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Ultrasound - A Versatile Gadget for the Perioperative Physician

Fareeda Karimbanakkal, Rajesh MC
Department of Anaesthesia, Pain & Peri-operative Medicine, BMH Calicut.

Address for Correspondence: Dr. Rajesh MC, Department of Anaesthesia, Pain and Perioperative Medicine, Baby Memorial Hospital, Kozhikode, Kerala, India. E-mail: rithraj2@yahoo.co.in

Abstract

One of the most advanced technologies in the field of anaesthesia is introducing ultrasound in day to day clinical practice. Widespread use of this gadget depends on its safety, cost-effectiveness, reliability, and efficacy for evaluating complex and variable anatomy prior to needle insertion. It offers excellent guidance for difficult venous access, epidural space identification, for regional anaesthesia and analgesia for acute and chronic pain, cardiac imaging using transesophageal echo, and assessment of the airway.

In this review, we are discussing established and future aspects of ultrasound imaging in anaesthesia practice by perioperative physicians.

Keywords: Ultrasound, airway assessment, nerve block, vascular access, regional block, transesophageal echo

Introduction

Ultrasound is a form of mechanical sound energy which travels through a conducting medium (e.g. body tissue) as a longitudinal wave producing compressions (high pressure) and rarefactions (low pressure). Ultrasound imaging is a simple, safe, and non-invasive technique to provides more accurate localisation of area of interest and thereby more accurate clinical assessment. Recent ultrasound machines (USG) are more compact, portable with better resolution and tissue penetration. Nowadays, ultrasound is one of the most widely and commonly used equipment in anaesthesia practice. As a perioperative physician, anaesthesiologists use USG in various conditions and procedures, including ultrasound-guided airway assessment, regional anaesthesia, vascular access, etc.

Uses of ultrasound in anaesthesia

A) Ultrasound-guided airway management

The scope of USG application in anaesthesia has widened considerably. Sound knowledge of the sonoanatomy of the upper airway can help the anaesthetist to use US in many airway-related conditions.

a) Assessment of the diameter of the subglottic upper airway and prediction of endotracheal tube size

Ultrasonography is a useful tool for assessing the narrowest diameter of the cricoid lumen [1]. It is most useful in paediatric population. In paediatric patients, subglottic upper airway diameter measured by ultrasonography is a good predictor of correct cuffed and uncuffed ETT sizes [2].

b) Airway assessment and Prediction of difficult laryngoscopy.

Ultrasonological evaluation of the airway, especially the anterior anatomy of the neck is an upcoming promising modality in the airway assessment and prediction of the difficult airway. Sonographic assessment of the upper airway is an emergency tool for the prediction of a difficult airway, particularly when an anatomic landmark is difficult to palpate, in an emergency situation, and in unconscious patients [4]. The hypothesis is that the fat pad affects the view during direct laryngoscopy such that the increasing thickness of pre tracheal soft tissue and pre-epiglottic space could be a strong indicator of difficult intubation [5]. Various ultrasound-assisted parameters have been used for preoperative airway assessment, including Hyomental Distance (HMD) in a extended position, HMD in the neutral position and the ratio between the two-HMDR, Pre epiglottic to epiglottic to mid vocal cord ratio (Pre-E/E-mVC), the distance from skin to the hyoid bone, skin to the epiglottis, and skin to the anterior commissure of vocal cords.

Figure 1. Skin to epiglottis distance measurement for airway assessment.

c) Role of ultrasound in percutaneous dilatational tracheostomy

Accurate identification of anterior neck structures during percutaneous dilatational tracheostomy can avoid complications like haemorrhage, tracheal stenosis, erosion into high mediastinal vessels, and injury to the thyroid isthmus. [7]. Before performing percutaneous dilatational tracheostomy, using ultrasound, the pretracheal area can be examined for tracheal midline, the approximate level of tracheal cartilages, anterior jugular veins, thyroid isthmus, vulnerable thyroid vessels, and any other aberrant vessels. Thus ultrasound helps in real-time guidance in the placement of dilators and tracheostomy tubes [1].

d) Prediction of post-extubation stridor

Laryngeal ultrasonography is a useful tool for the evaluation of vocal cords and laryngeal morphology in intubated patients. The air-column width measured by USG can identify patients at risk for post-extubation stridor, in whom caution should be exercised after extubation [8]. From a study by Kundra P et al, it was shown that after cuff deflation, an air-column width of 4.5 mm was associated with post-extubation stridor while patients who did not develop stridor had an air-column width of 6.4 mm [1].

