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ULTRASOUND IN CLINICAL ANAESTHESIA AND CRITICAL CARE: PRESENT AND FUTURE

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ABSTRACT

Ultrasound is a safe, portable, relatively inexpensive, and easily accessible imaging modality, making it a useful diagnostic and monitoring tool in medicine. Ultrasound has recently started to substitute for CT scans and fluoroscopy in many pain treatment procedures. Ultrasound is a unique tool which provides the anesthesiologist with diagnostic and monitoring capabilities enabling optimization of perioperative management. The superiority of ultrasound-guided block technique to blind techniques relies on subtle sensations, which may be unreliable even in experienced hands. Indeed, ultrasound has an important role in problem-based management of various anesthesiology emergencies such as hypoxia, hypotension, dyspnea, and cardiopulmonary arrest. Finally, procedural ultrasound applications in the field of anesthesiology are numerous and improve the quality of care.

INTRODUCTION

Anesthesiologists require quick and accurate diagnostic tools for the effective management of emergencies. Ultrasound (US) is a safe, easily accessible point-of-care imaging modality that is being increasingly adopted in modern anesthesiology practice. As physician-performed ultrasound becomes more practical and practiced, it is important to assure that anesthesiologists are aware of the expanding applications of this technology and the status of its use. Anesthesiologist have been performing diverse interventional procedures using anatomical landmarks over so many years with variable success rates, risks, and consequences of complications. Ultrasound has a role in vascular access, in neural access for nerve blocks and regional anesthesia, transesophageal echocardiography (TEE) for cardiac imaging with blood flows, and to assess the depth of epidural space in cases of difficult anatomy. In order to be successful with this technique, it is important to develop a thorough understanding of the sonoanatomy involved and practical skills. The normal or abnormal structures need to be imaged and interpreted before any intervention.[2]

Advantages of ultrasound-guided central venous catheterization include identification of the vein, detection of variable anatomy and intravascular thrombi, and avoidance of inadvertent arterial puncture. It is safer and less time consuming than the traditional landmark technique It is of particular benefit when used in patients with underlying coagulopathy or platelet dysfunction, by reducing the number of puncture attempts. Ultrasound can also be used for localization of central vein catheters and detection of postprocedural pneumothorax, as an alternative to chest radiography. Ultrasound-guided vascular access has helped in various challenging patient positions: in sitting patients, patient with kyphosis and fixed chin-on-chest deformity, and in the prone position.

Ultrasound arterial cannulation helps in reducing the number of attempts, shortening the procedure time, and increasing the success rate, even in children. A linear or hockey-stick probe can be used. However, it requires training to achieve a level of consistent proficiency.

There is a marked reduction in complication rates after implementation of US-guided central venous cannulation approaches. Although some complications still happen, rates of 4.6% have been reported, comparing with 10.5% when using landmark technique, which represents an absolute risk reduction of 5.9% (95% CI 0.5–11.3%). Most of these complications occur due to inadequate operator's experience; "overshooting" the needle to exit the vein or failing to differentiate between vein and artery.

Peripheral vascular access in pediatrics can be very challenging especially in small, obese, or dehydrated children or in those with previously failed venipuncture. Studies showed that ultrasound-guided peripheral vascular access may improve the success rate of difficult vascular access when performed by well-trained physicians.

System set up

The correct frequency transducer should be selected depending on the depth of penetration and the resolution needed. The high-frequency (10-14 MHz) transducers produce higher resolution images with low tissue penetration. The low-frequency (4-7 MHz) sound wave will show higher penetration in tissues but with poor image resolution. They are required for localization of deeper structures. The depth of tissue should be selected as with greater depth, structures appear smaller but cover a wider area. For optimum image, the area of interest should be within the focal area of the ultrasound beam.

Sterility during invasive procedures is maintained by covering the probe with a sterile plastic or latex sheath. Sterile or nonsterile gel is used to provide coupling of sound between probe and skin surface. Other gels, such as KY jelly or lidocaine gel, used for urinary catheterization may be too fluid for optimum effect.

Technique

With B-mode ultrasound, structures can be seen in transverse and longitudinal section to allow three-dimensional image. In general, needles are seen more easily in longitudinal section; however, the relationship of the needle tip to target and adjacent structures is better seen in transverse section. Tissue distortion produced with repeated movements of the needle or acoustic shadows give a guide to needle direction in the absence of a direct view. The image of needles or cannulae can be improved by incorporating a machine roughened surface to improve scatter of ultrasound. Many ultrasound probes incorporate either fixed or detachable guides to facilitate accurate insertion of needles.

Potential areas of ulility

The potential areas of ultrasound interventions in anesthesia are the airway assessment, for vascular access, for regional anesthesia and nerve blocks, pleural drainage, TEE, trauma, urinary catheterization, and nasogastric tube placement. The majority of such procedures are performed using surface markings alone for produced with repeated movements of the needle or acoustic shadows give a guide to needle direction in the absence of a direct view. The image of needles or cannulae can be improved by incorporating a machine roughened surface to improve scatter of ultrasound. Many ultrasound probes incorporate either fixed or detachable guides to facilitate accurate insertion of needles.

