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Imaging the Critically Ill

Casey D Bryant
Assistant Professor
Department of Anesthesiology
Section on Critical Care
Critical Care Medicine Program
Director
Wake Forest University School
of Medicine
Winston-Salem, North Carolina

Bedside Point-of-Care Ultrasound Use in the Critically Ill

Historical Perspectives and a Path Forward

Critical Care Ultrasound is a rapidly evolving field with an ever-expanding footprint in ICUs. While much progress has been made, ongoing efforts need to continue towards demonstrating impact on patient-oriented outcome measures and on defining educational curricula and competency requirements.

Point-of-care ultrasound (POCUS) is the real-time acquisition, interpretation, and clinical application of findings by the bedside clinician. This obviously differs from imaging obtained through traditional pathways leading to many advantages and applications of POCUS in the imaging of critically ill patients. Portability, rapid deployment, and non-invasiveness are major advantages allowing clinicians to answer clinical questions at the bedside and avoiding unnecessary risks and resources of intrahospital transport in pursuit of other imaging modalities. Critically ill patients are known to be at risk for adverse events during intrahospital transport due to multiple reasons including communication breakdown, multiple complicated and bulky pieces of life-supporting equipment, and haemodynamic instability (Blakeman and Branson 2013; Fanara et al. 2010; Warren et al. 2004). In a recent meta-analysis by Murata et al. (2022), an intrahospital transport adverse event rate of 26.2% (95% CI: 15.0–39.2) was shown. While life threatening events related to intrahospital transport were overall low at 1.47% in this study, the cumulative risk of transport and resource allocation must be weighed carefully when making these decisions for critically ill patients.

Critical Care Ultrasound (CCUS) has a growing number of indications and applications. Ultrasound guidance is recognised as the standard of care for improving safety and decreasing procedural complications during bedside procedures such as central vascular access, thoracentesis, and paracentesis (Saugel et al. 2017; Silverberg and Kory 2013; Ultrasound Guidelines: Emergency, Point-of-Care and Clinical Ultrasound Guidelines in Medicine 2017; Dancel et al. 2018; Havelock et al. 2010; Mayo et al. 2009; Cho et al. 2019; Millington and Koenig 2018). While the current evidence base for other applications has limitations overall in regards to small study sizes, reproducibility, and lack of demonstrated effects on patient-centred outcomes, areas undergoing further study that are of particular interest for those who care for critically ill patients include assessment of cardiac function, volume status and fluid responsiveness, presence of venous congestion, and confirmation of appropriate positioning of life-supporting devices such as temporary left-ventricular assist devices (LVADs) (Jalil and Cavallazzi 2018; Boyd et al. 2016; Cecconi et al. 2014; Beaubien-Souligny et al. 2020; Balthazar et al. 2021). A recent comprehensive consensus document was published by the European Society of Intensive Care Medicine (ESICM) detailing what the committee believed to represent reasonable expectations for basic skills of the intensivist in CCUS. In total, 74 total statements were made with strong agreement obtained for 49 of the CCUS skill items. These statements encompassed the breadth of heart, brain, lung, abdomen, and vascular CCUS imaging (Robba et al. 2021).

Historically, POCUS use in evaluating the critically ill was born out of Emergency Medicine (EM). The first position paper supporting POCUS use was written in 1990 by the American College of Emergency Physicians (ACEP) (ACEP Council resolution on ultrasound 1990) which was followed by a second document by the Society of Academic Emergency Medicine (SAEM) in 1991 (SAEM - Ultrasound position statement). POCUS training and competency has since become part of the standard for EM physician residency training with the first guidelines published by ACEP in 2001, defining the seven core POCUS competencies of the EM physician (ACEP emergency ultrasound guidelines 2001). POCUS education is now a requirement by the American College of Graduate Medical Education (ACGME) as part of EM residency to include training and competency in POCUS "for the bedside diagnostic evaluation of emergency medical conditions and diagnoses, resuscitation of the acutely ill or injured patient, and procedural guidance" (ACGME Program Requirements for Graduate Medical Education in Emergency Medicine ACGME-approved focused revision: June 12, 2022; effective July 1, 2022). Emergency ultrasound guidelines from ACEP help direct this requirement with benchmark recommendations that residency trainees should perform 25-50 exams of a particular application and depending on the number of applications utilised, complete 150-300 total exams during their training that have all undergone quality assurance (QA) review by emergency ultrasound faculty (Ultrasound Guidelines: Emergency, Point-of-Care and Clinical Ultrasound Guidelines in Medicine 2017).

