Abstract

More recently the intensivists have been focusing on interpreting the trans thoracic ECHO, differentiating between non-cardio-
genic and cardiogenic pulmonary edema, diagnosing pulmonary embolism as well as cardiac tamponade. They have also realized the
importance of fluid management by balancing fluid resuscitation and avoiding fluid overload in very sick patients with or without
shock. Whether to give fluid or not is always a great dilemma. There is no fool proof methodology for the same. The IVC collapsibility
has become very handy in critical care units to achieve fluid management goals non-invasively. Ultrasound has become the point of
care in this aspect of clinical problem which are fairly common in the ICU.

Keywords: Ultrasound; Intensive Care Medicine; Anesthesiology

Introduction

Point-of-care ultrasound (POCUS) has enabled intensivists and anesthesiologists in making immediate patient-care decisions and has
facilitated faster diagnosing and better care in intensive care units (ICU), operating rooms (OR) and emergency centers. This review sum-
marizes the various roles of ultrasonography in activities carried out by health care professionals caring for critically ill patients in ICU
and OR settings [1].

During the last two decades cardiac anesthesiologists have recognized the usefulness of transesophageal echocardiography and have
become skilled in its use. More recently, intensivists have focused on rapidly interpreting transthoracic echocardiography, differentiating
non-cardiogenic and cardiogenic pulmonary edema, diagnosing pulmonary embolism as well as cardiac tamponade. They have also en-
hanced their skills in determining the importance of fluid management by balancing fluid resuscitation and avoiding fluid overload in very
sick patients, with or without shock, with the help of POCUS. The IVC collapsibility index has become very useful in critical care units in
achieving non-invasive goal directed fluid therapy [2,3]. Ultrasound has become a landmark in diagnosing and monitoring several clinical
problems commonly encountered in ICU which include trauma, neurological emergencies, hemodynamic monitoring, airway manage-
ment, brain death. Rapidity and accuracy in obtaining pivotal information is one of the principal reasons for its popularity.

Application in procedural guidance:

Ultrasound guided venous and arterial cannulations

Ultrasound-guided vascular access was first described in the 70’s and has evolved to become a highly recommended method for pa-
tient safety. It has become a common practice to use it routinely for central venous access. It is also used for difficult peripheral vein and
arterial cannulation. It has become common practice to train residents for placing the lines with aid of ultrasound [4,5].
Ultrasound-guided central venous catheterization is now a standard of care which reduces the complication rate. Evidence indicates that the use of ultrasound during cannulations is associated with a reduced incidence of cannulation failure, arterial puncture, hematoma, and hemothorax in adult patients undergoing CVC insertion [6].

A study validating the usefulness of ultrasound and x-ray in detecting the CVC position and post procedure pneumothorax by ultrasound has shown that ultrasound can be safely used to detect the position of the catheter tip as well as detect complications like pneumothorax. It can be a better alternative to routine portable chest x ray and with a higher accuracy [7].

 Viewing the tip of the catheter at the level of the carina is the only marker in chest radiographs. Using the flush test after placing the CVC catheter during echocardiography might overcome the need for repeated chest radiographs. The distal port can be flushed with 10 ml of saline over a period of 3 seconds and the time of the onset of bubbles can be observed. Bubbles appearing within 1 - 2 seconds had been shown to predict the catheter tip at 1 - 2 cm from superior vena cava - right atrium junction. Bubbles seen after 3 seconds usually denote that the CVC tip has migrated from its correct position [8,9].

Vascular catheters might cause thrombosis which often goes unnoticed. A study showed that incidence of thrombosis in internal jugular central venous catheters on the 3rd and 6th day of ICU stay might reach 33%. Smaller thrombi were noted in males whereas women were prone to longer thrombi [10].

Ultrasound guided percutaneous tracheostomies

Intensive care patients often require tracheostomy for long-term ventilator support. The use of ultrasound for bedside tracheostomies has recently emerged as a simple and noninvasive tool [11].

A common procedure done at bedside in ICU is percutaneous tracheostomy. This technique very much replaced the surgical tracheostomy. It is less invasive, easy to master and has fewer complications. Ultrasound helps to locate the tracheal rings before the procedure and to detect blood vessels in the path of insertion. This helps to correctly map the place which is to be dilated and percutaneously insert the cannula. The application of ultrasound for percutaneous dilatational tracheostomy (PDT) is encouraging. In critically ill mechanically ventilated patients, PDT done using ultrasound guidance was shown to be non-inferior to bronchoscopic guided tracheostomies [12].

Application in hemodynamic management

Hemodynamically unstable patients can be managed using ultrasound to diagnose potentially reversible causes. In ICU, bedside ultrasound is a standard of care today. It provides insight into the most important elements of the circulatory system.

IVC (inferior vena cava) collapsibility index

One of the most reliable techniques for monitoring intravascular volume status involves the use of ultrasound in assessing inferior vena cava diameter and collapsibility index which have been shown to be accurate measures of right atrial pressure and fluid responsiveness in critically ill patients [13].

