------------------------------|---------------------------------|---------------|------|----------|
| Miller et al (89)     | IVC-CI                   | <10%        | 22%(11%-41%)        | 98%(89%-99%)         | N/A                             | N/A                             | 12.3          | 0.79 | N/A      |
|                       |                          | <15%        | 37%(22%-55%)        | 96%(86%-99%)         | N/A                             | N/A                             | 10            | 0.64 | N/A      |
|                       |                          | <25%        | 69%(51%-83%)        | 89%(77%-95%)         | N/A                             | N/A                             | 6.2           | 0.35 | N/A      |
|                       |                          | <33%        | 80%(63%-91%)        | 81%(68%-90%)         | N/A                             | N/A                             | 4.2           | 0.25 | N/A      |
|                       |                          | <40%        | 91%(76%-98%)        | 76%(62%-86%)         | N/A                             | N/A                             | 3.8           | 0.11 | N/A      |
|                       |                          | <50%        | 94% (79%-99%)       | 59% (45%-72%)        | N/A                             | N/A                             | 2.3           | 0.09 | N/A      |
|                       | Caval-aortic Ratio       | >0.4        | 99%(89%-100%)       | 2%(1%-10%)           | N/A                             | N/A                             | 1             | 0.51 | N/A      |
|                       |                          | >0.6        | 94%(77%-99%)        | 13%(5%-26%)          | N/A                             | N/A                             | 1.1           | 0.46 | N/A      |
|                       |                          | >0.8        | 84%(68%-95%)        | 52%(37%-66%)         | N/A                             | N/A                             | 1.8           | 0.32 | N/A      |
|                       |                          | >1.0        | 57%(39%-74%)        | 81%(67%-90%)         | N/A                             | N/A                             | 3             | 0.54 | N/A      |
|                       |                          | >1.2        | 33%(18%-52%)        | 96%(86%-99%)         | N/A                             | N/A                             | 8.3           | 0.69 | N/A      |
|                       |                          | >1.4        | 9%(2%-24%)          | 98%(90%-100%)        | N/A                             | N/A                             | 4.5           | 0.63 | N/A      |
| Farahamd et al. (120) | LVEF                     | < 45%       | 89.5%               | 92.1%                | 91.1%                           | 90.6%                           | N/A           | N/A  | N/A      |
|                       | IVC-CI                   | < 20%       | 35.1%               | 93.7%                | 83.3%                           | 61.5%                           | N/A           | N/A  | N/A      |
|                       | BLC                      | ≥10 B-lines | 73.7%               | 95.2%                | 93.3%                           | 80.0%                           | N/A           | N/A  | N/A      |
|                       | BBPC                     | ≥ 2 zones   | 78.9%               | 93.7%                | 91.8%                           | 83.1%                           | N/A           | N/A  | N/A      |
|                       | LVEF and IVC-CI          |             | 33.3%               | 98.4%                | 95.0%                           | 62.0%                           | N/A           | N/A  | N/A      |
|                       | LVEF and BLC             |             | 68.4%               | 98.4%                | 97.55                           | 77.5%                           | N/A           | N/A  | N/A      |
|                       | LVEF and BBPC            |             | 73.7%               | 96.8%                | 95.5%                           | 80.3%                           | N/A           | N/A  | N/A      |
|                       | IVC-CI and BLC           |             | 33.3%               | 98.4%                | 95.0%                           | 62.0%                           | N/A           | N/A  | N/A      |
|                       | IVC-CI and BBPC          |             | 33.3%               | 98.4%                | 95.0%                           | 62.0%                           | N/A           | N/A  | N/A      |
|                       | BLC and BBPC             |             | 73.7%               | 95.2%                | 93.3%                           | 80.0%                           | N/A           | N/A  | N/A      |
|                       | LVEF and IVC-CI and BBPC |             | 31.6%               | 98.4%                | 94.7%                           | 61.4%                           | N/A           | N/A  | N/A      |
| Carlino et al (102)   | Chest x-ray              | Chest x-ray |                     | 64.9% (47-79)        | 88.5% (77-95)                   | 77.4% (59-90)                   | 80.6% (69-89) | N/A  | 79.6%    |
|                       | NT-pro-BNP               | NT-pro-BNP  |                     | 80% (63-91)          | 69.7% (51-84)                   | 73.7% (57-86)                   | 76.7% (57-89) | N/A  | 75%      |

