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THE UTILITY OF POCUS IN INTENSIVE CARE AND BEYOND

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Abstract

Point-of-care ultrasound (POCUS) is a bedside imaging performed and interpreted by clinicians. It has revolutionized intensive care by enabling rapid and accurate assessment. Immediate identification of various pathologies helps in timely decision-making. Performing procedures under ultrasound guidance ensures the safety of interventions. This article incorporates evidence to discuss the strengths and limitations of POCUS in comparison with other imaging modalities. Areas under discussion include the utility of POCUS in evaluating pulmonary, cardiac, abdominal, and intracranial pathologies. Moreover, its utility in patients with deep vein thrombosis, pulmonary embolism, and hemodynamic compromise is also discussed. Furthermore, outcomes of POCUS-guided procedures are compared to outcomes of procedures performed using anatomical references alone. POCUS enables timely diagnosis and interventions, thereby, enhancing the efficiency of critical care provision.

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INTRODUCTION & BACKGROUND:

Previously, critical care providers utilized imaging modalities that are time-consuming and expensive. POCUS has gained popularity for its cost-effectiveness, time efficiency, portability, and lack of radiation. Real-time visualization of anatomical structures and dynamic assessment of physiologic parameters enable rapid and accurate diagnosis. In addition to timely interventions, it enables monitoring of patient response to therapy.

Using POCUS, pulmonary conditions such as pneumothorax, hemothorax, pulmonary edema, consolidation, and pleural effusion can be identified. It also assists in thoracentesis. In patients requiring mechanical ventilation, rapid visual feedback helps us guide ventilator management settings. Similarly, numerous cardiac pathologies can be identified using focused cardiac ultrasound examination (FoCUS) or echocardiography. FoCUS plays a pivotal role in diagnosing and managing patients with pericardial effusion and cardiac tamponade in the intensive care unit. Abdominal pathologies including bowel obstruction and perforation are also apparent. Renal pathologies such as hydronephrosis, intra-renal masses, and renal perfusion can also be identified. Visualization of an echogenic thrombus (deep vein thrombosis/DVT) is diagnostic. Evidence of right heart strain on ultrasonography in the setting of DVT is an alarming sign and necessitates further imaging (CT pulmonary angiogram) to rule out pulmonary embolism. Although brain ultrasound may be overlooked in some protocols, it enables the assessment of intracranial pressure, injury, and vascular pathologies. In shock, therapies can be tailored depending on the hemodynamic status and response to fluid resuscitation. Moreover, septic foci and their complications (abscess, pleural effusion) can be visualized. In trauma and emergencies, focused assessment with sonography for trauma is widely used. POCUS is also used to guide procedures such as securing and ensuring arterial/venous access, paracentesis, and arthrocentesis.

POCUS has revolutionized the management of critically ill patients. By using this unique technology, intensivists can improve patient care, improve resource utilization, and provide timely interventions to patients in intensive care units.

Methods

A comprehensive review of the literature was done. Data were collected from electronic databases (PubMed and Scopus) to identify relevant peer-reviewed articles. The following search terms were used, "POCUS'', "pulmonary", "cardiac", "abdominal", "renal", "DVT", "PE", "intracranial", "hemodynamic" and "procedure". Articles in the English language were included. The inclusion criteria were not exclusive to any specific study design. 122 relevant articles were included. Findings were presented using a narrative approach. The utility of POCUS in each respective area was then elaborated with evidence.

Review

Basic Principles

A portable ultrasound is used at the patient's bedside. First of all, ultrasound gel is applied on the skin over the area of interest, then the transducer is placed on it. Ultrasonic waves emitted by the transducer generate real-time images that are interpreted by the physician. Table 1 differentiates the characteristics of different probes used in POCUS.

