Point-of-care Ultrasonography in Critically Ill Patients

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ABSTRACT

Point-of-care ultrasonography has been used frequently by the physicians involved in managing critically ill patients. It allows direct visualization of pathology or abnormal physiological state at the bed side. The examination may be safely and effectively repeated as needed to follow the evolution of illness and the response to therapy. It is helpful to guide the therapy in patients with undifferentiated shock and for bedside diagnosis of common pathological conditions in acute care setting. It can facilitate common bedside procedures and interventions.

KEYWORDS

Critically ill, goal directed ultrasonography, point-of-care ultrasonography

INTRODUCTION

Ultrasonography is a safe and effective tool that helps physicians to reach the diagnosis and guide procedures. Point-of-care ultrasonography has rapidly grown in the past two decades.[1] It differes from standard sonography by radiologists and cardiologists. During goal directed bed side point-of-care ultrasonography, intensivist personally performs and interprets the ultrasound examination at bed side and immediately integrates the results into the overall clinical assessment and plan.[2] Ultrasonography is a user dependent procedure. As usage expands, there is a need to ensure competence and proper training.[3]

Basic principles of ultrasonography, probe selection, image acquisition and different ultrasonographic views are beyond the scope of this review. Current understanding and evidences behind the goal directed use of ultrasonography by bedside physician will be discussed in this review.

UTILITY IN CRITICALLY ILL PATIENTS

Role of point-of-care ultrasonography in different clinical scenarios of critically ill patients are discussed below:

Undifferentiated shock

Proper management of undifferentiated shock in acute care setting can be one of the most challenging issues. Physical examination findings can be misleading due to complex physiology of shock.[4] Accurate and prompt initial care of these patients can significantly affect the outcome.[5] Various protocols have been proposed and studied for algorithmic ultrasound assessment of the patients with undifferentiated shock. The protocols like FATE (Focus Assessed Transthoracic Echocardiogram),[6] ACES (Abdominal and Cardiac Evaluation with Sonography in Shock),[7] and RUSH (Rapid Ultrasound in Shock) can facilitate the intensivist or bedside physician to categorize the patient's underlying physiologic state of shock.[8]

The RUSH exam divides bedside ultrasound assessment into three steps: the pump, the tank and the pipes.[8] While assessing the pump, intensivist looks for the presence of pericardial effusion (Fig. 1) and cardiac tamponade, which may be compressing the heart and leading to obstructive shock. Global left ventricular function is determined, which allows for rapid identification of cardiogenic shock. Assessment is made for the presence of acute right ventricular strain. Increased size of right ventricle relative to the left ventricle may be a sign of massive pulmonary embolism in a hypotensive patient. Bedside echocardiography may help in risk stratification and may guide therapy in these patients.[9]

Figure 1. Subxiphoid view demonstrating pericardial effusion.

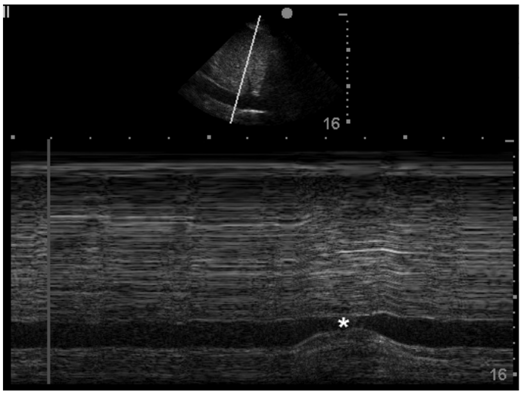

Figure 2. A hypovolemic and fluid responsive spontaneously breathing patient with significant variation of inferior venacava diameter with respiration. Asterisk denotes the diameter during inspiration.

