Society of Critical Care Medicine Guidelines on Adult Critical Care Ultrasonography: Focused Update 2024

RATIONALE: Critical care ultrasonography (CCUS) is rapidly evolving with new evidence being published since the prior 2016 guideline.

OBJECTIVES: To identify and assess the best evidence regarding the clinical outcomes associated with five CCUS applications in adult patients since the publication of the previous guidelines.

PANEL DESIGN: An interprofessional, multidisciplinary, and diverse expert panel of 36 individuals including two patient/family representatives was assembled via an intentional approach. Conflict-of-interest policies were strictly followed in all phases of the guidelines, including task force selection and voting.

METHODS: Focused research questions based on Population, Intervention, Control, and Outcomes (PICO) for adult CCUS application were developed. Panelists applied the guidelines revision process described in the Standard Operating Procedures Manual to analyze supporting literature and to develop evidence-based recommendations as a focused update. The evidence was statistically summarized and assessed for quality using the Grading of Recommendations, Assessment, Development, and Evaluation approach. The evidence-to-decision framework was used to formulate recommendations as strong or conditional.

RESULTS: The Adult CCUS Focused Update Guidelines panel aimed to understand the current impact of CCUS on patient important outcomes as they related to five PICO questions in critically ill adults. A rigorous systematic review of evidence to date informed the panel's recommendations. In adult patients with septic shock, acute dyspnea/respiratory failure, or cardiogenic shock, we suggest using CCUS to guide management. Given evidence supporting an improvement in mortality, we suggest the use of CCUS for targeted volume management as opposed to usual care without CCUS. Last, there was insufficient data to determine if CCUS should be used over standard care without CCUS in the management of patients with cardiac arrest.

CONCLUSIONS: The guidelines panel achieved strong agreement regarding the recommendations for CCUS to improve patient outcomes. These recommendations are intended for consideration along with the patient's existing clinical status.

KEYWORDS: acute respiratory failure; cardiogenic shock; critical care ultrasonography; guidelines; point-of-care ultrasound; septic shock

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Critical care ultrasonography (CCUS) is point-of-care ultrasonography performed and interpreted by the treating clinician of critically ill patients, regardless of the hospital setting, to augment diagnosis, manage care, and guide invasive procedures (1). CCUS has continued to evolve since the release of the Society of Critical Care Medicine (SCCM) CCUS guidelines in 2015 and 2016 (2, 3). Despite the exponential growth and use in everyday practice, we are uncertain of its effect on patient-important outcomes. Hence,

we aimed to update the guidelines by developing evidence-based recommendations related to clinical outcomes in patients with cardiac arrest, septic shock, acute dyspnea or acute respiratory failure, volume management, and cardiogenic shock via a rigorous evaluation of the evidence to date by a diverse panel of experts (4, 5).

These recommendations are meant to guide clinicians; however, individual patient and practitioner characteristics must be factored into guideline implementation and cannot replace a clinician's judgment. In the application of these guidelines, we assume that practitioners performing CCUS have appropriate equipment, training, and competency, supporting the need to better standardize CCUS training and quality assurance.

METHODOLOGY

Committee Membership and Conflict of Interest

The SCCM created a guideline committee to update the 2016 version of the guideline on the appropriate use of CCUS in the evaluation of critically ill patients (2). SCCM appointed two co-chairs (J.L.D.-G., S.N.) and two vice co-chairs (E.A., M.J.L.) who then assembled a diverse, multispecialty, multiprofessional expert panel for the Adult CCUS guideline update (6). The total guideline committee included 29 expert panelists in CCUS, two patient/family representatives, and two methodologists from the Guidelines in Intensive Care Medicine, Development and Evaluation group (S.S., K.L.) for a total of 33 panel members. Intellectual and financial conflicts of interest of each committee member were reviewed and addressed according to the SCCM Standard Operating Procedures.