The maximum and minimum IVC diameters are calculated by measuring the distance between anterior and posterior walls in M mode. The IVC collapsibility index is calculated using the formula [(maximum IVC diameter - minimum IVC diameter)/maximum IVC diameter]. In passively ventilated patients, responsiveness to fluid therapy is positive when the IVC collapsibility index > 18% (i.e. IVC collapsibility index x 100) [14].
Transaortic peak velocity and stroke volume variation variability

In the apical 5-chamber view, placing a continuous Doppler across the aortic valve peak velocity variation with respiratory cycle, in mechanically ventilated patients, has been shown to be an accurate predictor of fluid responsiveness. Stroke volume variation after a fluid challenge has also been demonstrated to be accurate [15].

Carotid Doppler is another useful ultrasound tool which can predict fluid responsiveness [16].

Application in detecting pulmonary embolism

One of the most life-threatening complications that might ensue in critically ill patients is pulmonary embolism. The etiology may be multifactorial. Immobilization, cancer and autoimmune disease are few of the causes seen in ICU. Therefore, thromboprophylaxis is a general rule unless contraindicated. The safety, ease of use, rapidity, low cost and easy accessibility makes bedside ultrasound pivotal for the diagnosis of deep venous thrombosis and pulmonary embolism [17]. Ultrasonographic findings which can lead to the diagnosis of acute pulmonary embolism are free-floating thrombus in the right heart, RV dilation (RV/LV mid-diameter ratio > 1:1), RV systolic dysfunction, flattening of the interventricular septum into the LV or evidence of deep venous thrombosis on compression ultrasound of the lower extremities [18,19].

Bedside screening echocardiography

Echocardiography includes many views (Figure 1) [20] Important aspects an intensivist looks for in critically ill patients are evidence of pulmonary embolism, ventricular systo-diastolic dysfunction, pericardial effusion and aortic dissection (Figure 1). Cardiac anesthesiologists might also use echocardiography for diagnosing major cardiac abnormalities which could influence perioperative outcome [21].

Figure 1: 2decho showing pericardial effusion.
Applications in regional anesthesia

Since anesthesiologists developed the art of giving regional perineural blocks using ultrasound guidance this has become a routine practice [22]. Ultrasound guidance helps to accurately deposit the local anesthetic, thereby enhancing the duration and quality of the block. Moreover, ultrasound guidance might reduce the dose of local anesthetics and incidence of complications [23-25]. Ultrasound is also useful in visualizing the epidural space and identifying midline structures improving the chances of placement of an epidural catheter or a spinal needle.

Role of Ultrasound in Neurointensive Care

Ultrasound in detecting intracranial pressure requires further research and, in the future, it might lead to changes in therapeutic management, ventilator adjustments and thereby modifying the outcome.

Application in diagnosis of intracranial hypertension

Optic nerve sheath diameter correlates with intracranial pressure. It is non-invasive and reliable in neurocritical patients [26]. Studies have shown that sensitivity and specificity might reach 0.9 and 0.85 respectively in diagnosing the increased intracranial pressure, while the area under the summary receiver-operating characteristic curve might reach 0.94 [27]. Raised intracranial pressure is a life-threatening complication of many central nervous system disorders namely trauma, stroke, intracranial hemorrhage, tumors or even infections. Invasive monitoring of intracranial pressure has been the method of choice but has recently been debated in many conditions. Hence, any bedside non-invasive test which proves sensitive and specific might be pivotal in the future.

In a study evaluating the reliability of optic nerve sheath diameter measured by ultrasound for detecting increased intracranial pressure (Figure 2), the authors found that the average cut off values of 4.6 mm and 4.8 mm, for female and males respectively, had 84.6% and 75% sensitivity in females and males in predicting intracranial pressure, whilst specificity was 100% [28,29]. Optic nerve sheath diameter also has been shown to be associated with results of magnetic resonance imaging. Comparing ultrasound optic nerve sheath diameter with the same MRI derived parameter, investigators have found a moderate correlation (r = 0.02, p< 0.05). These findings have strengthened the usefulness of ultrasound derived prediction of intracranial pressure [26].

Figure 2: ONSD measurement
Brain death testing

Cerebral blood flow velocity can be monitored by transcranial Doppler and its use has spread in the operating theater, for instance, during laparoscopy and anterior open inter-vertebral spinal fusion surgery [27]. Intensivists also monitor cerebral blood flow velocity in patients with stroke and intracranial hemorrhage as an ancillary test for brain death. Meta-analyses showed 95% sensitivity and 99% specificity to detect brain death [28]. The presence of reverberation flow pattern, systolic spikes or lack of flow in basilar and in both middle cerebral arteries observed in two examinations is highly reliable for the prediction of brain death in all patients [29] (Figure 3).