e) Elective transtracheal cannulation and emergency cricothyrotomy

USG helps to identify the trachea prior to both elective transtracheal cannulation and emergency cricothyrotomy and is helpful in situations where localizing the trachea is difficult due to neck mass or any other swelling [9].

f) Ultrasound-guided upper airway anaesthesia to facilitate awake intubation

In order to facilitate awake fiber-optic intubation, upper airway can be anaesthetised with a superior laryngeal nerve block, transtracheal nerve block etc. The superior laryngeal nerve, located between the hyoid bone and thyroid cartilage, can be easily visualized on a transverse ultrasonographic section across the hyoid bone and can perform block [10]

g) Endotracheal intubation, oesophageal intubation and double-lumen bronchial tube (DLT) placement

The most common methods of confirmation of endotracheal intubation is auscultation of the chest, end-tidal carbon dioxide detection, and chest expansion, but can utilize ultrasound for the confirmation of endotracheal intubation, detecting accidental oesophageal intubation, endobronchial intubation and predicting the correct size of double lumen tube etc.

USG imaging can visualise the motion of the diaphragm and pleura indicating lung expansion. Bilateral equal motion of the diaphragm towards the abdomen can be seen in USG if the ETT is inside the trachea. Further, "to-and-fro" movement of the pleura synchronised with ventilation (*lung-sliding sign*) can be visualised with intercostal ultrasonographic view at the lung-chest wall interface [11,12].

h) Detection of laryngeal mask airway position

A proper cuff position to seal the larynx is required for adequate ventilation through the LMA. Ultrasonography has been used to confirm the position of the laryngeal mask airway (LMA) cuff. The LMA cuff was inflated with fluid and the position of the LMA cuff was seen by US from the lateral approach. If the cuff was not visualised by US equally on both sides of the larynx, it should be repositioned [13].

i) Diagnosis of upper airway pathologies

Maxillary sinusitis can be detected before planning for nasal intubation. Normally, sinus is air filled, thus impairing the transmission of ultrasound waves. When filled with fluid, the waves penetrates the anterior wall, travels through the fluid, and strikes the posterior or lateral walls and reflects back to the transducer, resulting in an image of the sinus cavity. This is known as a *sinusogram*.

Assessment and diagnosis of inflammatory conditions of the upper airway like epiglottitis, presence of mucosal swelling and vocal cord function have also been assessed using an US [14].

B) Ultrasound-guided regional anaesthesia and analgesia

a) Peripheral nerve blocks

High-resolution ultrasound imaging allows direct visualization of peripheral nerves, block needle placement, and the distribution of local anaesthetic solution and thereby improves block success and minimizes local anaesthetic volume. In addition, ultrasound can also be used to visualize adjacent structures, such as blood vessels or pleurae, and therefore reduce the risk for complications from peripheral nerve blocks. A major advantage of ultrasound imaging is that variability in surface landmarks, body habitus, and patient positioning can be appreciated [15]

Ultrasound visibility of needles for a regional block primarily depends on the gauge and insertion angle, such that larger needles parallel to the ultrasound transducer are seen most easily. In short axis imaging, cylindrical structures such as nerves appear as circles. Long axis imaging is achieved by placing the transducer longitudinally, or parallel to the course of a nerve, such that it appears as a linear structure. With the in-plane approach, the block needle is introduced within the plane of imaging, such that the entire needle and bevel are seen as a linear structure. The out-of-plane needle approach involves passing the needle from outside the plane of imaging so that it intersects the scan plane as an echogenic dot [15].

Commonly used upper-limb blocks are interscalene block, supraclavicular block, infraclavicular block, axillary block, and peripheral nerve blocks such as median nerve, ulnar, radial, musculocutaneous nerve blocks etc.

Lower limb blocks are less common than upper limb blocks which includes lumbar plexus blocks, sciatic nerve blocks, femoral nerve blocks, saphenous nerve blocks, popliteal nerve blocks etc, used for both anaesthesia and analgesia.