Guideline Scope and Population, Intervention, Control, and Outcomes Development

With input from the panel and methodologists, the leadership developed Population, Intervention, Control, and Outcomes (PICO) questions. As the role of CCUS in aiding diagnosis seemed well established, the panel decided to review the effect of CCUS vs. usual care without CCUS on patient-important outcomes. The PICOs were examined and approved by all panelists. This included the use of CCUS compared with usual care without CCUS in adults, in the domains of cardiopulmonary resuscitation (CPR) during cardiac arrest, evaluation and management of septic shock, acute dyspnea or respiratory failure, volume resuscitation, and cardiogenic shock (**Table 1**). A list of all possible outcomes was created and then voted upon. Committee members rated outcomes according to patient importance on a scale from 1 to 9 (ranging from not important to critical), and only outcomes with an average scale of 7 or more were examined. The outcomes were then shared with our two patient/family representatives for input.

Systematic Review

A professional medical librarian developed a peer-reviewed search strategy for the PICO questions. We searched MEDLINE, Embase and Wiley CENTRAL databases, the World Health Organization's International Clinical Trials Registry Platform and the U.S. National Institute of Health's clincialtrials.gov trial registries, and abstracts presented at the European Society of Intensive Care Medicine and Society of Critical Medicine conferences on November 3, 2022, and then updated the search on February 6, 2024. Of **Supplemental Digital Content 1-9** (http://links.lww.com/CCM/H630), Supplemental Digital Content 5 highlights the search strategy; we screened citations of all potentially eligible articles without language or publication date restrictions while reviewers independently screened titles and abstracts and in duplicate to identify eligible studies. Two pairs of reviewers then independently evaluated the full text for eligible studies, extracting pertinent data from all studies using a pre-designed data-abstraction form. Study authors were contacted for missing or unclear information and disagreements between reviewers were resolved by consensus.

All analyses were performed using RevMan software (Review Manager [RevMan] V 5.4, The Cochrane Collaboration, 2020), random-effects models. Pooled binary outcomes are presented as relative risks (RRs) (7) and 95% CI (8) while continuous outcomes are presented as mean differences (MDs) and 95% CIs. Risk of bias for individual randomized controlled trials (RCTs) was assessed using the Cochrane Collaboration risk of bias assessment tool (9).

Development of Consensus and Clinical Recommendations

Guideline methodologists (K.L, S.S) assessed the quality of evidence using the Grading of Recommendations,

TABLE 1.
Population, Intervention, Control (Comparison), and Outcomes Questions

Population	Intervention	Control (Comparison)	Outcomes
In adult patients in cardiac arrest, does performing CCUS during the arrest compared with usual care improve outcomes?			
Adults who are undergoing resuscitation during a cardiac arrest	CCUS	Usual care without CCUS	Supplemental digital content
In adults with septic shock, does incorporation of CCUS in their management improve clinical outcomes when compared with conventional clinical care without CCUS?			
Acutely ill adult patients with septic shock	CCUS	Usual care without CCUS	Supplemental digital content
In adults with acute dyspnea or respiratory failure, does an integrated CCUS evaluation aid diagnosis and guide management to improve clinical outcomes compared with conventional clinical care without CCUS?			
Acutely ill adult patients with acute dyspnea or respiratory failure	Integrated CCUS to characterize, diagnose, and guide management	Usual care without CCUS	Supplemental digital content
In acutely ill adult patients, does the use of an integrated CCUS evaluation for targeted volume management and diuresis alter patient important outcomes when compared with usual care without CCUS?			
Adult patients who are acutely ill	CCUS	Usual care without CCUS	Supplemental digital content
In adults with cardiogenic shock, does the use of an integrated CCUS improve patient outcomes when compared with usual care without the use of CCUS?			
Adult patients with cardiogenic shock	CCUS	Usual care without CCUS	Supplemental digital content

CCUS = critical care ultrasonography.

