*S Afr Fam Pract* 2015;57(2)(Suppl 1):S10-S15



**S Afr Fam Pract**
ISSN 2078-6190 EISSN 2078-6204

**REFRESHER COURSE**

# Ultrasound and the Future of Anaesthesia

**Quan C**

*University of the Witwatersrand, CHBAH*
**Correspondence to:** *barrowceleste@gmail.com*

**Keywords:**

## Introduction

Ultrasound is an oscillating sound pressure wave with a frequency greater than the upper limit of human hearing (20 kilohertz). Medical ultrasound utilizes sound waves with a frequency of 1-18 Megahertz.

In the last decade or so, there has been an exponential increase in the use of ultrasound technology in the medical field, outside the realm of radiologists.

## Topics to be discussed

- Advantages and disadvantages of ultrasound
- Regional anaesthesia
- Vascular access
- FATE
- Gastric ultrasound
- Ocular ultrasound
- Lung and airway ultrasound
- Transcranial Doppler
- Chronic pain

## Advantages and Disadvantages of Ultrasound

Ultrasound has many advantages:

- Bedside availability. Point of care
- Non-invasive with minimal discomfort to the patient
- Easy to do repeated examinations
- Real-time
- Absence of ionizing radiation
- No need for contrast media
- No side–effects
- Once an ultrasound machine is purchased, the running costs are minimal except for the ultrasound gel.

Disadvantages are few and include:

- Operator-dependent
- Retrospective review of images provides only limited quality control
- Body habitus and other factors such as air can affect picture quality
- Different probes required for different examinations
- A good quality machine is expensive
- Ultrasound-induced injury may occur as a result of thermal and non-thermal (acoustic cavitation and non-cavitational) mechanisms[1]. This may be of relevance in ophthalmic and foetal ultrasound[2, 3].

## Regional Anaesthesia

Because the risks of regional anaesthesia are so low, showing that ultrasound improves safety has until now, defied statistical proof. Barrington finally has retrospective evidence that ultrasound guided regional anaesthesia may reduce the incidence of local anaesthetic systemic toxicity [4].

Other advantages of using ultrasound for regional anaesthesia include

- Shorter nerve block procedure time
- Fewer vascular punctures
- Less anaesthetic drug mass required
- Faster nerve block procedure time
- Longer nerve block duration [5].

To date, there is no data to prove that ultrasound decreases the risk of neurological injury. To prove this hypothesis would be very difficult as a very large study would be needed. To complicate matters, we also know that nerve injury has many causes other than actual nerve injury to a fascicle.

## Vascular Access

Ultrasound can be used for central line (internal jugular, subclavian and femoral) insertion as well as arterial and peripheral lines. Ultrasound can be used for marking, but ideally it should be used for real-time imaging. The National Institute for Clinical Excellence (NICE) guidelines from the United Kingdom state that "ultrasound guidance is recommended as the preferred method for insertion of central venous catheters."[6] This has been corroborated by the Agency of Healthcare Research and Quality (AHRQ) in the United States of America.[7]

Central line insertion is a common procedure with recognized complications. A 2003 estimate cited the insertion of >5 million central venous catheters in the United States, with a complication rate of 5 to 19% [8]. Complications include arterial puncture, haematoma, haemothorax, pneumothorax, arterio-venous fistula, venous air embolus, nerve injury, thoracic duct injury (on the left side), intra-luminal dissection and puncture of the aorta. The incidence of mechanical complications increases six fold when more than three attempts are made by the same operator [8]. The use of ultrasound imaging before and during vascular cannulation improves first-pass success and reduces complications [7].

In addition, ultrasound can be very useful in detecting anatomic variations as well as vessel patency (which can be an issue in patients such as those with renal failure who have had numerous central line cannulations). Ultrasound can also be used to confirm that the guide wire has gone caudad and not cephalad. Post insertion, ultrasound can be used to exclude pneumothorax.

### *Real-time versus static imaging*

Both static and real-time imaging are superior to landmark techniques. Although real-time ultrasound guidance outperforms the static skin-marking ultrasound approach, complication rates are similar [7]. Static imaging, however, negates the need for sterile probe covers and ultrasound gels.

### *Paediatric ultrasound guidance*

The United Kingdom's NICE guidelines recommend real-time imaging for central line cannulation in adults and children. However, data to support this practice is limited. An issue in paediatrics is compression of small veins by the ultrasound probe.

