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Point-of-Care Ultrasound in the Emergency Department

Irma Faruqi, Maryam Siddiqi and Rasha Buhumaid

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Abstract

Point-of-care ultrasound (POCUS) is a useful diagnostic tool and has become an integral part of the care provided in the Emergency Department. It has evolved over the past two decades to include diagnostic and therapeutic skills. POCUS helps emergency physicians improve their diagnostic accuracy and provide better overall patient care. This chapter will summarize 13 core POCUS applications that are considered within the diagnostic armamentarium of all emergency physicians.

Keywords: ultrasound, bedside ultrasound, point-of-care ultrasound, POCUS, emergency medicine

1. Introduction

The use of point-of-care ultrasound (POCUS) in the Emergency Department (ED) has come a long way, from 1994 when the first Emergency Medicine (EM) Ultrasound Curriculum was published by Mateer et al. to current times, when it has become a core competency in EM training [1]. In a specialty, that is synonymous with quick decision-making in the presence of limited resources, ultrasound is, arguably, the most powerful and often underutilized tool [2].

POCUS is a quick, focused, bedside ultrasound examination performed by one of the primary caregivers, and aimed at guiding the evaluation and management of the patient. As such, it works hand-in-hand with the history and physical examination of a patient in order to identify the presence or absence of certain pathology and evaluates the change in patient's condition in real time. At times, it assists in the treatment by guiding certain procedures that may be performed as part of the patient's management [3].

An emergency physician (EP) skilled in the use of this technology can optimize patient management by providing timely care, improving diagnostic accuracy, and increasing procedural safety. Moreover, in this day and age, when the cost of healthcare is under critique, ultrasound is also an effective means of cost reduction [4].

2. Emergency ultrasound core applications

The American College of Emergency Physicians (ACEP) classifies emergency POCUS into five functional clinical categories: **resuscitative**—POCUS use directly related to an acute resuscitation, **diagnostic**—POCUS utilized in an emergent diagnostic imaging capacity, **symptom or sign-based**—POCUS used in a clinical pathway based upon the patient's symptom or sign, **procedure guidance**—POCUS used as an aid to guide a procedure, and **therapeutic and monitoring**—POCUS use in therapeutics or physiological monitoring [4].

Included within the 5 categories are 13 core applications for emergency POCUS, which will be discussed in this chapter.

2.1. Ultrasound in trauma

Trauma is seen frequently in the ED. The latest National Center for Health (NCH) statistics revealed that trauma comprised almost 30% of all ED visits in the United States in 2014 [5]. Of these, chest and abdominal trauma pose unique challenges for the EPs, particularly in the case of blunt trauma. This is because injuries in blunt trauma are often concealed and imaging modalities like CT are not always feasible either due to limited resources or patient instability. In the past, these patients were evaluated by diagnostic peritoneal aspiration (DPA) or lavage (DPL). However, this modality has largely been replaced by focused assessment with sonography for trauma (FAST) due to its ability to provide expedient care [6], noninvasive nature, cost-effectiveness [7], and ease-of-learning [8] with similar accuracy [9–11]. Now, with the advent of extended focused assessment with sonography for trauma (EFAST), thoracic views are included as part of the exam, helping physicians quickly diagnose and treat pneumothorax and hemothorax, as well [12, 13].

EFAST in a trauma patient identifies hemoperitoneum (**Figure 1**), pericardial effusion (**Figure 2**), hemothorax (**Figure 3**) and pneumothorax (**Figure 4**)/(Video* 1). EFAST has been studied extensively in the setting of blunt trauma and to some extent, stable penetrating trauma. It has been shown to accurately diagnose hemoperitoneum in blunt abdominal trauma (BAT) non-invasively, decrease time-to-diagnosis in BAT, and lead to decreased need for DPA/DPL and fewer CTs [14–17]. Nonetheless, all applications of ultrasound are both operator- and patient-dependent, and the results vary from provider-to-provider and patient-to-patient. It is prudent to remember that while ultrasound has often been shown to be more sensitive than radiography at ruling out a pneumothorax/hemothorax [18–22], this is not the case with all injuries. All healthcare providers performing an EFAST must always be cognizant of its limitations in

*All videos are available in the online version.

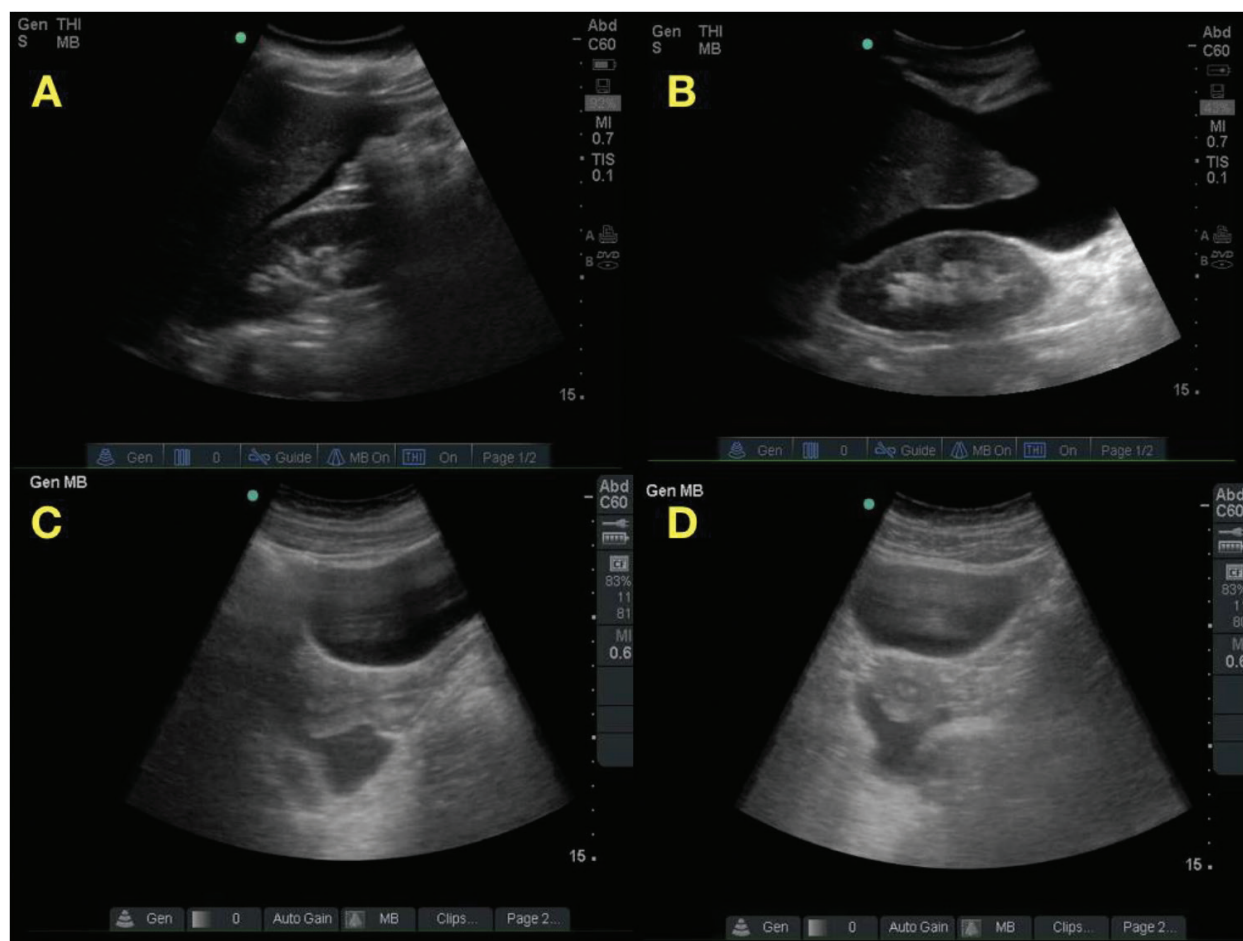


Figure 1. Positive intraperitoneal free fluid. In trauma setting, it is presumed to be hemoperitoneum. (A) Free fluid in the right upper quadrant view, hepatorenal space (Morison's pouch). (B) Free fluid in the left upper quadrant view, evident at the tip of the spleen extending to the space between the spleen and the kidney. (C) Free fluid in rectouterine pouch (pouch of Douglas) in a longitudinal view. (D) Free fluid in pouch of Douglas in a transverse view.