Vascular access

Ultrasound imaging indicates the presence, patency, position, and direction of vessels in the neck, axilla, antecubital fossa, femoral triangle, and other sites with reduce complications. There is increasing evidence that many complications can be avoided by the use of ultrasound for vascular access. There are increasing number of medico-legal cases due to the complications and failure of procedures which can be avoided by the use of ultrasound for imaging during vascular access, particularly in high-risk, difficult cases.

Surface landmark-guided venous access is a procedure with high success rates when performed in optimal circumstances. The indications, techniques, and complications of vascular access are well documented.[3,4]

Other uses for vascular ultrasound

Ultrasound can also be used as an alternative to X-ray to check for position of the guide wire or catheter being in the vessel. It can demonstrate the presence of a thrombus, seen as echogenic material which prevents the vein from being completely compressed by probe pressure. Ultrasound assessment of compressibility of lower limb veins without Doppler has been shown to be accurate in the diagnosis of deep vein thrombosis. The pulmonary embolism from upper body veins can also be recorded.

Ultrasound for chest

Needle-based techniques rely on a space between parietal and lung pleura to allow insertion of the needle tip and subsequent passage of guide wire. If insufficient space is present, lung puncture and pneumothorax are likely to occur. In critically ill patients, the small effusions can be seen easily. The trauma surgeons also assess the hemothorax by ultrasound.[5,6]

Ribs, sternal fractures, and the fluid-filled, collapsed, consolidated lung can be seen with ultrasound. There are reports detailing ultrasound appearances of the lung with pulmonary edema (comet tail sign), pneumonia, lung abscess, and pneumothorax (sliding lung sign).[7,8] Biopsy and drainage of diseased lung can also be performed under ultrasound control. Ultrasound has been used to assess diaphragmatic function after phrenic nerve damage and function of the abdominal wall muscles in respiration.[9]

Ultrasound for regional anesthesia

A successful regional block requires optimum distribution of local anesthetic around nerve and plexus structures. In recent years, real-time ultrasound guidance has been introduced as an aid to nerve localization.[10]

Ultrasound of peripheral nerve allows imaging of individual nerves, position of needle, and monitoring of local anesthetic spread. Higher frequencies (10-14 MHz) give a higher spatial resolution with low tissue penetration and are better for localizing superficial plexuses. Lower frequencies (4-7 MHz) are required for localization of deeper nerves.[11–13]

Air bubbles can cause shadowing and should be removed prior to injection. Bicarbonate containing solutions are avoided because of CO_2 production, which will interfere with imaging. Apparent visual needle contact with nerve may not necessarily elicit muscle contractions; therefore, combined use of ultrasound and electrical nerve stimulator improves quality of block and success rate. However, this has not been shown to confer any advantages.[14]

Central Neuraxial block

Spinal anesthesia can be challenging in patients of poorly palpable surface landmarks and in age-related changes of lumbar spine. The elderly and obese patients have shown to contribute technical difficulties due to poor quality surface landmarks and reduced ability to flex the lumbar spine. Ultrasound imaging has been shown to be superior to clinical palpation as a method of identifying lumbar intervertebral level. Ultrasound guidance for neuraxial anesthesia is limited by the presence of bony structures like laminae, spinous processes, and transverse processes, which do not allow the ultrasonic beam to pass through. The lumbar spine should be imaged using a curved-array 2-5 MHz in two views, longitudinal parasagittal and transverse midline.[15]

Ultrasound for lumber epidurals should be used along with loss of resistance techniques to guide needle orientation and to give an idea of the depth of ligamentum flavum. Studies have shown good correlation between ultrasonographically measured data on the depth of the lumbar epidural space and direct measurement at the time of lumbar puncture. A preprocedural ultrasound scan of lumbar spine has been shown to be beneficial in guiding lumbar epidural catheter insertion Also, the depth of the epidural space in adults needs imaging with low-frequency probes, which gives poor resolution. In such anatomical areas, imaging of muscle-fascial planes or muscle-tendon bone interfaces, rather than nerve itself, may be used to guide needle placement. Ultrasound guidance is associated with significant reduction of the puncture attempts, with more precise application of the catheter to improve analgesia quality with patient satisfaction.[16] Ultrasound visibility is higher in the paramedian as compared with the median plane and should be used to determine the least rotated vertebral body for epidural catheter insertion in spinal scoliosis.[17] Newer application of ultrasound is to visualize the cerebrospinal fluid leak in cases of postdural puncture headache and to apply autologous blood epidural patch.

