

Point-of-Care Ultrasonography

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MICHAEL J. ARNOLD, MD, and CHRISTOPHER E. JONAS, DO Uniformed Services University of the Health Sciences, Bethesda, Maryland

RACHEL E. CARTER, MD, Naval Hospital Jacksonville, Jacksonville, Florida

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Point-of-care ultrasonography (POCUS) is performed by a physician at the bedside and is standard practice in obstetric, emergency, and musculoskeletal medicine. When compared with formal sonography, POCUS is equivalent in screening for abdominal aortic aneurysm and as accurate in diagnosing deep venous thrombosis. POCUS has high accuracy for diagnosing pneumonia and detecting acute decompensated heart failure but is less accurate than computed tomography for identifying pulmonary embolism. POCUS confirmation of intrauterine pregnancy rules out an ectopic pregnancy. In the third trimester of high-risk pregnancies, umbilical artery Doppler ultrasonography can improve perinatal outcomes. Musculoskeletal POCUS is used to diagnose and guide treatment of many joint and soft tissue conditions. It is as accurate as magnetic resonance imaging in the diagnosis of complete rotator cuff tears. Ultrasound guidance improves outcomes in the placement of central venous catheters and fluid drainage from body cavities and lumbar punctures. Ultrasonography can reduce the use of CT for diagnosis of appendicitis; however, negative scan results do not rule out disease. POCUS can accurately diagnose and rule out gallbladder pathology, and

is effective for diagnosing urolithiasis. Focused cardiac ultrasonography can detect pericardial effusion and decreased systolic function, but is less accurate than lung ultrasonography at diagnosing acute heart failure. Limited evidence demonstrates a benefit of diagnosing testicular and gynecologic conditions. The American College of Emergency Physicians, the American Institute of Ultrasound in Medicine, the Society for Academic Emergency Medicine, the American College of Radiology, and others offer POCUS training. Training standards for POCUS have been defined for residency programs but are less established for credentialing.

Point-of-care ultrasonography (POCUS) is an evolving outpatient, inpatient, and urgent care diagnostic tool. Diagnostic timing decreases, and accuracy increases when POCUS augments the clinical examination and procedures. The use of POCUS in primary care is increasing because it reduces cost, radiation exposure, and imaging delays, and increases patient satisfaction. POCUS is also useful in resource-limited settings. The instruction of POCUS is increasing in family medicine residency programs, and resources for practicing physicians exist. However, widespread POCUS use is limited by the training burden required to gain and maintain skills. This article summarizes the strongest evidence for the effectiveness of POCUS in specific clinical conditions.

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SORT: KEY

RECOMMENDATIONS FOR PRACTICE

<i>CLINICAL RECOMMENDATION</i>	<i>EVIDENCE RATING</i>	<i>COM</i>
Screening for AAA can be performed accurately with POCUS. ⁴⁻⁸	C	Multi-disease oriented studies meta-analy
Lung ultrasonography is accurate for determining the source of acute respiratory distress. ²⁴⁻²⁸	C	Disea-orient studi syste- review
Ultrasonography differentiates cellulitis from abscess more accurately than clinical evaluation and reduces inappropriate incision and drainage and failure to resolve post drainage. ^{17,36}	C	Syste- review eight disea- orient coho- studi- case- studi- retro- review
Ultrasonography	C	Coch

Clinical Conditions with Strong, Consistent Evidence Supporting Use of POCUS

ABDOMINAL AORTIC ANEURYSM SCREENING

One-time abdominal aortic aneurysm (AAA) screening is recommended for men 65 to 75 years of age who smoked at least 100 cigarettes during their lifetime, with consideration for screening men who never smoked.¹ Screening reduces aneurysm rupture mortality by 34% (number needed to screen = 311 to prevent one death).² In a 2012 study, only 31% of eligible patients were screened and most used more costly or radiation-intensive imaging.³

Two studies with 80 and 45 participants yielded 100% sensitivity and specificity for AAA screening with POCUS in primary care.^{4,5} A meta-analysis of seven emergency department POC ultrasound studies demonstrated 99% sensitivity and 98% specificity for AAA diagnosis.⁶ In another trial, a medical student identified 15 of 16 aneurysms in 57 patients after three hours of training; and the missed aneurysm was an inconclusive study.⁷ In a large study of primary care AAA screening with 25 hours of physician training, scans were completed in an average of four minutes but showed a 21% false-positive rate; however, misdiagnosed scans showed abnormalities such as aortic ectasia or luminal thrombus.⁸ *Figure 1* shows POCUS scans of a normal abdominal aorta and an abdominal aortic aneurysm.