children, in penetrating trauma, diaphragmatic, hollow viscus and retroperitoneal injuries, pelvic trauma and obstetric patients, among others [23]. The bottom line is that a negative EFAST in a stable patient does not rule out significant injury and must frequently be followed by serial EFAST exams and/or CT according to the level of clinical suspicion.

2.2. First trimester pregnancy ultrasound

All emergency physicians are familiar with the diagnostic challenge posed by a female patient of reproductive age with acute abdominal pain and/or vaginal bleeding. This is particularly true when the patient's vital signs are on the verge of instability and some difficult, yet quick, decisions need to be made.

Obstetricians utilize ultrasound for a rather detailed examination of the pregnant patient, including gestational age and anomaly scans. In the ED, however, there is predominantly one all-important question that needs to be answered in the patient with a first-trimester pregnancy complicated by abdominal pain and/or vaginal bleeding—is there an intrauterine pregnancy



Figure 2. Pericardial effusion evident by the anechoic fluid in the pericardial space (marked by the *).

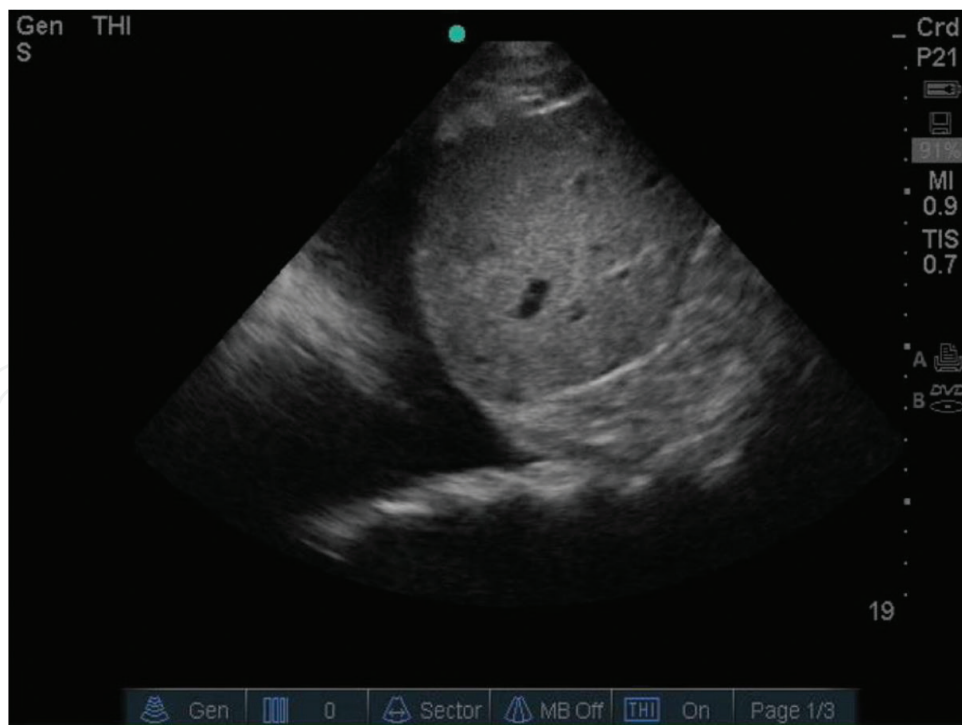


Figure 3. Anechoic fluid collection above the diaphragm. In trauma setting, it is presumed to be hemothorax; while in a non-traumatic setting, it is an undifferentiated pleural effusion.

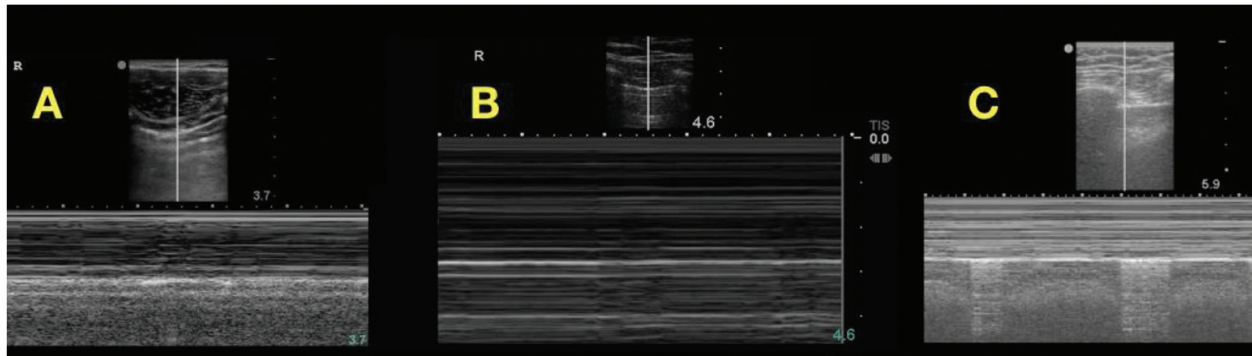


Figure 4. (A) Motion mode demonstrating pleural sliding (sea shore sign), ruling out pneumothorax in the area that is imaged; (B) demonstrates absent lung sliding (bar code sign), which in trauma setting suggests pneumothorax; (C) demonstrates a lung point, the area where half part of the pleura is sliding and the other half is not. Lung point is close to 100% specific for pneumothorax.

(IUP)? The identification of this condition effectively confirms that the patient is pregnant and decreases the chances of an undiagnosed ectopic pregnancy [24].

