Chapter 6

Point-of-Care Ultrasound in the Emergency Department

Irma Faruqi, Maryam Siddiqi and Rasha Buhumaid

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.74123

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 availble in the online version.

http://dx.doi.org/10.5772/intechopen.74123

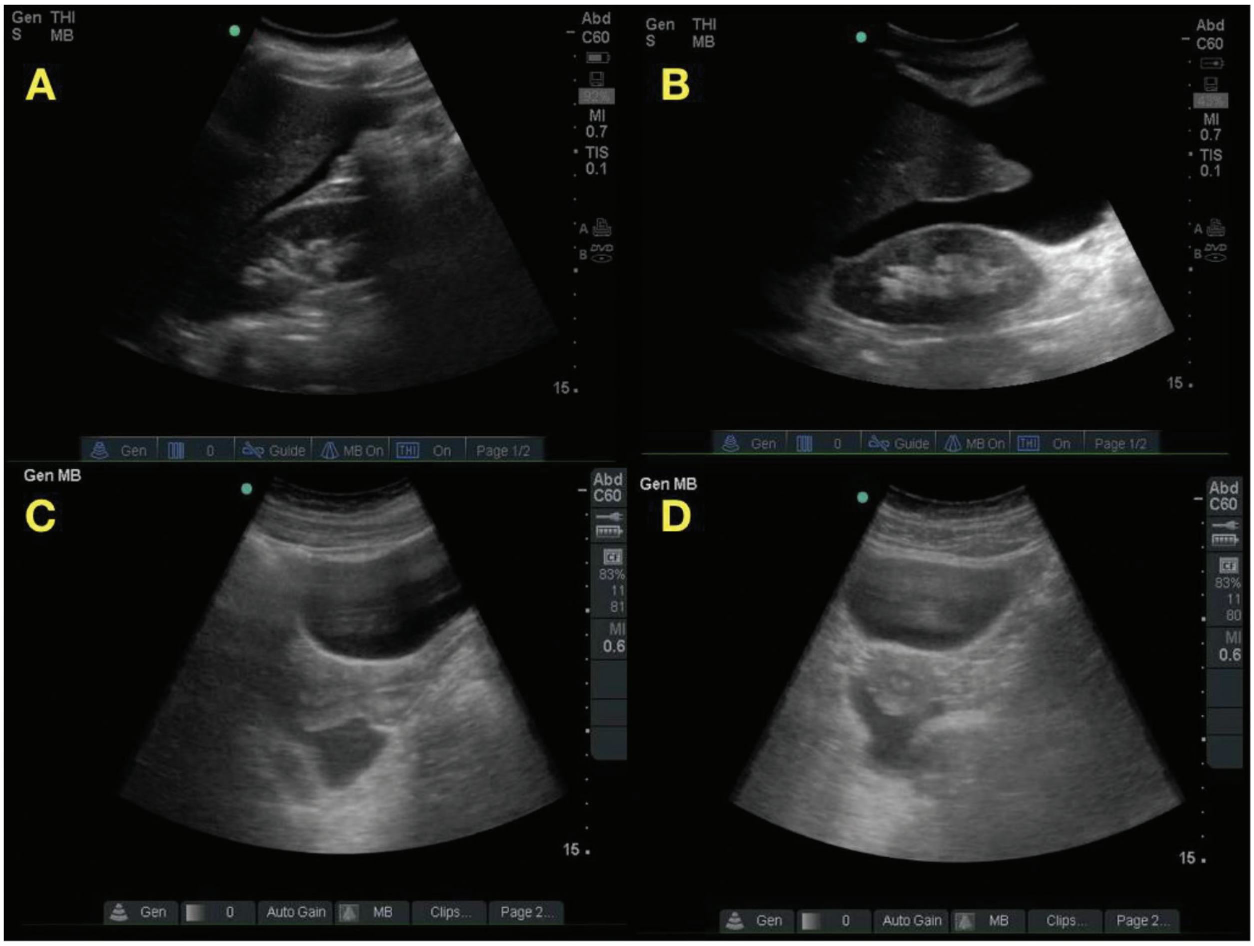

Figure 1. Positive intraperitoneal free fluid. In trauma setting, it is presumed to be hemoperitoneum. (A) Free fluid in the right upper quadrant view, hepatorenal space (Morison's pouch). (B) Free fluid in the left upper quadrant view, evident at the tip of the spleen extending to the space between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

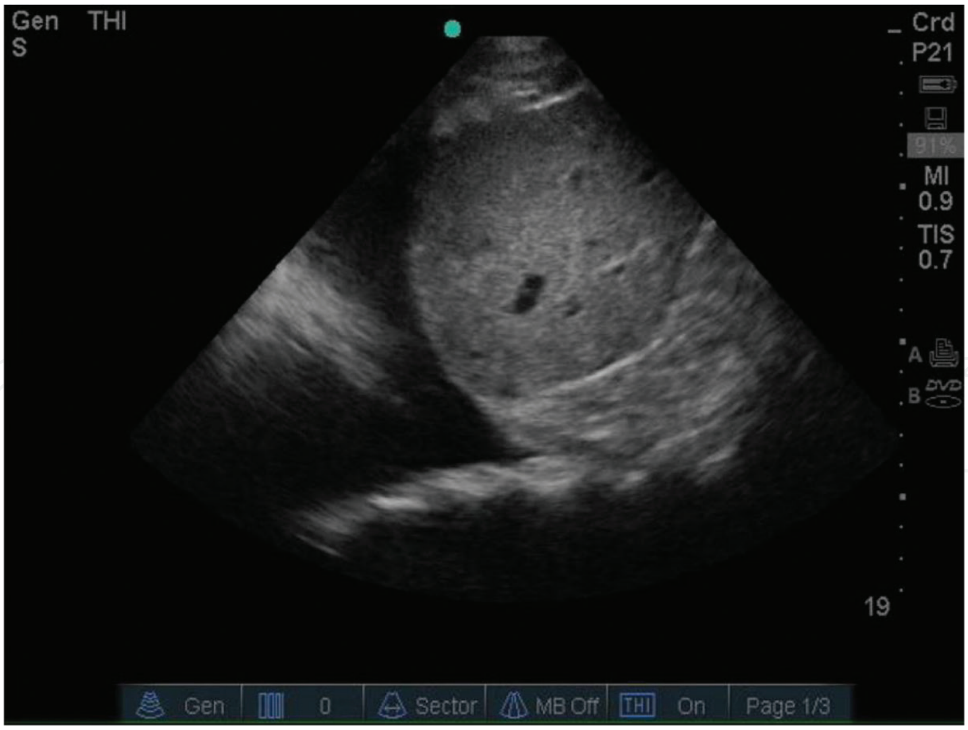

Figure 3. Anechoic fluid collection above the diaphragm. In trauma setting, it is presumed to be hemothorax; while in a non-traumatic setting, it is an undifferentiated pleural effusion.

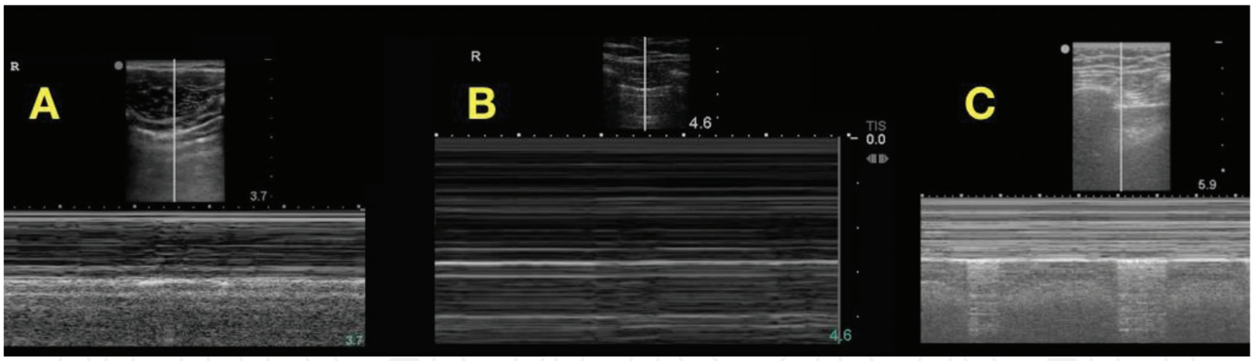

Figure 4. (A) Motion mode demonstrating pleural sliding (sea shore sign), ruling out pneumothorax in the area that is imaged; (B) demonstrates absent lung sliding (bar code sign), which in trauma setting suggests pneumothorax; (C) demonstrates a lung point, the area where half part of the pleura is sliding 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

