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Point of care ultrasound for the clinical anesthesiologist

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Diagnostic ultrasonography was first utilized in the 1940s. The past 70+ years have seen an explosion in both ultrasound technology and availability of ultrasound technology to more and more clinicians. As ultrasound technology and availability have grown, the utility of ultrasound technology in the clinical setting as only been limited by clinicians' imagination. Due to its lack of radiation, non-invasive nature, and gentle learning curve, medical ultrasonography is now a tremendously useful Point of Care technology in the clinical arena. What follows is a discussion of Point of Care Ultrasound (PoCUS) and how it can be incorporated in the daily practice of any regional anesthesiology. While most regional anesthesiologists usually focus on the interventional aspects of ultrasonography (i.e. nerve blocks), our discussion will center on the diagnostic value of ultrasonography—especially concerning assessment of cardiac physiology and pathophysiology, gastric anatomy, airway anatomy, and intracranial pathophysiology. After reading and reviewing this chapter, the learner will have the knowledge to start training themselves in a variety of PoCUS exams that will allow rapid diagnosis of normal and abnormal patient conditions. Once an accurate diagnosis is established, the anesthesiologist and his/her team can then confidently optimize an anesthetic pain, prevent harm, and/or treat a patient condition. In this day and age, the ability to rapidly establish an accurate diagnosis cannot be overstated—especially in a critical situation. It is the authors' sincerest hope that the following discussion will help regional anesthesiologist to become even better and well-rounded clinical leaders.

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Introduction

Point of Care Ultrasound (PoCUS) is the process of using ultrasound technology in a fast-paced, reproducible setting to quickly evaluate the patient and diagnose conditions without invasive measures. This most frequently occurs in emergency departments and intensive care units, but it can be done in practically any clinical setting. This noninvasive technology, that allows for instantaneous diagnose, has revolutionized emergency care and is rapidly growing as a modality to improve patient outcomes in both elective and critical situations. For anesthesiologists, it is most commonly used in the intensive care unit—particularly the cardiovascular ICU—as well as in the perioperative setting. Perioperative PoCUS assessments of the heart, airway, lungs, abdomen, and head are all safe, simple to learn, and reproducible with high sensitivity and specificity. There is little to no contraindication to its PoCUS and complications rarely arise. This paper will discuss PoCUS in depth for the cardiac, respiratory, gastrointestinal, and nervous systems and will specifically discuss uses for the anesthesiologist.

Cardiac ultrasound

Cardiac ultrasonography is rapidly becoming an indispensable tool in the management of patients in the perioperative setting. Point of care (POC) cardiac ultrasound can be useful in aiding diagnosis even in the setting of limited training, and can help clinicians reach correct diagnosis missed by physical examination alone [1–3]. In the operative room, focused transthoracic echo (TTE), when performed by anesthesiologists, can alter patient management and provide new information in hemodynamically unstable patients [4]. POC TTE has even been used as a preoperative screening tool including preoperative identification of patients at risk for post-induction hypotension [5,6].

TTE holds many advantages over traditional more invasive means of hemodynamic monitoring such as transesophageal echocardiography, esophageal dopplers, or pulmonary artery catheters. The non-invasive nature of TTE renders it with fewer complications, it is easier to perform in an awake patient, can be performed quickly, and has minimal exposure of radiation to the patient. POC TTE provides the clinician at the bedside with a real-time, dynamic imaging of the heart that can be performed in a time critical manner. The information gained can be of immense importance in making prompt therapeutic decisions in a rapidly decompensating patient. Disadvantages of TTE in the perioperative setting include inability to obtain quality images secondary to mechanical ventilation, wound dressings, drapes covering the chest cavity, obesity, and patient positioning.

Goal directed echocardiography (GDE)

Goal directed focused echocardiography describes the rapid qualitative assessment of the cardiac structures by the anesthesiologist at the bedside. The use of GDE in the perioperative setting aims to achieve rapid diagnosis and identification of hemodynamic instability. Thus, it differs from the comprehensive echocardiograms performed by cardiologists, sonography technicians with interpretation by cardiologists, and advanced critical care echocardiographers that utilize echocardiographic principals such as spectral doppler or tissue doppler imaging.