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FIGURE 1.

Screening for an abdominal aortic aneurysm. (A) Normal caliber aorta (2.38 cm) in the proximal aorta at the level of the celiac trunk. (B) Aneurysm (4.72 cm) within the midabdominal aorta.

Note: Normal is less than 3 cm; ongoing monitoring for 3 to 4.9 cm; surgical referral for 5 cm or greater or 2-cm change over one year.

DEEP VENOUS THROMBOSIS

Proximal compression leg ultrasonography accurately diagnoses deep venous thrombosis (DVT).⁹ Emergency department POCUS of common femoral and popliteal veins have 96% sensitivity and 97% specificity for detecting DVT.⁹ After two hours of training, primary care physicians diagnosed DVT with 90% sensitivity and 97% specificity.¹⁰ When examinations are repeated, diagnostic accuracy approaches 100%.¹¹ *Figure 2* shows a DVT diagnosed using POCUS.

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FIGURE 2.

Deep venous thrombosis within the popliteal vein in the right popliteal fossa.

PROCEDURAL GUIDANCE

POCUS is used for guidance in many procedures and has become the standard of care for some procedures (*Table 1*).^{12–17} In central venous catheter placement, ultrasound guidance reduces

complications, arterial puncture, and time to completion, and improves success.^{12,13}

Ultrasound guidance of thoracentesis and paracentesis reduces the rate of dry taps but not the number of passes or incidence of pneumothorax.^{14,15} Ultrasound guidance reduces bleeding (number needed to treat [NNT] = 391),¹⁵ and prevents failure in paracentesis (NNT = 12) and reduces traumatic lumbar puncture (NNT = 7).¹⁶ For superficial skin abscess drainage, ultrasound guidance reduces treatment failure (NNT = 9).¹⁷

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TABLE 1.
Ultrasound Guidance for Common Nonmusculoskeletal Procedures

PROCEDURE	EVIDENCE
Femoral central line	Only significant improvement was an increased likelihood of success with first attempt (NNT = 3) ¹³
Internal jugular central line	Reduced complication rate (NNT = 11), improved success rate (NNT = 10), reduced arterial puncture (NNT = 17), and reduced other complications (NNT = 67) while reducing time for the procedure by 30 minutes ¹²
Lumbar puncture	Prevent failed procedure (NNT = 12); prevented traumatic

Numerous musculoskeletal procedures are performed with POCUS guidance, including joint and soft tissue aspiration, injections, and nerve blocks. Ultrasonography is becoming a standard of care for some interventions.¹⁸ Ultrasound guidance reduces procedural pain scores by an average of -0.5 to -2 on a 10-point scale for subacromial, bicep tendon sheath, glenohumeral, and knee joint injections.^{19,20} Ultrasound guidance during knee arthrocentesis reduces pain by more than 50%.²¹ In nerve blocks, ultrasound guidance reduces the number of inadequate blocks (NNT = 9), paresthesia (NNT = 11), and vascular puncture (NNT = 14).²² *Table 2* summarizes the benefits of ultrasound guidance in musculoskeletal procedures.¹⁹⁻²³

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TABLE 2.

Ultrasound Use for Musculoskeletal Procedures

<i>PROCEDURE</i>	<i>NNT TO PREVENT MISSING TARGET</i>	<i>PATIENT OUTCOME</i>
Biceps tendon sheath injection	2	Average score improved 1.9 out of 10; functional improvement 1.1 out of 10
Carpal tunnel injection	Not reported	Average reduction in pain points; no difference in severity and no difference in functional electrodiagnostic results
Glenohumeral joint injection	5	Average score improved 0.6 out of 10; no functional difference in adhesions or capsular contracture

