01 - 493 Point-of-Care Ultrasound

493 Point-of-Care Ultrasound

Emerging Topics in Clinical Medicine PART 20 Wilma Chan, Nilam J. Soni, Paul H. Mayo

Point-of-Care Ultrasound DEFINITION Point-of-care ultrasound (POCUS) is defined as the acquisition, interpretation, and clinical integration of ultrasonographic views by a treating clinician in real time at the patient’s bedside. POCUS is distinct from consultative ultrasound where a clinician orders an ultrasound exam, a sonographer acquires a comprehensive set of images, an imag ing specialist (most often a radiologist or cardiologist) interprets the images, and the ordering clinician receives an ultrasound report and integrates findings into clinical decision-making (Fig. 493-1). The goal of POCUS is not to replace the imaging specialist or the highresolution data provided by computed tomography (CT) or magnetic resonance imaging (MRI), but rather to improve diagnostic and thera peutic decisions made by the treating clinician at the bedside. POCUS became part of trauma care in emergency departments in the 1980s, and subsequently, many specialties began incorporat ing POCUS into patient care. The 1999 House of Delegates from the American Medical Association passed a resolution (AMA HR. 802) enabling each specialty to define its own scope and appropriate use of POCUS. Specialty-based guidelines emerged supporting credentialing processes and defining standard scanning protocols to answer focused diagnostic questions. Common clinical scenarios, such as acute dys pnea, abdominal pain, and shock, can be rapidly characterized using POCUS (Table 493-1). In internal medicine, there has been expanding interest in POCUS since the 2000s. POCUS can enhance diagnostic accuracy, treatment, monitoring, and screening of patients, as well as improve patient and clinician confidence and procedural safety (Fig. 493-2). Physical Examination Point-of-Care Consultative Ultrasound Ultrasound ask select acquire interpret act Bedside Clinician Sonographer Radiologist or Cardiologist FIGURE 493-1 Workflow schematic comparing point-of-care ultrasound to physical examination and consultative ultrasound. Medical decision-making begins with asking a targeted question, selecting the diagnostic modalities, acquiring and interpreting images or other data, and ultimately, acting to incorporate the new findings into the patient’s care. The three different shapes represent various personnel in this process, and curved arrows demonstrate the exchange of information among providers across different stages. (Reproduced with permission from NJ Soni, BP Lucas: Diagnostic point-of-care ultrasound for hospitalists. J Hosp Med 10, 2014.)

Portable ultrasound machines are categorized as cart-based machines versus handheld devices with wired or wireless probes con nected to a tablet or mobile phone. Linear, curvilinear, and phasedarray probes are commonly available, and multifunctional probes are emerging. Linear high-frequency probes have excellent image resolu tion but limited penetration, so they are used primarily to examine superficial structures. Deeper structures are visualized with curvilinear or phased-array probes, which have a lower frequency. Portable ultra sound devices offer two-dimensional or gray-scale imaging, and color flow and spectral Doppler imaging. Important considerations when purchasing an ultrasound machine include portability, image resolu tion, screen size, probe types, imaging modes, battery life, disinfection, image archiving capability, and warranty. COMMON APPLICATIONS ■ ■CARDIAC In the 1990s, clinicians began to perform focused cardiac POCUS exams to guide immediate management, especially for urgent and life-threatening conditions. In intensive care units and emergency departments, cardiac POCUS is routinely used to rapidly categorize shock states and acute respiratory failure. In outpatient settings, it is often used for serial monitoring of stable patients with chronic forms of heart disease. A limited or focused cardiac POCUS exam includes five core views: parasternal long-axis, parasternal short-axis (mid-ventricular or papil lary muscle level), apical four-chamber, subcostal four-chamber, and inferior vena cava views. Clinicians with comprehensive training in echocardiography, including cardiologists and intensivists certified by the National Board of Echocardiography, may perform advanced Doppler measurements of cardiac pressures and function. Cardiac POCUS and consultative echocardiography are complementary tech niques where the clinical situation and operator skill determine which approach is most appropriate. Cardiac POCUS exams can guide immediate and ongoing clinical decision-making when performed serially. To categorize shock states, left ventricular systolic function can be qualitatively categorized as nor mal (Video 493-1), hyperdynamic (Video 493-2), moderately reduced (Video 493-3), or severely reduced (Video 493-4). Other findings detected by cardiac POCUS that can change immediate management include acute right ventricular failure (Video 493-5), cardiac tampon ade (Video 493-6), and gross valvular abnormalities, including severe regurgitation of the tricuspid (Video 493-7), mitral (Video 493-8), and aortic (Video 493-9) valves, as well as large valvular vegetations (Video 493-10). Competence in basic cardiac POCUS has become a mandatory component of an increasing number of specialties, including emer gency medicine, pulmonary medicine, critical care medicine, and anesthesiology. ■ ■LUNG AND PLEURA Historically, thoracic ultrasonography, comprised of lung and pleural ultrasound, was established by clinicians specialized in critical care, pulmonary, and emergency medicine. The pleural surface can be imaged through the intercostal spaces using high-frequency probes, while low-frequency probes penetrate deeper, allowing visualization of structures in the thorax. Ultrasound is superior to chest x-ray for detection of pneumothorax, early interstitial processes, and small pleu ral effusions and is superior to chest CT for characterization of early complex pleural effusions. Pleural fluid is seen as a relatively hypoechoic space bounded by the diaphragm, chest wall, and atelectatic lung (Video 493-11). Pleural effusions are quantified as small (Video 493-12), moderate (Video 493-13), or large (Video 493-14), and qualitatively assessed as simple, homogeneously echogenic, complex nonseptated (Video 493-15), or complex septated (Video 493-16). Ultrasound guidance to identify an