Table 1: Transducers used in POCUS

Type of transducer	**Phased array**	**Curvilinear**	**Linear**
Depth	35 cm	30 cm	9 cm
Frequency	1-5 MHz	2-5 MHz	5-10 MHz
Applications	Lungs, pleura, heart, and abdomen	Liver, gall bladder, urinary bladder, kidney, uterus, ovary, and aorta	Artery, vein, testicle, eye, breast, and musculoskeletal

Pulmonary pathologies

Lung ultrasound can identify lung masses, complex and located effusions, pulmonary edema, lung consolidation pneumothorax, and diaphragmatic dysfunction. It can also be utilized to guide procedures such as thoracentesis (by identifying a safe pocket). Its utility may be limited in patients with heavy musculature, obesity, and, edema and in patients who are unable to be positioned properly for complete examination [1]. Pleural effusions appear as either anechoic or complex pockets. Lung ultrasound can also be used for the detection of hemothorax. In patients with COVID-19, rather than just evaluating the lungs, multi-organ POCUS is advisable for the early identification of severe lung involvement and thrombotic changes [2]. The presence of lung sliding excludes pneumothorax, however, its absence may not always be diagnostic of pneumothorax. In its absence, other conditions such as bullous emphysema, pleurodesis, and pleural adhesions should also be considered. Pneumonia, tumor, infarction, and atelectasis may lead to consolidation, which can also be visualized. In patients requiring mechanical ventilation, POCUS guides us to adjust ventilator management settings through the provision of rapid visual feedback.

Comparison with other modalities

Lung ultrasonography is more sensitive than chest X-ray in detecting pulmonary edema in patients with acute decompensated heart failure. It should be used in the evaluation of patients with dyspnea at risk of acute decompensated heart failure [3]. When the accuracy of POCUS and standard evaluation is compared, POCUS is significantly more sensitive for diagnosing heart failure, whereas, a standard evaluation had better performance in diagnosing chronic obstructive pulmonary disease, asthma, and pulmonary embolism. No differences were found in the accuracy of diagnosing pneumonia, pleural effusion, pericardial effusion, acute coronary syndrome, and dyspnea from other causes [4].

Cardiac pathologies

Echocardiography is usually performed by cardiologists, whereas, focused cardiac ultrasound examination (FoCUS) is usually performed by other physicians. If the clinical presentation does not correlate with the FoCUS findings, comprehensive echocardiography should be performed. The different approaches for FoCUS are mentioned in Table 2.

Table 2: Focused cardiac ultrasound examination (FoCUS) views and targets
LV- Left Ventricular; RV- Right Ventricular

View	Target
Subcostal long-axis view	LV dimension, systolic function
Subcostal inferior vena cava view	RV systolic function
Parasternal long-axis view	Volume status
Parasternal short-axis view	Pericardial effusion, cardiac tamponade
Apical 4-chamber view	Gross signs of chronic heart disease, gross valvular abnormalities, and large intracardiac masses

Using pulse wave and continuous wave Doppler cardiac ultrasonography, we can evaluate right and left ventricular size and function, wall motion abnormalities, and valvular dysfunction. Using spectral Doppler, early detection of pericardial effusion and cardiac tamponade can be done. Upon identification, ultrasound-guided pericardiocentesis can then be performed to reduce the pericardial effusion. Significant right to left cardiac and pulmonary shunts can be detected using POCUS agitated saline bubble study. The usual underlying causes of these shunts are atrial septal defects, patent foramen ovale, and pulmonary arterio-venous malformations [5]. POCUS can also detect thoracic aortic aneurysms and dissections.

Abdominal pathologies

Abdominal ultrasound can detect bowel obstruction, perforation, acute appendicitis, acute cholecystitis, acute diverticulitis, hydronephrosis, ectopic pregnancy, and abdominal aortic aneurysm.

Bowel obstruction and perforation

With a sensitivity of 95% and specificity of 84%, POCU help diagnosing small bowel obstruction. Bowel contents, bowel wall, and air-fluid levels can be visualized [6]. For the detection of intraperitoneal air (perforation), the sensitivity of POCUS is 86% compared to the sensitivity of abdominal X-ray, which is 76% [7].

Fluid in the abdomen

The common locations for intraperitoneal free fluid accumulation are perihepatic space, perisplenic space, and pelvis (pouch of Douglas).

In trauma cases, focused assessment with sonography for trauma has widely replaced diagnostic peritoneal lavage. In these patients, fluid in the abdomen may indicate hemoperitoneum.

In non-trauma patients, the detection of free fluid may indicate ascites. Free fluid may also be due to bile leak, urinary leak, or due to ruptured ectopic pregnancy. Even small volumes of free fluid (10-50 ml) can be detected by experienced clinicians using this modality. In a study that included 300 non-trauma patients with acute abdominal pain, ultrasonography confirmed the diagnosis in 121 patients (40%; 95%CI, 34.4-45.5%), revealed a different diagnosis in 69 patients (23%; 95%CI, 18.2-27.7%) and could not diagnose pathology in 102 patients (34%; 95%CI, 28.6-39.3%). Ultrasonography changed the treatment plans in 47% of the patients (95%CI, 41.3-52.6%). [8].