RESPIRATORY DISTRESS

The bedside lung ultrasound in emergency (BLUE) protocol was developed to categorize findings in acute respiratory distress^{24,25} (*eTable A*). In lung ultrasonography, A lines are artifacts running parallel to pleura in healthy lung tissue (*Figure 3A*), whereas B lines are comet-tail artifacts found perpendicular to pleura from subpleural edema²⁴ (*Figure 3B*). Ultrasound findings are combined with clinical evaluation; unilateral B lines with fever and cough correlate with pneumonia, and bilateral A lines with wheezing suggest obstructive airway disease given that lung parenchyma is normal in bronchial obstruction.²⁴ POCUS of the lung is more sensitive than plain radiography in diagnosing other conditions, such as pleural effusion (94% sensitivity) and pulmonary contusion (92% sensitivity).^{26,27} POCUS of the lung decreases emergency department diagnostic time by two hours on average compared with standard radiography, computed tomography (CT), or echocardiography.²⁵

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eTABLE A

Bedside Lung Ultrasound Evaluation (BLUE) Protocol for Respiratory Distress

DIAGNOSIS	LUNG ULTRASOUND FINDINGS	S.
Asthma or chronic obstructive pulmonary disease	A lines (healthy lung)	8
Fluid overload	B lines	8
Pneumonia	One of the following findings: B lines with no lung sliding* B lines in one lung only Visualized area of consolidated lung	8
Pneumothorax	A lines with no lung sliding* and a possible focal area of	8

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FIGURE 3.

Common lung ultrasound findings. (A) A lines (arrow) run parallel to the probe and the pleura and are a refraction artifact in a normal lung. (B) B lines (arrow) are groupings of comet-tail artifacts running perpendicular to the pleura and reflect subpleural edema.

Although lung ultrasonography is less accurate than CT angiography for diagnosis of pulmonary embolism, POCUS can be valuable if CT is unavailable or contraindicated. A healthy lung ultrasound has a negative likelihood ratio (LR⁻) of 0.18, compared with a LR⁻ of 0.36 for a low-probability ventilation-perfusion scan and a LR⁻ of 0.11 for a negative CT angiogram.^{28,29} With a moderate-risk Wells score, a negative lung ultrasound reduces pulmonary embolism probability from 16% to 5% and a positive lung ultrasound increases pulmonary embolism probability to 55%.²⁸

ROTATOR CUFF TEAR

A Cochrane review of 20 studies of POCUS and formal sonography involving 1,147 shoulders demonstrated ultrasonography can diagnose full-thickness rotator cuff tears with equivalent accuracy to magnetic resonance imaging (MRI).³⁰ For partial-thickness rotator cuff tears and subacromial conditions, ultrasonography is less accurate than MRI.^{30,31} *Table 3* describes the accuracy of ultrasonography for shoulder conditions.³⁰⁻³³ *Figure 4* shows a POCUS scan of a complete rotator cuff tear.³⁴

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TABLE 3.
Musculoskeletal Ultrasonography of the Shoulder Compared with MRI

CONDITION	MUSCULOSKELETAL ULTRASONOGRAPHY	
	SENSITIVITY	SPECIFIC
Calcifying tendinitis	100%	85% to 98%
Full thickness rotator cuff tear	92%*	93%
Partial thickness rotator cuff tear	52%	93%
Subacromial bursitis	79% to 81%	94% to 98%

MRI = magnetic resonance imaging.

*—A Cochrane review found these sensitivities were equivalent.

Information from references 30–33.

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FIGURE 4.

Supraspinatus muscle (*black arrows*); complete tear (*white arrow*).

SKIN AND SOFT TISSUE INFECTIONS

Without imaging, differentiating cellulitis from an abscess can be difficult because clinical examinations can be incorrect in up to 22% of cases, delaying resolution and increasing risk.³⁵ A systematic review showed that POCUS reduces the failure-to-diagnose rate because negative scan results have a LR– of 0.05 for abscess.³⁶ POCUS also decreases inappropriate incision and drainage of cellulitis without abscess by up to 20% compared with clinical examinations.³⁶ One study demonstrated 86% sensitivity for diagnosing abscess with POCUS, compared with 77% for CT.³⁷ Ultrasonography also effectively rules out foreign bodies that can delay healing. In a small study, a normal POCUS scan had a 96% negative predictive value for subcutaneous foreign bodies.³⁸ *Figure 5* shows POCUS scans of cellulitis and abscess.

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FIGURE 5.