Pleural effusion Dullness to percussion

4.8 0.1 Visualization of pleural fluid

0.07 Pulmonary edema Crackles 19–64 82–94 3.4 NS Bilateral B-lines

10.4 0.06 Pneumonia Bronchial breath sounds

3.3 NS Consolidation pattern 94–95 90–96 13.5 0.06 Elevated CVP (>8 cmH20) Neck vein inspection 47–92 93–96 9.7 0.3 CVP >10 mmHg (IVC size >2 cm)

4.9 0.32 Reduced ejection fraction 3rd heart sound (S3) 11–51 85–98 3.4 0.7 LV systolic dysfunction 84–91 85–88 6.5 0.14 FINDING SENSITIVITY (%) SPECIFICITY (%) LR+ LR– FINDING SENSITIVITY (%) SPECIFICITY (%) LR+ LR– Elevated LV pressure 4th heart sound (S4) 37–71 50–70 NS NS PCWP 17 if IVC >2.0

4.4 0.3 Pulmonary Cardiac PATHOLOGY PHYSICAL EXAMINATION POINT-OF-CARE ULTRASOUND PART 20 Emerging Topics in Clinical Medicine TABLE 493-1 Comparison of Physical Examination Versus Point-of-Care Ultrasound Findings for Common Pathologies Egophony 4–16 96–99 4.1 NS Decreased breath sounds

5.2 0.1 Crackles 19–67 36–94 1.8 0.8

Congestive heart failure Rales 12–23 88–96 NS NS Bilateral B-lines

19.4 0.03 Abdominojugular test 55–84 83–98 8.0 0.3 CVP >10 mmHg (IVC size >2 cm)

4.9 0.32 Ascites Bulging flanks 73–93 44–70 1.9 0.4 Visualized ascites

0.04 Urinary retention (>400 mL) Palpation

1.9 0.3 Bladder volume (>600 mL)

3.84 0.05 Lower extremity DVT Calf swelling >2 cm 61–67 69–71 2.1 0.5 Compression venous ultrasonography

0.04 Abbreviations: CVP, central venous pressure; DVT, deep-venous thrombosis; IVC, inferior vena cava; JVP, jugular venous pulse; LE, lower extremity; LR, likelihood ratio; LV, left ventricle or left ventricular; NA, not applicable; NS, not Abdomen Source: Reproduced with permission from A Bhagra et al: Point-of-care ultrasonography for primary care physicians and general internists. Mayo Clin Proc 91:1811, 2016. probability) 38–87 71–99 6.3 NA Elevated JVP 10–58 96–97 3.9 NS LE edema

93–96 NS NS Homan's sign 10–54 39–89 NS NS Flank dullness 80–94 29–69 NS 0.3 Shifting dullness 60–87 56–90 2.3 0.4 Fluid wave 50–80 82–92 5.0 0.5 significant; PCWP, pulmonary capillary wedge pressure. Wells' score (high Soft Tissue and Musculoskeletal