A goal-directed echocardiographic exam comprises of four main views of the heart. These include the parasternal long axis (PLAX; Fig. 1), parasternal short axis (PSAX; Fig. 2), apical four chamber (A4C; Fig. 3), subcostal four chamber and inferior vena cava (IVC) (Figs. 4 and 5) views. Tables 1 and 2 describe the relevant sonoanatomy, clinical utility, as well as techniques on improving image acquisition for each view. Here we will review the most relevant and practical uses of GDE with respect to regional anesthesiology's clinical context.

Intravenous fluid therapy management

For regional anesthesiologists, the ability to identify patients who are hypovolemic prior to neuraxial blockade can be helpful in guiding therapy and initiating pre-emptive measures to reduce the risk and/or severity of hypotension. IVC ultrasound guided fluid therapy is an effective method in preventing post-spinal hypotension [7]. Additionally, in elderly patients undergoing spinal anesthetics, preoperative maximal diameter of IVC (dIVCmax) to IVC collapsibility index (IVCCI) ratio of less than 43 predicts spinal-induced hypotension. To obtain this ratio, the IVC is measured at its maximum diameter at the end of expiration (dIVCmax) and IVCCI during spontaneous, quiet breathing calculated as [(IVC maximal diameter − IVC minimal diameter)/IVC maximal diameter] [8].

Furthermore, ultrasound examination of the IVC allows for a quick non-invasive estimation of central venous pressure without a central venous catheter. During spontaneous ventilation, IVC

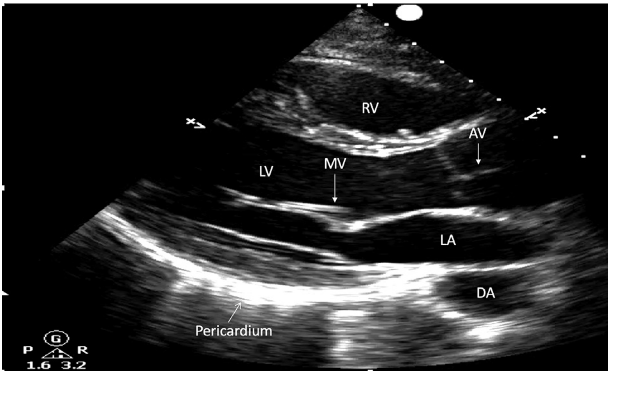

Fig. 1. Parasternal long axis view. LV: left ventricle, RV: right ventricle, MV: mitral valve, AV: aortic valve, DA: descending aorta, LA: left atrium.

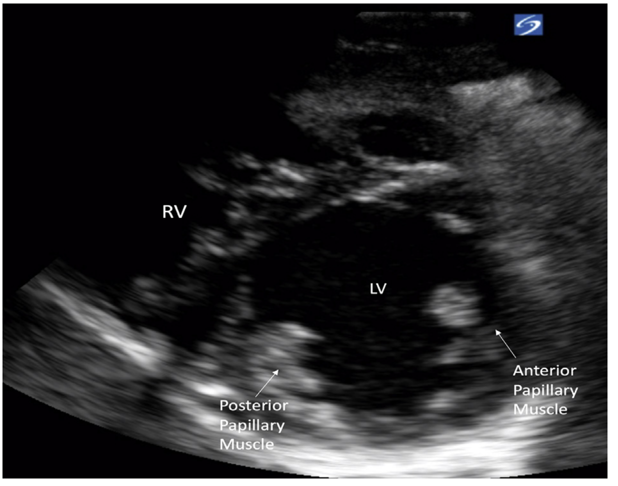

Fig. 2. Parasternal short axis view. RV: right ventricle, LV: left ventricle.

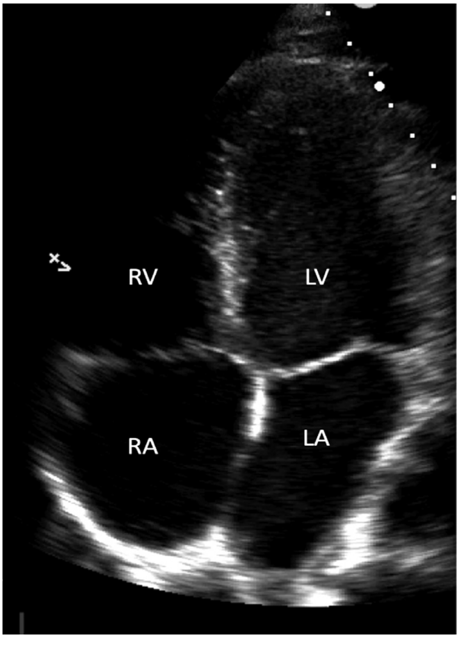

Fig. 3. Apical four chamber view. RV: right ventricle, LV: left ventricle, RA: right atrium, LA: left atrium.