Now thirty plus years later, critical care is still defining and refining its own path to POCUS success. As evidence for the growing use and interest in CCUS over time, the Société´ de Réanimation de Langue Française (SRLF)/American

College of Chest Physicians (ACCP) first described the criteria for competence in critical care ultrasonography. This document primarily focused on the various different skills and knowledge necessary to develop competency in pleural, vascular, thoracic, and basic and advanced echocardiography, although no minimum training requirement recommendations were made (Mayo et al. 2009). This was followed by International Guidelines in 2011, where it was recommended that in order to obtain competence in general CCUS and basic critical care echocardiography (BCCE), training should include attendance of a 10 hour training course for each discipline that focused on didactics, cases, and image-based learning. There was no overall consensus gained on the minimum number of studies that needed to be performed to obtain competence, although it was recommended that 30 fully supervised transthoracic echocardiograms was sufficient to obtain competence in basic critical care echocardiography (International expert statement on training standards for critical care ultrasonography 2011). The Society of Critical Care Medicine (SCCM) later published robust guidelines in 2015 and 2016 that offered evidence-based support for POCUS use by appropriately trained intensive care unit (ICU) practitioners in the areas of general POCUS and echocardiography, respectively (Frankel et al. 2015; Levitov et al. 2016). In the SCCM guidelines, it was assumed that those utilising ultrasound in the ICU would be "suitably trained and competent in the technical and interpretative components of the relevant examination". The authors noted further that, "It is beyond the scope to these guidelines to describe in detail the elements of training and competency" (Frankel et al. 2015). Also in 2015, Eliot et al. published CCUS learning goals for anaesthesia CC trainees, in which it was recommended that learners perform ≥50 exams that are all reviewed with expert CCUS faculty (Fagley et al. 2015). In 2019, through a collaboration between the National Board of Echocardiography, Inc., (NBE) and nine other specialty societies, the Special Competence in Critical Care Echocardiography board certification was first offered to intensivists and other appropriately experienced clinicians. This board certification includes a requirement of 150 comprehensive echocardiograms in addition to passing a written board exam. This represented a major step towards setting a bar of excellence obtainable for intensivists, although it did not address the minimum training requirements to support competency for general CCUS and BCCE use in the ICU (Díaz-Gómez et al. 2017; Panebianco et al. 2021). This was later followed by Rajamani et al. in 2022, with the publication of a longitudinal competence pathway for basic critical care echocardiography (BCCE). Pathway highlights include attendance of an introductory course, the performance of at least 40 BCCE exams with ongoing QA review and feedback, and subsequent summative and cognitive assessments along the path to competency achievement. This document represents the most evidence-based and robust longitudinal description of a pathway to competence in an application of CCUS to date.

“ultrasound guidance is recognised as the standard of care for improving safety and decreasing procedural complications during bedside procedures”

In the United States, the ACGME sets the standard and core requirements for residency and fellowship training programmes. As noted previously, ACGME core EM residency requirements include gaining competency with POCUS in evaluation and diagnosis, resuscitation, and procedural guidance (ACGME Program Requirements for Graduate Medical Education in Emergency Medicine ACGME-approved focused revision: June 12, 2022; effective July 1, 2022). ACEP guidelines then provide specific recommendations to benchmark a path to basic competency (Ultrasound Guidelines: Emergency, Point-of-Care and Clinical Ultrasound Guidelines in Medicine 2017). For reference, the ACGME requirements for Critical Care fellowship training programmes in regard to CCUS are variable and are listed in **Table 1.**