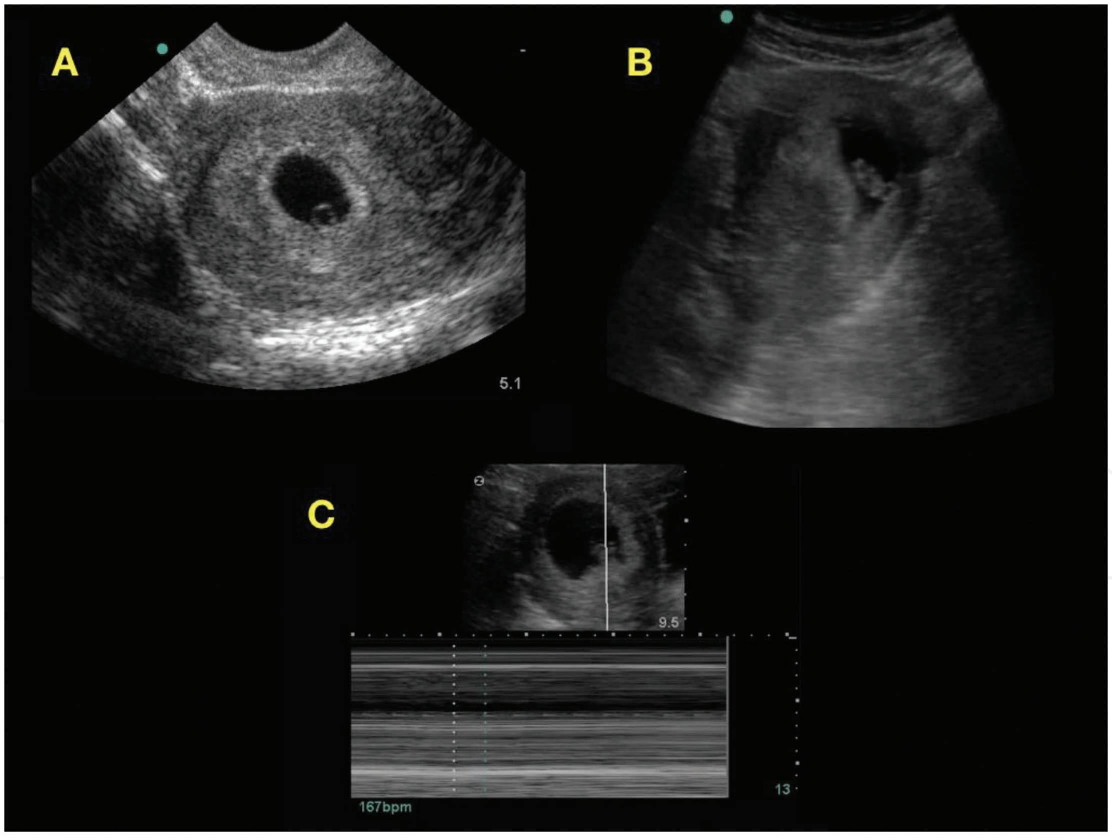

Figure 5. Pelvic ultrasound demonstrating signs of definitive intrauterine pregnancy. (A) Yolk sac within the gestational sac. (B) Fetal pole. (C) M-mode demonstrating the measurement of fetal heart rate.

(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).

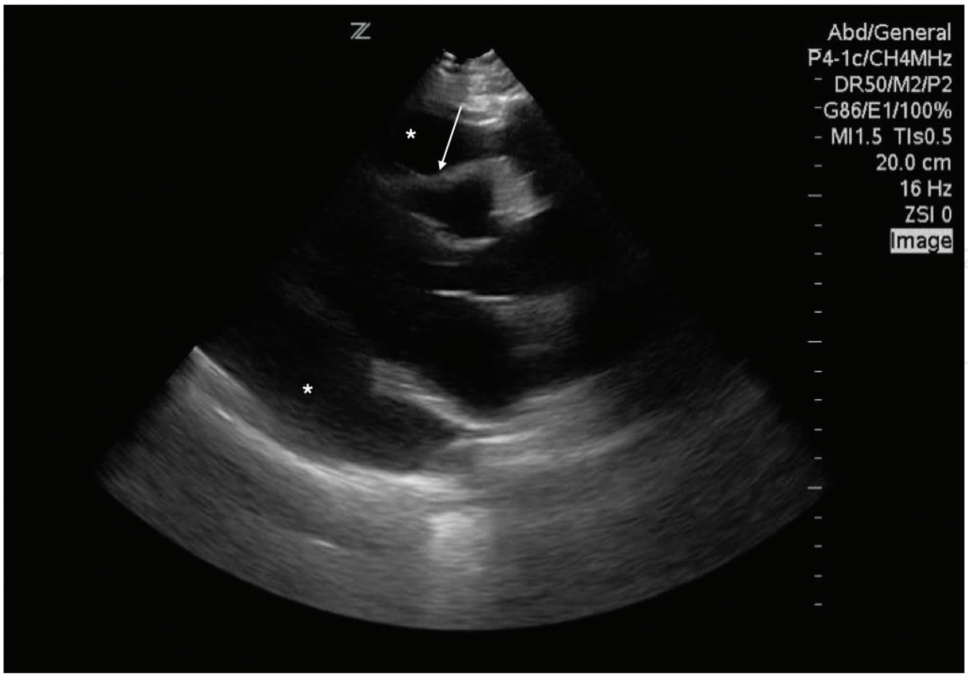

Figure 6. Cardiac ultrasound in parasternal long view demonstrating circumferential pericardial effusion (*) and collapse of the right ventricular wall during diastole (arrow) which is a sonographic sign of tamponade.

(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,

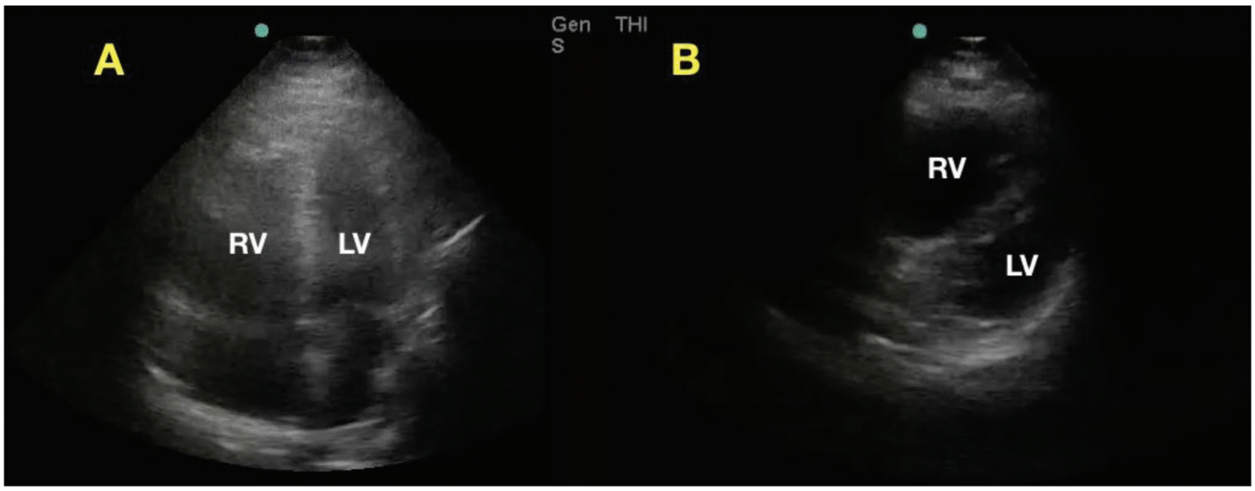

Figure 7. A case of pulmonary embolism with signs of right ventricular strain. (A) Apical four chamber view illustrating right ventricular (RV) enlargement. (B) Parasternal short view illustrating D sign; D-shaped left ventricular (LV) due to flattening of the interventricular septum from the raised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

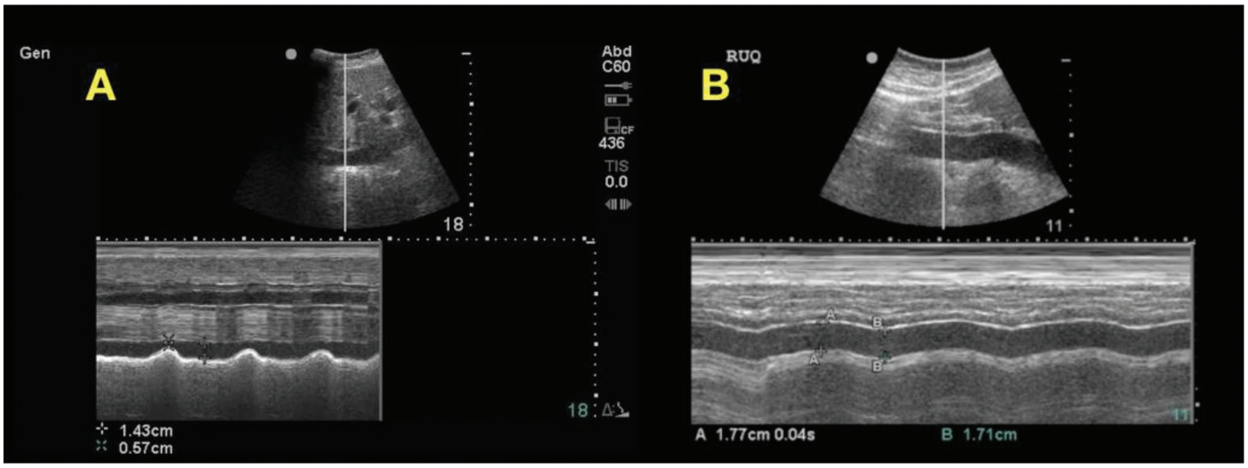

Figure 8. IVC imaged in M-mode. (A) Demonstrates small and collapsible IVC with respiratory variation. (B) Demonstrates plethoric IVC with minimal respiratory variation, which, in the right clinical setting, could suggest that the patient is volume overloaded.