measurement of less than 2.1 cm with an inspiratory collapse of greater than 50% during a sniff (a short rapid inspiration) correlates with a right atrial pressure (RAP) of 0–5 mm Hg; whereas an IVC greater than 2.1 cm with less than 50% collapse during sniff correlate with a RAP of 10–20 mm Hg [9]. Generally, a maximal IVC diameter of less than one centimeter is considered to be an indicator of hypovolemia. In a patient with small IVC, additional findings of a small, hyperdynamic LV with end systolic cavity obliteration are highly suggestive for hypovolemia. Although, a finding of end systolic obliteration alone should prompt further interrogation as a very low systemic vascular resistance state will produce similar finding.

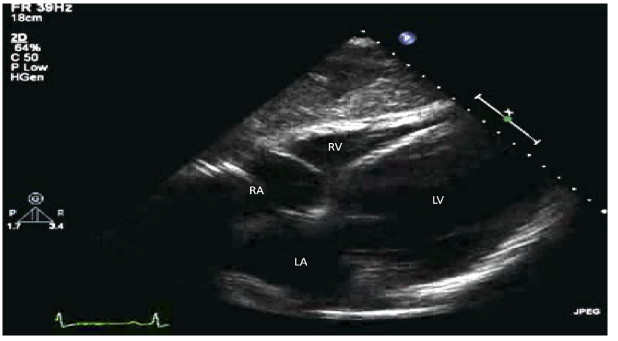

Fig. 4. Subcostal four chamber view. RA: right atrium, RV: right ventricle, LA: left atrium, LV: left ventricle.

Basic assessment of cardiac function

It is common for patients with cardiopulmonary comorbidities to present for operations without extensive cardiac workup. It can especially be challenging to assess cardiac functional status of such patients as many report limited exercise tolerance or sedentary lifestyle. Use of focused TTE in patients presenting for hip surgery operations with increased risk of cardiac disease has been shown to reduce mortality [10]. In such patients, focused evaluation of the left ventricle (LV) on POC echocardiogram can identify patients with poor left ventricular function and allow clinicians to adjust perioperative management.

A qualitative approach to LV systolic function estimation focuses on LV endocardial excursion, myocardial thickening, and septal motion of the anterior leaflet of the mitral valve. In this approach, attention is directed to whether endocardium moves symmetrically towards the center, does the myocardium increase in thickness by approximately 40% during systole in all its segments, and does the anterior leaflet tip of the mitral valve come within 1 cm of the interventricular septum on PSLAX view, which corresponds to an ejection fraction > 40%. This approach allows the examiner to characterize the LV function as either normal, hyperdynamic, reduced, or severely reduced [11].

Cardiac arrest

Use of bedside TTE in the perioperative period can be helpful in identifying reversible causes of cardiac arrest such as hypovolemia, myocardial infarction, RV failure, LV failure, tamponade, or pulmonary embolism (PE).

POC TTE has been successfully used by anesthesiologists to guide a prolonged resuscitation in ambulatory surgery setting [12]. Use of TTE in patients with pulseless electrical activity (PEA) arrest can help distinguish between pseudo-PEA (cardiac activity on ultrasound) versus true-PEA (no cardiac activity on ultrasound). Identifying this distinction can be important in prognostication as patients with true-PEA are noted to have an 8% chance of surviving to hospital admission versus patient's with pseudo-PEA who have a 55% chance of surviving to hospital admission [13]. The acquisition of echo images can be challenging in a cardiac arrest setting and should occur in a way that minimizes disruption of cardiopulmonary resuscitation (CPR).

Pulmonary embolism (PE)

Regional anesthesiologists are commonly called upon in the care of orthopedic surgical patients, especially those undergoing hip and knee arthroplasty procedures, a subset of population at the highest risk of thromboembolic disease amongst orthopedic procedures [14]. Thus, it is imperative for regional anesthesiologists to be familiar with the echocardiographic findings of a massive PE.