Pelvic POCUS can be used to rule out ectopic pregnancy in patients where a definitive sign of IUP (**Figure 5**) is identified. This cannot be applied to patients at risk of heterotopic pregnancy

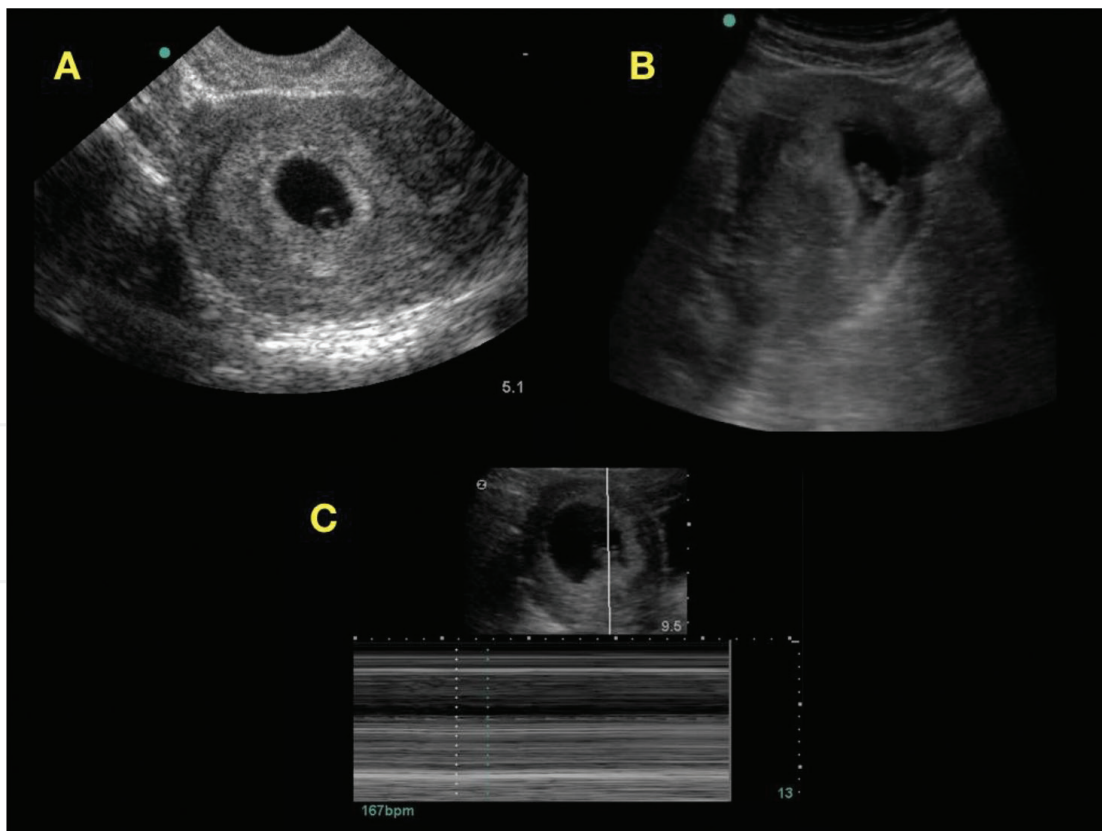


Figure 5. Pelvic ultrasound demonstrating signs of definitive intrauterine pregnancy. (A) Yolk sac within the gestational sac. (B) Fetal pole. (C) M-mode demonstrating the measurement of fetal heart rate.

(when extra-uterine and intrauterine pregnancies occur simultaneously) [25]. It is important to note that a transvaginal ultrasound can identify an IUP at lower beta-HCG levels 1000–2000 vs. 6000 mIU/mL for transabdominal ultrasound [26]. Discussion of algorithms for the diagnosis of ectopic pregnancy and the use of discriminatory zones in order to rule out an ectopic pregnancy is beyond the scope of this chapter. It is, however, imperative to note that heavy reliance on discriminatory zones to explain the presence or absence of certain ultrasound findings has been called into question, with recent guidelines highlighting close follow-up of equivocal cases instead of a rushed diagnosis of non-viable pregnancy with the consequent termination of pregnancy [27]. The use of POCUS in first-trimester pregnant patients has demonstrated decreased ED length-of-stay and time-to-ultrasound in the radiology department with a documented increase in patient satisfaction [28].

2.3. Basic cardiac ultrasound

Like other applications of POCUS, cardiac ultrasound, too, aims to answer specific questions in ED patients presenting with hypotension, dyspnea, possible pericardial effusion, cardiac arrest, cardiac trauma, chest pain, and patients after cardiac surgery [29]. These questions are [30]: (1) *Is there cardiac activity?* (Video* 2). Identifying the presence or absence of cardiac activity may help guide the resuscitation in cardiac arrest. Patients with asystole and absent cardiac activity on ultrasound have a very low survival rate [31]. (2) *Is there pericardial effusion or signs of tamponade?* Emergency physicians can rapidly and accurately identify pericardial effusion and recognize sonographic signs of tamponade. This is crucial especially in patients presenting with signs of undifferentiated shock as the management of tamponade with pericardiocentesis may be lifesaving (**Figure 6**)/(Video* 03).

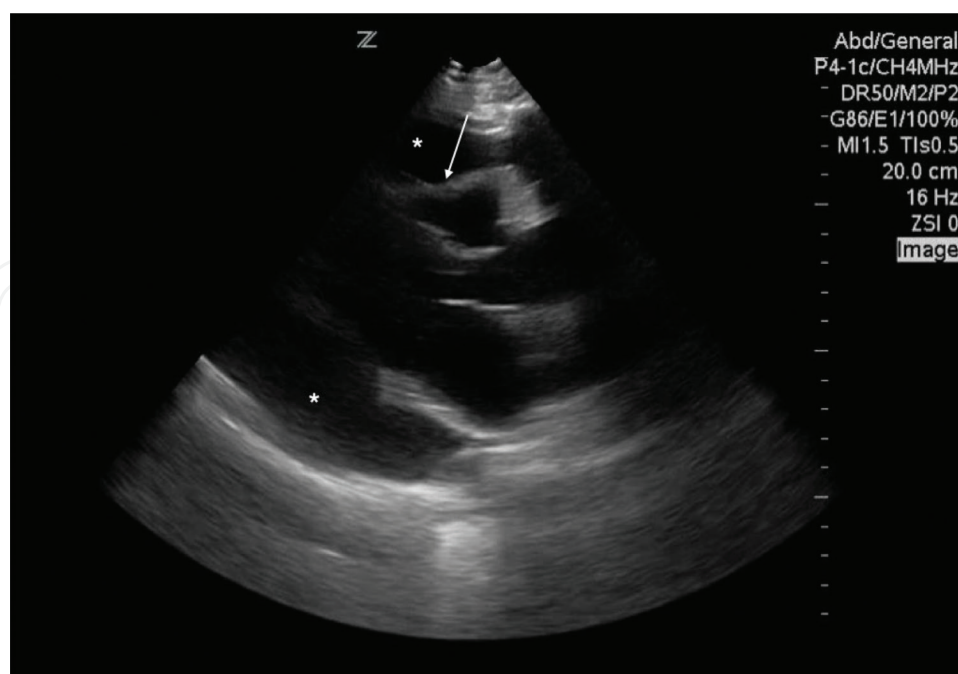


Figure 6. Cardiac ultrasound in parasternal long view demonstrating circumferential pericardial effusion (*) and collapse of the right ventricular wall during diastole (arrow) which is a sonographic sign of tamponade.

(3) *How is the global left ventricular systolic function?* EPs use visual estimation to quantify the systolic LV function as normal, decreased or hyper-dynamic (Video* 04). (4) *Is there right ventricle (RV) strain?* Signs of RV strain in the right clinical setting, although not specific, may be an indirect sign of massive pulmonary embolism [29] (**Figure 7**)/(Video* 05)

(5) *What is the status of the inferior vena cava (IVC)?* (**Figure 8**). Evaluation of the IVC along with the cardiac status can be used as an additional diagnostic tool to assess volume status and guide fluid resuscitation in patients with hypovolemic and septic shock.