### *Arterial cannulation*

Neither the NICE or AHRQ guidelines recommend the routine use of ultrasound for arterial cannulation. However, it may be useful to perform an Allen's test (confirm the presence of the ulna artery) prior to radial artery cannulization. The ultrasound may also be used as a rescue technique in low flow states.

### *Peripheral venous access*

AHRQ guidelines do not recommend the use of real-time imaging for peripheral venous access. However, ultrasound imaging may be useful for the insertion of peripheral intravenous central catheterization (PICC) lines.

## Focused Assessed Transthoracic ECHO (FATE)

FATE has been practiced since 1989. It is a simple and effective roadmap to interpret echocardiographic findings in a clinical context. It is easy to learn and quick to perform and can be applied in all possible clinical scenarios pre- and post-operatively, and in the intensive care or emergency setting. The patient can be supine or in the sitting position.

Transoesophageal ECHO (TOE) has been used for many years and its practice is almost routine in cardiac anaesthesia. However, TOE is generally performed after a patient is induced and usually lies within the realm of cardiac anaesthesiologists. FATE, on the other hand can be done pre-, intra- and post-operatively. Any trained anaesthesiologist presented with a cardiac patient for non-cardiac surgery, can employ FATE. In the preoperative setting (elective or emergency) a FATE study may prove useful in deciding whether or not to delay the patient and book a formal transthoracic ECHO. If continuing with the patient, FATE may be helpful in deciding whether invasive monitoring is required, drug choice as well as whether the patient requires intensive care post-operatively. FATE can also be used intra- and post-operatively or in the intensive care setting if a patient becomes hypotensive or dyspnoeic.

Cowie looked at three years' experience of FATE in the peri-operative period. Anaesthesiologists performed the FATE examination. Adequate images were obtained in 98% of cases. The undifferentiated systolic murmur was the commonest indication. Changes in peri-operative management occurred in 82% of patients. The author concluded that FATE performed by anaesthetists in the peri-operative period accurately detects major cardiac pathology and alters peri-operative management. The author did concede though, that even though FATE altered patient management, it is unclear whether it changed outcome[9, 10].

## Gastric Ultrasound

Most anaesthesiologists follow the American Society of Anesthesiologist's fasting guidelines[11]. Unfortunately, not all our patients do! In addition, sometimes, even if both the anaesthesiologist and the patient have followed the guidelines, misadventure does occur. Pulmonary aspiration is the leading cause of anaesthesia-related deaths in the United Kingdom [12]. Gastric ultrasound now enables us to determine the presence of gastric contents, which is a risk factor for aspiration [13].

The stomach is easily differentiated from other hollow viscera because of its five distinct sonographic layers (mucosal-air, muscularis mucosa, submucosa, muscularis propria and serosa). The gastric antrum is the region of the stomach most consistently identified (98-100% of cases) [13].

In the empty stomach, the antrum appears flat with anterior and posterior walls opposing. Healthy, fasted patients frequently have residual gastric volumes of up to 1,5mlkg$^{-1}$ [13]. Baseline gastric secretions and other fluid appear hypo- or anechoic. As gastric volume increases, the antrum becomes round and distended with thin walls. Air or gas bubbles give the appearance of a "starry night".

After a solid meal, a 'frosted-glass" pattern is seen due to air mixed with the food bolus during chewing and swallowing.

Gastric ultrasound may be clinically useful in situations in which aspiration risk is unclear or undetermined. Three common clinical scenarios may occur:

1. Patients have not followed fasting guidelines (communication gap or emergency surgery)
2. Delayed gastric emptying due to comorbidity (diabetic gastroparesis, renal and liver dysfunction, critically ill patients)
3. Unreliable or unclear history.

Gastric ultrasound can help clinicians individualize aspiration risk at the bedside and adjust anaesthetic management accordingly. An empty stomach implies a low aspiration risk. Solid gastric contents carry a high aspiration risk. If clear fluid is present in the stomach, sonographic assessment of volume can determine if the volume is consistent with baseline secretions (1.5 $mlkg^{-1}$) or if it is a higher volume posing aspiration risk.