In massive PE, cardiopulmonary collapse is a result of obstruction of a majority of the pulmonary vascular bed [15]. In such cases, a sudden increase in the right ventricular (RV) afterload causes its

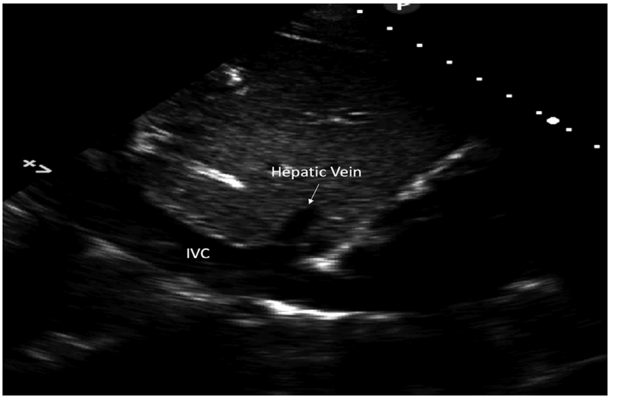

Fig. 5. Subcostal IVC view.

Table 1
Basic echocardiographic views, visualized structures, and clinical utility of each view.

View	Sonoanatomy	Clinical utility
Parasternal long axis (PLAX)	• RV outflow tract • Interventricular septum (IVS) • LV • AV • LA • MV • Descending aorta • Aortic root • Pericardium	• PLAX is usually the easiest view to obtain for beginners. • Assess gross LV function, presence of any RV strain, presence of pericardial effusion, and presence of severe MV or AV disease
Parasternal short axis, mid-papillary level (PSAX)	• RV • LV • Papillary muscles • Pericardium	• Assess gross LV function, wall motion abnormalities, interventricular septal kinetics, detect RV or LV dilation, and visualize for pericardial effusions • Assessment of volume status
Apical 4 chamber (A4C)	• RA • RV • LA • LV • Tricuspid valve (TV) • MV • Pericardium	• Qualitative assessment of LV and RV size and function, RA and LA size, interrogation of interatrial and interventricular septum, presence of pericardial effusion, and presence of severe MV or AV disease
Subcostal 4 chamber and IVC	• RA • RV • LA • LV • TV • MV • Pericardium • IVC	• Qualitative assessment of LV and RV size and function, RA and LA size, interrogation of interatrial and interventricular septum, presence of pericardial effusion, and presence of severe MV or AV disease • Examination of the IVC to determine right atrial pressure as well as ability to calculate IVC collapsibility index

dilation and eventual failure. This is detectable as an increase in RV diameter in the parasternal long-axis view. In this view, the RV dilation causes the right ventricular outflow tract to appear lake a “rounded soccer ball,” instead of its normal “egg-shape.” The increase in RV area and dilation can also be seen on the A4C view. A normal RV is two-thirds the size of the LV, a massive PE will cause the RV to appear larger than the LV. On the PSAX view, flattening of the interventricular septum (D-shaped septum) is noted as a result of high RV pressures. The LV in this view will look small due to inability of blood to travel from the RV to LV. On the subcostal views, this results in a plethoric appearance of the IVC with minimal respiratory variation.

Table 2
Technical tips.

View	Tips
PLAX	• This is the only basic cardiac view where the orientation marker is directed toward the patient's right shoulder • If having difficulty in identifying an adequate echo window in the parasternal views, the examiner can position the patient in the left lateral decubitus position. This helps displace the body weight to the left and brings the heart closer to the chest wall and minimizes the interference created by the lung interposition • Abduction of the left arm is also an easy and effective way to find an echo window
PSAX	• It is common for beginners to make inadvertent movements that result in image degradation when rotating the transducer from the PLAX to the PSAX. Thus, it may be easy to use both hands to rotate the transducer under direct visualization, and **ere** rotating the transducer, then look back to the ultrasound screen
A4C	• If having difficulty in obtaining images due to lung artifact the examiner should have the patient take a deep inhalation and record images during expiration as lung deflation will allow for a better access to the echo windows
Subcostal 4C and IVC	• The patient should be positioned supine for image acquisition in this view • Additional maneuvers that allow for better transducer position include flexing the patient's knees and hips which results in relaxation of the rectus abdominis muscles • Visualizing the cavo-atrial junction (IVC entering the right atrium) and the hepato-caval junction (hepatic vein emptying into the IVC) distinguishes the IVC from the pulsatile aorta

Tamponade

Regional anesthesiologists play an important role in the care of trauma patients. Cardiac tamponade is a life-threatening emergency that can be seen in this patient population. During unrecognized tamponade, intubation and positive pressure ventilation can lead to hemodynamic collapse. Recognition of tamponade on focused cardiac ultrasound can avoid such complications. The basic echocardiographic signs of tamponade include presence of a pericardial effusion, dilated IVC, late diastolic inversion of the RA free wall, RV diastolic collapse, and visualization of a swinging heart surrounded by a pericardial effusion [16].