Acute appendicitis

In patients with suspected acute appendicitis, gradual slow, and sustained compression at the point of tenderness is applied to displace the gas and visualize the underlying structure [9]. This technique superadded with self-localization can accurately diagnose acute appendicitis in clinically ambiguous cases and is valuable in establishing alternative diagnosis [10]. Ultrasound findings are indicative of acute appendicitis are visualization of a noncompressible tubular structure with a target sign greater than 6mm, distorted irregular mucosa, thickened momentum, and presence of fecalith and intraperitoneal fluid (perforation).

Acute diverticulitis, acute cholecystitis, and pseudomembranous colitis

The graded compression technique can also be applied to diagnosing diverticulitis. Positive findings include hypogenic mural thickening of the f colonic wall >4mm and a noncompressible target sign in the transverse section [11]. Acute cholecystitis can be diagnosed through the detection of increased gall bladder wall thickness >3mm, the presence of pericholecystic fluid, and positive Murphy's sign. Severe pseudomembranous colitis should be considered if the colonic wall is thickened with heterogeneous echogenicity and narrowing to the lumen [12].

Renal evaluation

POCUS can be used for evaluating hydronephrosis, intra-renal masses, and renal perfusion. However, it has low sensitivity for the detection of stones due to the limited acoustic window. Stones that are visualized are usually proximal to the ureteropelvic junction or distal to the vesicoureteric junction [13]. For the detection of stones, a computed tomography scan without contrast remains the gold standard.

Pregnancy evaluation

Bedside ultrasound can be used for the detection of intrauterine and ectopic pregnancy during all stages of pregnancy. However, it may miss an interstitial pregnancy (ectopic), therefore, a transvaginal ultrasound is preferred in uncertain cases [14].

Abdominal aortic aneurysm

Ultrasonography is the gold standard screening modality for detecting abdominal aortic aneurysms. Moreover, visualization of peripheral arterial obstructive lesions can be done through duplex ultrasonography (B-mode and color Doppler techniques).

Deep vein thrombosis

POCUS can accurately identify acute proximal deep vein thrombosis (DVT) when performed by experienced clinicians. Visualization of an echogenic thrombus is diagnostic for deep vein thrombosis. There is slight heterogeneity in the reported sensitivity and specificity of POCUS for detecting deep vein thrombosis. Results may vary depending on the setting (intensive care unit, emergency department) and the experience of the performing clinician (resident, attending). When performed by well-trained clinicians, it has a sensitivity of 100%, specificity of 95.8%, positive predictive value of 61.5%, and negative predictive value of 100% for the detection of DVT [15].

Pulmonary embolism

Deep vein thrombosis can be complicated by pulmonary embolism. Evidence of right heart strain on cardiac ultrasonography in the presence of an echogenic thrombus in the deep vein suggests pulmonary embolism. However, an incomplete visualization of the cardiac chambers may lead to misdiagnosis. On the other hand, chronic dilation may lead to a false interpretation of the acute condition. If left untreated, pulmonary embolism has a mortality rate of 26% [16]. Although POCUS provides valuable insight, the gold standard imaging modality for confirmation of pulmonary embolism is CT pulmonary angiogram.

Intracranial pathologies

Brain ultrasound

The literature supporting the use of ultrasonography in diagnosing neurological conditions and performing procedures is growing. The two types of brain ultrasound are traditional transcranial Doppler (TCD) and transcranial color-codded duplex sonography (TCCD). The windows for insonation and planes are presented in Table 3.