Gastric ultrasonography is a new diagnostic tool. Clinicians therefore have to question whether it is:

- Valid (does it assess what it intends to assess and how accurate is it)
- Reliable (how reproducible are the results)
- Interpretable (what are the clinical implications of specific findings)

As far as validity is concerned, most studies to date suggest that gastric ultrasound accurately determines gastric volume[13]. More studies are required to determine reliability and interpretability especially in the paediatric and obstetric population group.

## Ocular ultrasound

Ocular ultrasound is a quick and easy skill to learn. A high frequency probe is place against a closed eyelid in the transverse plane. Optic nerve sheath diameter (ONSD) correlates with intracranial pressure (ICP) and can be measured using ocular ultrasound. The ONSD is up to 5mm in diameter. ONSD is higher in the presence of raised ICP (>20mmHg). Measurement is taken 3mm posterior to he globe. An average of two measurements is used [14].

## Airway and Lung Ultrasound

The airway can be visualized ultrasonographically from the tip of the chin until the mid-trachea and pleura. There is overall, good concordance between ultrasonography and CAT scan as well as cadaveric dissection [15].

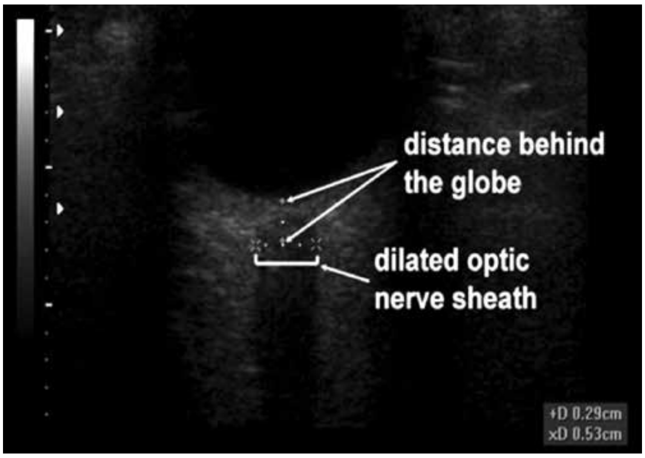


**Figure 1:** Sonographic view of the globe and the optic nerve. (Source: www.lifeinthe fastlane.com/ophthalmology-befuddler-015)

### *Identification of the cricothyroid membrane*

When managing a patient with a difficult airway, one can use the ultrasound to locate and mark the cricothyroid membrane. If an emergency cricothyroidotomy is required, time will be of the essence and a previously marked location will be helpful.

### *Diagnosis of Pneumothorax*

Lung ultrasonography is better then chest x-ray for ruling out pneumothorax. It has a sensitivity of 91% and a specificity of 98% in supine patients whereas chest radiography has a sensitivity of 50,2% and a specificity of 94,8% [17].

The presence of lung sliding or lung pulse or B-lines on ultrasound indicates that at the position under the transducer, the two pleural layers are in direct contact with each other (i.e. no pneumothorax exists at that location). In M-mode the "sea-shore sign" is present. If the lung is inflated but not ventilated, every heartbeat that is transmitted through the inflated lung causes

**Table 1:** Clinical Use of Airway Ultrasonography (16)

| Clinical applications of airway ultrasonography | Comment |
|---|---|
| Screening/prediction of difficult airway management | Only shown to be useful in smaller series in obese patients |
| Diagnosing pathology that can affect airway management | E.g. tumours in neck, tongue, vallecula, pharynx or larynx or in a Zenkers diverticulum that can present an increased risk of aspiration |
| Identification of the cricothyroid membrane | To be performed before managing a difficult airway. |
| Measuring gastric contents prior to airway management | |
| Airway related nerve blocks | |
| Prediction of the appropriate diameter endotracheal, endobronchial or tracheostomy tubes | |
| Differentiating between tracheal and oesophageal intubation | Detects oesophageal intubation before ventilation is initiated and works when there is no circulation (e.g. cardiac arrest) as opposed to $CO_2$ detection |
| Differentiating between tracheal and endobronchial intubation | Useful in noisy environments where a stethoscope is useless |
| Confirmation of gastric tube placement | |
| Diagnosis of pneumothorax | The fastest way to rule out a suspicion of intraoperative pneumothorax |
| Differentiating between different causes of dyspnea, hypoxia and pulmonary oedema | |
| Prediction of successful weaning from ventilator treatment | Obtained by measuring whether the respiratory forces of the patient and/or the width of the airway are large enough to allow for extubation |
| Localization of trachea and tracheal ring interspaces for tracheostomy and percutaneous tracheostomy | |