| Study (# of patients)       | Diagnostic Parameter   | Cut-point   | Sensitivity (95% CI) | Specificity (95% CI) | Positive Predictive Value (PPV) | Negative Predictive Value (NPV) | +LR                  | -LR               | Accuracy |
|-----------------------------|--|---|----------------------|----------------------|---------------------------------|---------------------------------|----------------------|-------------------|----------|
| Carlino et al (102) (Cont.) | Bilateral IS and/or effusion                                   | ≥3 B-lines; hypoanechoic space between parietal and visceral pleura | 100% (89-1000)       | 82% (70-90)          | 78% (64-88)                     | 100% (91-100)                   | N/A                  | N/A               | 89%      |
|                             | Dilated LA   | Eyeball evaluation (anteroposterior diameter >4 cm)                 | 92.3% (78-98)        | 77% (64-87)          | 72% (57-83)                     | 94% (83-98)                     | N/A                  | N/A               | 83%      |
|                             | LVEF   | ≤ 40%   | 59% (42-74)          | 90.2% (79-96)        | 79.3% (60-91)                   | 77.5% (66-86)                   | N/A                  | N/A               | 78%      |
|                             | Dilated LV   | Eyeball evaluation  | 38.5% (24-55)        | 91.8% (81-97)        | 75% (51-90)                     | 70% (59-80)                     | N/A                  | N/A               | 71%      |
|                             | Abnormal LV geometry   | Eyeball evaluation  | 84.6% (69-94)        | 80.3% (68-89)        | 73.3% (58-85)                   | 89.1% (77-96)                   | N/A                  | N/A               | 82%      |
|                             | IVC <sub>d</sub> ; IVC-CI                                      | Eyeball evaluation >2 cm; <50%                                      | 69.2% (52-83)        | 70.5% (57-81)        | 60% (44-74)                     | 78.2% (65-88)                   | N/A                  | N/A               | 70%      |
|                             | Bilateral IS and/or effusion & EF                              |   | 59% (42-74)          | 100% (93-100)        | 100% (82-100)                   | 79.2% (68-87)                   | N/A                  | N/A               | 84%      |
|                             | Bilateral IS and/or effusion & dilated LA                      |   | 94.9% (81-99)        | 93.4% (83-98)        | 90.2% (76-97)                   | 96.6% (87-99)                   | N/A                  | N/A               | 94%      |
|                             | Bilateral IS and/or effusion & either EF or dilated LA or both |   | 100% (89-100)        | 93.4% (83-98)        | 90.7% (77-97)                   | 100% (92-100)                   | N/A                  | N/A               | 96%      |
| Zanobetti et al (2683)      | LUS ECHO IVC*  |   | 88% (85.1-90.6)      | 96% (95-96.8)        | 85.8% (82.8-88.5)               | 96.6% (95.8-97.4)               | 21.73% (17.61-26.82) | 0.12% (0.10-0.16) | N/A      |

IVC-CI = Inferior vena cava collapsibility index.

Caval-aortic Ratio = Ratio of inferior vena caval diameter to aortic diameter.

LVEF = left ventricular ejection fraction.

BLC = B-line count.

BBPC = Bilateral B-pattern count.

NT-pro-BNP = N-terminal prohormone of brain natriuretic peptide.

IS = Ischemia.

LA = Left atria.

LV = Left ventricle.

IVC<sub>d</sub> = Average inferior vena cava diameter

LUS = Lung ultrasound.

ECHO = Echocardiogram.

\* = In addition, Zanobetti et al. reported an optimal concordance between ultrasound and ED diagnoses for HF of  $0.8 < < 1$ , while significantly more sensitive (88% vs. 77%;  $P < 0.001$ ), and significantly faster in forming a diagnosis ( $24 \pm 10$  min vs.  $186 \pm 72$  min;  $P = 0.025$ ). The difference in specificity between the two was insignificant (96% vs. 98%;  $P < 0.001$ ).

Table 2. Correlations between POCUS parameters and various comparison variables as well as evaluation of POCUS parameter change following diuretic administration [14-18]. Number of patients included in each study included in parentheses .

| Study (# of patients)         | Comparison Variable                                   | Diagnostic Parameter           | Time-point                       | Correlation Coefficient <i>r</i> / Coefficient of Determination $R^2$ | P-Value  |
|-------------------------------|---|--------------------------------|----------------------------------|---|----------|
| Tchernodriniski et al. (70)   | Administration of intravenous diuretic                | IVC <sub>max</sub>             | 1-2 hrs following administration | N/A   | <0.0001* |
|                               |   |                                | 3-4 hrs following administration |   | <0.0001* |
| Nixon et al.(150)             | Physical Volume Assessment                            | IVC <sub>d</sub>               | N/A                              | r=0.46  | 0.000    |
| Gundersen et al.(62)          | Diuretic Dose Adjustment                              | Volume Status based on POCUS   | First visit                      | $R^2=0.375$   | <0.001   |
|                               |   |                                | Follow-up                        | $R^2=0.391$   | <0.001   |
|                               |   | IVC-CI Score                   | First visit                      | $R^2=0.207$   | <0.001   |
|                               |   |                                | Follow-up                        | $R^2=0.062$   | <0.001   |
|                               |   | IVC <sub>max</sub> Score       | First visit                      | $R^2=0.115$   | 0.01     |
|                               |   |                                | Follow-up                        | $R^2=0.186$   | <0.001   |
|                               |   | PE                             | First visit                      | $R^2=0.09$  | 0.02     |
|                               |   |                                | Follow-up                        | $R^2=0.13$  | <0.01    |
|                               | Volume Status   | IVC <sub>max</sub>             | N/A                              | r=0.67  | <0.001   |
|                               |   | PE                             |                                  | r=0.67  | <0.001   |
| Dalen et al. (62)             | Reference Echocardiography Measurements (Reliability) | IVC <sub>max</sub>             | N/A                              | r = 0.89  | <0.001   |
|                               |   | IVC <sub>min</sub>             |                                  | r = 0.79  | <0.001   |
|                               |   | PE, left                       |                                  | r = 0.95  | <0.001   |
|                               |   | PE, right                      |                                  | r = 0.97  | <0.001   |
|                               |   | PE, both cavities              |                                  | r = 0.96  | <0.001   |
| Hacialisioğulları et al. (80) | Treatment following initial HF diagnosis in the ED †  | IVC <sub>max</sub>             | 3 hours following administration | N/A   | <0.001   |
|                               |   | IVC <sub>min</sub>             |                                  |   | <0.001   |
|                               |   | IVC-CI                         |                                  |   | <0.001   |
|                               |   | B-lines (left and right zones) |                                  |   | <0.001   |

\* = Comparison was made between diagnostic parameter measurements at different time-points compared to baseline, rather than to a reference variable.

