Southern African Journal of Anaesthesia and Analgesia. 2021;27(6 Suppl 1):S105-110
https://doi.org/10.36303/SAJAA.2021.27.6.S1.2721

South Afr J Anaesth Analg
ISSN 2220-1181 EISSN 2220-1173

FCA REFRESHER COURSE

Novel ultrasound techniques

KD Pegu

Department of Anaesthesiology, School of Clinical Medicine, Faculty of Health Sciences, Chris Hani Baragwanath Academic Hospital, University of the Witwatersrand, South Africa
Corresponding author, email: *kyleshpegu@yahoo.com*

Ultrasonography allows for rapid acquisition of high-resolution images of anatomic structures in real time. Urgent diagnostic uses of ultrasound (US) will include a rapid diagnosis or confirmation of perioperative haemodynamic instability, shock, cardiac dysfunction, acute respiratory failure, airway issues, intra-abdominal pathology or trauma, bladder distention and abnormal urine output. Multi-organ point-of-care ultrasound (POCUS) including lung ultrasound (LUS) and focussed cardiac ultrasound (FOCUS) as a clinical adjunct has played a significant role in triaging, diagnosis and medical management of COVID-19 patients.

An optic US can be done with the width of the optic nerve sheath being used as a marker for intracranial pressure. Perioperative POCUS of the airway has been shown to aid in the identification of a difficult airway, detection of the appropriate location of the endotracheal tube within the trachea, and with assistance with emergent cricothyrotomy procedures. LUS can be used to detect lung sliding which will be absent in any condition in which the pleurae are not directly opposed, stuck together, or in absent respiration. Interstitial lung syndromes, pneumothorax, alveolar syndrome, pleural effusions, pulmonary emboli and acute respiratory failure can be assessed.

Cardiovascular US is a safe and cost-effective tool for non-invasive examination of the real time cardiac status. Views include the subcostal view, apical four chamber view, parasternal long axis and parasternal short axis view.

By visualising the contents of the stomach, the risk of pulmonary aspiration can be determined more accurately compared to relying solely on predefined fasting times. The advent of focussed assessment with sonography in trauma enables clinicians to rapidly screen for injury. A qualitative assessment of bladder distension can be performed.

Ultrasonography identifies thrombus as non-compressibility of the imaged vein. The use of US guidance is frequently used for placement of venous and arterial catheters.

Keywords: novel ultrasound techniques, high-resolution images, anatomic structures

Introduction

Ultrasonography allows for rapid acquisition of high-resolution images of anatomic structures in real time.[1] Perioperative point-of-care ultrasound (POCUS) refers to performing ultrasonography at the patient's bedside either for diagnostic purposes or to aid in a procedure.[1] POCUS is not a replacement for a full qualitative ultrasound (US) examination, but rather provides anaesthesiologists with immediate access to clinical imaging for rapid and direct solutions.[2]

Perioperative indications for ultrasound use[1,3]

Urgent diagnostic uses include the following:

- Rapid diagnosis or confirmation of causes of perioperative haemodynamic instability or shock
- Hypovolaemia
- Cardiac dysfunction
- Hypoxia or acute respiratory failure
- Pneumothorax
- Airway issues – inappropriate location of endotracheal tube (ETT), marking sites for a cricothyroidotomy or tracheostomy
- Intra-abdominal abnormalities – free fluid or free air
- Abnormal urine output, bladder distention, obstructive hydronephrosis
- Severe preeclampsia

Elective diagnostic uses include the following:

Preoperative period

- Evaluation of signs and symptoms of heart failure
- Assessment of the volume and character of gastric contents
- Assessment of anatomy or pathology that may cause difficulties with laryngoscopy and endotracheal intubation

Intraoperative period

- Confirmation of appropriate positioning of the endotracheal tube
- Confirmation of lung isolation during procedures requiring one-lung ventilation by identifying lung sliding in the ventilated lung(s)

Postoperative period

- Confirmation of bladder distention
- Evaluation of the aetiology of postoperative hypoxia

Procedural uses for ultrasound include the following:

- Regional anaesthesia
- Ultrasound for vascular cannulation
- Intra-arterial cannulation

Ultrasound use during the COVID-19 era

Multi-organ POCUS including lung ultrasound (LUS) and focussed cardiac ultrasound (FOCUS) as a clinical adjunct has played a significant role in the triaging, diagnosis and medical management of COVID-19 patients.[4] Uses of US in COVID-19 patients are as follows:

Respiratory system assessment and monitoring

- Diagnose COVID-19 pneumonia in patients with normal vital signs
- Detect progression to acute respiratory distress syndrome (ARDS) or superimposed bacterial infection
- Guide respiratory support in COVID-19 patients with respiratory failure
- Investigate respiratory deterioration using multi-organ POCUS integrated with other clinical and biochemical variables
- Assess readiness for weaning, predict success and diagnose the causes of weaning failure in COVID-19 using multi-organ POCUS

Cardiovascular system and fluid administration

- Use FOCUS assessment of haemodynamic instability in moderate to severe COVID-19
- Use FOCUS to guide haemodynamic management in severe COVID-19

Deep venous thrombosis (DVT)

- Regular screening of critically ill COVID-19 patients as they have a high risk for venous thromboembolism (VTE)

The salient features for each system are discussed, but the physics of US, probe selection and regional anaesthesia is not covered here.

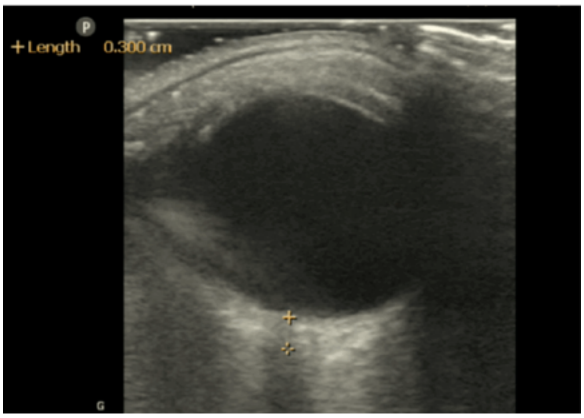

Figure 1: Optic US depicting measurement of optic nerve sheath diameter[6]

Ocular ultrasound[5]

- A linear transducer is placed on the eyelid and is pressed smoothly on the eyeball. It is done in three planes: axial horizontal, axial vertical and vertical transverse.
- The optic nerve sheath of the eye is measured. Normal ranges must be approximately 3 mm right behind the retina (Figure 1).
- Values of the optic nerve sheath higher than 5 mm were correlated with intracranial pressure (ICP) higher than 20 mmHg.

Airway ultrasound [7]

Perioperative POCUS of the airway has been shown to aid in all of the following:[3]

Mouth and tongue

- A longitudinal scan of the floor of the mouth and the tongue is obtained if the transducer is placed submentally in the sagittal plane so that the entire length of the floor of the mouth and the majority of the length of the tongue can be seen.
- When the tongue is in contact with the palate, then the palate can be visualised.

Oropharynx and hypopharynx

- These can be visualised for patency and pathology.

Larynx

- A midline sagittal scan through the upper larynx from the hyoid bone cranially to the thyroid cartilage distally reveals the thyrohyoid ligament, the pre-epiglottic space containing echogenic fat and, posterior to this, a white line representing the laryngeal surface of the epiglottis may be seen.
- A transverse midline scan cranially to the thyroid cartilage depicts the epiglottis. In the cricothyroid region, the probe can be angled cranially to assess the vocal cords and the arytenoid cartilages and thereafter be moved distally to assess the cricoid cartilages and the subglottis.

Vocal cords

- The true and false vocal cords can be visualised by moving the transducer in a cephalocaudad direction over the thyroid cartilage.

Cricothyroid membrane and cricoid cartilage

- This is seen on sagittal and parasagittal views as a hyperechoic band linking the hypoechoic thyroid and cricoid cartilages (Figure 2).

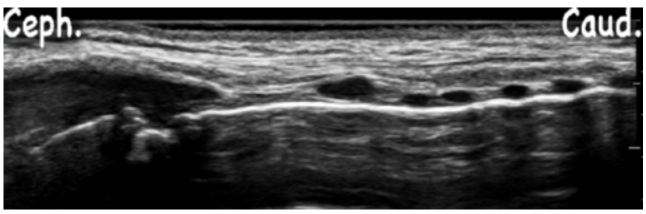

Figure 2: Sagittal view of the hyperechoic cricothyroid membrane in between the hypoechoic thyroid and cricothyroid membrane[8]

- The cricoid cartilage has a round hypoechoic appearance on the parasagittal view and an arch-like appearance on the transverse view.
- The cricothyroid membrane can be located and marked should an emergency cricothyroidotomy be required.