Valvular pathology

Of the various valvular pathologies, severe aortic stenosis has the highest impact on the practice of the regional anesthesia. Aortic valve area calculations such as the continuity equation are beyond the scope of basic echocardiography. Such measurements are time consuming, fraught with technical challenges, and not feasible in the fast-paced operative environment. Despite these limitations, in a patient with a new found systolic ejection murmur, visual inspection of the aortic valve with observation of the extent of restriction in aortic cusp opening can alert the anesthesiologist to the presence of a hemodynamically significant aortic stenosis [17].

Additionally, measurement of maximal aortic cusp separation (MACS) is a simple method to assess the severity of aortic stenosis with high sensitivity and specificity. In this method, the distance of aortic leaflet separation is measured in the PLAX view during mid-systole when aortic valve cusps are fully open. A MACS value below 8.25 mm reliably predicts severe aortic stenosis [18].

Gastric ultrasound

Pulmonary aspiration of gastric contents is a serious perioperative complication that can lead to significant morbidity and mortality [19]. Standard fasting periods recommended by American Society of Anesthesiologists as nil per os (NPO) (fasting for $\geq$2 h for clear fluids, $\geq$6 h for a light meal such as toast, and $\geq$8 h for a full meal consisting of fried/fatty food or meat) are used to ensure an empty stomach in patients [20]. Nevertheless, fasting guidelines are not applicable to non-elective surgical procedures and in patients with interindividual variability in gastric-emptying time due to certain physiologic conditions [21–23] or existing co-morbidities [24,25]. Gastric content and volume assessment before providing anesthesia is a new PoCUS (point-of-care ultrasound) application that can help determine aspiration risk. Addition of gastric PoCUS to clinical assessment is reported to change anesthetic management in 71% of patients with questionable and borderline adherence to fasting recommendations who presented for elective surgery [25].

Anesthesiologists routinely provide general anesthesia to patients without a secured airway—leading to an increased risk of aspiration in high risk patients (emergent or urgent trauma cases, unknown NPO status, or chronic pain on high-dose opioids). As anesthesiologists continue to expand upon their ultrasound (US) toolbox, gastric PoCUS has the potential to improve patient management and care by determining pulmonary aspiration risk at the bedside [26].

Clinical indication

Gastric PoCUS is an emerging tool, particularly useful when prandial status is unknown or questionable. The main indication is pre-anesthetic aspiration risk assessment in patients with questionable prandial status. This includes, urgent or emergency surgical procedures; systemic diseases like diabetic gastroparesis, end-stage renal or liver disease, critical illness, neuromuscular disorders; unconfirmed NPO status due to language barriers, altered mental status, inconsistent history; special patient population like severe obesity, pediatrics, obstetrics.

Gastric PoCUS findings have been validated in patients with normal gastric anatomy. In patients with structural abnormalities (for example, gastric cancer, previous lower esophageal or gastric surgery, hiatal hernia) or patients with high BMI (body mass index) > 40, quantitative volume assessment may be inaccurate but qualitative information on stomach contents can still be useful.

Quantitative assessment

Ideal patient positioning combines both supine and right lateral decubitus (RLD). In RLD positioning a greater proportion of stomach contents will move towards the more dependent antrum following gravity, thus increasing the sensitivity of the test to detect small volumes. If this positioning is not feasible like in critically ill patients, supine positioning is acceptable. Supine position alone can rule in, but not rule out, a full stomach. Supine positioning may not be sensitive enough to detect small amounts of gastric content, which will tend to be displaced to the fundus that is not easily accessible with US imaging.

In adult patients or children weighing more than 40 kg, a low-frequency large curvilinear probe (1–5 MHz) is required. In lean (<40 kg) or pediatric patients, a linear high-frequency probes (5–12 MHz) are best.