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].

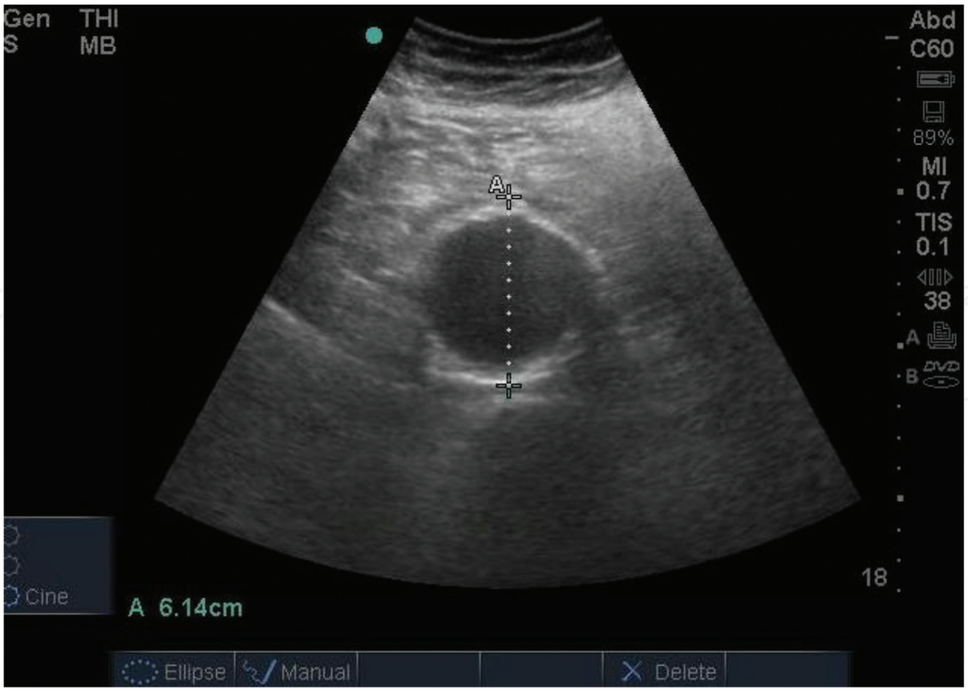

Figure 9. POCUS demonstrating an abdominal aortic aneurysm measuring 6 cm.

http://dx.doi.org/10.5772/intechopen.74123

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].

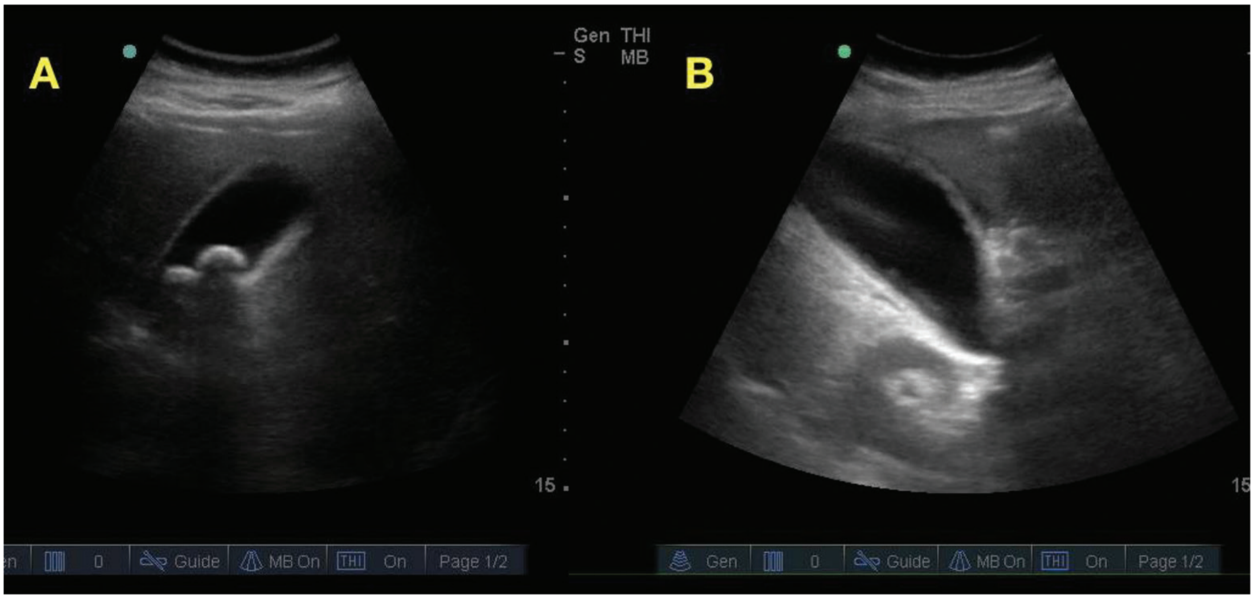

Figure 10. Biliary ultrasound demonstrating gallstones in (A) and cholecystitis in (B) suggested by the thickened gallbladder wall and pericholecystic fluid.

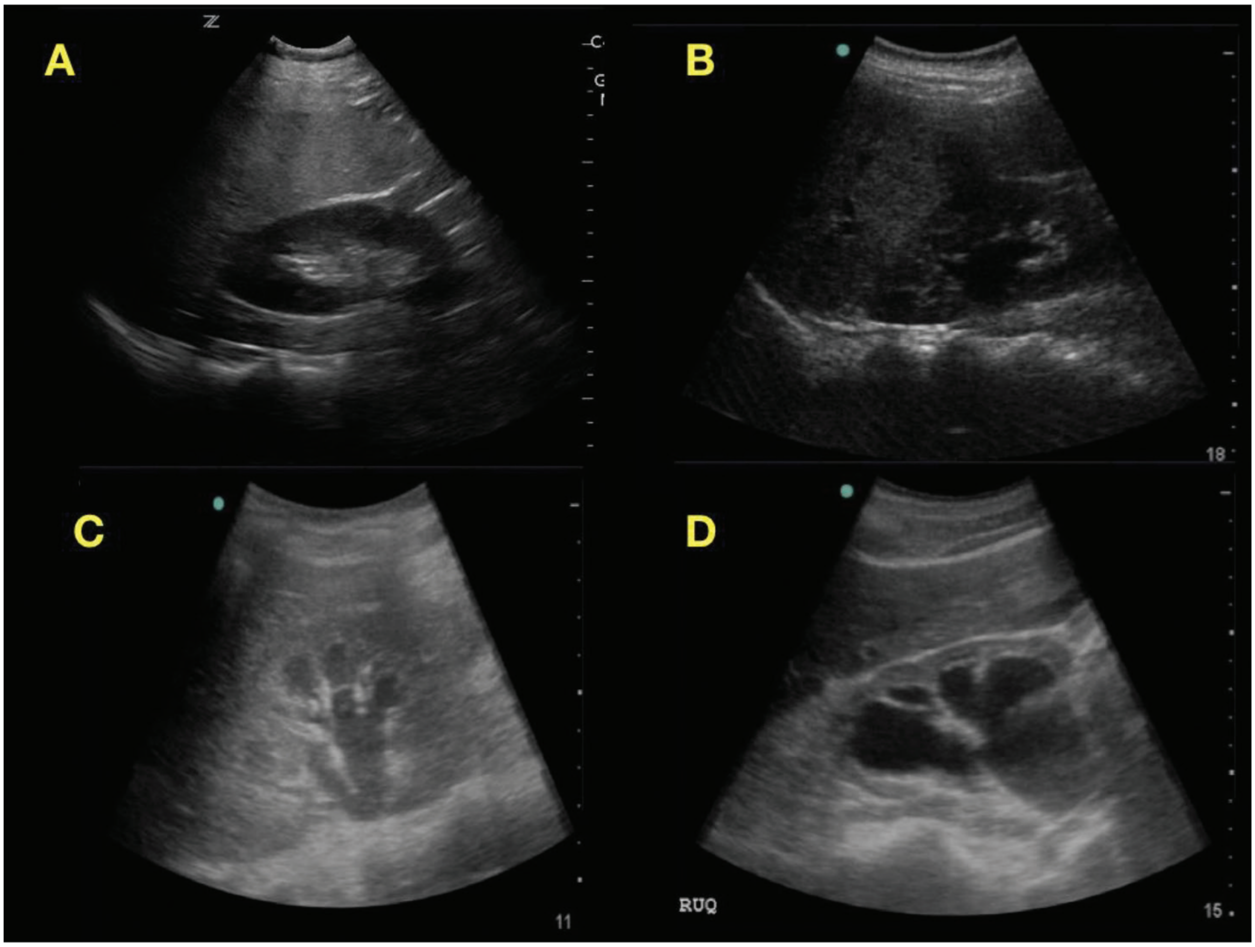

Figure 11. (A) Normal renal ultrasound, (B) mild hydronephrosis (only the renal pelvis is filled with fluid), (C) moderate hydronephrosis (fluid-filled renal pelvis extending to the renal calyces), (D) severe hydronephrosis (entire renal collecting system is dilated).