Ultrasound for airway assessment

Ultrasound imaging is a simple and noninvasive technique to provide a more accurate clinical assessment of the patient's airway. When combined with a thorough knowledge of regional anatomy, soft tissues can be visualized and identified. It is usually difficult to obtain a stable longitudinal image of the airway when using an external scanning over the midline of the anterior neck, due to the difficulty in maintaining good probe-skin contact over an uneven and curved surface.[18-20]

Ultrasound has been used to examine pretracheal anatomy before performing open surgical tracheostomy or percutaneous tracheostomy. It can assess the position of potentially dangerous vessels or other structures and the relative merits of a surgical or percutaneous tracheostomy decision. Accurate midline needle placement can also be assisted. Imaging of the thyroid lobes and isthmus (which have a characteristic grey appearance), anterior jugular veins, and midline of the trachea are possible.[21]

Ultrasound has a role for assessment and diagnosis of upper airway problems, including epiglottitis. The presence of mucosal swelling, fluid or the swollen tissues of disease states should allow areas not normally imaged to be seen because of ultrasound reflectance of air-filled structures. In the emergency room, ultrasound has been shown to determine the correct placement of an endotracheal tube. Vocal cord function has been assessed in adults and children with pharyngeal and tongue movements with swallowing being recorded.[22] A recent study has shown that ultrasound imaging is fairly accurate in estimating the glottic diameter.[23]

Ultrasound has been used in the diagnosis of maxillary sinusitis in nasally intubated cases. The presence of fluid in the sinuses allows their structure to be visualized which could not be seen when air filled.[24] The role of ultrasound in and around the airway requires further verification.

Ultrasound for heart and tee

Currently available TEE probes combine multiplanar ultrasound for cardiac imaging with Doppler to view blood flows. It is used in anesthesia to assess adequacy of repair and to detect residual pathology or prosthetic valve dysfunction in patients undergoing valvular or congenital heart surgery. Ultrasound is a sensitive tool for early detection of pulmonary embolism, especially in patients undergoing neurosurgery in the sitting position.[25]

Ultrasound in pediatrics

Ultrasound is particularly useful for neural blocks in children due to variability in anatomy according to age and constitution of the patient. Moreover, the neural structures are superficially located in children, higher frequency ultrasound probes can be used for better resolution. Spine interspaces and intervertebral foramina allow the ultrasonic beam to penetrate through, to visualize deeper structures.[26,27]

It is useful aid to verify epidural placement of local anesthetic agents and epidural catheters in children. Advantages include a reduction in bone contacts, faster epidural placement, direct visualization of neuraxial structures, and the spread of local anesthetic inside the epidural space. Studies have shown that ultrasound provides information on the distance of skin to ligament flavum in neonates, infants, and children.[28] Hence, the risk of dural puncture is reduced and the spread of local anesthetic agent can also be visualized.

Ultrasonographic visualization of the posterior rectus sheath is possible in children to provide effective analgesia for umbilical and epigastric hernia repair, laparoscopic surgery, pyloromyotomy, and other small midline incisions to offer considerable advantages over conventional, landmark-based techniques for regional anesthesia in children.[29]

Pain interventions

The use of ultrasound has been shown to have 100% accuracy in locating the caudal space and guiding epidural needles for caudal injections for low back pain. Ultrasound has been shown to offer excellent guidance in selective ganglion or nerve blocks for invasive pain therapy. Lumber sympathetic and celiac plexus have been shown to yield similarly good results with ultrasound imaging as with computed tomography scans. A new ultrasound-based approach to facet nerve block under guidance is simpler and avoids radiation.

Ultrasound guidance for stellate ganglion block is useful to monitor the puncture site, needle position, and spread of the local anesthetic.[30] The stellate ganglion block is commonly given for treatment of hydrohidrosis or complex regional pain syndrome of the upper limb.

The ultrasound may be used to identify myofascial trigger points. In the area of chronic pain, demonstration of neuromas or nerves infiltrated by tumor may offer new diagnostic or treatment opportunities. Currently, magnetic resonance imaging and other imaging modalities are more widely used for this purpose.

Gastric Ultrasound

A full stomach may lead to aspiration pneumonia and subsequent morbidities. Anesthesiologists may encounter patients with unknown prandial status, and even fasting "sufficient" time cannot guarantee an empty stomach in many cases (e.g., in the elderly or in patients with gastroparesis). Ultrasound can help in this setting, and the perioperative evaluation of bowel motility is also feasible by means of sonography. Current and potential applications of Gastric ultrasound are as follows: (1)assessment of gastric content and diagnosis of full stomach; (2)confirmation of gastric tube placement.

CONCLUSION

Ultrasound is a unique tool which provides the anesthesiologist with diagnostic and monitoring capabilities enabling optimization of perioperative management. Indeed, ultrasound has an important role in problem-based management of various anesthesiology emergencies such as hypoxia, hypotension, dyspnea, and cardiopulmonary arrest. Finally, procedural ultrasound applications in the field of anesthesiology are numerous and improve the quality of care.

We believe that ultrasound can be the third eye of the anesthesiologist that helps in the performance of previously blind procedures and allows discovery of many hidden spaces to uncover their mysteries. Anesthesiologists, in the near future, may need to carry a portable ultrasound around their neck instead of a stethoscope.

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