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Point-of-Care Ultrasound for the Trauma Anesthesiologist

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Abstract

Purpose of Review With advances in technology and availability of handheld ultrasound probes, studies are focusing on the perioperative care of patients, but a limited number specifically on trauma patients. This review highlights recent findings from studies using point of care ultrasound (POCUS) to improve the care of trauma patients.

Recent Findings Major findings include the use of POCUS to assess volume status of trauma patients upon arrival to measure the major vasculature. Additionally, several studies have advanced the use of POCUS to identify pneumothorax in trauma patients. Finally, the ASA POCUS certification and ASRA expert guidelines are examples of international organizations establishing guidelines for utilization and training of anesthesiologists in the field of POCUS, which will be discussed.

Summary Despite the COVID-19 pandemic, and considerable resources being diverted to fight this global healthcare crisis, advances are being made in utilization of POCUS to aid the care of trauma patients.

Keywords Point of care ultrasound · Trauma · Gastric POCUS · Thoracic POCUS · Traumatology · Pre-hospital

Introduction

Point of care ultrasound (POCUS) is an established modality for multiple medical specialties and its usage in healthcare has grown exponentially in recent years. The ultrasound, now with several hand-held models commercially available, has many benefits: it is relatively inexpensive, exams can be rapid and non-invasive, and it does not expose patients to radiation of other imaging modalities. Furthermore, it is the ideal tool in situations where rapid diagnosis and management are necessary. As well, trauma anesthesiology is now an established part of the field of "Traumatology," and anesthesiologists are primary traumatologists. Although this field is expanding rapidly, evidence is still forming on outcome measures, and more well-designed studies are needed to continue to expand the benefits of this modality in early trauma management.

A thorough literature search using keywords Emergency, Airway Emergency, Ultrasound, Ultrasonography, Point of Care Ultrasound, and Trauma revealed only a small selection of studies on POCUS for trauma patients, highlighting that the application to trauma anesthesiology has not been extensively investigated.

Bahner et al. developed a framework of indication, acquisition, interpretation, and medical decision-making (I-AIM) to define how focused sonography should be performed [1]. Applying the I-AIM parameters of POCUS to trauma patients offers the ability to evaluate quick hemodynamic changes, occult injuries, and rapidly changing clinical situations [2]. One recent study showed that a complete clinical exam (which includes both negative extended focused assessment with sonography for trauma (eFAST) and abdominal exam) could limit the need for full body computed tomography scan following severe thoracoabdominal blunt trauma [3•].

The American Society of Anesthesiology (ASA) has recently introduced POCUS certification with three primary applications (cardiac, lung, and abdominal ultrasound) and six secondary applications (airway, musculoskeletal/soft tissue, ocular, renal/genitourinary, transcranial Doppler, and deep venous thrombosis), and these clearly have implications in trauma care. Therefore, this paper will focus on the primary applications with regard to trauma and highlight some of the research into the secondary ones.

This article is part of the Topical Collection on *Anesthesia for Trauma*

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Finally, it must be acknowledged that virtually all areas of medicine, POCUS, and trauma anesthesiology, have been greatly impacted by the global Coronavirus Disease 2019 (COVID-19) pandemic. Our literature search of "point of care ultrasound" from October 2019 to September 2021 lead to over one-third of the results being COVID-19 related studies. Furthermore, how we practice trauma care has been affected with unknown disease status of patients and limited and cumbersome personal protective equipment, which limits the ability of providers to communicate [4]. These add a level of complexity and uncertainty to an already tense clinical environment.

Focused Cardiac Ultrasound to Assess Cardiovascular Status

While transesophageal echocardiography has been a cornerstone in cardiac anesthesiology, cardiac POCUS could potentially aid in trauma patients as it allows a quick, non-invasive assessment of basic hemodynamic parameters and cardiac function in high acuity settings. It can be done on transport, in the trauma bay, intraoperatively, and postoperatively in cases of decompensation in the intensive care unit (ICU). While Focus Assessed Transthoracic Echocardiography (FATE) certification is helpful in diagnosing more sophisticated cardiac abnormalities such as valvular abnormalities, a simple focused cardiac ultrasound (FoCUS') exam can be a quick "snapshot" during an acute emergency.