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].

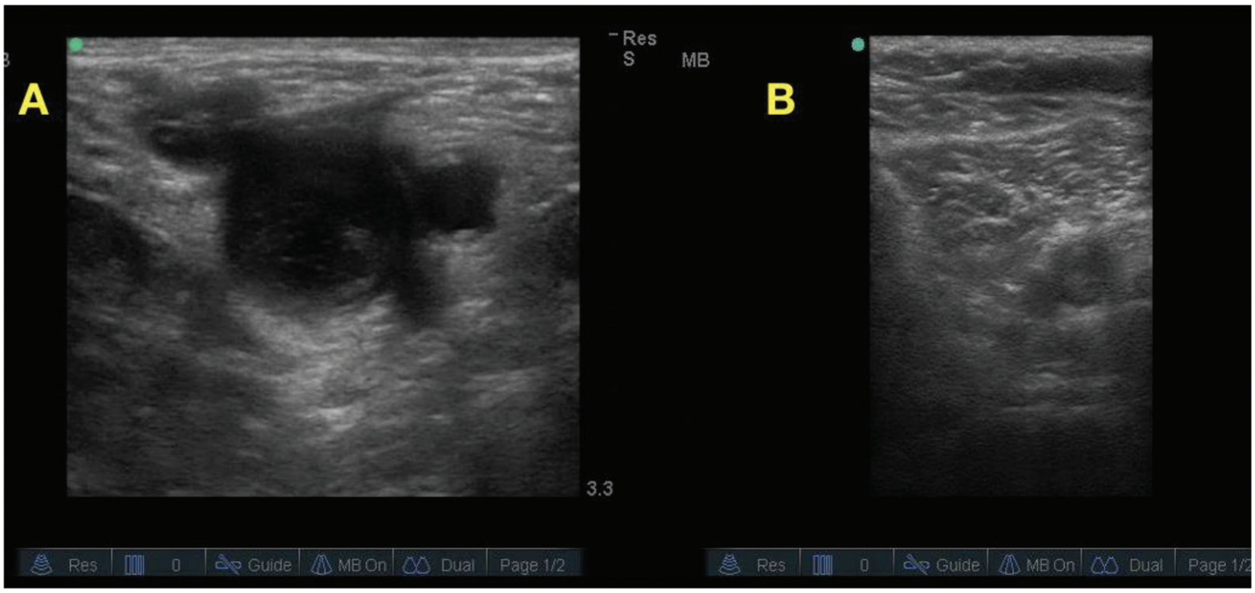

Figure 12. POCUS ultrasound demonstrates DVT of the left common femoral vein (A) and left popliteal vein (B) evident by the echogenic material within the lumen and non-compressible veins with graded compression.

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

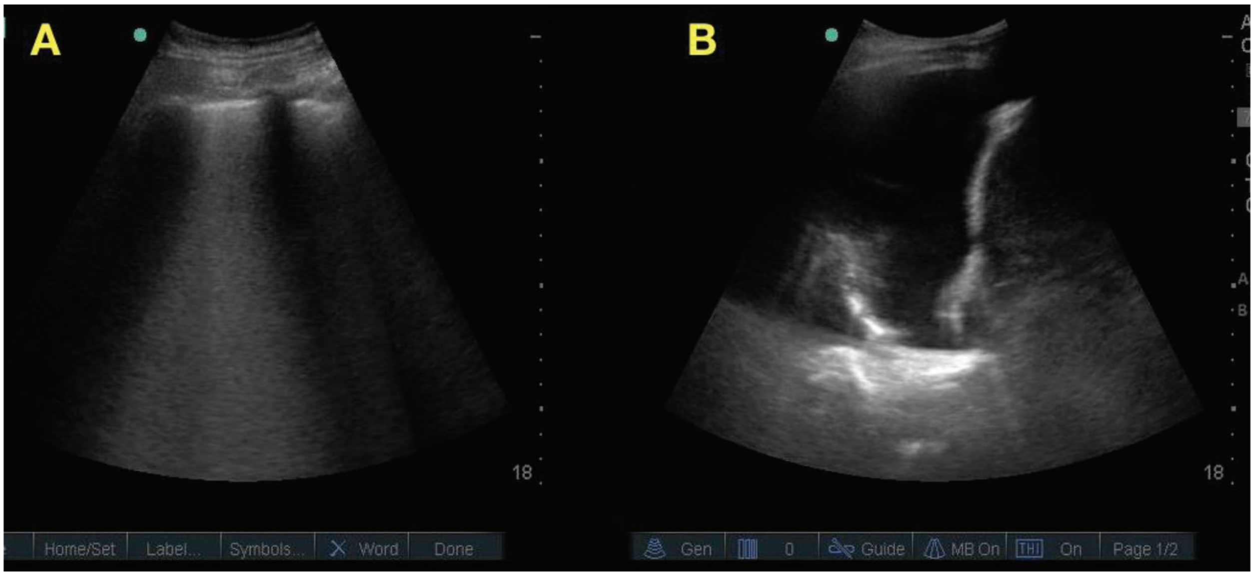

Figure 13. Case of acute cardiogenic pulmonary edema. Evident by B lines (A), which are the vertical narrow-based lines arising from the pleural line to the edge of the ultrasound screen, which was present in both hemithoraces, and bilateral pleural effusion (B). In addition, cardiac ultrasound showed 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**).

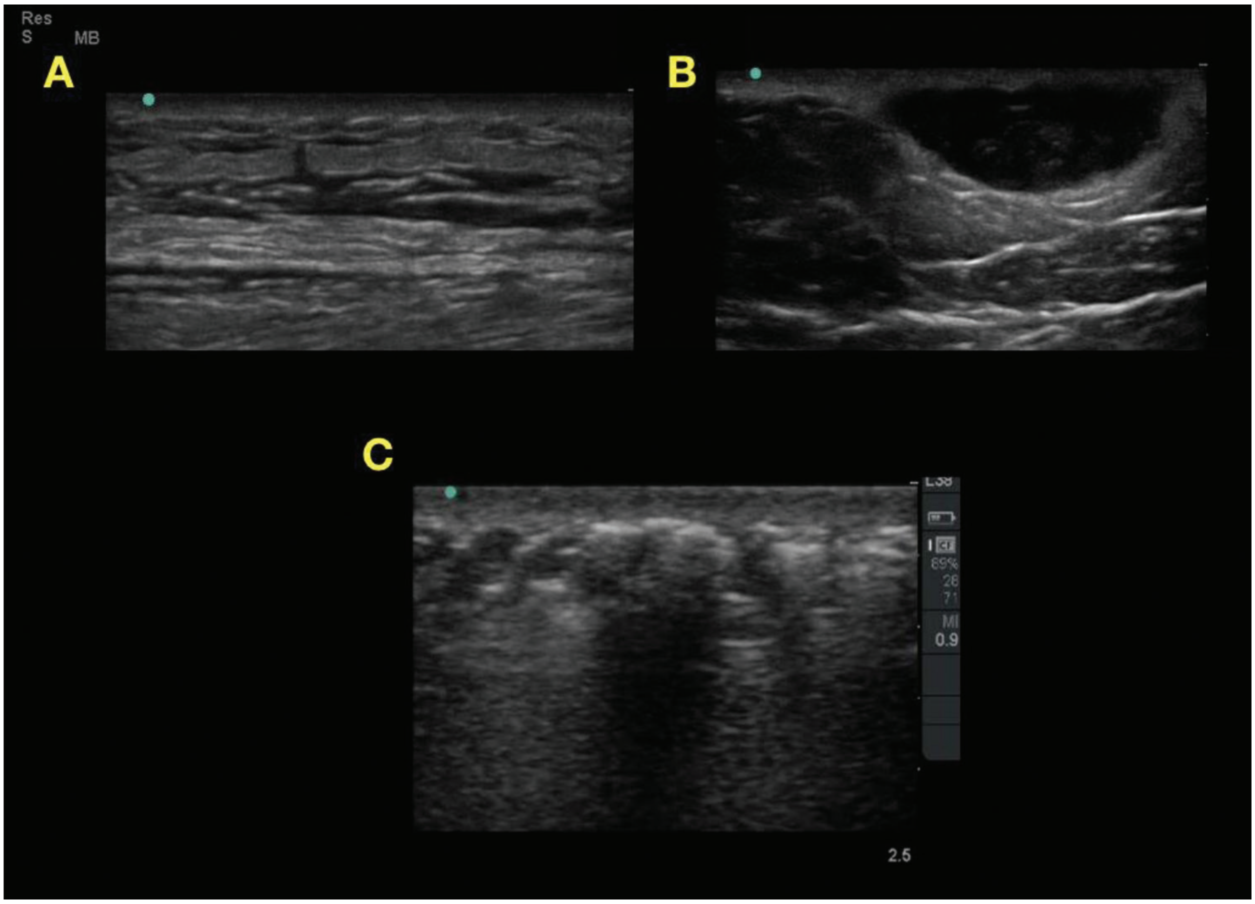

Figure 14. Soft tissue ultrasound demonstrating evidence of cellulitis (A), evident by increased echogenicity of the subcutaneous tissue separated by anechoic fluid appearing like cobble-stone. Case of abscess (B), evident by complex fluid collection mixed with debris. Case of necrotizing fasciitis (C)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