† = Treatment included intravenous furosemide at 80 ± 30 mg for all patients, nitroglycerin for 27 (33.8%), additional drugs (β blocker, calcium channel blocker, digital medicine, etc.) for 7 (8.8%), and noninvasive mechanical ventilation for 20 (25%).

Gundersen scoring (end-expiratory dimension scores 1, 2 and 3 refer to IVC<sub>max</sub> <1.7 cm, 1.7–2.1 cm and >2.1 cm, respectively, and for the IVC-CI scores 1, 2 and 3 refer to ≥50%, 35-50% and <35%, respectively).

IVC<sub>max</sub> = Maximum diameter of the inferior vena cava during end expiration.

IVC<sub>d</sub> = Diameter of the inferior vena cava (unspecified if min or max or average).

IVC<sub>min</sub> = Minimum diameter of the inferior vena cava during inhalation.

PE = Pulmonary effusion.

IVC-CI = Inferior vena cava collapsibility index.

and showed improvement with the administration of diuretics [17]. The utilization of POCUS parameters in the management of HF produces more definite results than a physical examination by providing a reference quantitative measurement, which can be used to evaluate the effect of diuresis.

#### *Heart Failure Outcomes Prediction by POCUS*

Akhabue et al., Khandwalla et al., Torres et al., Gustaffson et al., Goonewardena et al., and Hacıaloğulları et al. each evaluated the ability of POCUS to predict outcomes of patients with HF including readmission and composite endpoints of combined readmission or death (Table 3). The examined populations included adults who had been hospitalized for HF. The average age of these patients in each study was over 65, and the patient populations were well-diversified in both gender and race. Statistical methods for analysis included t-tests comparing outcomes as well as time-points (initial data collection vs. follow-up), ROC and Kaplan-Meier curves, and hazard, odds, and risk ratio calculations. Longitudinal studies analyzing survival and readmission likelihood assessed patients at two time points, comparing POCUS measurements at admission vs. discharge or at discharge vs. an outpatient follow-up visit within a year after discharge.

When comparing differences between outcome groups, Akhabue et al. found that differences in IVC-CI values were not significant between the no rehospitalization outcome vs. the rehospitalization and/or death outcome at discharge. However, the difference between the outcomes was significant at follow-up, indicating that POCUS is a better predictor of longevity at some time following the initial hospitalization event [19] (Table 3). Goonewardena et al. found IVC-CI was significant at discharge when applying a cut-off value for IVC-CI at <50% [20]. Furthermore, Akhabue et al. found that  $IVC_{max}$  was not significant between readmission/death and no readmission groups both at discharge and follow-up. However, when utilizing a cut-off point of >2.0 cm, the  $IVC_{max}$  differences between readmission/death vs. no readmission outcomes were significant both between admission and discharge [20] as well as between discharge and follow-up [19]. This is supported by Khandwalla et al., who found a non-significant difference in  $IVC_{max}$  values between patient groups with or without a previous HF hospitalization when a cut-off value was not utilized, despite a significant difference between  $IVC_{min}$  and  $IVC_{avg}$  values between the two groups [21].

When considering differences between time points, Akhabue et al. found a significant difference in  $IVC_{max}$  at discharge and follow-up for patients who were not readmitted [19]. Goonewardena et al. also demonstrated

that utilizing an IVC cut-off value rendered a significant difference between readmission vs. no readmission outcomes for IVC-CI – in addition to pro-BNP – at discharge, while  $IVC_{max}$  was not significant both at admission and discharge. They suggested that the prognostic capacity of IVC measurements with POCUS is greater or at minimum equal to that of proBNP [20]. Furthermore, Hacıaloğulları et al. found a significant difference in the  $IVC_{max}$  and  $IVC_{min}$  between HF patients who were discharged from the ED and those who were hospitalized during the initial scan taken in the ED, with mean  $IVC_{min}$  differences remaining significant following treatment administration during the final POCUS scan. POCUS of the right lung lobe also produced significant differences between these two outcomes during the initial and final scans. However, ejection fraction (EF) and BNP level differences remained non-significant [15].

Akhabue et al. observed a significant increase in the area under the ROC curve between discharge and follow-up for overall  $IVC_{max}$  values, the change between  $IVC_{max}$  values between discharge and follow-up, and IVC-CI values with a cut-point of <42% [19]. The predictive power of IVC measurements is further supported by the findings of Goonewardena et al., who noted large areas under ROC curve for an  $IVC_{max} > 2.0$  cm,  $IVC-CI < 38\%$ , and  $proBNP > 2,327$ . Goonewardena et al. also found an odds ratio of 6.1 for  $logBNP$  levels > 3.367 and 10.3 for an  $IVC_{max} > 2.0$  cm [20].