Table 3: Brain ultrasound acoustic windows and planes

Windows for insonation	Planes
Transtemporal window	Mesencephalic plane
Transorbital window	Diencephalic plane
Suboccipital window	Ventricular plane
Submandibular window	

Applications

Both traditional transcranial Doppler (TCD) and transcranial color-coded duplex sonography (TCCD) can be applied to evaluate the pulsatility index and Lindegaard/sousteil indexes. They can also measure the optic nerve sheath diameter [17]. In critically ill patients, they can identify increased intracranial pressure. Brain ultrasound can also detect intracranial hemorrhage and traumatic brain injuries. It can also be used for diagnosing vascular conditions (stroke, vasospasm due to subarachnoid hemorrhage) and neuromuscular diseases (motor neuron disease, focal neuropathies, and muscular dystrophy). Facilitation of certain procedures including ultrasound-assisted lumbar puncture, botulinum toxin injections, occipital nerve blocks, and trigger point injections can also be done [18].

Hemodynamic evaluation

Volume status

POCUS enables the assessment of volume status and response to fluid resuscitation. Hemodynamic assessment can be carried out by evaluating stroke volume, cardiac contractility, valvular diseases, and pulmonary congestion. For evaluation of venous congestion, the venous excess ultrasound grading system (VEXUS) can be used to calculate inferior vena cava diameter and examine hepatic, portal, and intraparenchymal renal venous flow patterns [19]. An advanced form of POCUS known as goal-directed Doppler echocardiography can provide insight into flow velocities and pressures across cardiac structures [20]. Pericardial effusion appears as an anechoic (black) space between the two pericardial layers. It can cause hypotension and hemodynamic compromise.

Sepsis and septic shock

Identification of septic foci as well as their complications (abscess, pleural effusion) is also made possible using POCUS. It should be utilized in the evaluation of sepsis and septic shock so that therapies can be tailored. For instance, patients with sepsis-induced cardiomyopathy require different clinical management than patients with septic shock and preserved cardiac function. In subacute shock, POCUS-guided management was associated with a higher 28-day survival rate in comparison with the control group [21].

POCUS guided procedures

Ultrasound is commonly used in the intensive care unit to obtain and ensure vascular access. It can be used for procedures such as peripheral and central intravenous access, arterial access, complex percutaneous extracorporeal membrane oxygenation (ECMO) cannulation, paracentesis, thoracocentesis, arthrocentesis, pericardiocentesis, lumbar puncture, and nerve blocks.

Central venous catheter

Placing a central venous catheter (CVC) using anatomical references alone is associated with a high risk of complications. These include pneumothorax and arterial puncture. This incidence is reported as high as 19% [22]. Ultrasonography can be used during CVC insertion, for confirmation of placement and exclusion of complications such as pneumothorax.

Veno-arterial extracorporeal membrane oxygenation catheterization

Using the Seldinger technique, POCUS-guided percutaneous catheterization can be the first choice for veno-arterial extracorporeal membrane oxygenation, especially for providers without angiotomy qualifications [23].

Fluid removal

POCUS reduces rates of pneumothorax during thoracentesis by 19% and bleeding complications during paracentesis by 68% [24]. Similarly, ultrasonography can be used to guide pericardiocentesis and for confirmation of the reduction of the pericardial effusion. Ultrasound can also identify joint effusions and guide arthrocentesis [25].

Lumbar puncture and nerve blocks

During lumbar puncture, ultrasound helps mark the spinous anatomy. It can also be applied to ensure the safety of regional procedures such as nerve blocks to avoid local anesthetic systemic toxicity (LAST). LAST occurs due to unintentional intravascular injection and can lead to cardiovascular collapse.

CONCLUSIONS:

POCUS has revolutionized critical care through its portability, cost-effectiveness, time efficiency, and lack of radiation. The strong suit of POCUS is its wide-ranging utility which includes its ability to identify various pulmonary, abdominal, neurological, cardiac, and vascular pathologies. The provision of valuable insight into the hemodynamic status and patient response to therapy makes it a useful tool for critically ill patients. Using ultrasound to guide procedures can improve the safety of these interventions. POCUS can be diagnostic for deep vein thrombosis and may be helpful during the evaluation of pulmonary embolism. However, like other imaging modalities, it does have certain limitations, including misdiagnosis. Therefore, CT pulmonary angiogram remains the gold standard imaging for diagnosing pulmonary embolism. Beyond critical care, its utility may be limited in detecting renal stones due to relatively lower sensitivity and specificity. Therefore, CT scan without contrast remains the gold standard. Abdominal ultrasound may miss an interstitial pregnancy (ectopic), therefore, a transvaginal ultrasound is preferred in uncertain cases. We recommend further studies be done to evaluate the strengths and limitations of POCUS.

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