While assessing the tank, inferior venacava is evaluated to assess the intravascular volume status and to predict fluid responsiveness. There exists a good correlation between central venous pressure and percentage change of inferior venacava with respiration (caval index). The caval index of 50% or more indicates central venous pressure of less than 10 mm Hg and a caval index of less than 50% indicates central venous pressure of 10 mm Hg or more.[10] In spontaneously breathing patients, a caval index of more than 40% was usually associated with fluid responsiveness (Fig. 2) as indicated by increase of subaortic velocity time index (VTI) by 15%.[11] In mechanically ventilated septic patients, respiratory change in inferior venacava was shown to be an accurate predictor of fluid responsiveness. A threshold caval index of 18% discriminated responders and non-responders with 90% sensitivity and 90% specificity.[12] FAST (Focused Assessment with Sonography in Trauma) exam of abdomen is performed to look for free intraperitoneal fluid (leakiness of tank) (Fig. 3). This examination consists of four standard views (right upper quadrant, left upper quadrant, pelvic and subcostal cardiac) for identification of fluid in the peritoneal cavity and within the pericardial

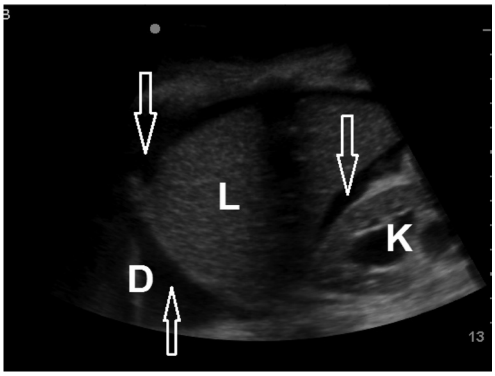

Figure 3. Right upper quadrant view of the FAST exam demonstrating free fluid (indicated by arrows); D = the Diaphragm, L = Liver, K = Kidney.

sac.[13] FAST exam has sensitivity of 79% and specificity of 99% for detecting intraperitoneal fluid collection.[14] Pelvic views of FAST exam has been shown to detect as small as 100 ml of intraperitoneal fluid.[15] FAST exam is extended to examine the thoracic cavity for presence of pneumothorax (causing compromise of tank) or presence of free fluid (pleural effusion or haemothorax). It is called extended FAST or E-FAST. Lungs are also scanned for the presence pulmonary oedema (as an indicator of tank overload) and presence of alveolar consolidation (for the possible cause of septic shock).

While assessing the pipes, patient is examined for presence of aortic aneurysm (causing rupture of pipes). Ultrasound examination of abdominal aorta involves imaging from the epigastrium down to iliac bifurcation. Aorta should be measured in short axis, obtaining the maximal diameter from outer wall to outer wall, including any thrombus present in the vessel. Diameter greater than 3 cm defines an abdominal aortic aneurysm. Rutpure is more common with aneurysms measuring larger than 5 cm.[16] Proximal aortic root is examined using the parasternal long axis view of the heart. Measurement greater than 3.8 cm is abnormal. Echogenic intimal flap may be visible within the aneurysm. Lower extremities should be examined for sonographic evidence of deep vein thrombosis (causing clogging of pipes) as majority of pulmonary emboli originate from lower extremity DVT. Venous compression sonography is an accurate noninvasive test for the diagnosis of symptomatic deep vein thrombosis.[17] Most proximal DVTs can be detected by limited compression examination of leg focusing on two main areas – proximal femoral vein, beginning at common femoral vein down through the confluence with the saphenous vein to the bifurcation into deep and superficial femoral vein and the popliteal vein, from high in the popliteal fossa down to trifurcation into calf veins.[18]

Cardiac arrest

Incorporation of bedside sonography during Advanced Cardiac Life Support (ACLS) in cardiac arrest patients can be helpful to find the cause of cardiac arrest like severe hypovolaemia, cardiac tamponade, massive pulmonary embolism and tension pneumothorax.[19] Absence of cardiac activitiy during ACLS, as detected by bedside focused echocardiography predicts a significantly lower likelihood of Return Of Spontaneous Circulation (ROSC). Meta-analysis of the data showed, as a predictor of ROSC during cardiac arrest, echocardiography has a pooled sensitivity of 91.6% and specificity of 80.0%.[20]