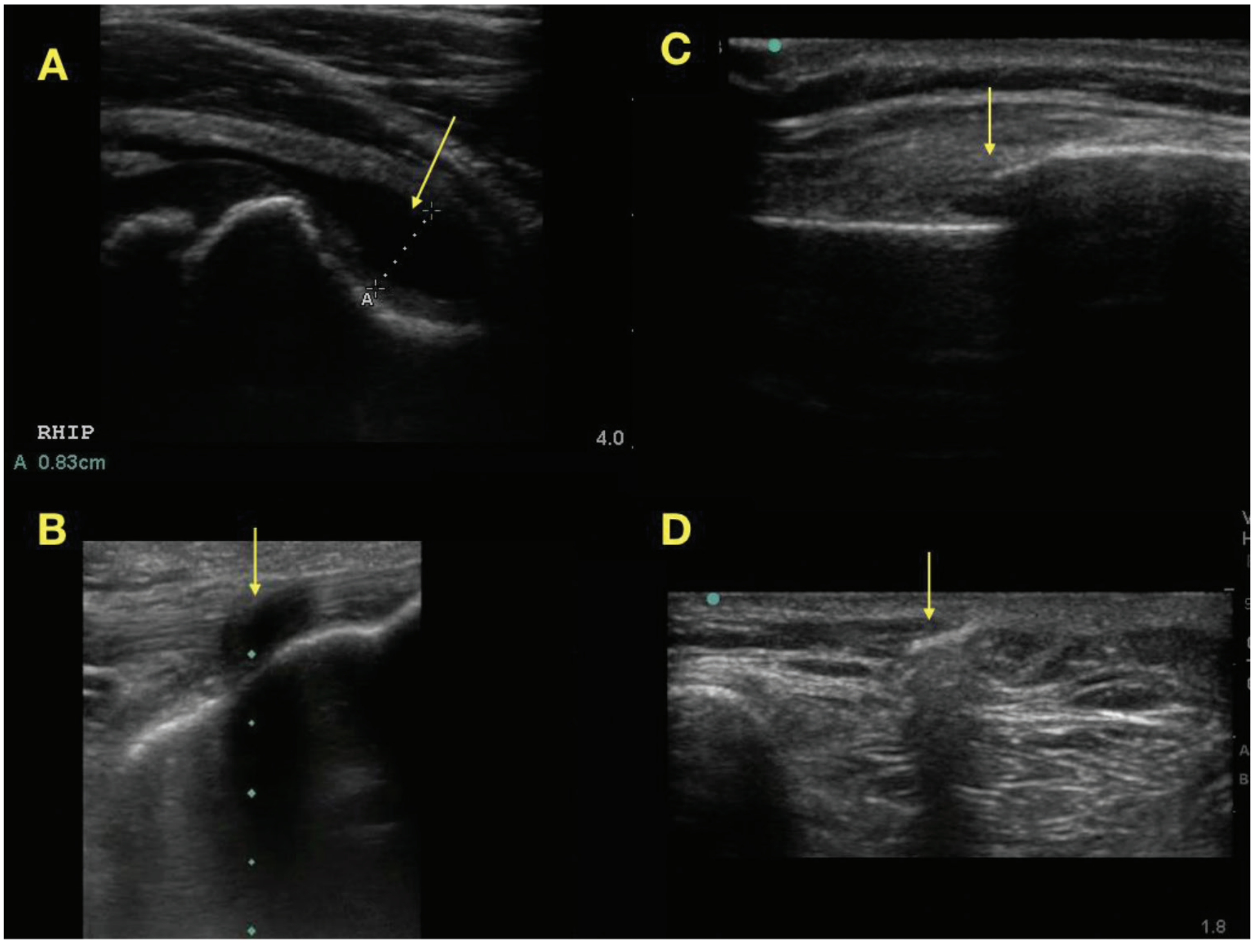

Figure 15. (A) POCUS showing hip effusion evident by the anechoic fluid in the joint space measuring 8.3 mm (arrow). (B) Case of patellar tendon tear evident by disruption of the fibular echo texture of the tendon (arrow). (C) Case of sternal fracture, evident by cortical disruption of the bone with 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 sheet diameter has been shown to correlate with increased intracranial pressure [106].

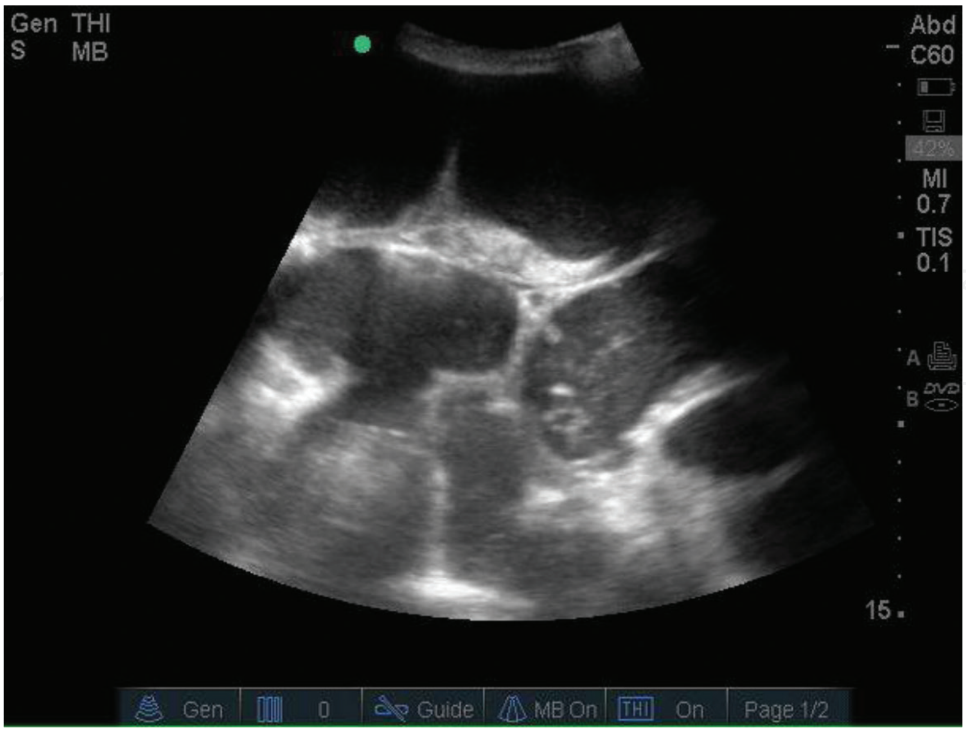

Figure 16. Case of small bowel obstruction evident by dilated (> 2.5–3 cm) fluid-filled small bowel loops and increased peristalsis of the dilated segment, as evidenced by the to-and-fro or whirling motion of the bowel contents (Video* 06).

http://dx.doi.org/10.5772/intechopen.74123

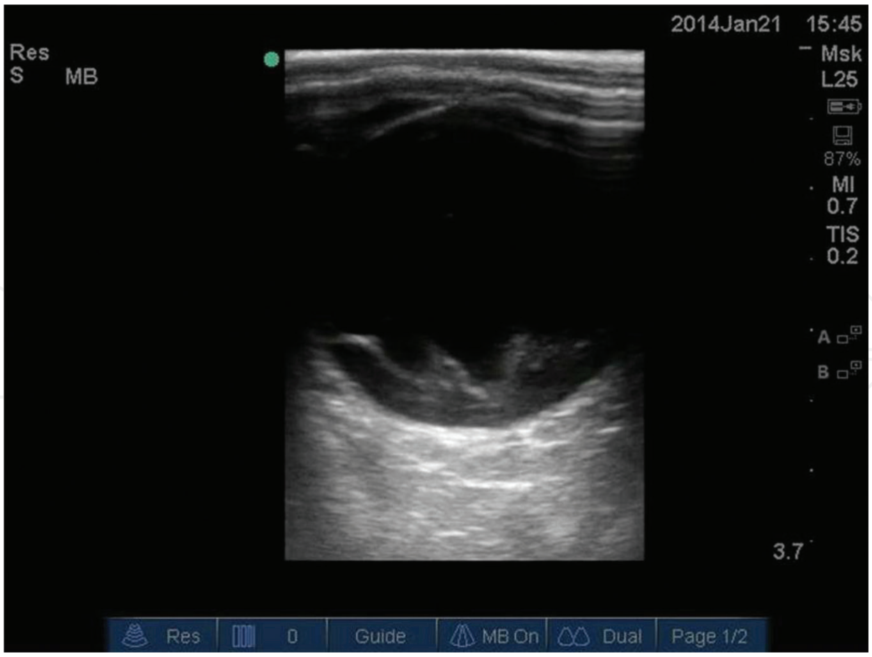

Figure 17. (A) Case of retinal detachment, evident by sharply defined, highly reflective linear membrane that is anchored to the optic disc.