EPs, with adequate training, have been shown to be as adept as cardiologists at the performance and interpretation of cardiac ultrasound [32, 33]. Its use in appropriate patients (as mentioned above) has consistently been shown to help narrow down differential diagnoses [34], diagnose and treat more accurately [35–38], and improve outcomes [39]. The use of POCUS to guide resuscitation in pulseless electrical activity (PEA) arrest has been proposed to help identify possible reversible causes such as cardiac tamponade and massive pulmonary embolism, and therefore, expedite management and improve survival [40].

2.4. Abdominal vascular US

In patients presenting to ED with abdominal, flank or back pain, an abdominal aortic aneurysm (AAA) is a diagnosis that no EP would want to miss. In spite of advances in modern medicine, mortality from ruptured aneurysms remains between 50 and 95% [41, 42] and increases by 1% each minute without appropriate intervention [43]. To make matters worse, palpation on physical exam misses roughly one out of every three patients with an AAA [44]. A ruptured AAA must also be considered in patients with unexplained hypotension, particularly in the elderly [45].

POCUS diagnoses an AAA when the identified abdominal aorta measures more than 3 cm (**Figure 9**). A significant percentage of patients do not have clinically evident aortic aneurysms,

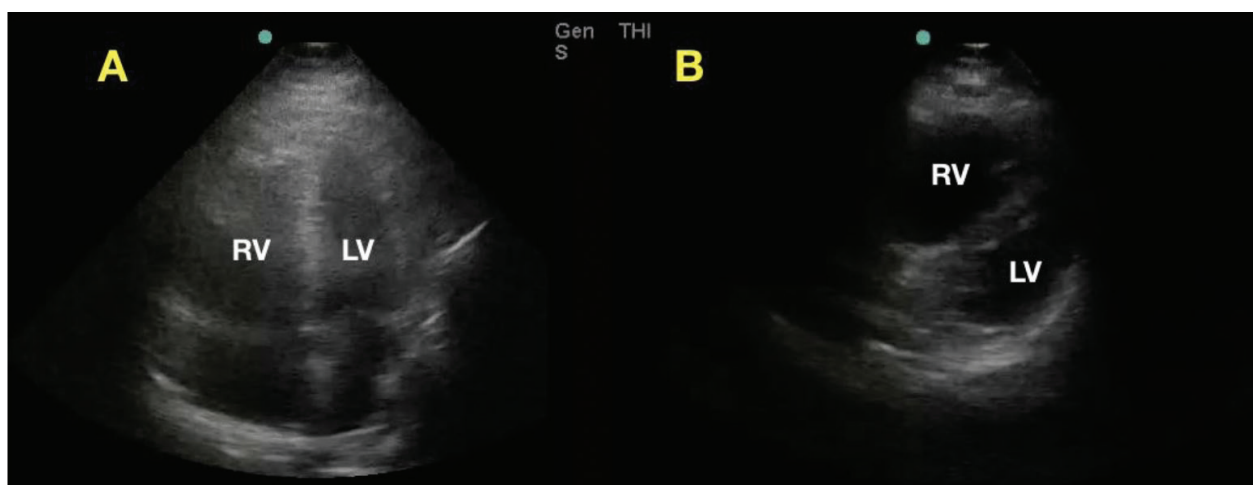


Figure 7. A case of pulmonary embolism with signs of right ventricular strain. (A) Apical four chamber view illustrating right ventricular (RV) enlargement. (B) Parasternal short view illustrating D sign; D-shaped left ventricular (LV) due to flattening of the interventricular septum from the raised RV pressure.

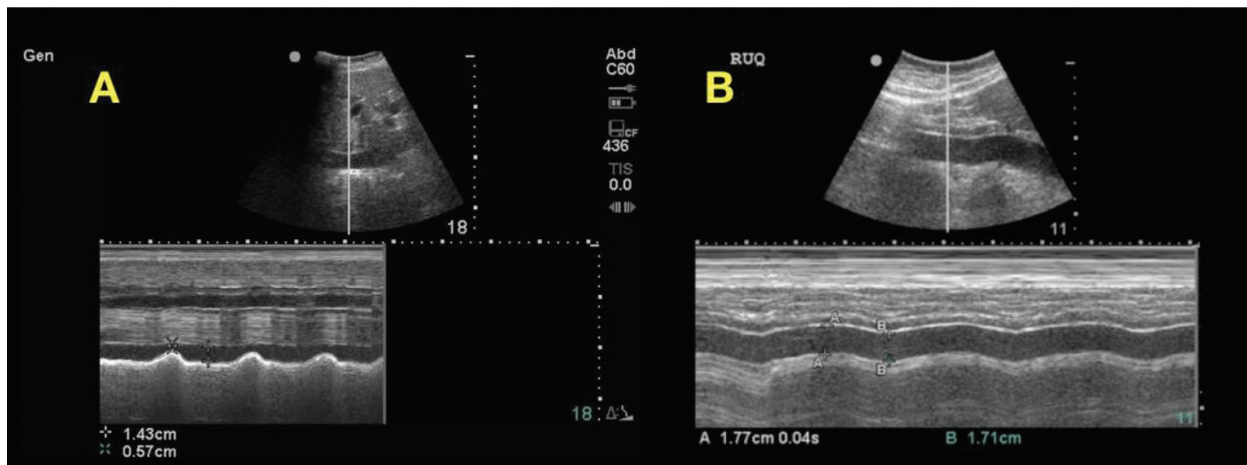


Figure 8. IVC imaged in M-mode. (A) Demonstrates small and collapsible IVC with respiratory variation. (B) Demonstrates plethoric IVC with minimal respiratory variation, which, in the right clinical setting, could suggest that the patient is volume overloaded.

and due to the time-dependent prognosis of the condition, ultrasound performed by the EP helps improve chances of survival [46]. Studies have consistently revealed that EPs are adept in the diagnosis of AAA [47, 48].

In spite of these supportive statistics, it must be mentioned that bedside ultrasound is neither the gold standard nor the imaging modality of choice in ruptured aneurysms. A CT must be performed to rule out AAA in stable patients with suspected AAA [49].