Airway assessment

Confirming endotracheal tube placement

Airway ultrasound aids in assessing the tongue, oropharynx, epiglottis, larynx, vocal cords, cricothyroid membrane, cricoid cartilage [30-39]. Ultrasound has also been used successfully in detecting the correct placement of endotracheal tube. This methodology can be an adjunct in management, however it cannot replace ETCO₂ monitoring. Ultrasonography is an effective technique in confirming intubation.

Lung ultrasound

Detecting pneumothorax

The lung ultrasound can be used to diagnose or exclude pneumothorax, ARDS, interstitial lung disease and pleural effusions. Anesthesiologist have used ultrasound to detect pneumothorax in the anesthetized patients [40]. This major, catastrophic life-threatening event

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*Figure 3: TCD showing diastolic reversal in brain death*
needs to be diagnosed and treated rapidly. Traditionally chest x rays have been the main rapid tool in diagnosing pneumothorax, however it is too time consuming. Pleural sliding in combination with B lines, lung point and lung pulse are very useful in diagnosing pneumothorax. A simple algorithmic approach has been shown to diagnose or exclude pneumothorax at bedside with good accuracy. Therefore, it has become a standard of care [41].

**Predicting difficult airway**

Prediction of the difficult airway is an ongoing area of research. It has been found that measurements of anterior soft neck tissue thickness at the level of the hyoid bone and thyrohyoid membrane can be utilized in predicting difficult laryngoscopies. No significant correlation has yet been found between ultrasonographic measurements and clinical screening tests.

**Detecting pneumonia**

Lung ultrasound has high sensitivity and specificity in detecting pneumonia. Lung ultrasound has been competing with computed tomography in the monitoring of pulmonary disorders [42]. Ventilator associated pneumonia can be diagnosed early and also can be monitored using lung ultrasound. However, there is inadequate evidence available on this argument. In a multicentric study conducted on 99 patients two dynamic linear absorbent air bronchograms produced 94% positive predictive value in diagnosis pneumonia [43] (Figure 4). Normal aerated lung is replaced with non-aerated lung in pneumonia. The ultrasound finding in patients with this condition shows a continuous pattern of B lines with irregularities along the subpleural regions. These areas of consolidations have been shown to turn into lobar consolidations [44,45].

![Ultrasound lung depicting static bronchogram](image)

*Figure 4: Ultrasound lung depicting static bronchogram*
Lung ultrasound in critically ill patients has gained great popularity since it has been described by David Lichtenstein. Meanwhile the nomenclature has changed and the various signs originally described have been better defined. Mastering this tool and using pivotal signs as the A profile, B profile, bat sign, sliding sign, stratosphere sign, lung point, lung pulse, lung point and blue protocol, and falls protocol can give better knowledge and expertise in chest medicine.

**Role of ultrasound in abdomen pathologies**

**Assessing residual gastric volume**

Ultrasound has been used to detect gastric content and volume and to prevent regurgitation and aspiration [46].

**Focused assessment with ultrasonography**

The role of ultrasound in critical care units in abdominal pathologies has been well documented. Diseases like Dengue fever can be suspected by the presence of ascites, gallbladder wall edema and hepatosplenomegaly. According to a study, the incidence of gall bladder wall edema > 3 mm in dengue fever is one of the most important indirect evidence of this viral infection [47] (Figure 5).

**Figure 5: USG abdomen showing GB wall edema.**
Role of ultrasound in diagnosing abdominal trauma has been well documented. Principle of Focused Assessment with Sonography for Trauma protocol (FAST) has been widely implemented in emergency medicine. A positive ultrasound is highly specific of hemoperitoneum. CT scan can be performed in less urgent cases if the patient is stable. In patients with a negative FAST, seeking other sources of bleeding may still require CT scan in order to find the cause of hypotension [48].

**Abdominal paracentesis**

Ultrasound guidance has been proven useful in helping physicians during paracentesis in patients in which a previously blind technique was unsuccessful. Various other studies have proven the usefulness of ultrasound-guided paracentesis in achieving a higher success rate. Hemoperitoneum is a major complication of paracentesis. In a study use of ultrasound reduced the complication rate from 1.25% in traditional blind cohort to 0.27% in the ultrasound cohort [49].

**Conclusions**

Point of care ultrasound in critically ill patients requires formal training. Fellowships in ultrasound for intensivists are being offered by various institutions to improve their skills. These programmes aid in obtaining basic ultrasound skills but a higher competence requires longer training. Ultrasound techniques are used regularly in ICU. These techniques can be added to clinical skills in practicing intensive care. Ultrasound technology in the ICU is a reliable aid, helping with diagnosing and invasive procedures. Ultrasound, with its non-invasiveness, cost effectiveness and radiation free safety profile has become one of the most useful diagnostic and management tools in many of the branches of emergency medicine, critical care medicine and anesthesiology. It is highly recommendable that ultrasound will be a standard of care in many fields.

**Bibliography**


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