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.

Author details

Irma Faruqi, Maryam Siddiqi and Rasha Buhumaid*

*Address all correspondence to: rbuhumaid@seha.ae

Emergency Department, Sheikh Khalifa Medical City, Abu Dhabi, United Arab Emirates

References

[1] Mateer J, Plummer D, Heller M, Olson D, Jehle D, Overton D, et al. Model curriculum for physician training in emergency ultrasonography. Annals of Emergency Medicine. 1994;**23**(1):95-102

[2] Sanders J, Noble V, Raja A, Sullivan A, Camargo C. Access to and use of point-of-care ultrasound in the emergency department. Western Journal of Emergency Medicine. 2015;**16**(5):747-752

[3] Kendall J, Hoffenberg S, Smith R. History of emergency and critical care ultrasound: The evolution of a new imaging paradigm. Critical Care Medicine. 2007;**35**(5):S126-S130

[4] ACEP Policy Statement. Ultrasound Guidelines: Emergency, Point-of-care, and Clinical Ultrasound Guidelines in Medicine [Internet]. 2016. Available from: https://www.acep.org/Clinical---Practice-Management/Ultrasound-Guidelines--Emergency,-Point-of-care,-and-Clinical-Ultrasound-Guidelines-in-Medicine/?__taxonomyid=471332 [Accessed: 2017-11-2]

[5] CDC National Center for Health Statistics. Emergency Department Visits. 2017. Available from: https://www.cdc.gov/nchs/data/nhamcs/web_tables/2014_ed_web_tables.pdf [Accessed: 2017-12-12]

[6] Melniker L, Leibner E, McKenney M, Lopez P, Briggs W, Mancuso C. Randomized controlled clinical trial of point-of-care, limited ultrasonography for trauma in the emergency department: The first sonography outcomes assessment program trial. Annals of Emergency Medicine. 2006;**48**(3):227-235

[7] Arrillaga A, Graham R, York J, Miller R. Increased efficiency and cost-effectiveness in the evaluation of the blunt abdominal trauma patient with the use of ultrasound. The American Surgeon. 1999;**65**:31-35

[8] McCarter F, Luchette FA, Molloy M, Hurst J, Davis K, Johannigman J, Frame S, Fischer J. Institutional and individual learning curves for focused abdominal ultrasound for trauma: Cumulative sum analysis. Annals of Surgery. 2000;**231**(5):689-700

[9] Boulanger B, McLellan B, Brenneman F, Ochoa J, Kirkpatrick A. Prospective evidence of the superiority of a sonography-based algorithm in the assessment of blunt abdominal injury. The Journal of Trauma. 1999;**47**(4):632-637

[10] Amer M, Ashraf M. Role of FAST and DPL in assessment of blunt abdominal trauma. The Professional Medical Journal. 2008;**15**:200-204

[11] Adeyinka A. Accuracy of the fast exam: A retrospective analysis of blunt abdominal trauma patients. Emergency Medicine: Open Access. 2015;**6**(1)

[12] Nandipati K, Allamaneni S, Kakarla R, Wong A, Richards N, Satterfield J, Turner J, Sung K. Extended focused assessment with sonography for trauma (EFAST) in the diagnosis of pneumothorax: Experience at a community based level I trauma center. Injury. 2011;**42**(5):511-514

[13] Sauter T, Hoess S, Lehmann B, Exadaktylos A, Haider D. Detection of pneumothoraces in patients with multiple blunt trauma: Use and limitations of eFAST. Journal of Emergency Medicine. 2017;**34**:568-572

[14] Medscape. Focused Assessment with Sonography in Trauma (FAST) [Internet]. 2017. Available from: https://emedicine.medscape.com/article/104363-overview?pa=x%2BhBzeRQuBsVbIfG%2F%2BPqyWuwzkM1A35BtfSIktWdH1J3FerFHEPLSCUAf8s%2FdVOA9rwpxt0deiB2TrZfl8JfrUeb0T8SAO%2FpBjZvSxPL9fk%3D [Accessed: 2017-12-12]

[15] Helling T, Wilson J, Augustosky K. The utility of focused abdominal ultrasound in blunt abdominal trauma: A reappraisal. The American Journal of Surgery. 2007;**194**(6):728-732 732-3

[16] Brooks A, Davies B, Smethhurst M, Connolly J. Prospective evaluation of non-radiologist performed emergency abdominal ultrasound for haemoperitoneum. Emergency Medicine Journal. 2004;**21** e5

[17] Brenchley J, Walker A, Sloan J, Hassan T, Venables H. Evaluation of focussed assessment with sonography in trauma (FAST) by UK emergency physicians. Emergency Medicine Journal. 2006;**23**:415-415

[18] Ding W, Shen Y, Yang J, He X, Diagnosis ZM. Of pneumothorax by radiography and ultrasonography: A meta-analysis. Chest. 2011;**140**(4):859-866

[19] Rothlin M, Naf R, Amgwerd M, Candinas D, Frick T, Trentz O. Ultrasound in blunt abdominal and thoracic trauma. The Journal of Trauma. 1993;**34**(4):488-495

[20] Dulchavsky S, Schwarz K, Kirkpatrick A, Billica R, Williams D, Diebel L, Campbell R, Sargysan A, Hamilton D. Prospective evaluation of thoracic ultrasound in the detection of pneumothorax. The Journal of Trauma. 2001;**50**(2):201-205

[21] Kirkpatrick A, Sirois M, Laupland K, Liu D, Rowan K, Ball C, Hameed S, Brown R, Simons R, Dulchavsky S, Hamiilton D, Nicolaou S. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: The extended focused assessment with Sonography for trauma (EFAST). The Journal of Trauma. 2004;**57**(2):288-295

[22] Ma O, Mateer J. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. Annals of Emergency Medicine. 1997;**29**(3):312-315

[23] Leone K, Gisondi M. Chest and abdominal trauma. In: Amnieva-Wang N, editor. A Practical Guide to Pediatric Emergency Medicine: Caring for Children in the Emergency Department. Cambridge University Press; 2011. p. 681-686

[24] ACEP. Tips and Tricks: First Trimester Pregnancy Ultrasound – Trans-abdominal Pelvis [Internet]. 2016. Available from: https://www.acep.org/content.aspx?id=98218#sm.000rcvzgk1aidwo10rv2ccbp2rblg [Accessed: 2017-12-10]

[25] Durham B, Lane B, Burbridge L, Subramaniam B. Pelvic ultrasound performed by emergency physicians for the detection of ectopic pregnancy in complicated first-trimester pregnancies. Annals of Emergency Medicine. 1997;**29**(3):338-347

[26] Houry D, Salhi B. Acute Complications of Pregnancy. In: Walls R, Hockberger R, Gausche-Hill M, editors. Rosen's Emergency Medicine – Concepts and Clinical Practice. Philadephia: Elsevier; 2017. p. 2282-2299

[27] Doubilet P, Benson C, Bourne T, Blaivas M, Barnhart K, Benacerraf B, Brown D, Filly R, Fox J, Goldstein S, Kendall J, Lyons E, Porter M, Pretorius D, Timor-Tritsch I. Diagnostic criteria for nonviable pregnancy early in the first trimester. The New England Journal of Medicine. 2013;**369**(15):1443-1451

[28] Wilson S, Connolly K, Lahham S, Subeh M, Fischetti C, Chiem A, Aspen A, Anderson C, Fox J. Point-of-care ultrasound versus radiology department pelvic ultrasound on emergency department length of stay. World Journal of Emergency Medicine. 2016;**7**(3):178-182

[29] Arntfield R, Millington S. Point of care cardiac ultrasound applications in the emergency department and intensive care unit - a review. Current Cardiology Reviews. 2012;**8**(2):98-108

[30] Doniger S. Focused cardiac ultrasound. In: Doniger S, editor. Pediatric Emergency and Critical Care Ultrasound. Cambridge: Cambridge University Press; 2013. p. 57-70

[31] Gaspari R, Weekes A, Adhikari S, Noble V, Nomura J, Theodoro D, Woo M, Atkinson P, Blehar D, Brown S, Caffery T, Douglass E, Fraser J, Haines C, Lam S, Lanspa M, Lewis M, Liebmann O, Limkakeng A, Lopez F, Platz E, Mendoza M, Minnigan H, Moore C, Novik J, Rang L, Scruggs W, Raio C. Emergency department point-of-care ultrasound in out-of-hospital and in-ED cardiac arrest. Resuscitation. 2016;**109**:33-39

[32] Farsi D, Hajsadeghi S, Hajighanbari J, Mofidi M, Hafezimoghadam P, Rezai M, Mahshidfar B, Abiri S, Abbasi S. Focused cardiac ultrasound (FOCUS) by emergency medicine residents in patients with suspected cardiovascular diseases. Journal of Ultrasound. 2017;**20**(2):133-138