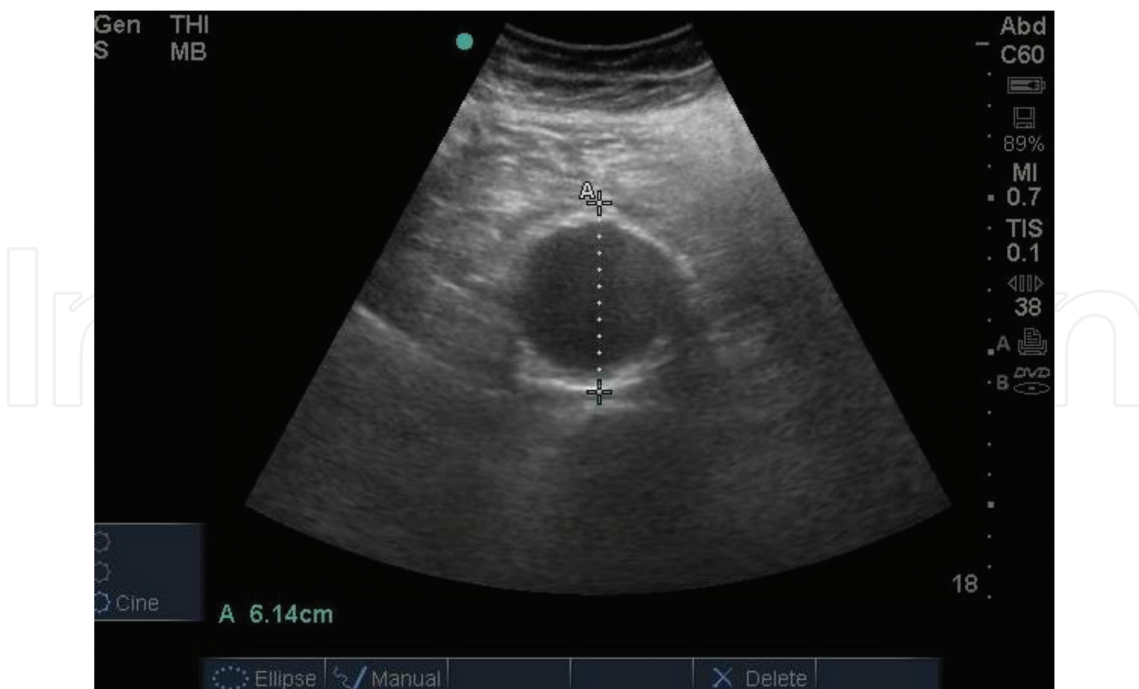


Figure 9. POCUS demonstrating an abdominal aortic aneurysm measuring 6 cm.

2.5. Biliary ultrasound

The differential diagnosis in patients presenting with epigastric or right upper quadrant pain, jaundice or even undifferentiated sepsis is broad, and POCUS can easily recognize gallstones and acute cholecystitis (**Figure 10**). A sonographic Murphy's sign, defined as abdominal tenderness from the pressure of the ultrasound probe, may be elicited during biliary imaging [50]. EPs have been shown to be as adept as trained sonographers in the identification of these conditions [51, 52]. Bedside biliary ultrasound can avoid misdiagnosing patients with acute cholecystitis or biliary colic [53], decrease ED length-of-stay [54], and expedite further management [55].

2.6. Urinary tract ultrasound

ED visits for complaints secondary to urolithiasis are exceedingly common [56, 57], and ultrasound is a highly useful and often underutilized tool in the evaluation of these patients [58]. In addition to the detection of hydronephrosis (**Figure 11**), urinary tract ultrasound can also be used to measure bladder volume, an element of particular importance in those with urinary retention. Ultrasound can also be used in patients in whom urinary tract pathology may be on the list of differential diagnoses, such as those with abdominal pain, hematuria, back pain or groin pain [59]. Multiple studies have consistently demonstrated that in patients with suspected nephrolithiasis, there is a decreased need for subsequent CT scans with the use of ultrasound in the ED, resulting in decreased exposure to ionizing radiation. Although CT is superior to ultrasound in terms of sensitivity for nephrolithiasis [60], an 'ultrasound-first' approach has not revealed any significant differences in terms of serious adverse events, return ED visits or hospital admissions [61–66].

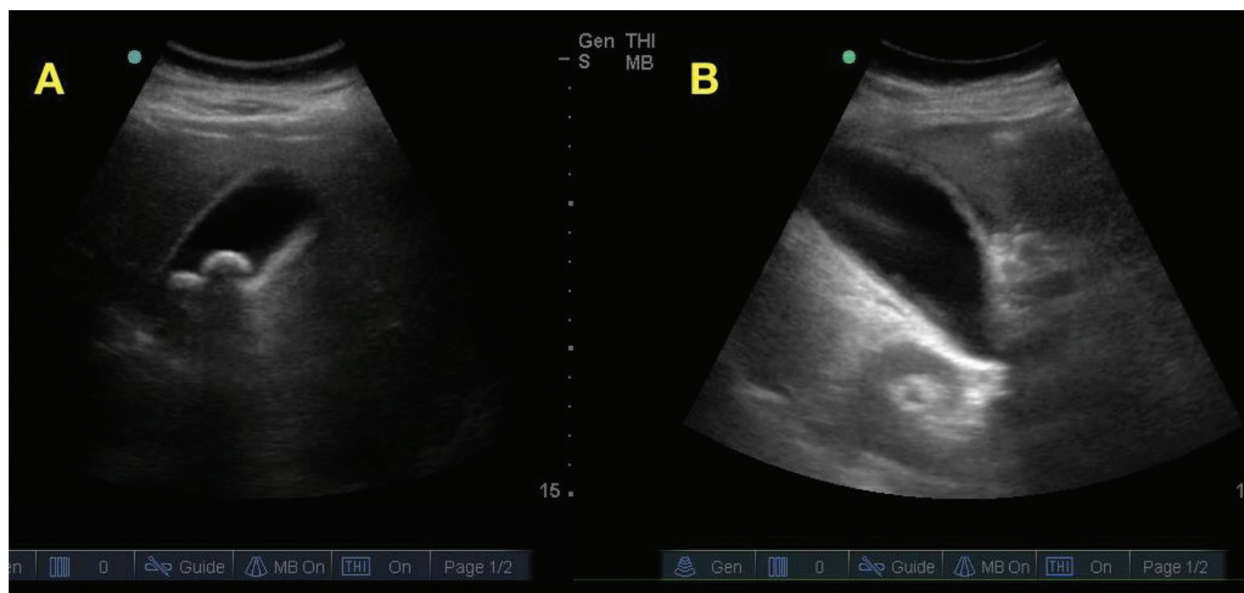


Figure 10. Biliary ultrasound demonstrating gallstones in (A) and cholecystitis in (B) suggested by the thickened gallbladder wall and pericholecystic fluid.