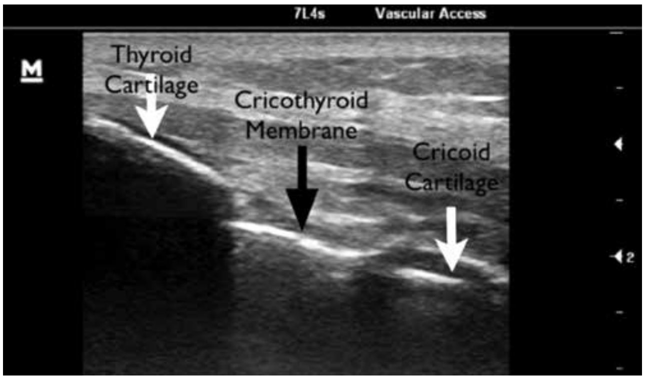


**Figure 2.** Longitudinal ultrasound view of the cricothyroid membrane. (Source www.aucklandems.com/2012/12/05/ultrasound-assisted-surgry-airway)

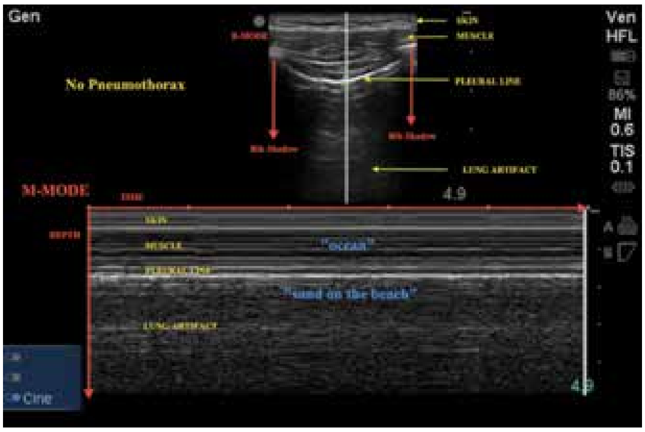


**Figure 3:** Sea-shore sign. B-mode image at the top and M-mode tracing beneath. The gray line through the center of the B-mode image corresponds to the Y-axis of the M-mode image. M-mode of normal lung has been described as having a "sand on the beach" appearance. The speckled appearance of the "sand" is caused by motion of the lung tissue underneath the pleura. (Source: www.em.emory.edu).

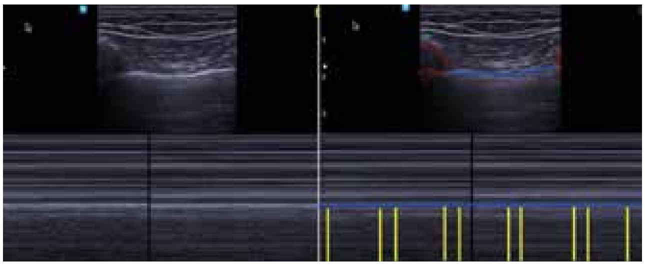

**Figure 4:** Lung pulse. The scanning image, upper: B-mode, lower: M-mode. Left: The ultrasound probe is placed transversely in an inter-space between two ribs during normal ventilation. Right: if the lung is inflated but not ventilated, every heartbeat that is transmitted though the inflated lung causes the two pleural layers (blue) to move a bit with each heartbeat, thereby creating the "lung pulse" artifact (yellow lines). Source: www.airwayelearning.com

the two pleural layers to move with every heartbeat, thereby creating the "lung pulse artifact". A pneumothorax beneath the transducer will prevent lung sliding or lung pulse from being seen on ultrasound. In M-mode, the "stratosphere sign" will be seen. If a transducer is placed at the border of the pneumothorax, the lung point will be present. The lung point is pathognomonic for pneumothorax. Ultrasonography is better for ruling out pneumothorax than for confirming pneumothorax.