Trachea

- A high-riding annominate artery may be identified above the sternal notch.
- The tracheal rings resemble a "string of beads" in the parasagittal and sagittal plane.
- The use of US to confirm ETT placement relies on the differing anatomy of the trachea and oesophagus. The trachea remains open due to cartilaginous rings, while the oesophagus will collapse unless filled. An oesophagus with an ETT will be more easily visualised next to the trachea than one without.[9]
- If the trachea was intubated – bullet sign[9] which is an increase in both the echogenicity and the posterior artifact indicating the presence of an air-filled ETT.
- For performing a tracheostomy, the position can be marked preoperatively.

Lung ultrasound[10]

- All signs in LUS arise from the pleural line except for subcutaneous emphysema which will abolish it.
- Air below the pleural line reflects most US back to the transducer generating artifacts called A lines.

Lung sliding

- Visceral and parietal pleurae are normally closely opposed with a minute amount of fluid between them and slide over one another.

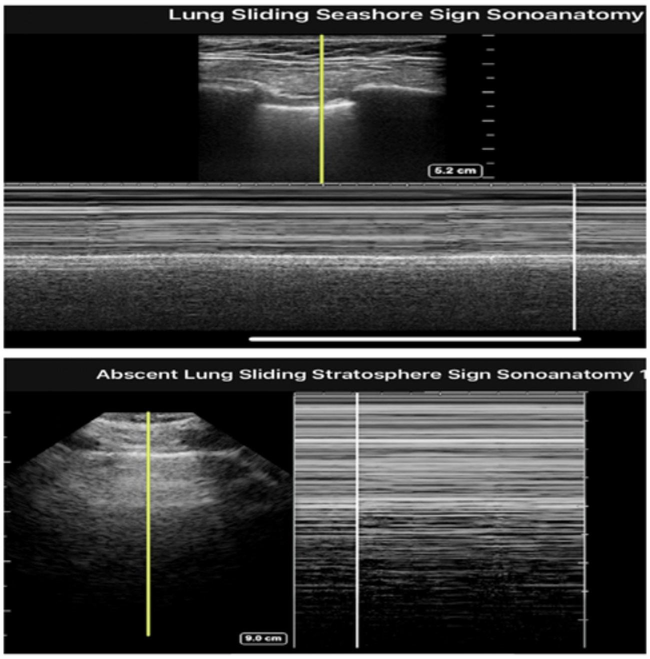

Figure 3: Lung sliding with the 'seashore sign' (above) and absent lung sliding with the 'barcode' or 'stratosphere' sign (below)[8]

- An M-mode image with lung sliding present will show the 'seashore sign' (Figure 3).
- Lung sliding will be reduced with low tidal volumes or in hyperinflated lungs.
- It will be absent in any condition in which the pleura are either not directly opposed (pneumothorax, effusion), are stuck together (pneumonia, ARDS, pleurodesis) or in absent respiration (pneumonectomy, one lung intubation) – the appearance of this on M-mode is horizontal straight lines – the 'barcode sign' (Figure 3).

Interstitial syndrome

- The US feature of interstitial syndrome is B lines. These are artifacts generated by the juxtaposition of alveolar air and septal thickening. The following are their characteristics:
  - Arise from the pleural line
  - Long, vertical hyperechoic lines
  - Look like comet tails
  - Erase A lines
  - Move with lung sliding
- Occasional B lines can be seen in normal lungs.
- When oedema becomes more severe, B lines become more numerous and closely spaced.
- Interstitial syndrome is a sonographic entity caused by:
  - Pulmonary oedema
  - Interstitial pneumonia or pneumonitis
  - Lung fibrosis

Pneumothorax

The features of a pneumothorax are the following:

- Abolished sliding
- Absence of B lines
- Presence of the lung point – point at which two pleural layers rejoin one another
- Absence of the lung pulse

Alveolar syndrome

The sonographic entity of alveolar syndrome encompasses consolidation and atelectasis.

Consolidation has the following three ultrasound patterns:

- Anterior consolidation
- Tissue-like sign
- Shred sign

Air bronchograms appear white, while fluid bronchograms are black.