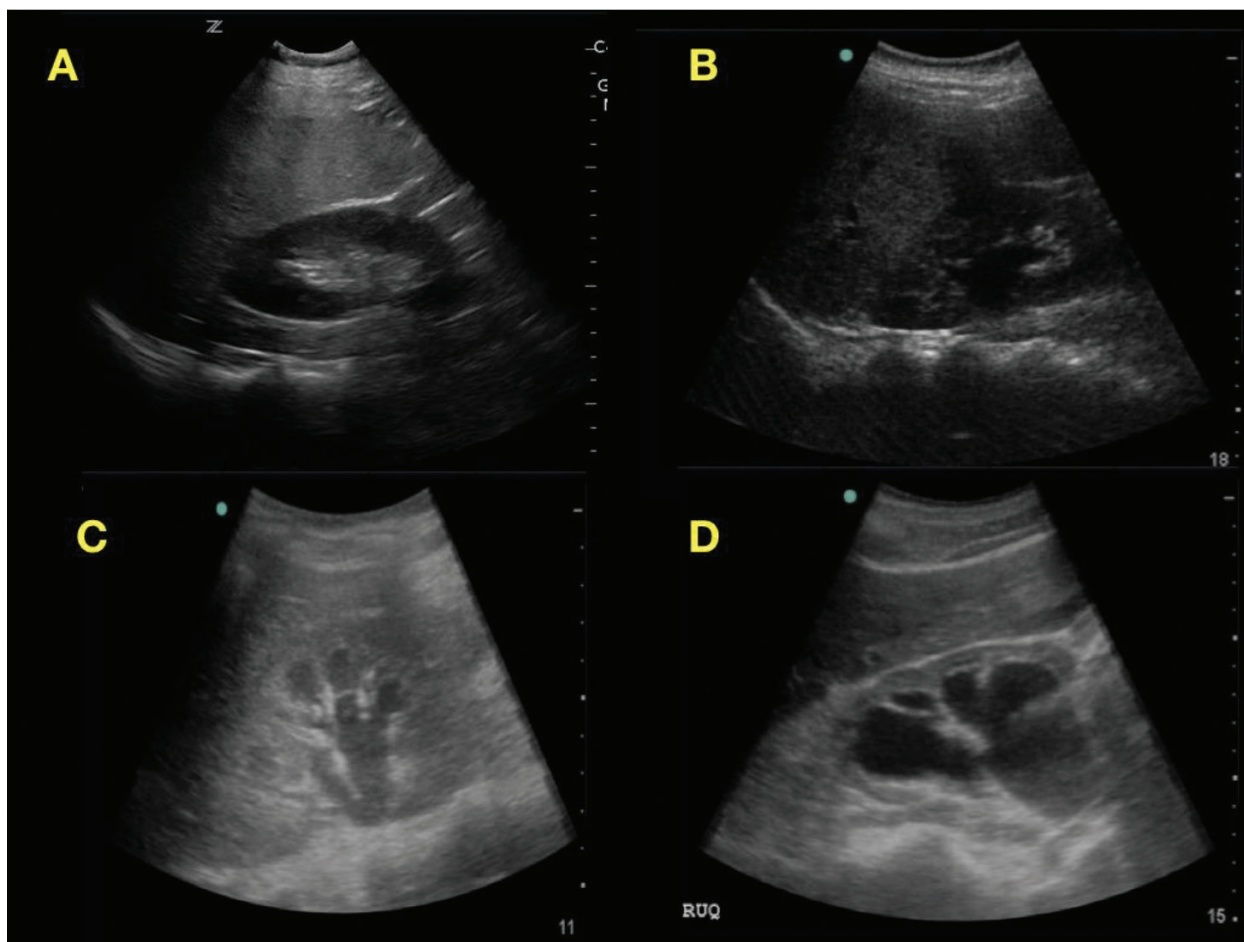


Figure 11. (A) Normal renal ultrasound, (B) mild hydronephrosis (only the renal pelvis is filled with fluid), (C) moderate hydronephrosis (fluid-filled renal pelvis extending to the renal calyces), (D) severe hydronephrosis (entire renal collecting system is dilated).

2.7. Ultrasound for deep vein thrombosis

The most common ED presentations for venous thromboembolism are deep venous thrombosis (DVT) and pulmonary embolism (PE). DVT is suspected in patients presenting with leg swelling, pain, warmth, and erythema. A study has shown that the sensitivity and specificity of these clinical symptoms and signs ranges from 72 to 97% and 19–48%, respectively [67]. In patients with suspected DVT, accurate diagnosis is essential to decrease the risk of propagation and development of PE that could lead to significant morbidity and mortality. With short training, EPs can use focused ultrasound protocol to accurately diagnose a proximal DVT in the highest probability areas (**Figure 12**) in symptomatic outpatients [68]. Several studies have suggested that incorporating POCUS along with pretest probability scoring systems (e.g. Wells Score) and/or D-Dimer improves the diagnostic accuracy of POCUS [69, 70, 72]. Using POCUS to diagnose DVT has been shown to decrease the need for comprehensive scans, decreased time-to-diagnosis, ED length of stay, and the need for return visits [71, 72]. All of these advantages make bedside ultrasound for DVT especially useful; however, it is important to understand its limitations. Most of the POCUS research was conducted on outpatients with suspected DVTs using a focused and specific protocol to diagnose only proximal (not distal or calf) DVTs [73].

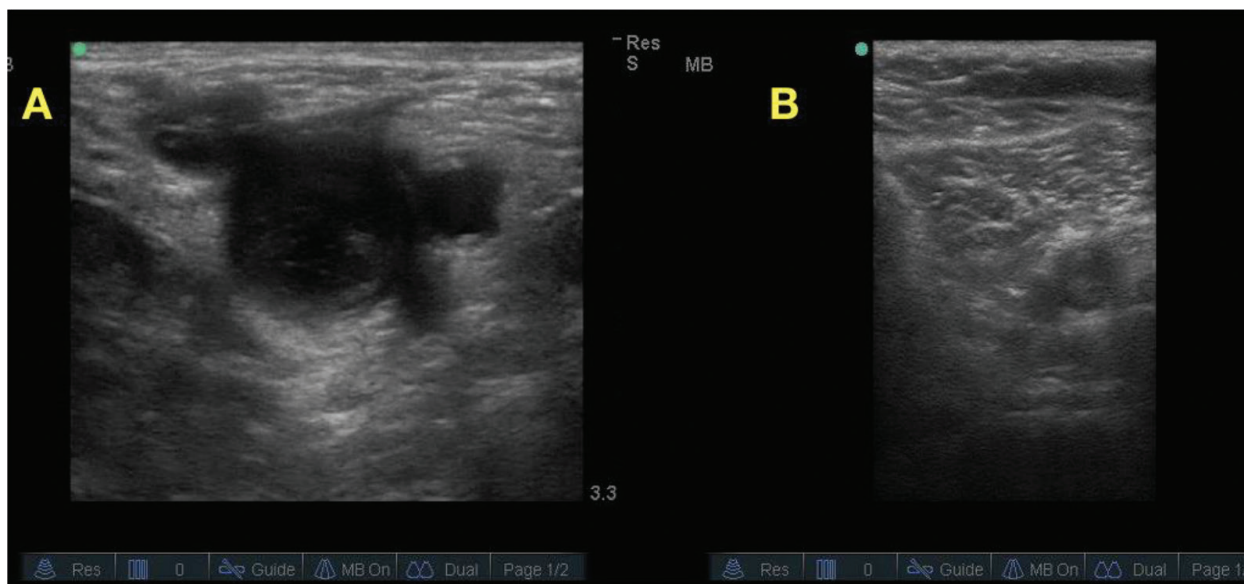


Figure 12. POCUS ultrasound demonstrates DVT of the left common femoral vein (A) and left popliteal vein (B) evident by the echogenic material within the lumen and non-compressible veins with graded compression.

2.8. Lung ultrasound

Lung POCUS may help in the evaluation of patients presenting to the ED with undifferentiated chest pain, shortness of breath (SOB) or respiratory distress. Lung POCUS can help diagnose pneumothorax (Video* 01), pleural effusion (**Figure 3**) and pulmonary edema (**Figure 13**). Ultrasound has a higher sensitivity than the traditional upright anteroposterior chest radiography for the detection of a pneumothorax [74]. Lung ultrasonography has been shown to be