Trauma patients often present in hypovolemic/hemorrhagic shock. Upon arrival, the pre-hospital blood loss is unknown and therefore, an immediate assessment of volume status is critical. The volume of the inferior vena cava (IVC) can be acquired to identify early stages of shock [5••] prior to changes in vital signs [6] and is predictive of transfusion requirements [7•]. Although computerized tomography (CT) is the traditional imaging modality to assess the IVC, CT can be time consuming and ill-advised for an unstable trauma patient. Therefore, POCUS is a more expeditious alternative to sending a potentially unstable patient to the CT scanner.

As such, POCUS measurements of the IVC size and collapsibility index have been used to assess volume status [8, 9] and have been studied extensively in ICU patients [10]. POCUS is clearly less invasive than traditional measurements of fluid status, such as central venous pressure or pulmonary arterial catheter measurements. Chardoli et al. (2018) showed that IVC diameter correlates with CVP and is effective at assessing changes in volume status in patients presenting to the ED in a hypotensive state. However, only a fraction of patients in this study suffered traumatic injuries. Very few studies have focused on the use of POCUS as an indication of volume status specifically in trauma patients. Doucet et al. [11••] showed that ultrasound measurements of the IVC during the first hour of resuscitation can predict the amount of fluid resuscitation necessary for the first 24 h in major trauma patients [11••].

Using the IVC as a target to assess volume status may be limited in multiple ways during trauma resuscitation. The IVC is the most commonly injured vessel with 3.2% sustaining an IVC injury [12, 13]. Even if the IVC remains intact, it is possible that obtaining a subcostal view could be limited by other abdominal injuries or sterility in the operative field. Additionally, abnormal intra-abdominal pressures and controlled ventilation can alter the results of IVC assessments [14, 15].

An alternative ultrasound target for volume status assessment would be the internal jugular (IJ) vein. Jassim et al. [16] showed that IJ volume can be more easily measured in ICU patients and that the IJ collapsibility index correlates better with CVP than measurements of the IVC [16]. In addition, these investigators were unable to acquire the image of the IVC in 20% of the patients (obesity, abdominal surgical sites), making the IJ a better target for initial assessment. However, there were no trauma patients included in this study, so the feasibility in this population needs further study.

In addition to using POCUS to assess vasculature, the heart itself can be assessed in the care of a patient in shock. Pericardial effusion and tamponade are readily seen on apical views of the heart. Right heart flattening and septal wall bowing are also signs of hypovolemia. As well, these views can evaluate ongoing response to fluid, blood, and medication therapy in an underfilled or poorly contracting heart.

Cardiac POCUS can predict survivability to hospital admission in patients presenting without a pulse. More specifically, if the subxiphoid view revealed any non-fibrillating motion, patients were considerably more likely to survive to hospital admission (23.5% vs 1.9%, respectively) [17]. In fact, presence of cardiac motion on ultrasound was recently shown to be the most important predictor of survivability when trauma patients present in pulseless electrical activity (PEA) cardiac arrest (odds ratio 33.91) [18]; however, survivability is exceedingly rare in patients who arrive in traumatic arrest, regardless of presence of cardiac motion detected on ultrasound [19•]. A recent meta-analysis showed that patients without cardiac motion on an apical view (which is typically done on eFAST) had negligible survival to hospital discharge, but the authors did recognize that the number of patients studied was too small to make recommendations on termination of resuscitation [20•]. Additional barriers to utilization of POCUS during cardiac arrest include the immediate availability of an ultrasound and the chaos of the clinical setting [21, 22••].