History & Physical Exam diagnostic procedure POCUS diagnose Consultative imaging Diagnosis Labs therapeutic procedure Treatment treat POCUS POCUS monitor No improvement Improvement POCUS screen Follow-up FIGURE 493-2 Clinicians can use point-of-care ultrasound (POCUS) as part of a patient's diagnosis, treatment, monitoring, and screening. A patient encounter begins with the history and physical examination, followed by a focused bedside ultrasound exam to narrow the differential diagnosis and guide workup. Treatment plans can include bedside procedures that are performed with ultrasound guidance. Serial POCUS exams can monitor disease processes and guide ongoing treatment decisions. Screening POCUS exams can detect asymptomatic, potentially treatable conditions. (Reproduced with permission from NJ Soni, BP Lucas: Diagnostic pointof-care ultrasound for hospitalists. J Hosp Med 10:120, 2015.) optimal site for pleural drainage reduces the risk of pneumothorax and bleeding complications. Normal air-filled lung tissue reflects sound waves, thereby pre venting visualization of aerated lung parenchyma. Two hallmarks of normal aeration of lung on ultrasound include lung sliding (Video 493-17), which results from respirophasic movement of the parietal and visceral pleural interface, and A-lines, which are horizontally ori entated reverberation artifacts seen deep to the pleural line of air-filled lungs (Video 493-18). Interstitial abnormalities manifest as B-lines, which are vertically orientated hyperechoic lines emanating from the pleural line to the bottom of the screen (Video 493-19). Depending on their density and distribution, B-lines can support a diagnosis of cardiogenic pulmonary edema, pneumonitis, acute respiratory distress syndrome, or interstitial lung diseases. Consolidation results in lung that is tissue dense on ultrasound. Mobile air bronchograms and blood flow detected by color flow Doppler are associated with pneumonia when seen in an area of consolidation (Video 493-20). Similar to chest x-ray and chest CT, identification of consolidation by lung ultrasound does not specify a diagnosis of pneumonia, and clinical correlation is required. ■ ■ABDOMEN Evaluation of peritoneal free fluid is a common abdominal POCUS application. POCUS cannot specify the type of fluid (i.e., ascites, blood, urine, bile, chyme) but can detect as little as 100–500 mL of peritoneal free fluid. When ascites is present (Video 493-21), POCUS can identify a safe site for paracentesis, improving procedural success and compli cation rates compared to landmark-based techniques. POCUS elimi nates attempts at paracentesis when an insufficient volume of ascites is present (Video 493-22). The best site, depth, and angle for needle insertion is determined using the ultrasound probe followed by color flow Doppler examination of the proposed trajectory of needle inser tion to avoid injury to abdominal wall blood vessels (Video 493-23). POCUS is used in the initial evaluation of acute renal failure and decreased urine output. Bladder ultrasound can rapidly identify presence or absence of urine in the bladder and confirm appropriate placement and function of a urinary catheter (Videos 493-24 and 493-25). Bladder ultrasound is more reliable than automated bladder

scanners for urinary retention, as bladder scanners can falsely report pelvic free fluid (i.e., ascites, cysts, small bowel obstruction) as elevated bladder volume. POCUS is effective to evaluate kidney size and echo genicity; identify renal cysts, large stones, and masses; and detect and grade hydronephrosis (Videos 493-26 to 493-28), thereby identifying obstructive uropathy.