[33] ClinicalGate. Emergency Cardiac Ultrasound: Evaluation for Pericardial Effusion and Cardiac Activity [Internet]. 2015. Available from: https://clinicalgate.com/emergency-cardiac-ultrasound-evaluation-for-pericardial-effusion-and-cardiac-activity/#bib1 [Accessed: 2017-12-13]

[34] Jones A, Tayal V, Sullivan D, Kline J. Randomized, controlled trial of immediate versus delayed goal-directed ultrasound to identify the cause of nontraumatic hypotension in emergency department patients. Critical Care Medicine. 2004;**32**(8):1703-1708

[35] Tayal V, Kline J. Emergency echocardiography to detect pericardial effusion in patients in PEA and near-PEA states. Resuscitation. 2003;**59**(3):315-318

[36] Dresden S, Mitchell P, Rahimi L, Leo M, Rubin-Smith J, Bibi S, White L, Langlois B, Sullivan A, Carmody K. Right ventricular dilatation on bedside echocardiography performed by emergency physicians aids in the diagnosis of pulmonary embolism. Annals of Emergency Medicine. 2014;**63**(1):16-24

[37] Russell F, Rutz F, Pang P. Focused ultrasound in the emergency department for patients with acute heart failure. Cardiac Failure Review. 2015;**1**(2):83-86

[38] Rozycki G, Feliciano D, Ochsner M, Knudson M, Hoyt D, Davis F, Hammerman D, Figueredo V, Harviel J, Han D, Schmidt J. The role of ultrasound in patients with possible penetrating cardiac wounds: A prospective Multicenter study. The Journal of Trauma and Acute Care Surgery. 1999;**46**(4):543-552

[39] Plummer D, Brunette D, Asinger R, Ruiz E. Emergency department echocardiography improves outcome in penetrating cardiac injury. Annals of Emergency Medicine. 1992;**21**(6):709-712

[40] Gaspari R, Weekes A, Adhikari S, Noble V, Nomura J, Theodoro D, Woo M, Atkinson P, Blehar D, Brown S, Caffery T, Douglass E, Fraser J, Haines C, Lam S, Lanspa M, Lewis M, Liebmann O, Limkakeng A, Lopez F, Platz E, Mendoza M, Minnigan H, Moore C, Novik J, Rang L, Scruggs W, Raio C. A retrospective study of pulseless electrical activity, bedside ultrasound identifies interventions during resuscitation associated with improved survival to hospital admission. A REASON study. Resuscitation. 2017;**120**:103-107. DOI: 10.1016/j.resuscitation.2017.09.008

[41] Kochanek K, Xu J, Murphy S, Minino A, Kung H. Deaths: Final data for 2009. National Vital Statistics System (US). 2011;**60**(3):1-116

[42] Ernst C. Abdominal aortic aneurysm. The New England Journal of Medicine. 1993; **328**:1167-1172

[43] Medscape. Abdominal Aortic Aneurysm [Internet]. 2017. Available from: https://emedicine.medscape.com/article/1979501-overview [Accessed: 2017-12-11]

[44] Fink H, Lederle F, Roth C, Bowles C, Nelson D, Haas M. The accuracy of physical examination to detect abdominal aortic aneurysm. Archives of Internal Medicine. 2000; **160**(6):833-836

[45] Singh M, Koyfman A, Martinez J. Abdominal Vascular Catastrophes. In: Graham A, Martinez J, editors. Abdominal and Gastrointestinal Emergencies. Pennsylvania: Elsevier; 2016. p. 327-340

[46] Walker A, Brenchley J, Sloan J, Lalanda M, Venables H. Ultrasound by emergency physicians to detect abdominal aortic aneurysms: A UK case series. Emergency Medicine Journal. 2004;**21**:240-242

[47] Kuhn M, Bonnin R, Davey M, Rowland J, Langlois S. Emergency department ultrasound scanning for abdominal aortic aneurysm: Accessible, accurate, and advantageous. Annals of Emergency Medicine. 2000;**36**(3):219-223

[48] Dent B, Kendall R, Boyle A, Atkinson P. Emergency ultrasound of the abdominal aorta by UK emergency physicians: A prospective cohort study. Emergency Medicine Journal. 2007;**24**(8):547-549

[49] EB Medicine. Ultrasound for Abdominal Aortic Aneurysm [Internet]. 2018. Available from: http://www.ebmedicine.net/topics.php?paction=showTopicSeg&topic_id=252&seg_id=4863 [Accessed: 2018-06-01]

[50] ACEP. Focus On: Bedside Biliary Ultrasound [Internet]. 2010. Available from: https://www.acep.org/Content.aspx?id=64648#sm.000rcvzgk1aidwo10rv2ccbp2rblg [Accessed: 2017-12-11]

[51] Woo M, Taylor M, Loubani O, Bowra J, Atkinson P. My patient has got abdominal pain: Identifying biliary problems. Ultrasound. 2014;**22**(4):223-228

[52] Scruggs W, Fox J, Potts B, Zlidenny A, McDonough J, Anderson C, Larson J, Barajas G, Langdorf M. Accuracy of ED bedside ultrasound for identification of gallstones: Retrospective analysis of 575 studies. Western Journal of Emergency Medicine. 2008;**9**(1):1-5

[53] Degerli V, Korkmaz T, Mollamehmetoglu H, Ertan C. The importance of routine bedside biliary ultrasonography in the management of patients admitted to the emergency department with isolated acute epigastric pain. Turkish Journal of Medical Sciences. 2017;**47**:1137-1143

[54] Blaivas M, Harwood R, Lambert M. Decreasing length of stay with emergency ultrasound examination of the gallbladder. Academic Emergency Medicine. 1999;**6**(10):1020-1023

[55] Adhikari S, Morrison D, Zeger W, Chandwani D, Krueger A. Utility of point-of-care biliary ultrasound in the evaluation of emergency patients with isolated acute non-traumatic epigastric pain. Internal and Emergency Medicine. 2014;**9**(5):583-587

[56] Fwu C, Eggers P, Kimmel P, Kusek J, Kirali Z. Emergency department visits, use of imaging, and drugs for urolithiasis have increased in the United States. Kidney International. 2013;**83**(3):479-486

[57] Pearle M, Calhoun E, Curhan G. Urologic diseases in America project: Urolithiasis. The Journal of Urology. 2005;**173**(3):848-857. DOI: 10.1097/01.ju.0000152082.14384.d7

[58] Innes G, Scheuermeyer F, Law M, McRae A, Weber B, Boyda H, Lonergan K, Andruchow J. Sex-related differences in emergency department renal colic management: Females have fewer computed tomography scans but similar outcomes. Academic Emergency Medicine. 2016;**23**(10):1153-1160

[59] ACEP. Focused Renal Sonography [Internet]. 2012. Available from: http://www.acepnow.com/article/focused-renal-sonography/?singlepage=1 [Accessed: 2017-12-12]

[60] Sheafor D, Hertzberg B, Freed K, Carroll B, Keogan M, Paulson E, DeLong D, Nelson R. Nonenhanced helical CT and US in the emergency evaluation of patients with renal colic: Prospective comparison. Radiology. 2000;**217**(3):792-797

[61] Smith-Bindman R, Aubin C, Bailitz J. Ultrasonography Vs CT for suspected nephrolithiasis. The New England Journal of Medicine. 2014;**371**:1100-1110

[62] Leo M, Langlois B, Mitchell P. Bedside Ultrasound versus Computed Tomography in Diagnosing Renal Colic and Predictors of 30 Day Return Visits. Annals of Emergency Medicine. October 2014;**64**(4):S25

[63] Edmonds M, Yan J, Sedran R. The utility of renal ultrasonography in the diagnosis of renal colic in emergency department patients. Canadian Journal of Emergency Medicine. 2010;**12**(3):201-206

[64] Park Y, Jung R, Lee Y. Does the use of bedside ultrasonography reduce emergency department length of stay for patients with renal colic? A pilot study. Clinical and Experimental Emergency Medicine Journal. 2016;**3**(4):197-203

[65] Riddel J, Case A, Wopat R. Sensitivity of emergency bedside ultrasound to detect hydronephrosis in patients with computed tomography-proven stones. The Western Journal of Emergency Medicine. 2014;**15**(1):96-100

[66] Gaspari R, Horst K. Emergency ultrasound and urinalysis in the evaluation of flank pain. Academic Emergency Medicine. 2005;**12**(12):1180-1184

[67] EB Medicine. Ultrasound For Deep Venous Thrombosis [Internet]. Available from: http://www.ebmedicine.net/topics.php?paction=showTopicSeg&topic_id=252&seg_id=4864 [Accessed: 2017-12-12]

[68] Nunn K, Towards TP. Evidence based emergency medicine: Best BETs from the Manchester Royal Infirmary. Using the ultrasound compression test for deep vein thrombosis will not precipitate a thromboembolic event. Emergency Medicine Journal. 2007 Jul; **24**(7):494-495

[69] Bernardi E, Camporese G, Buller H. Serial 2-point ultrasonography plus D-dimer vs whole-leg color-coded Doppler ultrasonography for diagnosing suspected symptomatic deep vein thrombosis: A randomized controlled trial. Journal of the American Medical Association. 2008;**300**(14):1653-1659