The variability in recommendations likely exists as there is overall a paucity of evidence as to what constitutes POCUS competence in the critical care realm (Rajamani et al. 2020). Without prospectively validated longitudinal studies demonstrating a path to sustained basic competence, it is obviously challenging for national and international societies to make formal recommendations regarding a benchmark. Given the heterogeneity of ACGME programme requirements regarding POCUS education and the lack of a clear benchmark for basic CCUS competence, the amount and intensity of ultrasound training in fellowship has been highly variable. In one survey of Surgical Critical Care programme directors in the U.S. published in 2018, >75% of responding programmes believed that CCUS in training should be a priority although the educational curricula utilised was highly variable. Despite the strong support for CCUS training, less than a quarter of surveyed programmes required a benchmark number of studies to be performed (24.6%) or required fellows to save images (21.3%). 7.5% of programmes still provided no CCUS training at all, although this was an improvement from prior surveys (Carver 2018). A 2014 survey of ACGME-accredited surgical, medicine, anaesthesia, and pulmonary critical care programmes similarly demonstrated a large of amount of variability in CCUS training. Less than half of all programmes reported a specific curriculum, and this held across the surgical (31%), medicine (33%), anaesthesia (46%), and pulmonary (43%) subspecialties. Perhaps more concerning, only 38% of programmes performed image review, which is an essential component to feedback and improvement (Mosier et al. 2014). Wong et al. (2019) previously noted the relative paucity of formal training programmes and competencies in CCUS internationally, as well. It is worth noting that this heterogeneity and low percentage of programmes with formal curricula

Fellowship Programme	POCUS Education Requirement Verbiage
Critical Care Medicine	• "Fellows must demonstrate competence in procedural and technical skills, including use of ultrasound techniques to perform thoracentesis and place intravascular and intracavitary tubes and catheters" • Regarding use of ultrasound, "fellows must demonstrate knowledge of indications, contraindications, limitations, complications, techniques, and interpretation of results of those diagnostic and therapeutic procedures integral to the discipline, including the appropriate indication for and use of screening tests/procedures"(ACGME Program Requirements for Graduate Medical Education in Critical Care Medicine ACGME-approved Focused Revision: February 7, 2022; Effective July 1, 2022).
Pulmonary and Critical Care Medicine	• "Fellows must demonstrate competence in procedural and technical skills, including use of ultrasound techniques to perform thoracentesis and place intravascular and intracavitary tubes and catheters". • "Fellows must demonstrate knowledge of imaging techniques commonly employed in the evaluation of patients with pulmonary disease or critical illness, including the use of ultrasound" (ACGME Program Requirements for Graduate Medical Education in Pulmonary Disease and Critical Care Medicine ACGME-approved Focused Revision: February 7, 2022; effective July 1, 2022).
Surgical Critical Care	• "Fellows must have supervised training that will enable them to demonstrate competence in the following critical care skills: application of transoesophageal and transthoracic cardiac ultrasound"(ACGME Program Requirements for Graduate Medical Education in Surgical Critical Care ACGME-approved focused revision: June 12, 2022; effective July 1, 2022).
Anaesthesiology Critical Care Medicine	• "The ICU must have ultrasound equipment available to perform diagnostic assessment for procedures such as thoracentesis, paracentesis, vascular access (i.e., peripherally-inserted central catheters, central catheter placement, and arterial cannulation), and comprehensive ultrasound evaluation, including echocardiography and focused assessment with sonography examinations (i.e., Focused Assessment with Sonography for Trauma – FAST)." • Fellows must demonstrate knowledge of those areas appropriate for a subspecialist in anaesthesiology critical care medicine, including monitoring equipment for the care of critically-ill patients and basic concepts of bioengineering, to include the principles of ultrasound, Doppler, and other medical imaging techniques relevant to critical care medicine" (ACGME Program Requirements for Graduate Medical Education in Anesthesiology Critical Care Medicine ACGME-approved focused revision: June 13, 2020; effective July 1, 2020).
Neurocritical Care	• No requirements regarding ultrasound education (ACGME Program Requirements for Graduate Medical Education in Neurocritical Care ACGME-approved: September 26, 2021; effective September 26, 2021).