Acute respiratory failure

Bedside ultrasonography can help clinicians make a rapid diagnosis in patients with acute respiratory failure. Lung ultrasonography is an important diagnostic tool in a number of pathological conditions like pneumonia, atelectasis, lung interstitial syndrome, pulmonary embolism, pneumothorax and pleural effusion (Fig. 4).[21] The sonographic signs of pneumothorax are presence of lung point, absence of lung sliding, absence of B-lines and absence of lung pulse. Multiple B-lines is the sonographic sign of lung interstitial syndrome and may be seen in pulmonary oedema, pneumonia, diffuse parenchymal lung disease, atelectasis, pulmonary contusion, pulmonary infarction and pleural disease. Lung ultrasound is able to monitor aeration changes and the effect of therapy in a number of conditions presenting with acute respiratory failure like acute pulmonary oedema, acute respiratory distress syndrome, acute lung injury, community-acquired pneumonia and ventilator-associated pneumonia.[22]

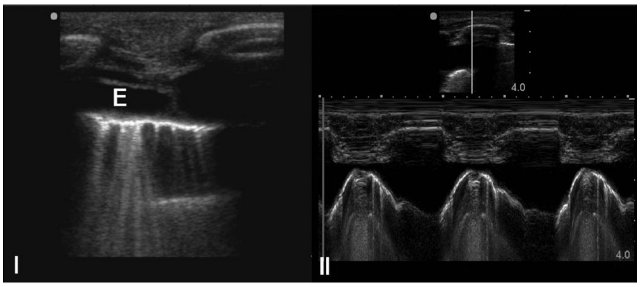

Figure 4. I (Left): Lung Ultrasound showing pleural effusion (E) with multiple B lines. II (Right): M mode of the same image showing sinusoid sign.

In the hands of a trained person, it is a sensitive and specific tool for diagnosing pneumothorax, pneumonia, pulmonary oedema, pulmonary embolism, asthma and chronic obstructive pulmonary disease.[23] A meta-analysis compared anterior-posterior chest radiograph with transthoracic ultrasonography for diagnosis of pneumothorax. It showed that bedside ultrasonography performed by clinicians had higher sensitivity and similar specificity compared with chest radiography in the diagnosis of pneumothorax. Accuracy of ultrasonography strongly depended on the skill of the operator.[24] Routine use of lung ultrasound was found to be associated with reduction of number of chest radiographs and CT scans performed in ICU.[25]

Evaluation of the diaphragm

Diaphragmatic function is a major determinant of the ability to successfully wean patients from mechanical ventilation. Diaphragmatic dysfunction is common in mechanically ventilated critically ill patients and can be a major cause of weaning failure.[26] Disuse atrophy of diaphragm can occur even after brief period of mechanical ventilation or after the administration of paralyzing agents.[27,28] Invasive tests for assessment of diaphragmatic function are not readily available and are uncomfortable for patient.[29] Ultrasonography is a non-invasive and reproducible method for assessing hemidiaphragmatic movement.[30]

Bedside sonographic evaluation of the diaphragm is a useful non-invasive method for quantifying diaphragmatic movement in a variety of normal and pathological conditions. It can assess the characteristics of diaphragmatic movement such as amplitude, force & velocity of contraction, special pattern of diaphragmatic motion and changes in diaphragmatic thickness during inspiration. These parameters can provide valuable information for the assessment and follow up of patients with diaphragmatic weakness or paralysis.[31] In mechanically ventilated patients, it is useful in bedside diagnosis of diaphragmatic dysfunction and thus identify the patients at high risk of difficulty weaning. The best cut-off values of diaphragmatic excursion during tidal breathing for predicting primary weaning failure were 14 mm for the right diaphragm and 12 mm for the left diaphragm.[32]

Airway management

Bedside ultrasonography can facilitate airway management in critically ill patients. It can be used to assess upper airway and trachea. Quantification of pretracheal soft tissue by ultrasound at the level of vocal cord can help to predict difficult laryngoscopy in obese patients.[33] Bedside sonography can be helpful in confirming endotracheal intubation. Combination of transcricothyroid membrane ultrasonography and ultrasonographic lung-sliding evaluation was found to be a sensitive and specific way of confirming endotracheal intubation in emergency department.[34] Ultrasound screening of pretracheal vascular structures before percutaneous dilatational tracheostomy may minimize the risk of bleeding.[35] Before percutaneous dilatational tracheostomy, portable ultrasonic scanning of anterior neck is particularly beneficial for patients with landmarks that are difficult to visualise or palpate.[36]