Thoracic POCUS

The use of ultrasound to detect traumatic pneumothorax (PTX) has been studied in emergency departments since the late 1980s. Ultimately, thoracic POCUS emerged as the fundamental tool to diagnose PTX rapidly and accurately as it is superior to standard supine chest radiograph and is a component of the eFAST. In a multicenter, prospective study of 157 patients with blunt chest trauma, the sensitivity of thoracic POCUS for detecting PTX was 75% and the specificity 100% [22••]. Most recently, a meta-analysis including 13 studies and 1271 trauma patients demonstrated thoracic POCUS diagnostic superiority to standard supine chest radiograph [23•]. Finally, the sensitivity and specificity for thoracic POCUS were 91% and 99% respectively, compared to supine chest radiograph (47% and 100%, respectively). These results are independent of the mechanism of trauma and type of provider performing scans. These authors suggest that thoracic POCUS should be performed following the FAST exam prior to a supine chest radiograph. If the POCUS exam is indicative of a PTX and the patient is in respiratory distress or shock, a tube thoracostomy could be placed immediately.

A high sensitivity is critical in a disease that is grave but treatable like PTX. The sensitivity of these scans is affected by concomitant hemothorax, pulmonary contusion, or subcutaneous emphysema, which can all lead to false negative test results for PTX [22••]. High PEEP settings can prevent lung sliding detection, possibly causing false positive results [24].

Ultrasound findings suggesting PTX include absence of lung sliding, presence of B-lines, lung pulse, and a "lung point." Additionally, the "barcode" sign is present when scanning in M mode (Fig. 1). The most sensitive anatomic location to scan for a PTX is just below the clavicle at the parasternal border down to liver or cardiac lung points followed by the mid clavicular line down to liver or cardiac lung points (Fig. 2, left side). This scanning method would cover lung zones 2, 3, and 4 and have a sensitivity of 91.6% (Fig. 2, right side) [25••]. A single view chest US was as almost sensitive as a four-view exam, suggesting that more views and longer exams do not improve the diagnostic accuracy of multiple views [26]. Hence, in a time-sensitive clinical situation, one must weigh the benefit of more thorough exams with risks of wasting valuable time.

Thoracic ultrasound is also superior to chest radiography in the identification of hemothorax in a trauma patient. In a recent meta-analysis of 7321 patients from 12 studies, the sensitivity/specificity of US in the detection of hemothorax was 0.67 and 0.99, respectively [27]. As stated above, there are areas of the lung that are anatomically challenging to scan with POCUS and therefore, thoracic ultrasound is not as sensitive as traditional [28, 29] and can miss other hematomas particularly in the mediastinum [30]. More recently, the identification of the "extension of the thoracic spine" sign has been shown to be highly specific for hemothorax and can be identified during the initial e-FAST exam [31•]. Several studies have investigated lung contusion diagnosis with POCUS, with varying results for accuracy [32, 33].