POCUS can diagnose an abdominal aortic aneurysm (AAA) with high sensitivity and specificity (Videos 493-29 and 493-30). A pro tocol that emphasizes complete visualization of the abdominal aorta from celiac trunk through the iliac bifurcation in both transverse and longitudinal planes can provide a reliable evaluation of the aorta. POCUS use for AAA screening may reduce morbidity and mortality among high-risk patients. POCUS has utility for evaluation of small-bowel function. Normally, the small bowel is partially filled with air that obscures visualization due to scattering of sound waves. When a small-bowel obstruction (SBO) develops, the air-filled loops of bowel become fluid-filled, per mitting visualization of the bowel walls. Diagnostic criteria for SBO by ultrasound include dilation of the bowel (diameter >2.5 cm), fluidfilled small-bowel loops (confirmed by appearance of plicae circularis at the perimeter), and hyperactive to-and-fro peristalsis within loops of small bowel (Video 493-31). Combining patient history, physical examination, and a systematic survey of all four quadrants by ultra sound, clinicians can diagnose SBO rapidly and reliably. For a new diagnosis of SBO, POCUS can expedite early intervention and surgical consultation. For recurrent SBO, POCUS can reduce repeat radiation exposure by CT scans and expedite initiation of medical management. CHAPTER 493 ■ ■LOWER EXTREMITY DEEP-VEIN THROMBOSIS Two-dimensional compression ultrasound is a rapid and accurate diag nostic technique for deep-vein thrombosis (DVT) that clinicians can learn after brief training programs. A point-of-care lower extremity com pression ultrasound exam yields similar diagnostic accuracy for detec tion of DVTs as traditional duplex or triplex ultrasound exams. DVTs commonly form at venous junctions because of high turbulence, and hence, compression ultrasound is performed at major branchpoints of the venous system. A perpendicular compression technique is required to ensure complete venous compression with wall-to-wall touching. A noncompressible vein is diagnostic of DVT (Video 493-32), and visual ization of intraluminal clot is not required to diagnose a DVT. Point-of-Care Ultrasound ■ ■SKIN AND SOFT TISSUE POCUS allows rapid differentiation between skin and soft tissue infec tions (SSTIs) and reactive lymph nodes, seromas, hematomas, hernias, thrombophlebitis, DVT, cysts, and bursitis. For SSTIs, POCUS can reduce unnecessary attempts at incision and drainage and avoid delays in surgical intervention. SSTIs range from cellulitis to phlegmon, abscess, and necrotizing fasciitis. POCUS can accurately distinguish abscess from cellulitis, but diagnostic accuracy is more variable for necrotizing fasciitis. To diagnose cellulitis, POCUS identifies subcuta neous edema described as “cobblestoning” (Video 493-33). Abscesses appear as irregular, enclosed areas superficially with compressible material and absent central flow on color Doppler (Video 493-34). ■ ■VASCULAR ACCESS Current evidence supports use of ultrasound guidance for insertion of central venous catheters (CVCs) in the femoral, internal jugular, and axillary veins. Ultrasound guidance for insertion of internal jugular CVCs improves procedure success rates and reduces complications, particularly pneumothorax and arterial punctures. A preprocedure ultrasound survey identifies potential vessels to cannulate and can reveal unsuspected venous thrombosis, atypical anatomy, and venous stenosis. During insertion, real-time visualization of the needle tip reduces procedure attempts and needle redirections, which reduces the risk of complications. Sonographic confirmation of the guidewire in the target vein provides a safety check prior to venous dilation and insertion of the CVC. For peripheral intravenous (PIV) catheter insertion, ultrasound can increase cannulation success rates while reducing puncture attempts, time to cannulation, and trauma to surrounding structures,

particularly in patients with anticipated difficult PIV placement or after failed attempts using standard techniques. Ultrasound identifies peripheral veins that are large, linear, and superficial, and real-time ultrasound guidance allows visualization of the needle tip entering the vessel lumen.