To image the stomach, the epigastrium is scanned in a sagittal or parasagittal plane immediately inferior to patient's xiphisternum and the transducer is swept widely from left to right subcostal margin until descending aorta or IVC is seen in long axis. The Stomach with its prominent muscularis layer will be located superficially between left lobe of liver anteriorly and pancreas posteriorly [27,28]. Important regional vascular landmarks are aorta, IVC and superior mesenteric artery and vein. Rocking the transducer gently, sliding, and/or a heel to toe movement may also be necessary to identify the antrum at the level of aorta. The antrum is usually located at a depth of 2–3, but in severely obese patients it may be as deep as 7 cm [21]. Depth, gain, tissue harmonics and focal zone can then be adjusted to center the antrum and to reduce image artifacts. If a clear fluid content or volume estimate is desired, measure antral cross-sectional area of the gastric antrum (CSA) in RLD as a mean of 3 readings, between peristaltic contractions and estimate gastric volume as follows: (Volume (ml) $= 27.0 + 14.6 \times$ Right-lat CSA $- 1.28 \times$ age) [29].

Qualitative assessment

A qualitative appearance of the antrum is used to establish the nature of gastric content. When the stomach is empty, the antrum appears collapsed with juxtaposed anterior and posterior walls. It appears round to ovoid in shape and can be compared with a ‘bull's eye’ or ‘target’ pattern.

A 'starry night' appearance is a common finding soon after ingestion of liquids. If the antrum is distended with thin walls and has a hypoechoic appearance it likely contains clear or thin fluid. Immediately after a solid meal a distended antrum (full stomach) will be filled with a 'ground glass' or 'frosted-glass' patterned material. If the antrum is distended with content of mixed echogenicity probably it is full of solid food.

The following are ultrasound classifications for the antrum: grade 0 if it appears empty in both supine and RLD positions, grade 1 if when fluid is apparent in RLD only (correlates with low gastric volume), grade 2 if clear fluid is apparent in both supine and RLD positions (correlates with higher than baseline volume). Grade 0 and 1 carries low risk of aspiration whereas grade 2 antrum carries high risk of aspiration. Particulate fluid or solid gastric content is considered to pose a serious risk of aspiration—often correlated with poor patient outcome.

Both qualitative and quantitative findings on the gastric ultrasound exam help in risk stratification of patients. This further helps in choosing the right choice of anesthetic plan for a particular patient rather than a general assumption based on hours of fasting. In conclusion, gastric PoCUS is an emerging tool to decrease diagnostic uncertainty and help weigh the risk-benefit ratio of different anesthetic interventions. However, large clinical trials are required for gastric PoCUS to potentially become a new standard for evaluation of preoperative NPO status.

Airway ultrasound assessment

In recent years, the use of ultrasound for airway assessment and management has grown considerably with promising results. While accurate anatomical assessment of the airway using ultrasound is dependent on operator skill, numerous studies have shown that clinician competency to reliably obtain accurate images requires minimal training and is easily reproducible [30]. This section will review relevant airway anatomy and the utility of ultrasound use for airway assessment and management.

Review of basic anatomy

All clinicians who are responsible for airway assessment and management need to have an understanding of basic airway anatomy. Generally, the airway can be divided into upper and lower sections. The upper airway consists of the mucous membrane lined pharynx and larynx. The pharynx is subdivided into the nasopharynx, oropharynx, and hypopharynx. The nasopharynx includes the posterior nasal cavity and is divided from the oropharynx via the palate and skull base. The oropharynx consists of the region between the palate and hyoid bone and connects the nasopharynx and hypopharynx. The hypopharynx is the area below the hyoid bone and connects the oropharynx to the cartilaginous larynx. The larynx contains the components necessary for speech including the epiglottis and vocal cords. The lower airway consists of the trachea and lungs. The tubular shape of the trachea is supported by C-shaped hyaline cartilage which allows for esophageal motility during swallowing. A detailed discussion of lung anatomy is beyond the scope of this section.

For the purpose of ultrasound assessment, the airway can be divided anatomically into suprahyoid and infrahyoid regions [31]. Suprahyoid anatomical structures include the mylohyoid, geniohyoid, tongue, and hyoid bone. Pertinent infrahyoid structures include the epiglottis, thyrohyoid membrane, preepiglottic space, thyroid cartilage, and tracheal cartilage. Curved low frequency transducers can be used to visualize deeper submandibular and supraglottic structures while linear high frequency transducers are best suited to visualize superficial structures [31–36]. Ultrasound images of both the suprahyoid and infrahyoid structures have been found to correlate well with computed tomography [37]. The clinical relevance of assessment of these aforementioned structures will be discussed below.