[70] Ageno W, Camporese G, Riva N. Analysis of an algorithm incorporating limited and whole-leg assessment of the deep venous system in symptomatic outpatients with suspected deep-vein thrombosis (PALLADIO): A prospective, multicentre, cohort study. The Lancet Hematology. 2015;**2**(11):e474-e480

[71] Zuker-Herman R, Ayalon D, Berant R. Comparison between two-point and three-point compression ultrasound for the diagnosis of deep vein thrombosis. Journal of Thrombosis and Thrombolysis. 2018;**45**(1):99-105

[72] Poley R, Newbigging J, Sivilotti M. Estimated effect of an integrated approach to suspected deep venous thrombosis using limited-compression ultrasound. Academic Emergency Medicine. 2014;**21**(9):971-980

[73] Hunter F. BET 1: Emergency physician performed 2-point bedside compression ultrasound for deep venous thrombosis. Emergency Medicine Journal. 2014;**31**:944-946

[74] Lubna F, Laura H, Derek W. Sonographic diagnosis of pneumothorax. Journal of Emergencies, Trauma and Shock. 2012;**5**(1):76-81

[75] Lichtenstein D, Goldstein I, Mourgeon E. Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. Anesthesiology. 2004;**100**(1):9-15

[76] Al Deeb M, Barbic S, Featherstone R. Point-of-care ultrasonography for the diagnosis of acute cardiogenic pulmonary edema in patients presenting with acute dyspnea: A systematic review and meta-analysis. Academic Emergency Medicine. 2014;**21**(8):843-852

[77] Martindale J, Wakai A, Collins S. Diagnosing acute heart failure in the emergency department: A systematic review and meta-analysis. Academic Emergency Medicine. 2016; **23**(3):223-242

[78] Subramaniam S, Bober J, Chao J. Point-of-care ultrasound for diagnosis of abscess in skin and soft tissue infections. Academic Emergency Medicine. 2016;**23**(11):1298-1306

[79] Barbic D, Chenkin J, Cho D. In patients presenting to the emergency department with skin and soft tissue infections what is the diagnostic accuracy of point-of-care ultrasonography for the diagnosis of abscess compared to the current standard of care? A systematic review and meta-analysis. British Medical Journal. 2017;**7**:e 013688

[80] Mercier E, Bedside M-CF. Ultrasound for the diagnosis of necrotising fasciitis. Emergency Medicine Journal. 2014;**31**(8):692-693

[81] Adhikari S, Blaivas M. Utility of bedside sonography to distinguish soft tissue abnormalities from joint effusions in the emergency department. Journal of Ultrasound in Medicine. 2010;**29**:519-526

[82] Vieira R, Levy J. Bedside ultrasound to identify hip effusion in pediatric patients. Annals of Emergency Medicine. 2010;**55**(3):284-289

[83] Barata I, Spencer R, Suppiah A. Emergency ultrasound in the detection of pediatric long-bone fractures. Pediatric Emergency Care. 2012;**28**(11):1154-1157

[84] Chartier L, Bosco L, Lapointe-Shaw L. Use of point-of-care ultrasound in long bone fractures: A systematic review and meta-analysis. Canadian Journal of Emergency Medicine. 2017 Mar;**19**(2):131-142

[85] Wang CC, Linden KL, Hansel J. Otero sonographic evaluation of fractures in children. Journal of Diagnostic Medical Sonography. 2017;**33**(3):200-207

[86] Dubrovsky A, Kempinska A, Bank I. Accuracy of ultrasonography for determining successful realignment of pediatric forearm fractures. Annals of Emergency Medicine. 2015;**65**(3):260-265

[87] Gottlieb M, Cosby K. Ultrasound-guided hematoma block for distal radial and ulnar fractures. Journal of Emergency Medicine. 2015;**48**(3):310-312

[88] Eckert K, Janssen N, Ackermann O. Ultrasound diagnosis of supracondylar fractures in children. European Journal of Trauma and Emergency Surgery. 2014;**40**(2):159-168

[89] Adhikari S, Marx J, Crum T. Point-of-care ultrasound diagnosis of acute Achilles tendon rupture in the ED. American Journal of Emergency Medicine. 2012;**30**:634.e3-634.e4, 634.e4

[90] Nesselroade R, Nickels L. Ultrasound diagnosis of bilateral quadriceps tendon rupture after statin use. Western Journal of Emergency Medicine. 2010;**11**(4):306-309

[91] Berg K, Peck J, Boulger C, Bahner D. Patellar tendon rupture: An ultrasound case report. British Medical Journal Case Report. 2013:bcr2012008189

[92] Jarraya M, Hayashi D, de Villiers R. Multimodality imaging of foreign bodies of the musculoskeletal system. AJR. American Journal of Roentgenology 2014;203(1):W92-102

[93] Friedman D, Forti R, Wall S. The utility of bedside ultrasound and patient perception in detecting soft tissue foreign bodies in children. Pediatic Emergency Care. 2005;**21**(8):487-492

[94] Nienaber A, Harvey M, Cave G. Accuracy of bedside ultrasound for the detection of soft tissue foreign bodies by emergency doctors. Emergency Medicine Australasia. 2010;**22**(1):30-34

[95] Taylor M, Lalani N. Adult small bowel obstruction. Academic Emergency Medicine. 2013;**20**(6):528-544

[96] Pongpornsup S, Tarachat K, Srisajjakul S. Accuracy of 64 sliced multi-detector computed tomography in diagnosis of small bowel obstruction. Journal of the Medical Association of Thailand. 2009;**92**(12):1651-1661

[97] Frager D, Medwid S, Baer J. CT of small-bowel obstruction: Value in establishing the diagnosis and determining the degree and cause. American Journal of Roentgenology. 1994;**162**(1):37-41

[98] Mallo R, Salem L, Lalani T. Computed tomography diagnosis of ischemia and complete obstruction in small bowel obstruction: A systematic review. Journal of Gastrointestinal Surgery. 2005;**9**(5):690-694

[99] Suri S, Gupta S, Sudhakar P. Comparative evaluation of plain films, ultrasound and CT in the diagnosis of intestinal obstruction. Acta Radiologica. 1999;**40**(4):422-428

[100] Jang T, Schindler D, Kaji A. Bedside ultrasonography for the detection of small bowel obstruction in the emergency department. Emergency Medicine Journal. 2011;**28**(8):676-678

[101] Unluer E, Yavasi O, Eroglu O. Ultrasonography by emergency medicine and radiology residents for the diagnosis of small bowel obstruction. European Journal of Emergency Medicine. 2010;**17**(5):260-264

[102] Babineau M, Sanchez L. Ophthalmologic procedures in the emergency department. Emergency Medicine Clinics of North America. 2008;**26**(1):17-34 v-vi

[103] Jacobsen B, Lahham S, Retrospective Review PA. Of ocular point-of-care ultrasound for detection of retinal detachment. The Western Journal of Emergency Medicine. 2016;**17**(2):196-200

[104] Nagaraju R, Ningappa R. Bhimarao. Role of high resolution ultrasonography in the evaluation of posterior segment lesions. In The Eye Journal of Evidence Based Medicine and Healthcare. 2015;**2**(2):97-112

[105] Lee S, Hayward A, BellamKonda V. Traumatic lens dislocation. International Journal of Emergency Medicine. 2015;**8**:16

[106] Major R, Girling S, Boyle A. Ultrasound measurement of optic nerve sheath diameter in patients with a clinical suspicion of raised intracranial pressure. Emergency Medicine Journal. 2011;**28**(8):679-681

[107] Karakitsos D, Labropoulos N, De Groot E. Real-time ultrasound-guided catheterisation of the internal jugular vein: A prospective comparison with the landmark technique in critical care patients. Critical Care. 2006;**10**(6):R162

[108] Hind D, Calvert N, McWilliams R. Ultrasonic locating devices for central venous cannulation: Meta-analysis. British Medical Journal. 2003;**327**(7411):361

[109] Stolz L, Stolz U, Howe C. Ultrasound-guided peripheral venous access: A meta-analysis and systematic review. The Journal of Vascular Access. 2015;**16**(4):321-326

[110] Barr L, Hatch N, Roque P. Basic ultrasound-guided procedures. Critical Care Clinics. 2014;**30**(2):275-304 vi

[111] Finoff J, Hall M, Adams E. American medical Society for Sports Medicine position statement: Interventional musculoskeletal ultrasound in sports medicine. Clinical Journal of Sport Medicine. 2015;**25**(1):6-22

[112] Chou E, Dickman E, Tsou P. Ultrasonography for confirmation of endotracheal tube placement: A systematic review and meta-analysis. Resuscitation. 2015;**90**:97-103

[113] Hatch N, Wu T, Barr L. Advanced ultrasound procedures. Critical Care Clinics. 2014; **30**(2):305-329 vi

[114] Rupp S, Apfelbaum J, Blitt C. Practice guidelines for central venous access: A report by the American Society of Anesthesiologists Task Force on central venous access. Anesthesiology. 2012;**116**(3):539-573