### *Pleural Effusions*

Ultrasound demonstrates a sensitivity of 92% (vs x-ray 57%) and a specificity of 93% in detecting pleural effusions [18]. Pleural

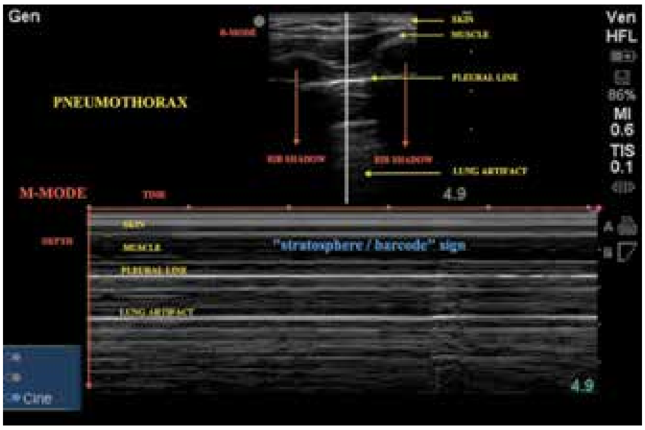


**Figure 5:** "Stratosphere" or "Barcode" sign. The lack of motion-over-time in the collapsed lung creates a linear appearance over the M-mode image. (Source: www.em.emory.edu).

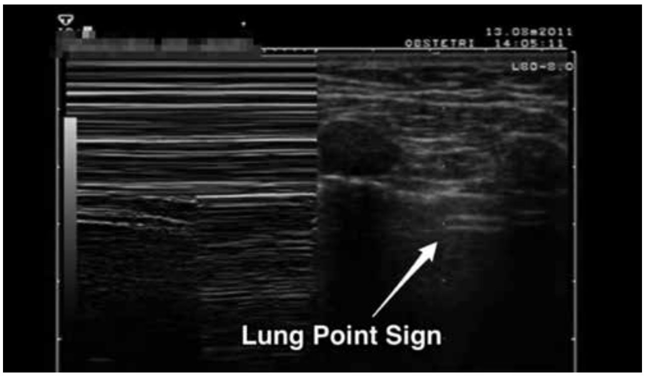


**Figure 6:** Lung point sign is the point at which the "seashore" meets the "stratosphere" sign. this is the point between normal lung and pneumothorax. If seen, this sign is 100% specific for pneumothorax. (Source:www.nesarajah.com)

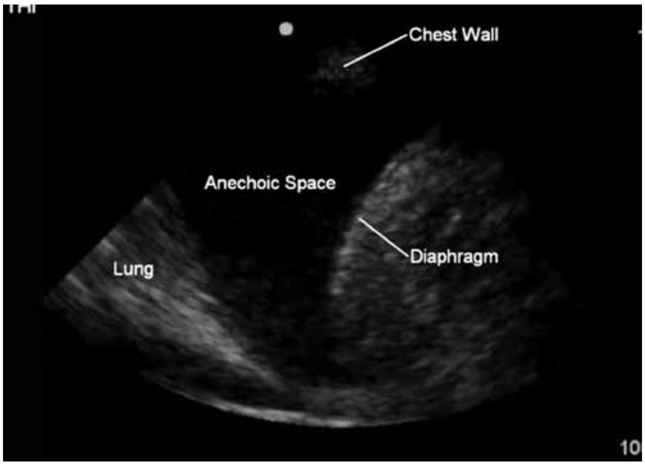


**Figure 7:** Pleural effusion seen sonographically as an anechoic space between atelectatic lung, chest wall and diaphragm. (Source: www.critcaresono.com)

effusions present as hypo echoic (dark) areas, which are roughly quadrangular in shape (Quad sign) and limited by the chest wall and the atelectatic lung. Ultrasound allows determination of effusion location, presence of septations, differentiation of transudate and exudate and estimations of volume. Lung ultrasound may also be used to guide thoracentesis and position of a chest tube, thereby decreasing complications by 15% [18].

### *Lung Ultrasound*

In the emergency room, operating theatre, recovery room and intensive care unit, hypoxic patients may require urgent and appropriate diagnosis for its management. Pneumothorax, pulmonary oedema, pulmonary embolism and Adult Respiratory Distress Syndrome (ARDS) are pathologies where ultrasound can be an important tool for diagnosis. Lichtenstein et al, has introduced a quick and accurate protocol (BLUE protocol) for a rapid diagnosis and differentiation of acute respiratory failure in the critical care setting [19]. This protocol could possibly be extrapolated to our anaesthetized patients in the operating room. Lung ultrasound has a higher diagnostic yield than chest x-ray for the aforementioned conditions [20]. It is easier to carry out, less time consuming and gives immediate answers. However, some limitations include subcutaneous emphysema, pleural calcifications and obesity.