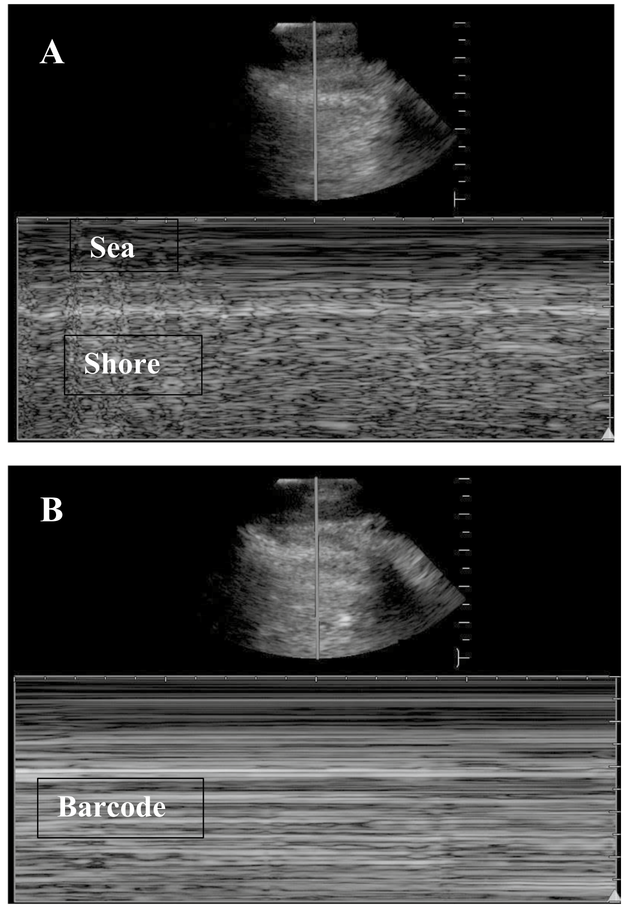

Fig. 1 Detection of pneumothorax using M mode. **A** Using M mode to scan normal lung tissue gives the appearance of the "seashore sign." Where the "sea appearance" represents skin, muscle, and the pleural line and the "shore" is the image of lung artifact with lung motion. **B** Similar view of the upper muscle and pleural line, however, the "Barcode" sign represents lack of lung motion present in pneumothorax

In addition to these uses of lung ultrasound to detect thoracic injuries, thoracic ultrasound can be used to guide lung isolation in an emergent thoracotomy or other emergency procedures where one lung ventilation is necessary [34]. This may be useful in trauma patients when gold-standard fiberoptic bronchoscopy cannot be obtained. A further benefit was that this modality took significantly less time than FOB. The authors extrapolated this to conclude POCUS also cost less to perform.

Gastric POCUS

The well-known focused assessment with sonography for trauma (FAST)[35] abdominal exams has established value in treating the acute trauma patient. The FAST exams involve a systematic scanning for occult hemorrhage;

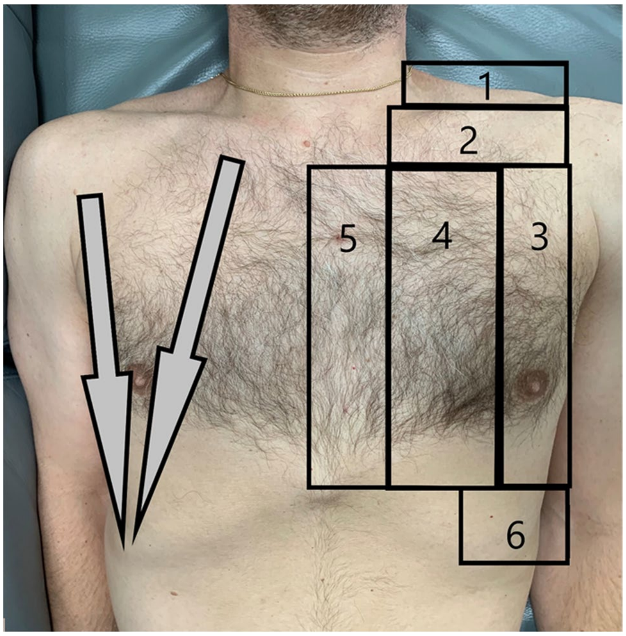

Fig. 2 Optimal POCUS scanning for detection of PTX. Left, POCUS scanning pattern for a sensitivity of 91.6% (20). Right, Zones of the lung by anatomic locations. Of note, zone 7 is considered posterior and not pictured here

however, they do not assess stomach contents for NPO status, which would be of particular interest to trauma anesthesiologists. Although trauma patients are typically treated as "full stomach," gastric POCUS is superior to clinical judgment in prediction of full stomach status in urgent preoperative situations [36]. POCUS can be used to assess stomach contents in patients who cannot respond to questions about dietary history (low GCS, intoxication) or patients with significant pain or anxiety, both of which are common situations in polytrauma care [37]. One observational study of 45 polytrauma patients who were scanned in supine and right lateral decubitus positions showed concordance between expected stomach volume and the volume suctioned in the right lateral decubitus (RLD) position. The authors noted no aspiration events occurred in these polytrauma patients, but they did not note if their assessments changed their anesthetic approach, which would be a medical decision-making goal of using this modality [38•].