Neuro critical care

Raised intracranial pressure (ICP) is a frequent finding in neurological critically ill patients. Though invasive ICP monitoring is the gold standard for measuring ICP, it has the risk of intracerebral haemorrhage and infection.[37] Non-invasive estimation of ICP may be hepful in choosing patients who may need invasive monitoring and it may help in management of patients when invasive ICP measurement is not immediately available.[38] Ultrasonography of Optic Nerve Sheath Diameter (ONSD) is a very well-studied modality for the non-invasive assessment of ICP. In a systematic review and meta-analysis of studies, it was shown to be a reliable bed side tool for detecting intracranial hypertension. In clinical decision making, it may help physicians decide to transfer patients to specialized centers or to place invasive device when specific recommendations for this placement do not exist.[39] ONSD measurement was shown to have a good reproducibility with minimal interobserver difference.[40] Bedside ultrasonography can be helpful in pupillary assessment of neurologic patients who present with significant eyelid oedema, thus allowing complete neurological assessment of the patient.[41]

Transcranial Doppler ultrasonography (TCD) is a non-invasive bedside technique which helps to monitor blood flow velocity in the basal cerebral arteries and provides useful informations about cerebral haemodynamics. Doppler ultrasound detects cerebral vasospasm by assuming that an increased flow velocity is a sign of arterial narrowing and thus decreased perfusion. Vasospasm following subarachnoid haemorrhage is common and is a very important cause of morbidity and mortality. Bedside TCD can be useful to recoginize the development of cerebral vasospasm in patients with subarachnoid haemorrhage.[42] American Heart Association & American Stroke Association guidelines for the management of aneurysmal subarachnoid haemorrhage recommends TCD to monitor for the development of arterial spasm in these patients.[43]

Bedside procedures

Cannulation of veins and arteries is an important aspect of patient care for the administration of fluids and medications and for monitoring purpose. Real-time ultrasound guided venipuncture is associated with fewer immediate complications and faster access. It is recommended that properly trained clinicians use real-time ultrasound during internal jugular cannulation whenever possible to improve cannulation success and reduce the incidence of complications. Real-time ultrasound is also recommended for confirmation of successful vessel cannulation.[44] In a systematic review and meta-analysis of randomized controlled trials, real-time two-dimensional ultrasound guidance for radial artery catheterization was shown to improve first-pass success rate with 71% improvement in the likelihood of first-attempt success.[45] For the patients with difficult intravenous access, ultrasound guided peripheral intravenous access was found to be more successful than traditional blind technique, required less time, decreased the number of percutaneous punctures and improved patient satisfaction.[46]

Thoracentesis and paracentesis are common bedside needle insertion procedures. Though generally considered safe, a meta-analysis of studies found the rate of pneumothorax to be 6.0% following the thoracentesis. Ultrasonography use was associated with significantly lower risk of pneumothorax.[47] Haemorrhage is not an uncommon complication following large volume paracentesis in cirrhotic patients with portal hypertension.[48] In an observational cohort study, ultrasound guidance during thoracentesis decreased the risk of pneumothorax by 19%. Similarly, ultrasound guidance during paracentesis decreased the bleeding complications by 68%.[49]

COMPETENCY AND TRAINING

Ultrasonography has widespread utility in the diagnosis and treatment of critically ill patients. It is a valuable and accessible tool for intensivists. So, the intensivists who practice ultrasonography should be trained and attain competence with critical care ultrasonography (CCUS) in three main areas-general critical care ultrasound,[50] basic critical care echocardiography and advanced critical care echocardiography. Basic critical care echocardiography and general critical care ultrasound should be a required part of training of every ICU physician. Advanced level critical care echocardiography is an optional component of the training.[51]

CONCLUSION

Bedside goal directed point-of-care ultrasonography by a trained intensivist, when integrated with clinical assessment in critically ill patients, can be valuable in early detection of physiological derangement and guiding the management. In addition, it can enhance safety for some important bedside procedures.

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