When evaluating survival, Torres et al. found a significant difference in patients below the cut-off value of  $IVC_{max} \geq 2.3$  cm vs. patients above the cut-off, as well as for patients both above the  $IVC_{max}$  cut-off and below the mean arterial pressure (MAP) cut-off of < 93.3 mmHg independent of echo-based LVEF [22]. Khandwalla et al. found an increased risk ratio for patients with a mean IVC between 2.0 cm and 2.5 cm, and an additional 14% and 38% increased risk seen with IVC diameters 0.2 cm and 0.5 cm above 2.5 cm respectively in the risk of HF hospitalization ( $p < 0.05$ ) [21]. However, Gustaffson et al. did not observe a significant difference in patients above or below an  $IVC_{max}$  cut-off of >1.8 cm, but found a significantly reduced survival for patients determined to have either comet tail artifacts (CTA) and/or PE [23]. Akhabue et al. found a significantly greater hazard ratio of 6.8 for patients with an  $IVC-CI < 42\%$  [19].

Four studies – Khandwalla et al., Torres et al., Gustafsson et al., and Goonewardena et al. – determined the correlation coefficient between POCUS measurements and  $proBNP/logBNP$  levels, New York Heart Association (NYHA) class, atrial fibrillation, and chronic ischemic heart disease. The results used were those adjusted for other variables such as mean weight,

Table 3. Collection of statistical measures assessing the ability of POCUS in the assessment of hospitalization or combined hospitalization and mortality [15, 19-23]. Number of patients included in each study included in parentheses.

| Study (# of patients)   | Outcome                                   | Diagnostic Parameter        | Cut-Point | Time-Point | P-value Between Outcomes (<0.05) | P-value Between Time Points (<0.05)            | Area under ROC or Kaplan-Meier Curve/p-value  | Hazard Risk Ratio/Odds ratio (95%CI) |                  |
|-------------------------|---|-----------------------------|-----------|------------|----------------------------------|--|---|--------------------------------------|------------------|
| Akhabue et al. (49)     | Readmission or death vs no-readmission    | IVC <sub>max</sub>          | >2.1 cm   | Discharge  | NS                               |  | With Cut-Point: 0.57<br>Without Cut-Point: 0.58   | N/A                                  |                  |
|                         |   |                             |           | Follow-up  | NS                               | Readmission/death: NS<br>No readmission: 0.038 | With Cut-Point: 0.60<br>Without Cut-Point: 0.66<br>Change between Discharge and Follow-up: 0.65 | N/A                                  |                  |
|                         |   | IVC-CI                      | <50%      | Discharge  | NS                               |  | With Cut-Point: 0.62<br>Without Cut-Point: 0.69   | N/A                                  |                  |
|                         |   |                             |           | Follow-up  | 0.040                            | Readmission/death: NS<br>No readmission: NS    | With Cut-Point: 0.60<br>Without Cut-Point: 0.66<br>Change between Discharge and Follow-up: 0.59 | N/A                                  |                  |
| Khandwalla et al. (355) | 1+ hospitalization vs. no hospitalization | IVC <sub>max</sub> + IVC-CI | N/A       | Discharge  | N/A                              | N/A  | With Cut-Point: N/A<br>Without Cut-Point: 0.66  | N/A                                  |                  |
|                         |   |                             |           | Follow-up  |                                  |  | With Cut-Point: N/A<br>Without Cut-Point: 0.72  | N/A                                  |                  |
|                         |   | Mean IVC <sub>d</sub>       | N/A       | N/A        | N/A                              | <0.01  | N/A   | N/A                                  | 1.0              |
|                         |   |                             |           |            |                                  |  |   |                                      | 1.79 (1.27-2.52) |
|                         |   |                             |           |            |                                  |  |   |                                      | 2.39 (1.55-3.67) |
|                         |   |                             |           |            |                                  |  |   |                                      | 1.14 (1.06-1.21) |
|                         |   |                             |           |            |                                  |  |   |                                      | 1.38 (1.16-1.62) |
|                         |   |                             |           |            |                                  |  |   |                                      | 1.89 (1.36-2.64) |
|                         |   | IVC <sub>max</sub>          | N/A       | N/A        | N/A                              | NS   | N/A   | N/A                                  | 1.02 (0.96-1.10) |
|                         |   |                             |           |            |                                  |  |   |                                      | 1.06 (0.90-1.26) |
| 1.13 (0.81-1.58)        |   |                             |           |            |                                  |  |   |                                      |                  |
|                         |   |                             |           |            |                                  |  |   |                                      |                  |