Atelectasis are identified as follows:

- Atelectasis and consolidation are difficult to tell apart with LUS.

- Bronchograms are suggestive but have a low specificity.
- To distinguish compression atelectasis from consolidation is to drain a pleural effusion (if present) and see if the lung re-aerates.

Pleural effusions

- This is easily identified between the diaphragm and lung posterolaterally. The lung will float on top of an effusion.
- The quad sign
- The sinusoid sign

Pulmonary emboli

- Small, peripheral infarcts can sometimes be seen which are wedge-shaped with defined margins.
- The main strength of LUS in pulmonary embolism is to rule out other causes of respiratory failure.

Acute respiratory failure

- Blue protocol[11]
- The operator looks for lung sliding anteriorly and B lines at two anterior points on each hemithorax.
- If a diagnosis is not reached, then the operator scans the leg veins for a DVT.
- If there is no DVT, then consolidation is looked for posterolaterally.
- This simple protocol has the ability to greatly enhance the speed and accuracy of diagnosis in patients with acute respiratory failure.

Intensive care setting

Diagnosis and treatment

- Blue protocol and above

Fluid management

- Absence of B lines can reassure that fluid will not be detrimental to gas exchange. Their presence should, in most circumstances, dissuade practitioners from giving further fluid.
- B lines appear with interstitial oedema.
- B lines will disappear with treatment of pulmonary oedema.

Lung aeration, positive end-expiratory pressure (PEEP) and weaning

- Lung aeration is assessed after pleural drainage. LUS has been used to assess lung recruitment with PEEP.
- Loss of aeration assessed by LUS during a spontaneous breathing trial predicts post-extubation distress.

Cardiovascular ultrasound

This is a safe and cost-effective tool for non-invasive examination of the real time cardiac status.[12] Indications for a transthoracic echocardiography perioperatively includes the following:[13]

Preoperatively

- Shortness of breath
- Poor historians
- Shocked patients
- Intubated patients/rapid assessment of deteriorating patients
- Cardiac indications: assessment of right and left ventricular function, valvular pathologies, intravascular volume status, pericardial effusion, pleural effusion, pneumothorax, pulmonary hypertension, thromboembolism and regional wall motion abnormalities (RWMAs) can be done.

Intraoperatively

- Tachycardia
- Hypotension
- Hypoxia/Hypoxaemia
- Monitoring a therapeutic intervention (e.g. guide fluid and inotropic administration)
- Cardiac arrest in conjunction with advanced cardiovascular life support (ACLS) principles – confirm no ventricular activity and find reversible causes
- Myocardial insufficiency – grossly dilated/poor functioning ventricles
- Myocardial ischaemia – RWMAs
- Pulmonary embolism – dilated right ventricle/fixed dilated inferior vena cava (IVC)
- Hypovolaemia – underfilled left ventricle/collapsing IVC
- Pericardial effusion/tamponade

Postoperative

- Hypotension
- Potential sources of traumatic pericardial effusion and haemodynamic compromise in the postoperative period – guides pericardiocentesis

Cardiac views[14]

The basic views include the following (Figure 4):

Subcostal view

- The subcostal four chamber view is obtained to display left atrium (LA), left ventricle (LV), right atrium (RA) and right ventricle (RV). The interatrial septum (IAS) is best screened in this view as it is perpendicular to the echo signal. The interventricular septum (IVS), mitral valve (MV) and tricuspid valve (TV) are observed while the RV free wall thickness can also be estimated.
- IVC diameter and collapsibility can be determined.
- Pericardial effusion can also be precluded.
- This view is applicable in particular during cardiopulmonary resuscitation and with patients with poor windows as in the obese, cardiac or thoracic surgery patients.

Apical four chamber view

- This view displays LA, MV, LV, RA, TV, RV, IAS and IVS.

- Analysis of ventricular function, contractility, dilatation and hypertrophy is possible in this view.
- Pericardial effusion is evident.

Parasternal long axis view

- This view demonstrates LA, MV, LV, AV, RV and descending aorta. The LV apex is not imaged in this view.
- The LV systolic function, dilatation and hypertrophy of chambers, interventricular septal hypertrophy, mitral and aortic valve function, descending aortic dilatation, pericardial and pleural effusion can be assessed.
- The pericardial effusion can be differentiated from a pleural effusion.