The RLD position is not always feasible in trauma patients. While there seems to be some utility in evaluating gastric volume, there is no data to suggest improved outcomes. The plan will likely not change from a rapid sequence intubation even if there appears to be no residual contents in the gastric antrum. There has never been a quantification of the exact gastric volume that definitively leads to an aspiration event. However, there is some utility in making the gastric POCUS helpful in a binary manner — declaring the stomach "full" (greater than 1.5 ml/kg clear liquid or ANY solid matter) or "not full" [37]. This view of the antrum is relatively easy to ascertain, so a quick assessment may indeed be helpful and not add any time to the evaluation of the acutely injured patient [39, 40]. More studies will be needed to determine if this modality does indeed lead to improved outcomes in the trauma patient.

Airway POCUS

To date, the majority of POCUS airway studies have focused on confirming that the endotracheal tube (ETT) is in the trachea and to identify the cricothyroid membrane for a surgical airway. A recent meta-analysis confirmed there may be some utility in preoperative POCUS airway assessment to predict difficult airway for routine anesthetic care[41] and there is evidence that these airway scans, when used in combination with the classic clinical airway exams, can reasonably predict difficult airway management [42]. The prediction of difficult airway relies on measurement of airway anatomical structures, which presents a challenge in rapidly deteriorating trauma patients.

A recent study used ultrasound to predict the difficulty of intubation of 60 trauma patients. They utilized a rapid, non-invasive airway ultrasound exam and found that thickness of anterior neck tissue at the level of the hyoid bone and thyrohyoid membrane could reasonably predict a difficult airway [43•]. The most common mechanism of injury in this study was road traffic accidents (58.3%); however, they did exclude any patients with obvious head or neck trauma. In this case, the ultrasound exam was merely used to predict difficult airway and not identify any sub-clinical airway trauma. Of note, they did report that the ultrasound exam took less than 2 min, whereas the quickest time for a FAST exam is reported at approximately 60–80 s [44, 45].

There is preliminary data that traumatic pathologies (e.g., paratracheal hematoma and tracheal injury) can be identified by airway POCUS prior to intubation [46••, 47]. These injuries are rare in most trauma patients, but based on the mechanism of injury and index of suspicion, the benefits of performing an airway US may outweigh the risks of delaying the intubation [48]. The authors of this study did not comment on the time required to perform the examination other than mentioning it was performed during a 3-min preoxygenation phase. Furthermore, POCUS has been shown to be quicker and more effective than traditional auscultation and capnography for confirming tracheal intubation during emergent rapid sequence intubation following trauma [46••].

A benefit of the ultrasound imaging modality is that the glottis can be visualized in real time and the ETT placement can be confirmed more rapidly than the traditional 5-point auscultation or gold standard confirmation with end-tidal carbon dioxide. Additional US confirmation can be obtained confirming lung sliding in the left lobe (confirms ETT position appropriately above the carina), a clearly visible posterior wall of the esophagus, and absence of the classic "double tract" sign, which is indicative of esophageal intubation. In the era of the novel COVID-19 virus, quick, efficient airway management is paramount in an effort to ensure safety of medical providers.

In addition to being a valuable tool that might identify a difficult or injured airway, POCUS can be used to help identify anatomic landmarks necessary to perform a surgical airway. Cricothyrotomy has traditionally been performed by palpating the superficial anatomic structures in order to access the airway (Fig. 3). In situations of obesity, neck swelling, or trauma, identification may be complicated. A recent study showed that utilizing neck ultrasound helped identify the cricothyroid membrane (CTM) in obese patients more readily than the traditional palpation technique [49]. The authors recognized that the use of ultrasound did take longer than the landmark technique (23.5 s vs. 16.9 s, $p < 0.001$). These authors note that a cervical collar would complicate or preclude the use of ultrasound of any airway structures.