| Study (# of patients)    | Outcome  | Diagnostic Parameter | Cut-Point                    | Time-Point | P-value Between Outcomes (<0.05) | P-value Between Time Points (<0.05) | Area under ROC or Kaplan-Meier Curve/p-value | Hazard Risk Ratio/Odds ratio (95%CI)   |   |
|--------------------------|--|----------------------|------------------------------|------------|----------------------------------|-------------------------------------|--|--|---|
| Khandwalla et al. (355)  | 1+ hospitalization vs. no hospitalization                | IVC <sub>min</sub>   | Per 0.2 cm increase          | N/A        | <0.01                            | N/A                                 | N/A  | 1.13 (1.07-1.19)   |   |
|                          |  |                      | Per 0.5 cm increase          |            |                                  |                                     |  | 1.36 (1.19-1.54)   |   |
|                          |  |                      | Per 1.0 cm increase          |            |                                  |                                     |  | 1.84 (1.42-2.38)   |   |
| Torres et al. (123)      | Mortality vs. no mortality                               | IVC <sub>max</sub>   | ≥ 2.3 cm                     | N/A        | N/A                              | N/A                                 | P-value: 0.0070                              | <b>Univariate:</b> 1.06 (1.02-1.11)  |   |
|                          |  |                      | ≥ 2.3 cm and MAP < 93.3 mmHg |            |                                  |                                     |  | P-value: 0.0003  | <b>Multivariate:</b> 1.06 (1.01-1.10)                           |
| Gustafsson et al (104)   | Hospitalization or death vs. no hospitalization or death | LVEF                 | N/A                          | N/A        | N/A                              | N/A                                 | N/A  | <b>Univariate:</b> 0.98 (0.96-1.00)<br><b>Multivariate:</b> 0.98 (0.96-1.00) |   |
|                          |  | IVC <sub>max</sub>   | >1.8 cm                      | N/A        | N/A                              | N/A                                 | N/A  | N/A  |   |
|                          |  | CTA                  | >3 comet tails               | N/A        | N/A                              | N/A                                 | N/A  | N/A  | <b>Model 1:</b> 3.5 (1.5-7.9)<br><b>Model 2:</b> 2.9 (1.3-6.6)  |
|                          |  | PE                   | Present vs. absent           | N/A        | N/A                              | N/A                                 | N/A  | N/A  | <b>Model 1:</b> 3.9 (1.4-10.8)<br><b>Model 2:</b> 1.9 (0.6-6.2) |
|                          |  | CTA or PE            |                              | N/A        | N/A                              | N/A                                 | N/A  | N/A  | <b>Model 1:</b> 3.7 (1.6-8.5)<br><b>Model 2:</b> 4.9 (1.2-20.1) |
|                          |  | BNP                  | 2,327                        | Admission  | N/A                              | N/A                                 | N/A  | 0.69   | N/A   |
| Goonewardena et al. (75) | Readmission vs No Readmission                            | logBNP               | 3,367                        | Admission  | 0.28                             | N/A                                 | N/A  | Odds: 6.1  |   |
|                          |  |                      |                              | Discharge  | 0.04                             | N/A                                 | N/A  |  |   |
|                          |  | IVC <sub>max</sub>   | >2.0 cm                      | Admission  | 0.02                             | N/A                                 | N/A  | 0.78   | Odds: 10.3  |
|                          |  |                      |                              | Discharge  | 0.001                            | N/A                                 | N/A  |  |   |
|                          |  | IVC <sub>min</sub>   | N/A                          | Admission  | 0.03                             | N/A                                 | N/A  | N/A  | N/A   |
|                          |  |                      |                              | Discharge  | <0.001                           | N/A                                 | N/A  | N/A  |   |
| IVC-CI                   | <50%   | Admission            | 0.10                         | N/A        | N/A                              | 0.74                                | N/A  |  |   |
|                          |  | Discharge            | 0.002                        | N/A        | N/A                              |                                     |  |  |   |

| Study (# of patients)      | Outcome                                     | Diagnostic Parameter | Cut-Point     | Time-Point   | P-value Between Outcomes (<0.05) | P-value Between Time Points (<0.05) | Area under ROC or Kaplan-Meier Curve/p-value | Hazard Risk Ratio/Odds ratio (95%CI) |     |
|----------------------------|---|----------------------|---------------|--------------|----------------------------------|-------------------------------------|--|--------------------------------------|-----|
| Hacıaloğulları et al. (80) | Discharged from ED vs. Admitted to hospital | BNP                  | N/A           | N/A          | NS                               | N/A                                 | N/A  | N/A                                  |     |
|                            |   | EF %                 | N/A           | N/A          | NS                               | N/A                                 | N/A  | N/A                                  |     |
|                            |   | IVC <sub>max</sub>   | N/A           | Initial Scan | 0.042                            | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   |                      |               |              | NS                               | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   | IVC <sub>min</sub>   | N/A           | Initial Scan | 0.014                            | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   |                      |               |              | 0.025                            | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   | IVC-CI               | N/A           | Initial Scan | NS                               | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   |                      |               |              | NS                               | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   | Right Lung Zones     | N/A           | Initial Scan | Zone 1: 0.016                    | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   |                      |               |              | Zone 2:0.01                      | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   |                      |               |              | Zone 3: NS                       | N/A                                 | N/A  | N/A                                  | N/A |
|                            |   | Left Lung Zones      | N/A           | Initial Scan | Zone 1: 0.001                    | N/A                                 | N/A  | N/A                                  | N/A |
| Zone 2:0.012               | N/A   |                      |               |              | N/A                              | N/A                                 | N/A  |                                      |     |
| Zone 3:0.006               | N/A   |                      |               |              | N/A                              | N/A                                 | N/A  |                                      |     |
| PE: Right and Left         | N/A   | Initial Scan         | Zone 1: 0.028 | N/A          | N/A                              | N/A                                 | N/A  |                                      |     |
|                            |   |                      | Zone 2: NS    | N/A          | N/A                              | N/A                                 | N/A  |                                      |     |
| PE: Right and Left         | N/A   | Initial Scan         | Zone 3: NS    | N/A          | N/A                              | N/A                                 | N/A  |                                      |     |
|                            |   |                      | Zone 1: 0.004 | N/A          | N/A                              | N/A                                 | N/A  |                                      |     |
| PE: Right and Left         | N/A   | Initial Scan         | Zone 2:NS     | N/A          | N/A                              | N/A                                 | N/A  |                                      |     |
|                            |   |                      | Zone 3:NS     | N/A          | N/A                              | N/A                                 | N/A  |                                      |     |
| PE: Right and Left         | N/A   | Initial Scan         | NS            | N/A          | N/A                              | N/A                                 | N/A  |                                      |     |
|                            |   |                      | NS            | N/A          | N/A                              | N/A                                 | N/A  |                                      |     |