Parasternal short axis view

- Displays the anterior mitral leaflet and the posterior mitral leaflet.
- Three aortic valve leaflets are seen.
- The walls of LV, IVS and part of RV are also seen.
- Further tilting of the transducer gives a view with anterolateral and posteromedial papillary muscles.
- The walls of LV can be visualised to diagnose RWMAs.
- Hypovolaemia can also be diagnosed in this view.

Fluid assessment[15]

- Assess for changes in the IVC diameter throughout the respiratory cycle in order to determine fluid responsiveness.
- A Doppler measurement of the maximal ascending aortic flow velocity immediately before and after performing a passive leg raise – variation of greater than 14% has a high positive predictive value for the patient being fluid responsive.

Abdominal ultrasound

Gastric ultrasound[16,17]

By visualising the contents of the stomach the risk of pulmonary aspiration can be determined more accurately compared to relying solely on predefined fasting times.

- It is done in the right lateral decubitus (RLD) position.
- Gastric antrum is initially imaged with the transducer in a sagittal plane in the epigastric region, immediately below the xiphisternum.
- When the stomach is empty, the antrum appears small, flat and collapsed (Figure 5) and there is a low risk of aspiration.
- Gastric secretions and clear fluids are anechoic or hypoechoic in appearance.
- Thick fluids are more echoic and homogenous in nature with distention of the antrum.
- Solids appear hyperechoic with a heterogeneous consistency within a distended antrum and there is a higher than baseline risk of aspiration.
- Quantitative assessment is achieved by determining the antral cross-sectional area (CSA) in the RLD.
- Gastric volume (ml) = 27 + [(14.6) x (CSA of antrum in the RLD)] – [1.28 x age (yrs)].
- Quantification of gastric content is important in the presence of clear fluid:
    - < 1.5 ml/kg may likely carry a low risk of pulmonary aspiration.
    - > 1.5 ml/kg suggests recent ingestion of fluids or delayed emptying.

Free fluid in abdomen[18]

The advent of focussed assessment with sonography in trauma (FAST) enables clinicians to rapidly screen for injury. The

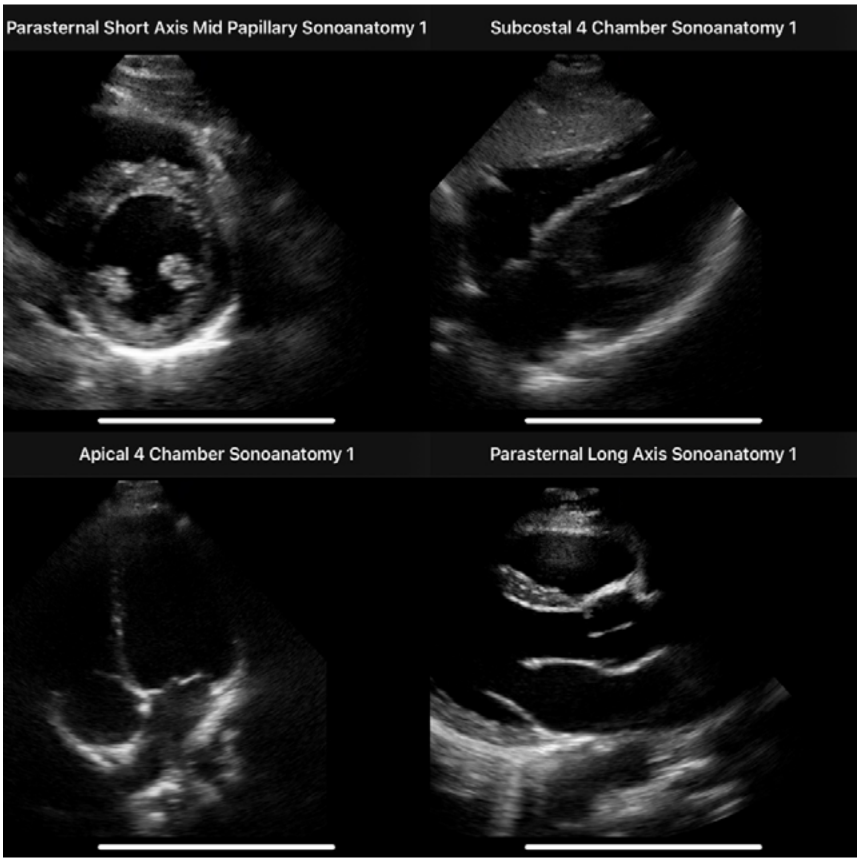

Figure 4: Basic cardiac views[8]

