Early signs of tamponade may be detected by cardiac point-of-care ultrasound

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Case
A 35-year-old male with a past medical history of end stage renal disease on hemodialysis and a chronic pericardial effusion secondary to dialysis presented to the Emergency Room (ER) with a 2-week history of a flu-like illness and pleuritic chest pain. He was compliant with dialysis three times per week. His blood pressure was 150/85 mmHg with a heart rate of 85 beats per minute and the remainder of his vital signs were stable. Pulsus paradoxus was not present. His jugular venous pulsation (JVP) was not visible, he had soft heart sounds, and no pericardial rub was heard. An ECG showed sinus rhythm with low voltages. Chest X-ray showed an enlarged cardiac silhouette. A point-of-care ultrasound (POCUS) exam using a hand-held GE V-Scan™ probe was used to look for a pericardial effusion. Two sets of subcostal images, performed 3 hours apart, are shown below (Figures 1 & 2; see also online Videos S1-S4). The patient's blood pressure and heart rate during the second set of images was 160/90 mmHg and 75 bpm respectively. A formal transthoracic echocardiogram conducted following the first set of POCUS images confirmed that there was a 3 cm circumferential pericardial effusion that had increased in size from a baseline of 1.5 cm. There was partial early systolic right atrial collapse but no other features of cardiac tamponade.

Question
What intervention was likely performed between the 2 sets of images?

A. Pericardiocentesis with removal of 500 cc of pericardial fluid.
B. ASA 650 mg and Colchicine 0.5 mg PO
C. 500 cc bolus of NS
D. Lasix 40 mg IV with 500 cc of diuresis

(Answer after References section)

The case is of a 35-year-old male with acute pericarditis complicated by a large pericardial effusion with no evidence of tamponade clinically. The initial POCUS images show mild partial collapse of the right atrium with a small (< 2cm) and collapsing (> 50%) inferior vena cava (IVC) suggesting volume depletion. The patient then received 500 cc of fluids during his scheduled dialysis session and a repeat POCUS scan 3 hours later shows near resolution of the right atrial collapse.

A pericardiocentesis (option a) is unlikely to have been performed on this patient since the amount of pericardial fluid has not changed. A removal of 500 cc would be expected to have seen a significant decrease in the size of the effusion.

Although high dose ASA and Colchicine (option b) are used to treat pericarditis, and may reduce inflammation and accelerate resorption of the pericardial fluid, three hours is too early to begin seeing a hemodynamic response to these drugs.

The diuretic effect (option d) would be expected to reduce intravascular volume and lower right atrial pressure. The expected response would be to increase the degree of right atrial collapse.

Case discussion
This case illustrates important aspects of cardiac tamponade physiology. Given the stable blood pressure, the patient was not in clinical tamponade. However, the POCUS images showed evidence of right atrial collapse, an early feature...
of the hemodynamic effect of increasing pericardial pressure. This case illustrates that tamponade is a pathophysiologic continuum rather than an “all or none” phenomenon and the clinical manifestations of tamponade only occur in the latest stages of this continuum [1]. Cardiac tamponade is classically defined as compression of the heart by the accumulation of pericardial fluid under pressure [2]. When pericardial fluid accumulates slowly, pericardial compliance increases to accommodate the increase in volume, without an increase in pressure. As the pericardial fluid volume increases, the intrapericardial pressure increases. With a further increase in pericardial fluid, the pericardium eventually becomes maximally stretched and can no longer expand to accommodate the additional pericardial volume [3]. The intrapericardial volume becomes fixed and the heart must compete with the intrapericardial fluid for this fixed volume. As the intrapericardial pressure increases, it first equalizes with the lower right sided chamber diastolic pressures, and then the left. The result is decreased chamber size and diastolic filling, chamber collapse and a subsequent reduction in stroke volume. This results in falling of cardiac output and blood pressure which manifests as clinical cardiac tamponade. The right atrium is the first chamber to show signs of early compression, due to its thinner walls. Right atrial collapse is an extremely sensitive marker of cardiac tamponade, with a reported sensitivity of 100% and specificity of 82% in one study [4].

The physiologic findings of tamponade may occur earlier and at lower intra-pericardial pressures in hypovolemic patients. This phenomenon is known as “low pressure tamponade”. Clinical recognition of low pressure tamponade may be difficult because most patients lack the typical physical findings of pulsus paradoxus and distended neck veins. In the case of our patient, the small (< 2 cm) and collapsing (> 50%) inferior vena cava suggested a low right atrial pressure of approximately 3 mmHg. Although a formal diagnosis requires a cardiac catheterization measuring intrapericardial and right atrial pressures, it is likely that our patient was in the very early stages of low-pressure tamponade that improved with the administration of fluids. Patients with low pressure tamponade may improve with fluids initially, but more severe cases often require aspiration of the effusion [5,6].

Another important concept within the continuum of cardiac tamponade is that of “ventricular interdependence”, which is the physiologic basis of the pulsus paradoxus. It is important to note that a hand-held ultrasound machine may not be capable of showing this phenomenon. A formal echocardiogram with Doppler is required to show signs of ventricular interdependence.

POCUS has not been validated for the purposes of diagnosing tamponade and a thorough clinical exam, formal echocardiogram, and possible cardiac catheterization remain the gold standard [7]. Nevertheless, this case shows that with good image quality, POCUS may demonstrate some dynamic pathophysiologic changes within the spectrum of cardiac tamponade. There has been a growing interest in integrating bedside ultrasound training into the medical undergraduate curriculum. Comprehensive studies show that bedside ultrasound is a skill that medical students are able to learn and enhances their anatomy knowledge, clinical accuracy and physical exam skills [8,9]. The focus of this training has been in the acquisition of ultrasound operational skills. This case demonstrates another potential way of incorporating ultrasound into the medical curriculum, whereby an experienced imager may use the hand-held ultrasound device as a bedside teaching tool to aid in the understanding in complex cardiac pathophysiology. Future studies are needed to determine whether this application of bedside ultrasound is of value for trainees. Finally, the utility of cardiac POCUS to assist in fluid management in the renal unit, as in this case, may be an interesting area of future study.

References
3. Roy CL, Minar MA, Brookhart MA, Choudhry NK. Does This Patient With A Pericardial Effusion Have Cardiac Tamponade? JAMA. 2007 Vol 297, No. 16; 297: 1810-1818

Answer: c)