**Table 2:** Clinical Use of Lung Ultrasonography

| Clinical applications of lung ultrasonography | Comment |
|---|---|
| Pneumothorax | Diagnosis and localization |
| Interstitial Syndrome | |
| Pleural effusion | Diagnosis and differentiation of underlying cause. Selecting optimal puncture site for pleurocentesis |
| Pulmonary consolidation and pneumonia | |
| Atelectasis | |
| Pulmonary oedema | Differentiation from ARDS |
| Pulmonary embolism | |
| Monitoring lung disease | Severity, progress and response to therapy |
| Mechanical ventilation optimization | |

## Transcranial Doppler (TCD) (21)

TCD is a noninvasive ultrasound study used to measure cerebral blood flow velocity (CBF-V) in the major intracranial arteries. In involves the use of low-frequency (≤ 2MHz) ultrasound waves to insonate the basal cerebral arteries through relatively thin bone windows. It is relatively inexpensive, repeatable and portable.

Applications of TCD include:

- Vasospasm in sickle cell disease
- Subarachnoid haemorrhage
- Intra- and extracranial arterial stenosis and occlusion
- Brainstem death diagnosis
- Head injury
- Cerebral microembolism
- Autoregulatory testing

However, TCD is highly operator dependent with a long learning curve. It can be difficult with 10-20% of patients having inadequate transtemporal acoustic windows.

## Chronic Pain (22)

Ultrasound is being used for the performance of chronic pain intervention and has begun to substitute CT scans and fluoroscopy. Some of the current and potential applications of ultrasound in chronic pain procedures include:

4. Neuraxial blocks
5. Nerve root blocks (e.g. cervical and lumbar)
6. Stellate ganglion blocks
7. Lumbar transforaminal injections for radicular pain
8. Facet joint blocks
9. Epidural blood patches
10. Intraarticular joint injections
11. Implantation peripheral nerve stimulator
12. Interventional procedure for chronic pelvic pain (pudendal neuralgia, piriformis syndrome and "border nerve" syndrome).

## Conclusion

Ultrasound is an old modality with numerous modern day diagnostic and monitoring uses. It allows anaesthesiologists to optimize perioperative management in many spheres and gives instantaneous and real-time answers.

Ultrasound can be the "third-eye" of the anaesthesiologist that helps in the performance of previously "blind" procedures and allows visualization of previously "hidden" spaces. Moreover, ultrasound gives anaesthesiologists immediate answers, which can be acted upon timeously, thereby benefiting the patient. However, the limitations of ultrasound must be kept in mind. Ultrasound must be used in conjunction with sound clinical skills and other diagnostic and monitoring modalities in an intelligent manner. A fool with a stethoscope or a needle will remain a fool even with an ultrasound!

## Most helpful resources for: "How to do it"

1. Regional anaesthesia
   - RAPSA (Regional Anaesthesia and Pain Society of South Africa) is a special interest group of SASA (South Africa Society of Anaesthesiologists) run various workshops throughout the country.
2. Vascular access
   - Troianos, CA; Hartman, GS et al. Guidelines for Performing Ultrasound Guided vascular Cannulation: Recommendations of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. Journal of the American Society of Echocardiography.2011;(24):1291-318
3. FATE
   - CASSA (Cardiothoracic Anaestheisa Society of South Arica) is a special interest group of SASA and run regular FATE course throughout the year.
4. Gastric ultrasound
   - Van de Putte, P; Perlas, A. Ultrasound assessment of gastric content and volume. British Journal of Anaesthesia. 2014;113(1):12-22
5. Ophthalmic ultrasound
   - www.lifeinthefastlane.com/ophthalmology-befuddler-015/
6. Airway and lung ultrasound
   - http://www.airwaymanagement.dk/ultrasonography-in-airway-management
   - Gargani, L; Volpicelli, G. How I do it: Lung ultrasound. Cardiovascular Ultrasound 2014, 12:25
7. Transcranial Doppler
   - Naqvi, J; Yap, KH; Ahmad, G; Ghosh, J. Transcranial Doppler Ultrasound: A Review of the Physical Principles and major Applications in Critical Care. International Journal of Vascular Medicine. 2013, 629378