Predicting difficult airway management

Throughout the years, numerous physical exam findings have been established for clinicians to help predict potential difficult airway management. These conventional markers include but are not limited to patient height, weight, BMI, race, Mallampati score, thyromental distance, cervical spine range of motion, jaw mobility, and dentition [38]. While these assessments have been widely adopted internationally, they have varying degrees of sensitivity and specificity leaving clinicians vulnerable to the dreaded cannot intubate cannot ventilate situation. Several studies have found that preoperative airway assessment with ultrasound has increased sensitivity and specificity relative to these conventional assessments.

The failure to visualize the hyoid bone using sublingual ultrasound can predict difficult intubation with a positive likelihood ratio of 21.6 [34]. Another study found that a shorter hyomental distance ratio in morbidly obese patients is a sensitive predictor for difficult airway management. The hyomental distance ratio is the distance between the hyoid bone and mandibular mentum in the neutral position compared to the hyperextended neck position [39]. A hyomental distance ratio of 1.0–1.05 was found to be associated with difficult airway management compared to those patients with a hyomental distance ratio of 1.12–1.16 [39].

Increased pretracheal tissue at the level of the vocal cords has been shown to be predictive of difficult airway management in obese patients of middle eastern descent [40]. However, it is worth noting that these findings were not duplicated when applied to western patient populations [41]. Small pilot studies have also shown that an anterior neck thickness greater than 2.8 cm at the hyoid bone and the thyrohyoid membrane are accurate predictors of difficult intubation but larger studies are needed prior to validation for routine screening [42].

Ultrasound has also been found to be sensitive and specific for the detection of subglottic stenosis. Several studies have found that ultrasound evaluation of the narrowest diameter of the cricoid lumen, or the transverse diameter, correlate well when compared with findings from magnetic resonance imaging [39,43]. Detection of subglottic stenosis allows for practitioners to preemptively chose the correct endotracheal tube size, minimizing the potential for complications like hypoxia or airway trauma due to repetitive manipulation [43,44]. Ultrasound evaluation of subglottic transverse diameter has been found to be superior to both age based and height based formulas to estimate the correct endotracheal tube size [44,45].

Regional anesthesia

Ensuring adequate anesthesia of the airway via regional techniques is an essential component for successful awake intubation in patients with a known or suspected difficult airway. Ultrasound utilization can help facilitate regional techniques when normal anatomical landmarks are difficult to assess due to causes such as morbid obesity or a history of previous surgery involving the airway or neck. The superior laryngeal nerve affords sensation to the epiglottis and to the airway mucosa to the level of the vocal cords. This nerve can be visualized in the space between the hyoid bone and thyroid cartilage when scanning transversely at the level of the hyoid bone [46]. Visualization of anatomical landmarks and needle placement under ultrasound guidance is known to increase the success of any given regional anesthesia procedure.

Confirmation of airway placement

Capnography and auscultation of the lungs are the most commonly used methods to confirm appropriate airway placement in the normal healthy patient. However, these conventional methods may not be as accurate or reliable in situations like cardiovascular collapse, emergent difficult airway management with potential esophageal intubation, or severe refractory bronchoconstriction. Successful intubation can be confirmed quickly and easily via transtracheal ultrasound by the “double tract” or “double lumen” signs characterized by two hyperechoic lines [47,48]. Multiple studies have shown that transtracheal ultrasound is a rapid and reliable method to confirm proper airway placement and correlates well when compared to end tidal capnography [47,48].

Utilization in emergency situations

Preparation is a critical component for the successful management of emergent difficult airway scenarios. A cricothyrotomy is lifesaving technique to secure a definitive airway in unstable patients who are unable to be intubated or ventilated by conventional methods. The procedure

Table 3
Papilledema and optic nerve sheath diameter.

	Optic nerve sheath diameter normal	Optic nerve sheath diameter enlarged
No papilledema	Normal	Hyper-acute ICP elevation
Papilledema	Pseudopapilledema	ICP elevation

involves cannulating the cricothyroid membrane by either a needle or percutaneous approach. The cricothyroid membrane is most often identified by locating the space below the thyroid prominence and above the cricoid cartilage. Sometimes these anatomical landmarks can be difficult to recognize due to patient body habitus or pathology affecting the area such as a thyroid mass. The use of ultrasound has been proven to be a quick and effective adjunct to structures when the anatomical landmarks are distorted. With only minimal training, clinicians have been found to be able to identify the cricothyroid membrane using ultrasound in less than 25 s [49]. A subsequent study done on cadavers found that clinicians were able to identify the cricothyroid membrane in less than 4 s and complete the procedure with a high success rate in less than 30 s [50]. After successful cricothyrotomy, a formal tracheostomy is generally performed within 24 h to establish a more definitive and secure airway.