Ultrasonography of skin and soft-tissue infection. (A) Cellulitis, with scattered fluid pockets in a cobblestoning pattern (*arrows*) but without a distinct fluid collection. (B) Abscess (2.7 cm) with fluid collection in the subcutaneous fat.

Evidence Supporting Use of POCUS

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APPENDICITIS

POCUS has been studied to reduce CT imaging in suspected appendicitis. The pooled sensitivity of POCUS for appendicitis is 91% when performed by surgeons and physicians who work in the emergency department.³⁹ A meta-analysis of POCUS performed by emergency department physicians showed 84% sensitivity and 91% specificity, with higher accuracy in children.⁴⁰ Ultrasonography can confirm appendicitis; however, a negative ultrasound does not rule out disease because perforated appendicitis is often missed because of findings including loculated fluid collections, dilated bowel, appendicoliths, and increased liver echogenicity.⁴¹ In children, a negative ultrasound with a low-risk clinical decision score sufficiently rules out appendicitis.⁴²

BILIARY COLIC

Biliary ultrasonography aids cholecystitis diagnosis in suspected biliary colic. POCUS has 90% sensitivity and 88% specificity compared with CT or surgical findings.⁴³ In comparison, CT has 92% sensitivity.⁴⁴ Diagnostic accuracy is nearly 100% when gallstones are found with gallbladder wall thickening and pericholecystic fluid or sludge (*Table 4*).⁴⁵ POCUS is highly accurate at diagnosing gallstones; however, cholecystitis occurs without stones in 14% of cases.⁴⁶ *Figure 6* shows biliary POCUS findings.

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TABLE 4.

Accuracy of Point-of-Care Ultrasonography for Cholecystitis

	<i>SENSITIVITY</i>	<i>SPECIFICITY</i>
Individual findings		
Gallstones	84%	49%
Gallbladder wall thickening	54%	92%
Pericholecystic fluid	23%	98%
Sludge in gall bladder	23%	91%
Common bile duct dilation	21%	88%
Combinations of findings		
Gallstones and gallbladder wall thickening	54%	93%
Gallstones and sludge and	23%	100%

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FIGURE 6.

Gallbladder ultrasound image. (A) Normal gallbladder (*arrow*) without visualized stones or wall thickening. (B) Gallstone and posterior shadowing without gallbladder changes. (C) Cholecystitis demonstrated by multiple gallstones (*long arrows*), a thickened gallbladder wall (*short arrow*), and visualized sludge (*thick arrow*).

BOWEL PERFORATION

Free abdominal air can create ultrasound artifacts, including anterior echogenic lines, and internal echoes within fluid and resonance artifacts. In one study, POCUS had 92% sensitivity in the detection of free air compared with 78% for upright chest radiography; both had 53% specificity.⁴⁷

DECREASED CARDIAC EJECTION FRACTION

Focused cardiac ultrasound sensitivity for decreased cardiac ejection fraction varies from 74% to 94%.⁴⁸ In most studies, cardiac ultrasonography is less sensitive for the diagnosis of acute decompensated heart failure than the 88% sensitivity of lung ultrasonography.⁴⁹ Yet, evidence supports the use of focused cardiac ultrasonography for gross cardiac function estimation. A study of 50 patients admitted for acute decompensated heart failure showed that residents found ejection fraction in less than 40% of patients with 94% sensitivity and specificity.⁵⁰ In another study, emergency medicine residents missed decreased systolic function one-half of the time.⁵¹ E-point septal separation (EPSS) is the measurement of the minimal separation of the anterior mitral valve leaflet and the ventricular septum, which corresponds to ejection fraction. In a study with 80 patients, EPSS diagnosed ejection fraction at 30% or less with 100% sensitivity but only 44% positive predictive value, attributed to false positives.⁵²

ELEVATED INTRACRANIAL PRESSURE

Optic nerve sheath diameter measured with POCUS enables noninvasive detection of elevated intracranial pressure, with 90% sensitivity and 85% specificity.⁵³

INTERNAL BLEEDING IN TRAUMA

The focused assessment with sonography for trauma (FAST) examination represents one of the first POCUS protocols and has replaced diagnostic peritoneal lavage (DPL) for detection of internal bleeding. A Cochrane review found 74% sensitivity and 96% specificity for thoracoabdominal bleeding.⁵⁴