## References


1. Miller D, Smith N, Bailey M, Czarnota G, Hynynen K, Makin I. Overview of Therapeutic Ultrasound Applications and safety Considerations. Journal of Ultrasound Medicine. 2012;34(4):623-34
2. Palte HD, Gayer S, Arrieta E, Shaw ES, Nose I, Lee E, et al. Are Ultrasound-Guided Ohthlamic Blocks Injurious to the Eye? A Comparative Rabbit Model Study of Two Ultrasound devices Evaluating Intraorbital Thermal and Structural Changes. Anesthesia and Analgesia. 2012;115:194-201.
3. Abramowicz JS. Benefits and risks of ultrasound in pregnancy. Seminars in Perinatology. 2013;37(5):295-300.
4. Barrington MJ, Kluger R. Ultrasound Guidance Reduces the Risk of Local Anesthetic Systemic Toxicity Following Peripheral Nerve Blockade. Regional Anesthesia and Pain Medicine. 2013;2013(38):289-99.
5. Laur JJ, Weinberg GL. Comparing safety in Surface Landmarks Versus ultrasound-Guided Peripheral Nerve Blocks. Regional Anesthesia and Pain Medicine. 2012;37(6):569-70.
6. National Institute of Clinical Excellence. Guidance on the use of ultrasound locating devices for placing central venous catheters. In: NHS, editor. 49 ed. United Kingdom2002.
7. Agency for Healthcare Research and Quality. Ultrasound guidance of central vein catheterization. In: Making healthcare safer: a critical analysis of patient safety practices. Rockville: ; 2001. p. 245-53.
8. McGee D, Gould M. Preventing complications of central venous catheterization. New England Journal of Medicine. 2003;348:1123-33.
9. Klein A, Snell A, Nashef S, RM H, Kneeshaw J, Arrowsmith J. The impact of intra-operative transoesophageal echocardiography on cardiac surgical practice. Anesthesia and Analgesia. 2009;64:947-52.
10. Michelena H, Abel M, Suri R. Intraoperative echocradiography in valvular heart disease: an evidence-based appraisal. Mayo Clinic Proceedings. 2010;85:646-55.
11. American Society of Anesthesiologists Committee on Standards and Practice Parameters. Practice Guidelines for Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration: Application to Healthy Patients Undergoing Elective Procedures. Anesthesiology. 2011;114(3):$95-511.
12. Woodall NM, Frerk C, Cook TM. Can we make airway management (even) safer-lessons from national audit. Anaesthesia. 2011;66(Suppl. 2):27-33.
13. Van de Putte P, Perlas A. Ultrasound assessment of gastric content and volume. British Journal of Anaesthesia. 2014;113(1):12-22.
14. Dubourg J, Javouhey E, Geeraerts T, Messerer M, Kassai B. Ultrasonography of optic nerve sheath diamete for detection of rased intracranial pressure: a systematic review. Intensive Care Medicine. 2011;37:1059-68.
15. Tsui B, Ip V, Walji A. Airway sonography in live models and cadavers. Journal of ultrasound in medicine: official journal of the American Institute of Ultrasound in Medicine. 2013;32(6):1049-58.
16. Teoh WHL, Kristensen MS. http://www.airwayelearning.com Denmark: Ambu A/S; 2014.
17. Alrajhi K, Woo M, Vaillancourt C. Test characteristics of ultrasonography for the detection of pneumothorax: a systematic review and meta-analysis. Chest. 2012;141(3):703-8.
18. Havelock T, Teoh R, Laws D, Gleeson F. Pleural procedures and thoracic ultrasound: British Thoracic Society Pleural Disease Guideline. Thorax. 2010;65(Supplement 2):61-76.
19. Lichtenstein DA, Meziere GA. Relevance of Lung Ultrasound in the Diagnosis of Acute Respiratory Failure. The BLUE protocol. Chest. 2008;134:117-25.
20. Volpicelli G, Elbarbary M, Blaivas M, Lihtenstein DAea. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Medicine. 2012;38:577-91.
21. Naqvi J, Yap KH, Ahmad G, Ghosh j. Transcranial Doppler Ultrasound: A Review of the Physica Principles and Major Applications in Critical Care. International Journal of Vascular Medicine. 2013;2013:629378.
22. Terkawi AS, Karakitsos D, Elbarbary M, Blaivas M, Durieux ME. Ultrasound for the Anesthesiologists: Present and Future. The Scientific World Journal. 2013;2013(Article ID 683685):15 pages.