IVC<sub>max</sub> = Maximum inferior vena cava diameter during end expiration. Mean IVC<sub>d</sub> = Average inferior vena cava diameter during the respiration cycle  
 IVC-CI = Inferior vena cava collapsibility index. CTA = comet tail artifact  
 IVC<sub>min</sub> = Minimum inferior vena cava diameter during inhalation. PE = pulmonary effusion  
 BNP = Brain natriuretic peptide  
 logBNP = logarithm of brain natriuretic peptide value  
 EF % = ejection fraction in percentage

age, and atrial fibrillation.

These studies determined significant, but weak, correlations between IVC<sub>d</sub> and proBNP/logBNP levels, as well as between CTA or PE and proBNP/logBNP levels. Additionally, Gustaffson et al. found a similar correlation between CTA or PE and NYHA class [23], while Torres et al. found a weak positive correlation between IVC<sub>max</sub> and atrial fibrillation as well as a weak negative correlation between chronic ischemic cardiac disease [22].

**Discussion**

The collection of evidence from this review suggests that IVC diameter assessment with POCUS is a useful diagnostic tool in terms of both sensitivity and specificity compared to historical methods utilized for patients presenting with AD in the ED. IVC measurement and IVC-CI calculations are particularly effective in determining diagnosis when complemented with lung ultrasound examining B-lines and the presence of PE. Despite loosely correlating with other HF markers such as

physical examination assessment of volume status and pro-BNP, POCUS IVC and IVC-CI demonstrate effects of diuretic administration, making them a quick, non-invasive, and relatively easy method to assess treatment effect for both hospitalized and outpatient HF patients (Figure 2).

Furthermore, IVC diameter measurements, particularly when coupled with a lung ultrasound scan, may serve as a prognostic tool in predicting readmission or mortality in hospitalized HF patients. The results from Table 3 show that an IVC > 2.0 cm is generally associated with significantly increased risk; this is corroborated by Akhabue et al. who found the same for a calculated IVC-CI < 42%. Studies evaluating the predictive ability of POCUS also found that the presence of significant interstitial lung fluid (defined as >3 B-lines) and/or PE in the thoracic cavity reflects worse patient prognosis. As POCUS becomes fully integrated as a standard of care for hospitalized HF patients, these markers can signal the need for more intensive patient monitoring and treatment plans. While Goonewardena et al. show that