OBSTETRIC AND GYNECOLOGIC CONDITIONS

Ultrasonography is standard in pregnancy management. Many obstetric parameters, such as first-trimester dating, amniotic fluid levels, fetal position, and antepartum testing, are defined with ultrasonography. Ultrasonography is required to diagnose placental abnormalities. Visualization of intrauterine pregnancy rules out ectopic pregnancy with a LR⁻ of 0.08.⁵⁵

A Cochrane review found that screening the umbilical artery with Doppler ultrasonography

reduces the risk of perinatal death (number needed to screen = 203) when performed during the third trimester in a high-risk pregnancy attributed to diabetes mellitus, hypertensive disorders, or other issues increasing perinatal mortality risk.⁵⁶ The review could not define which intervention or protocol triggered by an abnormal Doppler study is the preferred method to reduce mortality. Recent evidence verifies ultrasound screening at 36 weeks of gestation is effective in determining breech presentation.⁵⁷

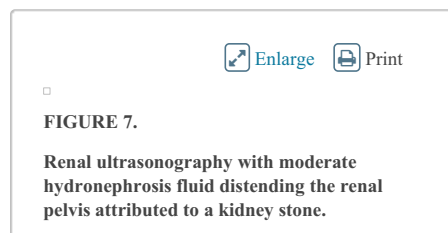
POCUS is used to evaluate pelvic pain and vaginal bleeding in women; however, accuracy has not been studied. POCUS effectively evaluates intrauterine device placement, but accuracy has not been assessed.⁵⁸

PERICARDIAL EFFUSION

Focused cardiac ultrasonography includes limited cardiac views and specific measurements to obtain functional information on the dynamic heart. Focused cardiac ultrasonography is most effective in detecting pericardial effusion, with 100% sensitivity in one study.⁵⁹ Reproducibility of focused cardiac ultrasonography was questioned by another study demonstrating that residents in emergency medicine miss pericardial effusion one-half of the time.⁵¹ Demonstration of effusion and tamponade can be lifesaving despite limitations.

RENAL COLIC

POCUS can identify urolithiasis and hydronephrosis with 70% sensitivity and 75% specificity in suspected renal colic. Finding at least moderate hydronephrosis increases specificity to 94%.⁶⁰ Hydronephrosis identification is improved with increased physician ultrasound experience.⁶¹ A large multicenter trial showed that the emergency department POCUS evaluation of suspected urolithiasis produced equivalent clinical outcomes to CT evaluation.⁶² *Figure 7* shows hydronephrosis attributed to urolithiasis on renal ultrasonography.



RETINAL DETACHMENT

Retinal detachment can be diagnosed with 97% sensitivity, but 83% specificity because retinal detachment can be confused with a benign vitreal detachment in older adults.⁶³

Clinical Conditions with Limited Evidence Supporting Use of POCUS

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SCROTAL PAIN

A study with 36 patients showed that a POCUS examination of acute scrotal pain identified testicular torsion with 95% sensitivity and 94% specificity.⁶⁴

MUSCULOSKELETAL CONDITIONS

OUTSIDE THE SHOULDER

Ultrasonography is often used to diagnose musculoskeletal conditions because of its ability to localize patient conditions and perform a dynamic assessment, but data comparing musculoskeletal ultrasonography to other radiologic modalities is limited. Most studies are small and compare ultrasonography to clinical examination findings, but the evidence is emerging for soft tissue structures.⁶⁵ A systematic review found plantar fascial thickness of 4 mm or greater on ultrasonography is diagnostic for plantar fasciitis.⁶⁶ In a study of 45 patients, complete and partial distal biceps tendon tears were diagnosed using POCUS with 95% sensitivity compared with surgical findings.⁶⁷

FRACTURE

Ultrasonography is less accurate than plain radiography for extremity fractures but is useful when radiography is unavailable.⁶⁸ POCUS can diagnose extremity fractures with 85% sensitivity and 73% specificity compared with plain radiography.⁶⁹ A small study suggests POCUS diagnoses rib fractures with 63% sensitivity, with feasibility limited by pain.⁷⁰