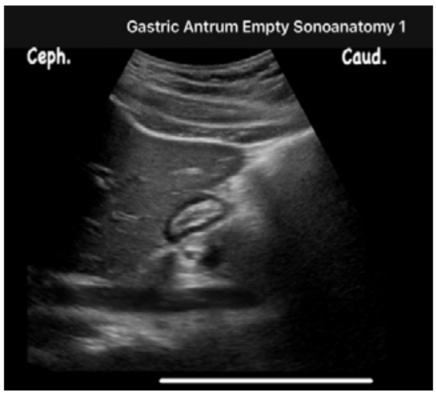

Figure 5: Empty gastric antrum[8]

right upper quadrant (RUQ), left upper quadrant (LUQ) and suprapubic area will be scanned.

- RUQ: a coronal view is performed over the right flank. The interface between the liver and kidney is visualised. Free fluid might be seen. Scan anterior to posterior identifying Morison's pouch and the superior and inferior pole of the kidney.
- LUQ: a coronal view over the left flank. Identify the space between the spleen and diaphragm and the spleen and the kidney. Scan through anterior to posterior of the splenodiaphragmatic space and superior and inferior pole of the kidney looking for free fluid.
- Pelvic: sagittal view just superior to the pubic symphysis. Identify the bladder. Scan medial to lateral to identify fluid posterior and superior to the bladder.

Bladder ultrasound[19]

- A qualitative assessment of bladder distension is performed by noting the location of the bladder dome to the umbilicus.
- Bladder volume that correlates with catheterised volume can be calculated with the following formula: bladder volume = 0.75 x width x length x height.
- The width and length are measured in a transverse plane and the height in a sagittal plane.
- Although not absolute, bladder volumes greater than 600 ml are concerning for bladder outlet obstruction.

Vascular ultrasound[19]

Components in this area include the following:

Detection of DVT

- Ultrasonography identifies thrombus as non-compressibility of the imaged vein (Figure 6). Compression ultrasonography is performed in a transverse orientation. Compressible veins are considered patent and without thrombus, while non-compressible veins are diagnostic of thrombus. If a thrombus is visible within the vein, the compression component of the examination is not required.
- For the lower extremity, the patient should be in the supine position in order to image the femoral veins.
- Upper extremity may also be assessed.

Vascular access

- Central venous access: several studies have shown reduced complications, mainly arterial puncture and pneumothorax with ultrasonography guidance.
- Peripheral venous access: ultrasonography is preferred for the placement of a peripherally inserted central venous catheter.
- Arterial access: US improves success and reduces complication rates.

Conflict of interest

The author declares no conflict of interest.

ORCID

KD Pegu https://orcid.org/0000-0002-3977-3030

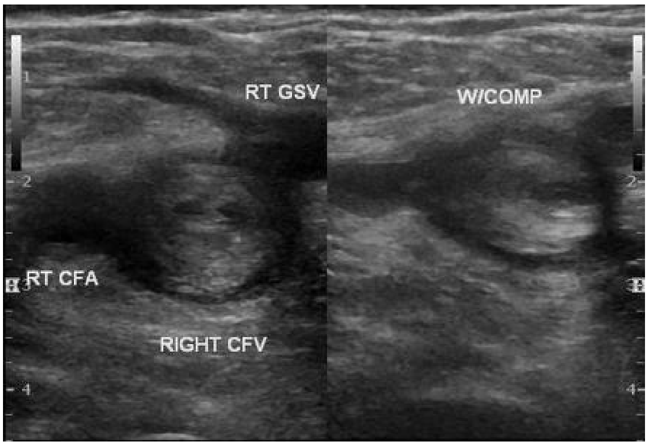

Figure 6: A DVT is depicted on the left while the vein not being compressible is on the right[20]