Finally, POCUS is now being utilized to assess penetrating vascular injuries of the neck [50]. As discussed above, POCUS is a valuable tool to assess the volume and integrity of the vasculature in trauma patients.

Pre-hospital POCUS

POCUS is starting to be utilized by paramedics and pre-hospital healthcare professionals. It has been shown that POCUS skills can be easily taught to our pre-hospital care colleagues. A systematic review of 12 studies with 187 paramedics showed that basic trauma sonography could be taught in 6 to 8 h [51]. Paramedics can be trained in a short amount of time to use POCUS to identify PTX [52] and confirmation of endotracheal intubation [53]. More than half of the trauma patients transported via helicopter experience hypotension, potentially suggesting hypovolemia, and could potentially benefit from an early estimate of hypovolemia/blood loss while still in transport [54]. It is clear that earlier assessment and diagnosis are a potential benefit; however, improved clinical outcome or survival has not been definitively shown.

Pre-hospital personnel training is not standardized nationally, and the ultrasonography training programs have also been varied and lack consistency across programs. Just as there is a continued need for anesthesiologists to become proficient in trauma ultrasound skills, there exists a need for pre-hospital personnel to continue to develop training curriculae and national training standards and create well-structured studies to evaluate outcomes where these skills are used [55].

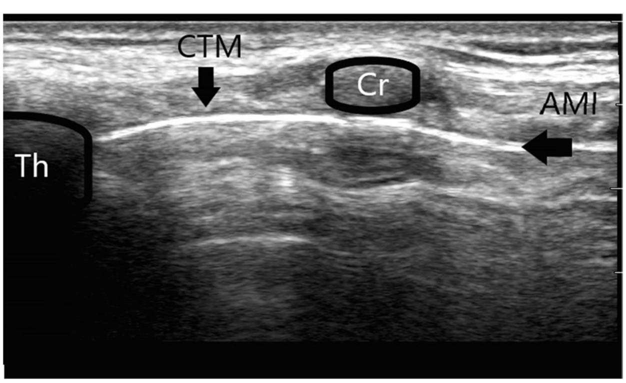

Fig. 3 Identification of the cricothyroid membrane (CTM). POCUS can be used to identify the CTM. In this ultrasound image, the CTM can be seen between the thyroid cartilage (Th) and the cricoid (Cr). The hyperechoic air-mucosal interface (AMI) is readily identifiable

Trans-ocular Sonography for Elevated ICP

Trans-ocular sonography has been used to identify the optic nerve sheath (ONS) and to investigate if the measurement of its diameter correlates with increased intracranial pressure (ICP) as cerebrospinal fluid readily moves between the subarachnoid space and the ONS. A measurement of ≥ 5 mm has correlated with ICP of 20 mmHg or higher [56]. Although there was initial evidence from a small observational study on trauma patients [57], no further studies have been published specifically on the use of ocular POCUS in trauma patients. Diameter of the optic nerve sheath has been correlated with elevated ICPs [58•].

This modality is not without its controversies like common artifact interfering with measurements and difficulty in training even experienced providers to identify ONS [59]. Inferior and transverse ocular scans yield the best images, and despite only moderate correlation with MRI measurements, the relative size can be used as a cursory examination [60]. Despite these challenges, protocols are being developed to standardize these examinations, [61] and this technique continues to be pursued in other areas of anesthesia care specifically obstetric anesthesiology [62, 63].

A quick assessment of the optic nerve sheath could expedite surgery much as a positive eFAST exam propels the same. Although this could be an efficient and useful tool for trauma anesthesiologists to procure, at the current time, no firm evidence of its efficacy exists. Given the current data, we recommend caution with medical decision-making utilizing this procedure.