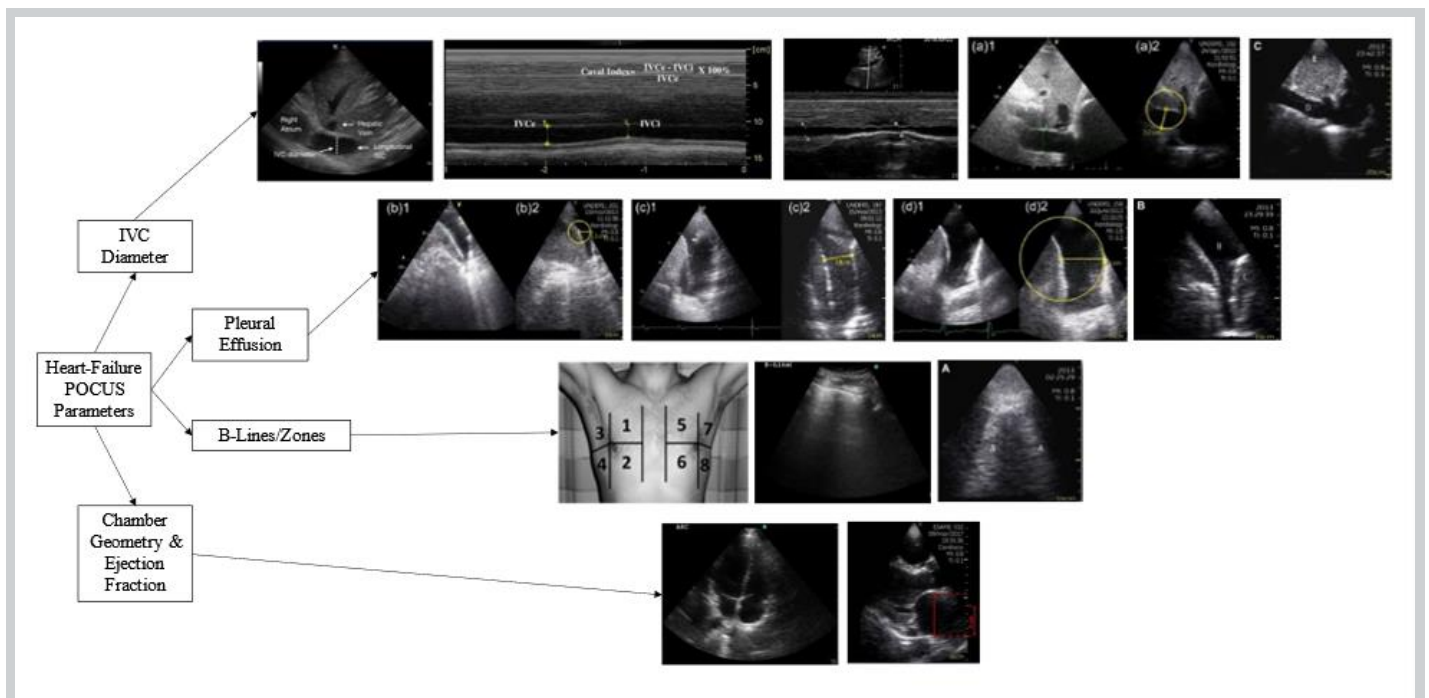


Figure 2. Collection of Images Presented Using Selected POCUS Measurement Parameters. Top to Bottom: IVC Diameter, PE, B-Lines/Zones, Chamber Geometry & Ejection Fraction. Left to Right Row 1 Miller et al., localization of IVC and IVC-CI calculation in M-Mode; Farahmand et al., IVC diameter measurement in M-mode; Dalen et al., end-expiratory IVC diameter (IVC<sub>max</sub>); Gustaffson et al., IVC diameter measurement. Left to Right Row 2 Gundersen et al., PE in the cost diaphragmatic angle, lower lobes bulging into the effusion, and a significant excess of PE; Gustaffson et al., bilateral PE in the infrascapular region. Left to Right Row 3 Anderson et al, demarcation of the 8 thoracic zones considered in B-zone scoring; Farahmand et al., One B-line in the superior anterior right zone; Gustaffson et al., multiple B-lines/comet tail artifacts. Left to Right Row 4 Farahmand et al., 4-chamber view used to estimate ejection fraction; Carlino et al., Anteroposterior diameter of dilated left atrium in the parasternal long-axis view [9,10,12, 16, 22].



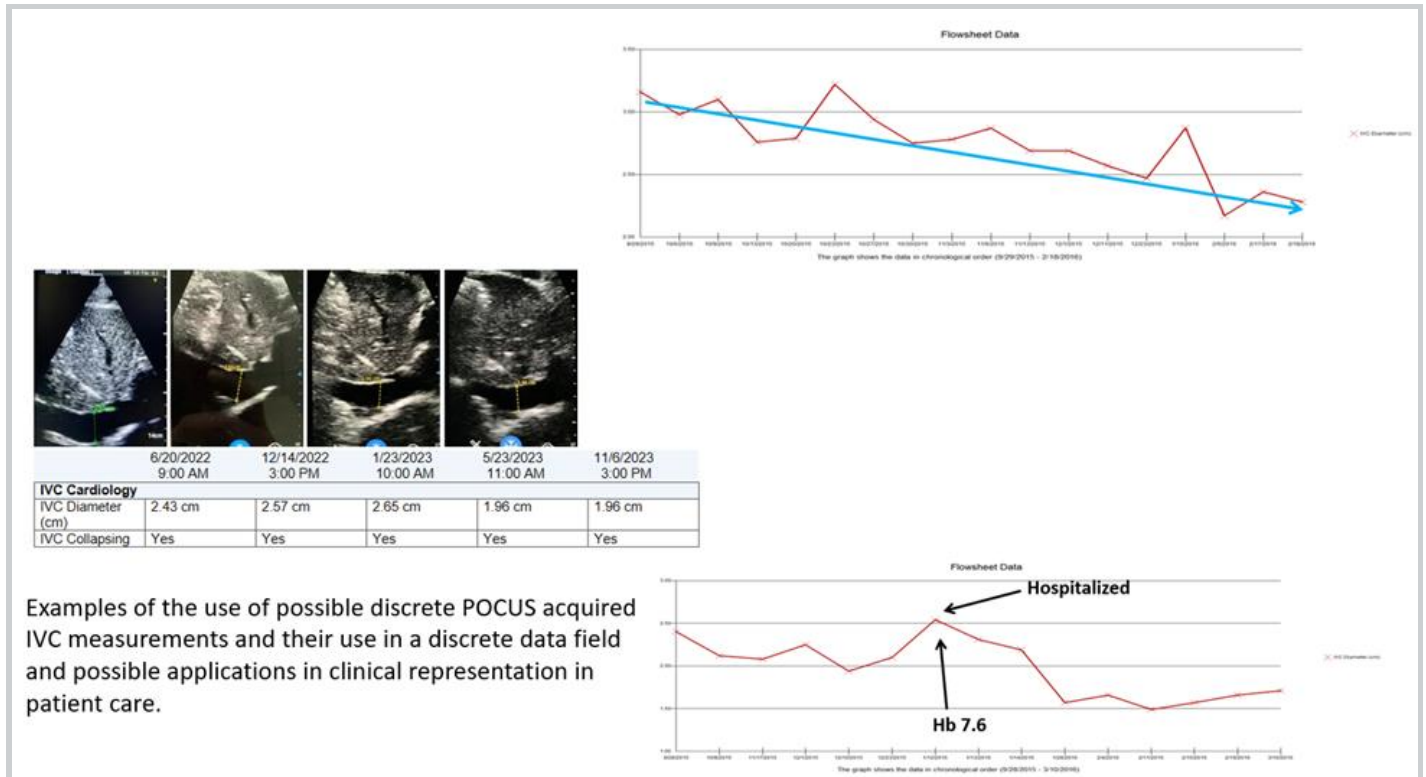
logBNP measures have similar predictive capacity for readmission as POCUS, using POCUS is potentially more feasible in more dynamic clinical environments. POCUS is non-invasive and provides instant visual results that can be captured, shared, and compared between users and serially over time.