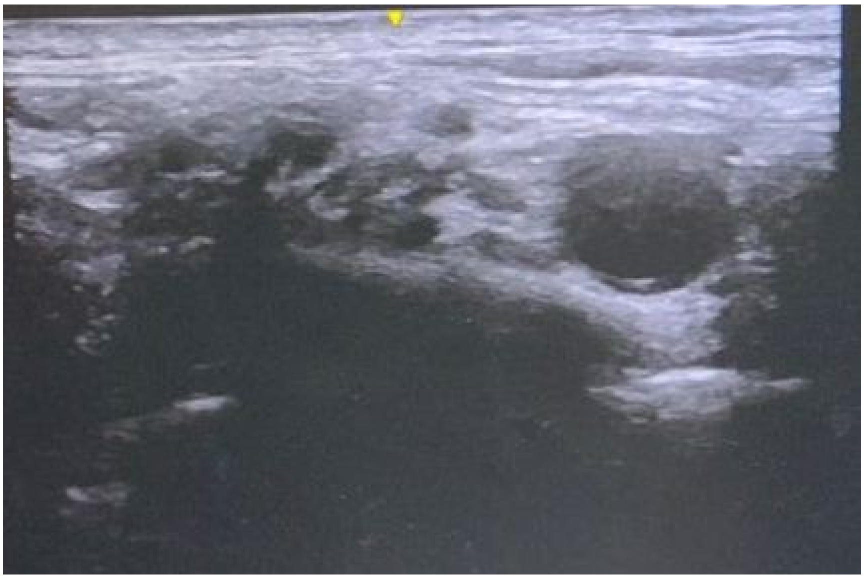

Figure 2: Supraclavicular block.

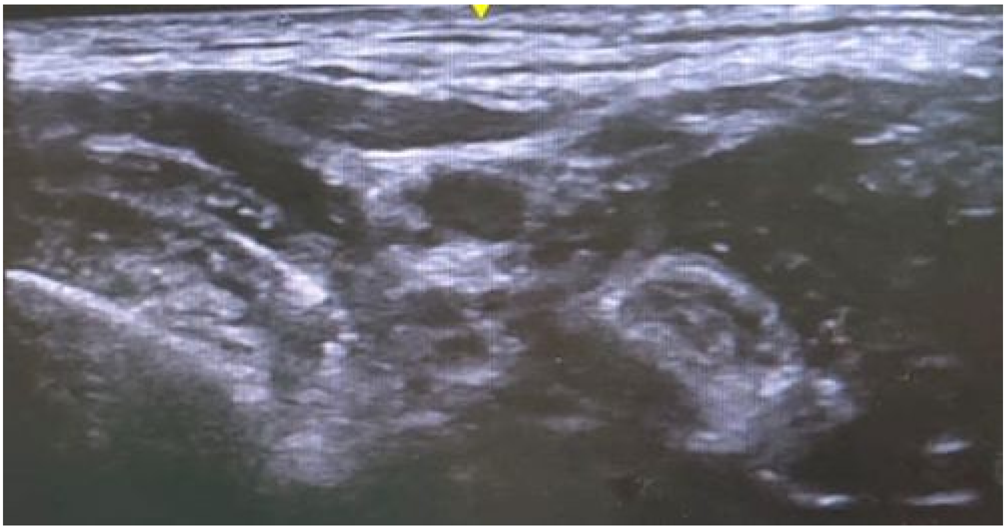

Figure 3: Interscalene block

b) Ultrasound-guided central neuraxial blockade

Spinal anaesthesia can be challenging in patients with poorly palpable surface landmarks and age-related changes in the lumbar spine. In these scenarios, ultrasound imaging is shown to be superior to palpation for the identification of intervertebral levels. Ultrasound guidance for neuraxial anaesthesia is limited by the presence of bony structures like laminae, and spinous processes, which do not pass the ultrasonic beam. The locations of the interlaminar spaces were identified by visualizing the ligamentum flavum-duramater complex and posterior aspect of the vertebral body [16].

Epidural anaesthesia also can be performed using ultrasound by measuring the depth of epidural space along with loss of resistance techniques to guide needle orientation and to give an idea of the depth of ligamentum flavum [17].

Newer application of ultrasound is to visualise the CSF leak in cases of PDPH and to apply epidural blood patch [17].

c) Blocks for acute and chronic pain

Ultrasound guided blocks are given to relieve both acute and chronic pain either as a single injection or continuous catheter techniques. It provides safer pain relief, provides faster functional recovery, and earlier discharge after surgery.