TRAINING ■ ■PATHWAYS Ultrasound training is a longitudinal process for clinicians as they progress through medical school, residency, and fellowship and enter clinical practice. Training recommendations for POCUS have been developed for different stages of medical education but with varying definitions of competence. Regardless of the clinical rank of the learner, competence in POCUS requires mastery of ultrasound knowledge (e.g., clinical indications, applications, limitations, artifacts), image acquisition, image interpretation, and clinical integration. Image acqui sition and interpretation skills are learned at varying rates and require deliberate practice. ■ ■CERTIFICATION Currently, there is no widely accepted certification for POCUS. Some residency and fellowship training programs, such as critical care and emergency medicine, require comprehensive training in POCUS, and hospitals generally grant POCUS privileges to physicians with board certification in these specialties. In contrast, internal medicine resi dency training does not require comprehensive POCUS training, and board certification in internal medicine does not imply competence in POCUS. Several internal medicine residency programs and profes sional societies have developed POCUS training courses. PART 20 Emerging Topics in Clinical Medicine ■ ■CREDENTIALING AND PRIVILEGES Clinical privileges are governed by the rules and regulations of indi vidual hospitals. A hospital's credentialing and privileging committee is responsible for developing criteria for granting privileges for POCUS use, which may be guided by specialty-specific guidelines. Some hos pitals will designate a local POCUS expert to assess competence in POCUS prior to granting privileges for POCUS use in patient care. Hospital credentialing and privileging bodies may designate POCUS as a core privilege of a specialty (e.g., emergency medicine privileges include POCUS use) or as add-on privileges separate from the primary specialty's skills. Some well-established POCUS applications, such as ultrasound-guided CVC insertion, are commonly designated as core privileges when use of ultrasound guidance is standard of care. In contrast, less common POCUS applications, such as peripheral nerve blocks, may be designated as add-on privileges. FUTURE DIRECTIONS The increasing portability and affordability of ultrasound devices have allowed internal medicine clinicians to incorporate POCUS into front line patient care. Increasing POCUS use in internal medicine requires development of effective training programs during residency training and for internists in-practice. Tele-ultrasound has shown promise for training clinicians and delivering patient care remotely. In the coming years, artificial intelligence will facilitate both POCUS training and use in clinical care, and remote serial monitoring of common conditions like heart failure may be possible with patients' use of POCUS. ■ ■FURTHER READING American College of Emergency Physicians Ultrasound Guidelines: Emergency, point-of-care, and clinical ultrasound guidelines in medicine. Available at: https://www.acep.org/siteassets/ new-pdfs/policy-statements/ultrasound-guidelines--emergency-pointof-care-and-clinical-ultrasound-guidelines-in-medicine.pdf. Accessed December 3, 2024. Mayo PH et al: American College of Chest Physicians/La Societe de Reanimation de Langue Francaise statement on competence in criti cal care ultrasonography. Chest 135:1050, 2009. Qaseem A et al: Appropriate use of point-of-care ultrasonography in patients with acute dyspnea in emergency department or inpatient

settings: A clinical guideline from the American College of Physicians. Ann Intern Med 174:985, 2021. Soni NJ et al: Point-of-care ultrasound for hospitalists: A position statement of the Society of Hospital Medicine. J Hosp Med 14:E1, 2019. Soni NJ, Arntfield R, Kory PD: Point-of-Care Ultrasound, 2nd ed. Philadelphia, Elsevier/Saunders, 2019. Spencer KT et al: Focused cardiac ultrasound: recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr 26:567, 2013. VIDEO 493-1 Normal cardiac function. VIDEO 493-2 Hyperdynamic cardiac function. VIDEO 493-3 Reduced cardiac function. VIDEO 493-4 Severely reduced cardiac function. VIDEO 493-5 Acute right heart failure. VIDEO 493-6 Cardiac tamponade. VIDEO 493-7 Tricuspid valve regurgitation. VIDEO 493-8 Mitral valve regurgitation. VIDEO 493-9 Aortic valve regurgitation. VIDEO 493-10 Tricuspid valve vegetation. VIDEO 493-11 Lung atelectasis. VIDEO 493-12 Small pleural effusion. VIDEO 493-13 Moderate pleural effusion. VIDEO 493-14 Large pleural effusion. VIDEO 493-15 Homogenous pleural effusion. VIDEO 493-16 Loculated pleural effusion. VIDEO 493-17 Pleural sliding. VIDEO 493-18 A-Line artifact. VIDEO 493-19 B-Line artifact. VIDEO 493-20 Lung consolidation. VIDEO 493-21 Large-volume ascites. VIDEO 493-22 Small-volume ascites. VIDEO 493-23 Abdominal wall vessels with color Doppler. VIDEO 493-24 Urinary catheter balloon in empty bladder. VIDEO 493-25 Malfunctioning urinary catheter. VIDEO 493-26 Mild hydronephrosis. VIDEO 493-27 Moderate hydronephrosis. VIDEO 493-28 Severe hydronephrosis. VIDEO 493-29 Abdominal aortic aneurysm. VIDEO 493-30 Abdominal aortic aneurysm. VIDEO 493-31 Small-bowel obstruction. VIDEO 493-32 Deep-vein thrombosis. VIDEO 493-33 Cellulitis. VIDEO 493-34 Simple abscess.

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