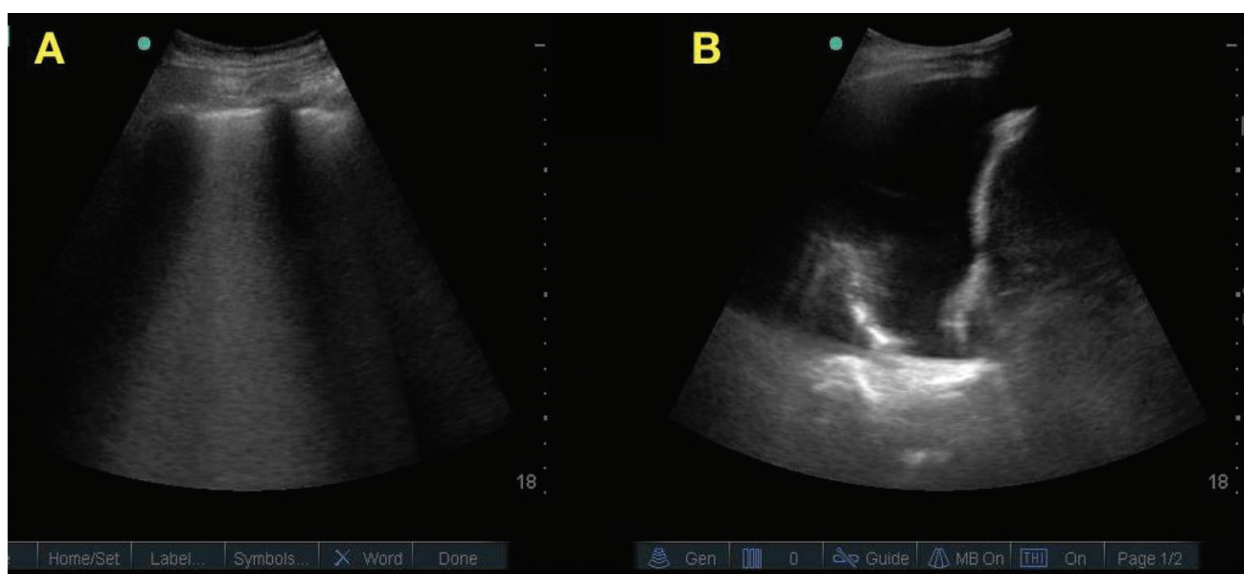


Figure 13. Case of acute cardiogenic pulmonary edema. Evident by B lines (A), which are the vertical narrow-based lines arising from the pleural line to the edge of the ultrasound screen, which was present in both hemithoraces, and bilateral pleural effusion (B). In addition, cardiac ultrasound showed decreased left ventricular systolic function (not included in the figure) which supports the diagnosis of acute cardiogenic pulmonary edema.

superior to chest radiography in the detection of pleural effusions with a sensitivity and specificity of 92 and 93%, respectively [75]. Studies have shown that POCUS is a good diagnostic tool to diagnose acute cardiogenic pulmonary edema [76, 77].

2.9. Soft tissue ultrasound

Skin and soft tissue infections are common in the ED. Physical examination findings may be insufficient to differentiate cellulitis from an abscess. Soft tissue ultrasound is one of the easiest ultrasound examinations to perform. It can be used as an adjunct to clinical evaluation of patients presenting to the ED with suspected soft tissue infections. Studies have shown that POCUS helps differentiate cellulitis, abscess and necrotizing fasciitis (**Figure 14**), and therefore, improves the diagnostic accuracy and management [78–80].

2.10. Musculoskeletal ultrasound

Musculoskeletal complaints are very common in the ED. The use of POCUS can help EPs diagnose joint effusion, long bone fractures, tendon injury and retained foreign body (FB) (**Figure 15**).

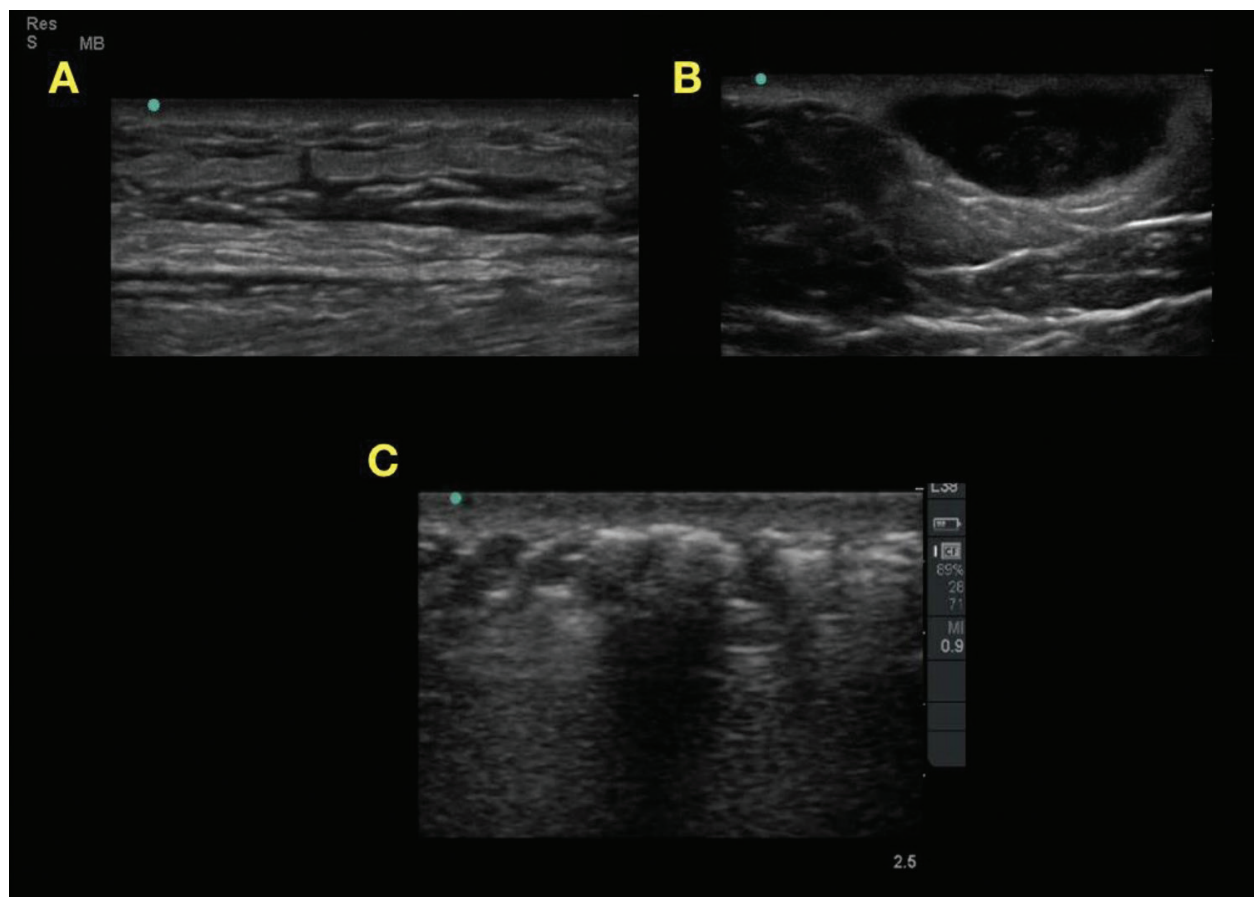


Figure 14. Soft tissue ultrasound demonstrating evidence of cellulitis (A), evident by increased echogenicity of the subcutaneous tissue separated by anechoic fluid appearing like cobble-stone. Case of abscess (B), evident by complex fluid collection mixed with debris. Case of necrotizing fasciitis (C) evident by subcutaneous thickening, fluid in the facial planes and air and shadowing.