References

1. Zimmerman J, Birgenheier N. Overview of perioperative uses of ultrasound [Internet]. UpToDate; 2021. Available from: https://www.uptodate.com/contents/overview-of-perioperative-uses-of-ultrasound. Accessed 29 Jul 2021.
2. Dietrich CF, Goudie A, Chiorean L, et al. Point of care ultrasound: a WFUMB position paper. Ultrasound Med Biol. 2017;43(1):49-58. https://doi.org/10.1016/j.ultrasmedbio.2016.06.021.
3. Ramsingh D, Bronshteyn YS, Haskins S, Zimmerman J. Perioperative point-of-care ultrasound: from concept to application. Anesthesiology. 2020;132(4):908-16. https://doi.org/10.1097/ALN.0000000000003113.
4. Hussain A, Via G, Melniker L, et al. Multi-organ point-of-care ultrasound for COVID-19 (PoCUS4COVID): international expert consensus. Crit Care. 2020;24(1):702. https://doi.org/10.1186/s13054-020-03369-5.
5. Restrepo JNJ, León OJ, Florez LAQ. Ocular ultrasonography: a useful instrument in patients with trauma brain injury in emergency service. Emerg Med Int. 2019;9215853. https://doi.org/10.1155/2019/9215853.
6. Ahn J, Dinh V, Deschamps J, et al. Ocular ultrasound made easy: step-by-step guide. Available from: https://www.pocus101.com/ocular-ultrasound-made-easy-step-by-step-guide#Step_4_Measure_Optic_Nerve_Sheath_Diameter_ONSD. Accessed 2 Sept 2021.
7. Kristensen MS. Ultrasonography in the management of the airway. Acta Anaesthesiol Scand. 2011;55(10):1155-73. https://doi.org/10.1111/j.1399-6576.2011.02518.x.
8. AnSo Anaesthesia Sonoanatomy. Version 1.1 [software]. 2021. Available from: https://www.anaesthesiasonoanatomy.com/.
9. Hajjar M, Ireland A. Ultrasound confirmation of ETT placement; 2019. Available from: https://www.nuemblog.com/blog/us-ett. Accessed 28 Aug 2021.
10. Miller A. Practical approach to lung ultrasound. BJA Educ. 2015;16(2):39-45. https://doi.org/10.1093/bjaceaccp/mkv012.
11. Lichtenstein DA, Mezière GA. The BLUE-points: three standardized points used in the BLUE-protocol for ultrasound assessment of the lung in acute respiratory failure. Crit Ultrasound J. 2011;3(2):109-10. https://doi.org/10.1007/s13089-011-0066-3.
12. Margale S, Marudhachalam K, Natani S. Clinical application of point of care transthoracic echocardiography in perioperative period. Indian J Anaesth. 2017;61(1):7-16. https://doi.org/10.4103/0019-5049.198407.
13. Griffiths SE, Waight G, Dennis AT. Focused transthoracic echocardiography in obstetrics. BJA Educ. 2018;18(9):271-6. https://doi.org/10.1016/j.bjae.2018.06.001.
14. Nagre AS. Focus-assessed transthoracic echocardiography: implications in perioperative and intensive care. Ann Card Anaesth. 2019;22(3):302-8. https://doi.org/10.4103/aca.ACA_88_18.
15. Pourmand A, Pyle M, Yamane D, Sumon K, Frasure SE. The utility of point-of-care ultrasound in the assessment of volume status in acute and critically ill patients. World J Emerg Med. 2019;10(4):232-8. https://doi.org/10.5847/wjem.j.1920-8642.2019.04.007.
16. Van de Putte P, Perlas A. Ultrasound assessment of gastric content and volume. Br J Anaesth. 2014;113(1):12-22. https://doi.org/10.1093/bja/aeu151.
17. El-Boghdadly K, Wojcikiewicz T, Perlas A. Perioperative point-of-care gastric ultrasound. BJA Educ. 2019;19(7):219-26. https://doi.org/10.1016/j.bjae.2019.03.003.
18. Richards JR, McGahan JP. Focused assessment with sonography in trauma (FAST) in 2017: what radiologists can learn. Radiology. 2017;283(1):30-48. https://doi.org/10.1148/radiol.2017160107.
19. Huggins J, Mayo P. Indications for bedside ultrasonography in the critically-ill adult patient; 2021. Available from: https://www.uptodate.com/contents/indications-for-bedside-ultrasonography-in-the-critically-ill-adult-patient?source=history_widget. Accessed 28 Aug 2021.
20. Abougazia A. Lower limb deep venous thrombosis (DVT); 2020. Available from: https://radiopaedia.org/cases/lower-limb-deep-venous-thrombosis-dvt?lang=gb. Accessed 2 Sept 2021.