Table 1. ACGME Programme Requirements for Ultrasound Training in Critical Care Fellowship

continues to exist despite calls for a formal CCUS curriculum by Neri et al. all the way back in 2007. Common barriers reported in the survey studies include lack of faculty expertise, insufficient time, and not enough bedside scanning supervision (Carver 2018; Mosier et al. 2014). In summary, we now have a bar of excellence as set by the Special Competence in Critical Care Echocardiography board certification followed by a framework for obtaining BCCE competency but have highly variable curricular and educational offerings in fellowship training and do not have clear benchmarks on what constitutes overall basic competence for CCUS in its many applications. This has resulted in significant heterogeneity amongst educational offerings by ACGME accredited critical care fellowship programmes in the U.S.

While recognising the training, curricular, and evidentiary limitations mentioned above, it must be acknowledged that ultrasound is also already in use in ICUs throughout the world. As ongoing efforts are underway to better define the training requirements and path to competence, efforts must continue to increase the quality of current CCUS use in individual ICUs and hospital systems. While credentialing, privileging, and billing are outside of the focus and scope of this article, the core elements of a successful CCUS programme will be discussed. For starters, an ultrasound with appropriate transducer(s) that can perform the variety of CCUS skills is a necessity. As technology is constantly changing, the layout of the ultrasound equipment will continue to adapt and change as well. Traditional cart-based setups include separate probes for vascular and body imaging, while newer technologies are allowing for hand-held devices and for the functions of the various probes to be combined into a single probe (Baribeau et al. 2020; Lee and DeCara 2020). There are benefits and limitations to these different probe and machine configurations as related to cost, image quality, and portability. Consultation with a local ultrasound expert is recommended when deciding on the best setup to meet the needs of the individual ICU. Given increasing overall complexity of patient populations, expanding use of new technologies such as temporary mechanical cardiac support, and growing expectations of basic CCUS skills for intensivists along with the availability of Special Competence in Critical Care Echocardiography board certification, a machine capable of performing the full array of cardiac and Doppler assessments in addition to procedural-based and vascular imaging is becoming a necessary piece of equipment in the modern ICU (Safford et al. 2007; Robba et al. 2021; Díaz-Gómez et al. 2017; Bartos 2020; Balthazar et al. 2021). The machine should be digital imaging and communications in medicine (DICOM) capable so that images and clips can be transferred automatically to an image archiving system. Storing images and clips is imperative to ensure the best patient care, standardised documentation, clear communication amongst the care team, and QA (Flannigan and Adhikari 2017; Lewis et al. 2022). Each individual programme can decide how to store images, whether it be sending the studies directly to a system such as picture archiving and communication system (PACS), or to an intermediary archiving software repository that allows for separate delineation and storage of academic and diagnostic studies (Mani 2021). Archived images from studies should be reviewed for QA by the local ultrasound director or expert, with feedback provided and remediation performed when necessary. The overall framework for the process will have to be ultimately determined by the programme, but previous guidelines suggest QA review of all images be performed during the benchmarking or training process and at least 5-10% of ongoing studies performed by credentialed clinicians continue to undergo QA review (Ultrasound Guidelines: Emergency, Point-of-Care and Clinical Ultrasound Guidelines in Medicine 2017). Image review and overall administration of a successful programme can be very time consuming so protected time or similar arrangement for the director of the CCUS program similar to the model utilised successfully in EM should be considered (Compensated Time for Faculty Academic Administration and Teaching Involvement 2019). Depending on the size of the overall programme and volume of studies performed, it may become necessary to have more than one clinician with time protected to assist with this job duty.

In conclusion, CCUS is a rapidly evolving field with an ever-expanding footprint in ICUs. While much progress has been made, ongoing efforts need to continue towards demonstrating impact on patient-oriented outcome measures and on defining educational curricula and competency requirements. With ongoing use a reality in the modern ICU, a formal CCUS programme is essential to ensure best practices and QA.

Conflict of Interest

None. ■

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