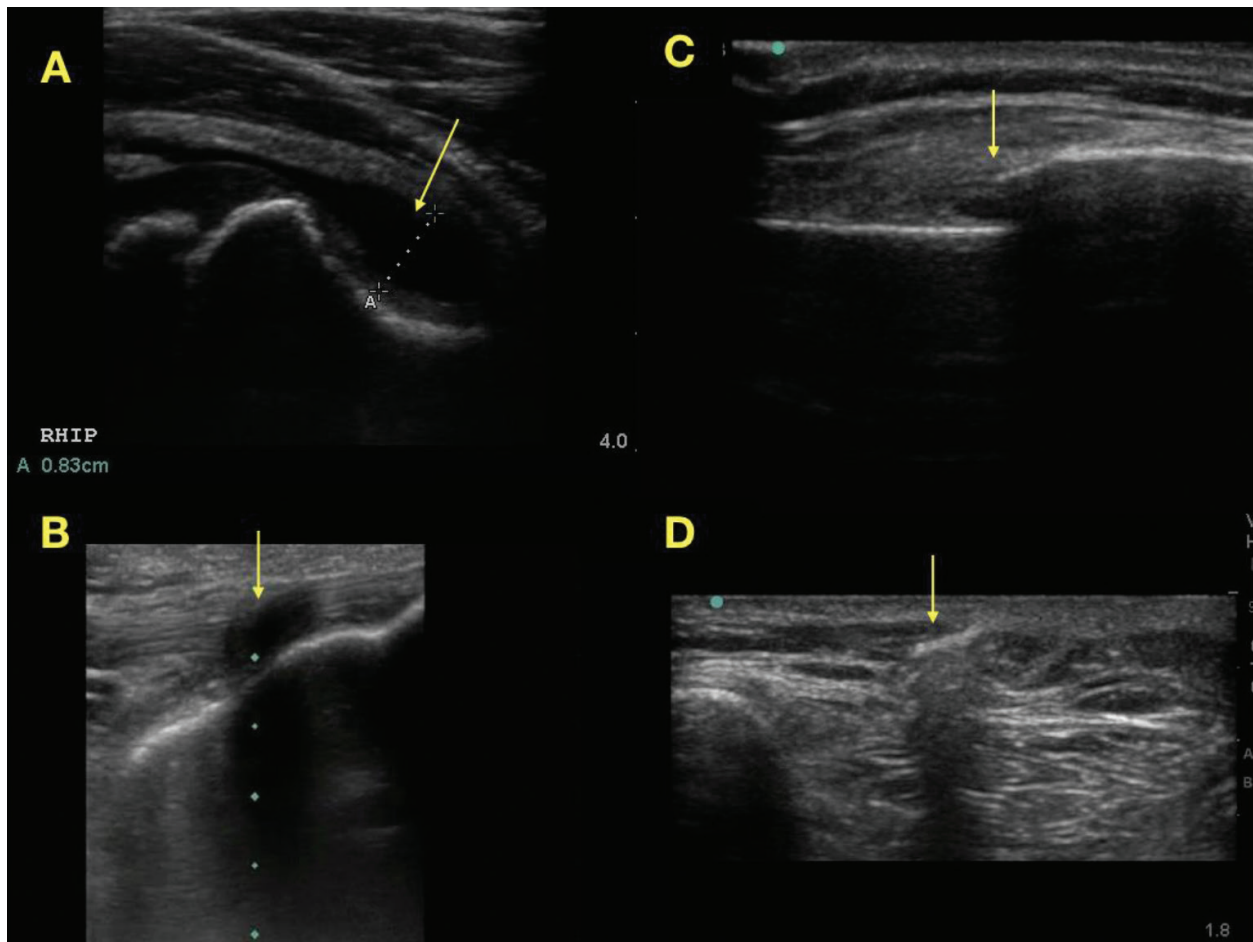


Figure 15. (A) POCUS showing hip effusion evident by the anechoic fluid in the joint space measuring 8.3 mm (arrow). (B) Case of patellar tendon tear evident by disruption of the fibular echo texture of the tendon (arrow). (C) Case of sternal fracture, evident by cortical disruption of the bone with step-off (arrow). (D) Case of retained glass in the leg that was identified as a hyperechoic structure (arrow) with posterior shadowing. FB was removed with the assistance of POCUS.

In a study of patients with joint pain, erythema, and swelling, POCUS changed the management in 65% of cases and reduced the rate of joint aspiration from 72.2 to 37% [81]. POCUS has been shown to be a good diagnostic tool to diagnose hip effusion in children [82]. It can be used to guide arthrocentesis in a safer manner via the shortest route, thus improving success rates and reducing complications [83].

POCUS has been shown to accurately diagnose long bone fractures [84, 85], assist in fracture reduction, determine realignment, and perform hematoma block [85–87]. In shorter bones and areas close to joints, POCUS is found to be inaccurate in identifying a fracture but might identify indirect signs such as soft tissue swelling and joint effusion [88].

EPs can use POCUS to help identify major tendon injuries such as achilles, quadriceps and patellar tendons [89–91].

The evaluation of retained FB can be challenging. Traditional radiography can be used to identify radiopaque FB in soft tissues and muscles. In cases of suspected radiolucent retained FB, POCUS can be used to accurately identify the location and size of FB and assist with its removal [92–94].

2.11. Bowel ultrasound

Small bowel obstruction (SBO) is a common cause of acute abdomen. It accounts for about 2% of patients presenting to ED with abdominal pain [95]. CT with contrast is considered to be the gold standard for the diagnosis of SBO as it has high sensitivity and specificity for the diagnosis [96–98]. It can often determine the location, cause, and complications related to bowel obstruction [99]. However, due to its cost and radiation, it is not the ideal initial imaging modality of choice in all suspected cases. Abdominal X-ray (AXR) is typically considered the initial imaging modality of choice in all suspected cases of SBO presenting to the ED. In recent years, POCUS has been utilized as a screening imaging modality for suspected cases of SBO (**Figure 16**). POCUS is more accurate, more sensitive, and more specific than AXR [95, 100, 101].

2.12. Ocular ultrasound

Patients present to the ED with a variety of ocular emergencies, ranging from simple conjunctivitis to sight-threatening diseases. The challenge lies in the assessment of such emergencies due to limited equipment availability and physician training; moreover, ophthalmology consultation is not available in all settings. This may place considerable burden on the EP to make a rapid decision [102].

Ocular ultrasound can non-invasively diagnose retinal detachment with high sensitivity (**Figure 17**) [103], vitreous hemorrhage/detachment [104], globe rupture, and lens dislocation [105]. Measurement of optic nerve sheath diameter has been shown to correlate with increased intracranial pressure [106].



Figure 16. Case of small bowel obstruction evident by dilated (> 2.5–3 cm) fluid-filled small bowel loops and increased peristalsis of the dilated segment, as evidenced by the to-and-fro or whirling motion of the bowel contents (Video* 06).



Figure 17. (A) Case of retinal detachment, evident by sharply defined, highly reflective linear membrane that is anchored to the optic disc.

2.13. Ultrasound for procedure guidance

POCUS is used to guide various ED procedures such as central venous catheter insertion [107, 108], difficult peripheral arterial and venous catheter insertion [109, 110], arthrocentesis [111], airway management [112], thoracentesis, paracentesis, lumbar puncture, and regional nerve blocks [113]. Using POCUS for procedure guidance helps improve the success rate and decrease the complication rate [110, 113] and is considered the standard of care for central venous catheter insertion [114].

3. Conclusion

The use of POCUS in the ED has grown over the past two decades and has evolved from basic uses (that are discussed in this chapter) to include more advanced applications. Despite the limitation of POCUS, it has numerous advantages that justify its use. The advantages include, but are not limited to, improving the diagnostic accuracy for certain complaints, decreasing ED length-of-stay, improving patient satisfaction, improving procedure success rate, and decreasing procedure complication rates. Any EP practicing in this day and age in a center with POCUS availability has little excuse to justify not utilizing this powerful resource for the best of their patients.

Conflict of interest

All authors declare to have no conflict of interest.

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