POCUS Education and Training

Historically, there has been a lack of training in POCUS, which is a major barrier to implementation into the average anesthesiologist's practice. A recent study showed that anesthesia providers are very comfortable using ultrasound for vascular access and do it almost daily, whereas they rarely utilize this modality for intraoperative cardiothoracic assessment and management [64]. In 2021, the American Society of Regional Anesthesia and Pain Medicine assembled a group of experts to formulate recommendations regarding the education of POCUS. They identified barriers such as lack of equipment, standardized curricula, and sufficient faculty [65••]. Their recommendations outline the importance of the I-AIM framework, the minimal number of supervised scans that should be performed to indicate proficiency, and stress that these should be done on live patients and not simulators [65••, 66••]. Recently, the ASA has developed a five-part, online formal POCUS certification for physician anesthesiologists and trainees that will hopefully overcome the barriers identified above. It is our opinion that ultimately all residency programs will be required to incorporate POCUS training and milestones into their educational programs in order to train our future anesthesiologists in this rapidly expanding field.

Future

There are multiple potential indications to incorporate POCUS into our management of trauma patients. As we do so, it is critical that we consider how POCUS can also be taught and utilized in pre-hopsital care. With the introduction of the ASA's formal certification, more anesthesiologists will advance this modality to improve patient care, particularly for the trauma patient. High-quality research to identify the clinical efficacy of POCUS in the trauma population and how it will affect clinical outcomes is needed [67•].

One limitation to POCUS is that image quality depends on the skill and experience of the provider. With all the advancements in POCUS in the medical field, researchers are now exploring ways to incorporate deep-learning technology and artificial intelligence into the platforms of ultrasound analysis to improve its accuracy and diagnostic capability [68].

Conclusions

Although there is significant potential for POCUS to assist in the perioperative care of the critically ill patient, most of the studies to date have not focused specifically on trauma patients. Moving beyond the well-established FAST exam, anesthesiologists are beginning to explore how POCUS can have a positive impact on the care of patients who suffer trauma.

This is a unique subset of patients that requires specialized care that may not allow for a full POCUS exam for several reasons. Although most of the evidence to date suggests that POCUS exams can be taught readily and performed relatively expeditiously, time to immediate definitive care is critical in trauma patients. Furthermore, the extent of a trauma patient's injuries is not always immediately known and therefore, extensive caution is used to minimize the risk of exacerbating occult injuries. The positioning required for the ideal ultrasound exam simply may not be feasible.

Given that there is evidence that POCUS can assist in prehospital care, we strongly encourage the anesthesiology community to be stewards in the training and promotion of this modality.

Despite these limitations, it is evident that we need further research to elucidate the definitive benefits of using POCUS to improve the care of trauma patients. Although there is good evidence that POCUS results in superior imaging for some anatomical studies in acute care patients, this has not been definitively proven to improve outcomes in major trauma cases. We recommend anesthesiologists consider POCUS in their evaluation of the trauma patient, but as such, care must be taken to avoid being distracted by incidental findings that may have no impact on the patient's current traumatic condition. In such a high acuity clinical situation, extreme caution must be used to minimize any wasted time investigating a finding that is irrelevant in a potentially unstable patient. This highlights the need for sophisticated training and standardization of POCUS protocols to minimize delays in resuscitation [69]. Furthermore, skilled sonographers are required to interpret the ultrasound exam and assess the findings. As Kelly et al. (2020) point out in their commentary, one must consider patient-specific, disease-specific, and imaging-specific factors when interpreting the necessity and validity of a POCUS exam in such high acuity, often life-threatening clinical situations [70].

We believe that with the increasing availability of affordable, handheld ultrasounds, backed by the knowledge gained to date, POCUS has significant benefits that can benefit the care of the perioperative patient, and most likely, this includes those who suffer traumatic injuries. This is clearly substantiated by the introduction of the ASA's POCUS certification process. Furthermore, we urge our anesthesiology colleagues to continue to implement programs, educate our future providers, and perform POCUS research in efforts to improve care of the trauma patient.

Declarations

Conflict of Interest Eric R. Heinz and Anita Vincent have no conflict of interest to declare.

Human and Animal Rights and Informed Consent This article does not contain studies with human/animal subjects by either of the authors.

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