Training and Competency

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POCUS is being integrated into medical school and residency curricula. The American Academy of Family Physicians recommends ultrasound guidelines emphasizing a faculty champion with curricula including didactics, hands-on learning, and assessment.⁷¹ These guidelines recommend 150 to 300 reviewed scans for general competency, 25 to 50 scans for any specific examination, and five to 10 scans for ultrasound procedural guidance, and are based on emergency medicine requirements.⁷¹ For musculoskeletal applications, the American Institute of Ultrasound in Medicine recommends 50 diagnostic and 50 ultrasound-guided procedures.¹⁸

For credentialed physicians, POCUS accreditation is less clear. Numerous instructional resources teaching ultrasound skills are available, including many that are free (*Table 5*^{71,72}). Certificate programs for nonmusculoskeletal POCUS are offered by the American College of Chest Physicians and the Alliance for Physician Certification and Advancement. The American Institute of Ultrasound in Medicine and the American College of Radiology offer accreditations in musculoskeletal ultrasonography.^{18,71,72} The American Board of Family Medicine does not currently recognize certification in POCUS, so credentialing decisions are deferred to privileging hospitals.⁷¹ The American Institute of Ultrasound in Medicine recommends 50 procedures annually and dedicated continuing medical education for physicians to maintain ultrasound skills.¹⁸ No other organizations have specific recommendations for maintaining privileges.

TABLE 5.

Resources for Learning Point-of-Care Ultrasonography

RESOURCE

5 Min Sono
<http://5minsono.com/>

American College of Emergency Physicians
 Sonoguide
<https://www.acep.org/sonoguide/introduction.html>

American Institute of Ultrasound in Medicine
<https://www.aium.org>

European Society of Musculoskeletal Radiology

Editor's Note: Dr. Arnold is the medical editing fellow for *AFP*.

Data Sources: A PubMed search was completed using the key terms point-of-care ultrasound, focused cardiac ultrasound, ultrasound credentialing, musculoskeletal ultrasound, and bedside ultrasound. After the significant injuries and diagnoses were identified, searches were performed for each modality. The searches included systemic reviews, meta-analyses, randomized controlled trials, and review articles. Also searched were the Cochrane database, Essential Evidence Plus, and Clinical Evidence. Also, references in these resources were searched. Search dates: January to March 2019, June 2019, and December 2019.

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The Authors show all author info

MICHAEL J. ARNOLD, MD, FAAFP, is an assistant professor in the Department of Family Medicine at the Uniformed Services University of the Health Sciences, Bethesda, Md....

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Point-of-care (POC) ultrasonography is performed and interpreted at the bedside by the treating physician. In recent years, the use of this particular form of focused ultrasonography has commonly increased. Although formerly POC ultrasonography belonged to a few specialties, such as radiologists and cardiologists; however, there is an increase in the application of ultrasonography in other specialties also. The use of ultrasonography is rapidly evolving within the acute care specialties, such as emergency medicine, intensive care and anaesthesiology (both used peri-operatively[1] and in the Emergency ultrasound or point-of-care ultrasound (POCUS) is the application of ultrasound at the point of care to make immediate patient-care decisions. It is performed by the health care professional caring for the injured or ill persons. This point-of-care use of ultrasound is often to evaluate an emergency medical condition, in settings such as an emergency department, critical care unit, ambulance, or combat zone. Key words: ultrasound, ultrasonography, point of care, emergency department, pediatric emergency medicine, imaging. ABBREVIATIONS: US, ultrasonography; ED, emergency department; ACEP, American College of Emergency Physicians; PEM, pediatric emergency medicine; CT, computed tomography. Point-of-care US can expedite clinical decisionmaking, direct follow-up diagnostic imaging, aid in procedural guidance and improve patient satisfaction.1-6 Point-of-care US is designed to answer specific yes/no questions in real time. The point-of-care US examination has important qualities as an imaging modality. A brief overview of point-of-care ultrasound (POCUS) in the ICU: for the already converted, a reminder of how POCUS has changed ICU practice; for the ultrasound naïve, an aperitif to leave the reader with interest in this evolving paradigm shift of patient care. As intensivists, we have all faced this scenario: a 28-year-old woman, 35 weeks pregnant, presenting to the emergency department with respiratory failure, acute kidney failure and a non-diagnostic chest radiograph. Thoracic ultrasonography may help in identification of the cause of respiratory failure. A-lines are horizontal repetitions of the pleural line, and indicate a

normal aeration pattern of the lung.