Assessment of intracranial pressure (ICP)

PoCUS uses extend into the central nervous system. It is the most widely used and validated method of evaluating ICP elevation. The necessary ultrasound image is obtained via a sagittal or coronal cross-section of the orbit while the patient's eyelid is closed. Liberal amounts of ultrasound transmission gel should be used for this assessment so as to minimize the amount of pressure placed on the ocular structures during measurement [11]. The qualitative ICP estimation is obtained by measuring the optic nerve sheath diameter 3 mm behind posterior extent of the retina. <5 mm is considered normal, 5–6 mm is a grey zone that requires further testing in many cases, and >6 mm is abnormal, suggesting ICP elevation. PoCUS can also be used to evaluate papilledema. The Considering diagnostic performance of papilledema versus optic nerve sheath diameter, a 2016 prospective multicenter study by Lochner et al. comparing 21 patients with known intracranial hypertension versus age-matched controls showed ultrasonographic papilledema was present bilaterally in 20/21 (95%) of patients with intracranial hypertension, and was absent bilaterally in all 21 control patients [51]. Overall, papilledema out-performed optic nerve sheath diameter, which had 93% sensitivity and 67% specificity, using a cutoff of 5.9 mm. Papilledema also performed well as a diagnostic marker in a 2014 retrospective chart-review series of 87 by Carter et al. [52]. Furthermore, Bauerle et al. performed a prospective study involving 10 patients diagnosed with idiopathic intracranial hypertension and 25 patients with neurologic disorders not associated with intracranial hypertension [53]. Ultrasonographic papilledema was present bilaterally in 9/10 patients and absent in 25/25 control patients. Papilledema again out-performed optic nerve sheath diameter (which had 90% sensitivity but only 84% specificity using a cutoff value of 5.8 mm).

Although papilledema is traditionally considered a finding on ophthalmoscopy, it can also be evaluated with PoCUS. Ultrasound evaluation for papilledema is measured using the same view as that for the optic nerve—see previous paragraph. If papilledema is present the clinician will observe the optic disc bulging into the vitreous humor [11]. Therefore papilledema and ICP elevations can be combined into one examination—instead of the two traditional examinations ophthalmoscopy and the invasive lumbar puncture. In theory, papilledema and optic nerve sheath diameter could be integrated in a 2 × 2 table as shown in Table 3 to differentiate various intracranial pathologies.

Conclusion

PoCUS is an important tool in the everyday workflow of a many different medical scenarios, especially for the emergency medicine physician and anesthesiologist. With improving provider aptitude and increasing utility, PoCUS seemingly has no limit as to its clinical application and could be considered the future of the physical exam and a vital procedural aid. Its non-invasive nature and ability to yield rapid results has revolutionized emergency and intensive care medicine. As we have discussed, it is extremely useful in the anesthesiologist's day-to-day workflow for the peri-operative and clinical assessment of the heart, airway, abdomen, and head. It is safe, relatively simple to learn, reproducible with high sensitivity and specificity, has little to no contraindications, and complications rarely arise as a result of its use. From TEE to ICP, PoCUS is a dynamic solution to a massive array of clinical problems and is likely a large part of the future of our profession.

Practice points

- PoCUS is the process of using ultrasound technology in a fast-paced, reproducible setting to quickly evaluate the patient and diagnose conditions without invasive measures.
- This noninvasive technology, that allows for instantaneous diagnose, has revolutionized emergency care and is rapidly growing as a modality to improve patient outcomes in both elective and critical situations.
- Point of care (POC) cardiac ultrasound can be useful in aiding diagnosis even in the setting of limited training, and can help clinicians reach correct diagnosis missed by physical examination alone.

Research agenda

- PoCUS seemingly has no limit as to its clinical application and could be considered the future of the physical exam and a vital procedural aid.
- Small pilot studies have also shown that an anterior neck thickness greater than 2.8 cm at the hyoid bone and the thyrohyoid membrane are accurate predictors of difficult intubation but larger studies are needed prior to validation for routine screening.

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