POCUS as both a diagnostic and management tool can be used to image anatomic changes over time and reflect changes in physiology. Pathophysiologic changes associated with the onset of HF and treatment of HF can be observed as quantifiable changes in anatomy as seen with POCUS. An increase in measured IVC diameter correlates with an increase in CVP [24]. Therapies that reduce or normalize CVP are central to the clinical management of HF [25]. An increase in CVP is caused by reduced output into arterial circulation and a backing up of blood in venous circulation, as well as fluid retention due to reduced renal function [26]. The presence of B-lines and PE demonstrate physiologic responses to volume overload associated with HF that can result in lung congestion and reduced respiratory capacity [27]. While POCUS has the capacity to acquire this information at the bedside, physical examinations provide more limited assessments of volume status and cannot quantitatively assess volume changes. This

limitation is often insufficient to reliably manage acute and chronic HF [28].

The simplicity, accuracy, and reproducibility of POCUS is ever-increasing along with advancements in technology and imaging systems, such as automated tissue differentiation tools that can enhance image resolution and image assessment and increase clinical accuracy of bedside POCUS diagnoses. As the POCUS technology and user experience grows, ongoing investigations and use-cases for POCUS in varying clinical settings and scenarios will expand. The expansion of scientific study with POCUS as a dynamic imaging tool will intensify with ongoing improvements in technology and the decreased cost of devices and software. Standardized workflows and image acquisition and measurements can further the study and demonstrate pathways for differential outcome assessment in HF management.

Including a review of the current research that demonstrates the merits of POCUS-use in the management of HF patients highlights opportunities for future study. POCUS and its regular use warrants exploration for the development of a systematic methodology and simplified POCUS measurement set to study and standardize for scaling up the clinical use of POCUS both for HF management and other clinical



Examples of the use of possible discrete POCUS acquired IVC measurements and their use in a discrete data field and possible applications in clinical representation in patient care.

Figure 3. Examples of the use of point of care ultrasound (POCUS) acquired inferior vena cava (IVC) measurements and their use in a discrete data field within the electronic health record and for representation of these data for patient care applications.

conditions. We offer a possible option to standardize a specific assessment and measurement of the IVC that can be shared and compared as a discrete data field with an accompanying image in clinical care notes and the shared patient medical record. As with a standard vital sign, this IVC assessment can have a generalized range and a patient specific range that represents physiologic and anatomic changes (Figure 3).

Additionally, with the inevitable improvement in POCUS image acquisition, image quality, user ubiquity, and user comfort, there is opportunity for future studies to explore POCUS strategies for chronic disease management and tighter control and maintenance of euvolemia in HF patients. This review of the use of POCUS in hospitalized HF patients may offer insights for future investigators to generate research hypotheses for future study.

## Conclusion

The review suggests that POCUS, and particularly the measurement of the IVC, can serve as a useful tool to diagnose HF in patients presenting with AD in the ED, to monitor the efficacy of diuretic administration and predict dose adjustments, and to evaluate the prognosis of patients hospitalized with HF. The ability of POCUS in both diagnostic and treatment settings is likely optimized when combining IVC measurements with lung US parameters.

## Disclosure statement

The authors report no relevant disclosures or conflicts of interests related to this work.


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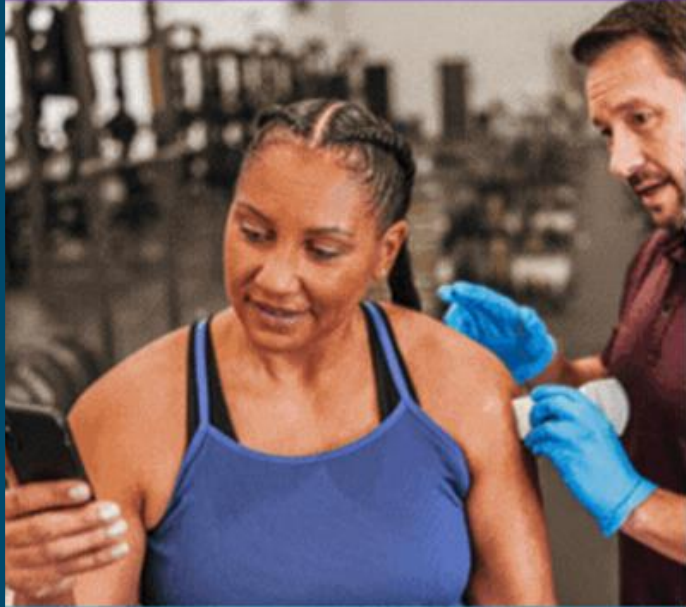
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