C) Ultrasound-guided vascular access

Vascular access includes central venous access, peripheral venous access, and arterial access. Ultrasound technology helps anaesthesiologists in obtaining various vascular access with less difficulty and fewer complications [18]. Ultrasound-guided vascular access provides numerous benefits, including visualization of the targeted vessel, reduced venipuncture attempts, reduced risk of accidentally accessing an unintended artery, visualization of anatomical variations, and avoiding thrombosed veins [19]. Colour Doppler serves as a useful tool to differentiate between venous and arterial vessels. Arterial vessels will demonstrate a pulsatile flow on colour Doppler while the venous vessels will demonstrate a continuous flow on colour Doppler [19].

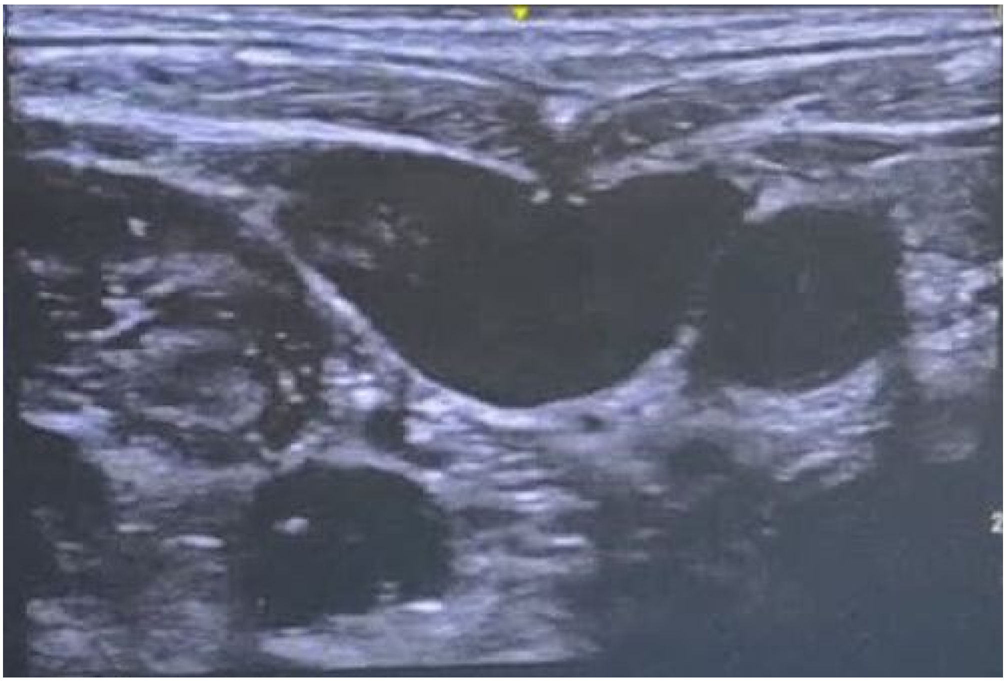

Figure 4: Central venous cannula entering the internal jugular vein.

Vascular ultrasound can also be utilized to identify deep venous thrombosis (DVT) intraoperatively or in intensive care unit (ICU) patients. Vascular ultrasound utilization by physicians is a reliable and accurate method to rule out DVT [20].

D) Diagnostic modality

Perioperative physician utilises ultrasound for diagnosing pleural, pericardial effusion, intra-abdominal haemorrhage, perforated hollow viscus, focused assessment with sonography in trauma (FAST) [21].

a) FAST (Focused Assessment with Sonography for Trauma)

It is indicated in patients with blunt or penetrating trauma to chest or abdomen to detect free intraperitoneal, intrathoracic and pericardial fluid by placing ultrasound probe in various sites like subxiphoid, right upper quadrant, left upper quadrant, suprapubic, right anterior thoracic, left anterior thoracic. It allows the emergency physician to determine whether the patient has pneumothorax, haemothorax, pleural effusion, pericardial effusion, lodged foreign body, etc [22].

E) Monitoring

a) Transesophageal echo

Intraoperative TEE monitoring is a powerful monitoring and diagnostic tool that involves feeding a small ultrasound device into a patient's oesophagus to evaluate heart function and structure [23].

TEE is utilized by the anaesthesiologists during surgery to provide real-time information to aid in identifying the etiology of certain hemodynamically unstable patient presentations. It can help the anaesthesiologist to obtain immediate insight on certain clinical conditions and consequently alter perioperative patient management. Such conditions include valvular abnormalities, biventricular function, pericardial tamponade, volume status, and cardiac ischemia, cardiac output monitoring [24].

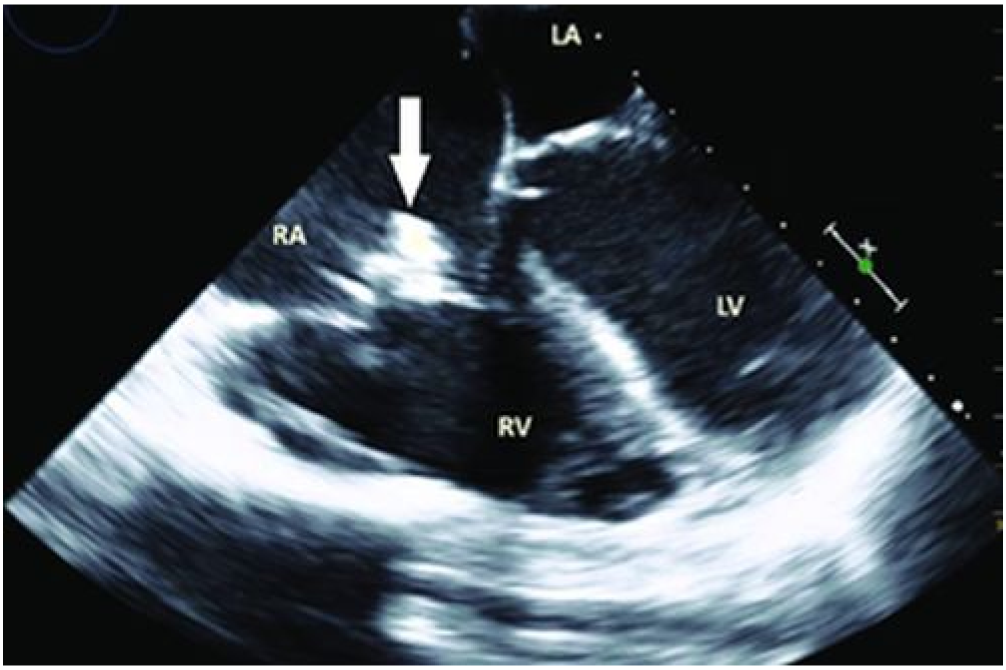

Figure 5: Transesophageal echo showing chambers of heart.

F) Other areas of interest

a) Pulmonary Ultrasound

Pulmonary POCUS has traditionally been used in critical care and emergency medicine but its use in the perioperative setting has been growing rapidly [25]. Its uses include evaluating pleural effusions, pulmonary oedema, pneumothoraxes, atelectasis, and bilateral ventilation [26]. Intraoperatively, the apical segments of the lung and posterior axillary line are usually accessible, which makes it a powerful tool to utilize in real-time acute lung pathology during the intraoperative period [27].

One of the most common applications intraoperatively includes the evaluation for possible pneumothorax if mechanical ventilation is not maintained, hypoxemia occurs or if asymmetrical breath sounds are auscultated. Patients are especially at risk for pneumothorax after central venous catheter placement, blunt or penetrating chest trauma or those with genetic risk factors for spontaneous pneumothorax. On pulmonary ultrasound, the presence of pneumothorax is typically indicated by the absence of lung sliding on the affected side [28].

b) Gastric Ultrasound

Estimation of gastric volume allows the anaesthesiologists a fast and easy way to determine a patient's aspiration risk [29]. In some situations, the fasting status of a patient may be difficult to ascertain (i.e., emergency surgical cases, patients with altered mental status, gastroparesis, even sometimes in diabetes mellitus). Gastric ultrasound becomes incredibly useful in such situations [30]. By measuring the cross-sectional area of the gastric antrum using ultrasound, anaesthesiologist can accurately assess the gastric volume of their patients [31].

Conclusion

Ultrasound is a reliable bedside tool that is increasingly utilized in the perioperative settings. As reviewed above, the application of USG by anesthesiologists to different organ systems and in a variety of perioperative contexts helps the clinician to make a perioperative decision. USG is utilized for the assessment of aspiration risk, vascular access, and ultrasound-guided nerve blocks. The USG can also be utilized to confirm correct endotracheal tube placement in complex airway situations. Cardiac US provides invaluable information that helps in assessing challenging hemodynamically unstable situations. Pulmonary US can identify numerous pulmonary conditions including pneumothorax, pulmonary edema, pleural effusion, and lung consolidation. As highlighted by this review, the diverse utility of POCUS by anesthesiologists enriches the quality of healthcare patients receive in perioperative settings.

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