Assessment, Development, and Evaluation (GRADE) methodology and rated quality as high, moderate, low, or very low based on the following domains: risk of bias, inconsistency, indirectness, imprecision, publication bias, and other criteria. The subgroups used the GRADE Evidence-to-Decision framework to generate recommendations. The GRADEpro guideline development tool online software (https://gradepro.org/) was used to produce the evidence summary tables. For each PICO, the subgroups created either a Strong recommendation or a Conditional Recommendation, either for, or against, the intervention (**Table 2**). After finalizing preliminary recommendations, committee members received electronic links to indicate their agreement or disagreement (**Table 3**). SCCM requires 75% of eligible members to vote, and at least 80% consensus is required.

Recommendations

Recommendation 1. We suggest either using CCUS or usual care without CCUS to guide management of adult patients in cardiac arrest (Conditional Recommendation, For or Against; Very Low Quality of Evidence).

Evidence Summary. We identified 13 observational trials and one RCT that compared the use of CCUS to usual care without CCUS in adults in cardiac arrest (7, 10–22). One study focused on traumatic arrests, seven looked at predominantly atraumatic arrests, and the remainder did not specify or were mixed. Four studies exclusively examined pulseless electrical activity or asystole while the remainder did not specify or had a mix of all rhythms. Two studies used transesophageal echocardiography (TEE) (14) and transthoracic echocardiography (TTE), while the reminder did not specify or used TTE exclusively. See **Supplemental Digital Content 9** (http://links.lww.com/CCM/H630) for the evidence summaries of all PICOs.

CCUS has an uncertain effect on the proportion of patients that obtain return of spontaneous circulation (23) (RR, 1.21; 95% CI, 0.67–2.19; very low certainty). CCUS also has an uncertain effect on mortality at hospital discharge (7, 10, 17, 19, 20), proportion of patients with favorable neurologic outcomes, establishing diagnostic findings (11), adverse events, and duration of CPR pauses (all very low certainty). Five studies found that usual care was associated with a shorter duration of pulse checks (13, 15,

TABLE 2.
Grading of Recommendation Assessment, Development, and Evaluation Classification of Strengths of Recommendations and Their Implications

	Strong Recommendation "We Recommend…"	Conditional Recommendation "We Suggest…"
Implications for	Desirable effects of intervention clearly outweigh undesirable effects, or clearly do not	Benefits of the intervention are less certain, either because of low-quality evidence or because evidence suggests desirable and undesirable effects are closely balanced
Patients	Most individuals in this situation would want the recommended course of action, and only a small proportion would not	The majority of individuals in this situation may want the suggested course of action, but others may not based on the quality of evidence and/or the closely balanced effects
Clinicians	Most individuals should receive the recommended course of action. Adherence to this recommendation according to the guideline could be used as a quality criterion or performance indicator. Formal decision aids are not likely to be needed to help individuals make decisions consistent with their values and preferences	Different choices are likely to be appropriate for different patients, and therapy should be tailored to the individual patient's circumstances. Those circumstances may include the patient/family's values and preferences
Policymakers	The recommendation can be adapted as policy in most situations, including for use as performance indicators	Policymaking will require substantial debates and involvement of many stakeholders. Policies are also more likely to vary between regions. Performance indicators are reliant on deliberation and consensus about management options

TABLE 3.
Table of Recommendations

Recommendations	Recommendation Strength, Direction, and Quality of Evidence
1) We suggest either using CCUS or usual care without CCUS to guide management of adult patients in cardiac arrest	Conditional recommendation, for or against; very low quality of evidence
2) We suggest using CCUS in the management of adults with septic shock to improve clinical outcomes	Conditional recommendation, for; low quality of evidence
3) We suggest using CCUS to aid with diagnoses and to guide the management of adults with acute dyspnea or acute respiratory failure to improve clinical outcomes	Conditional recommendation, for; low quality of evidence
4) We suggest the use of CCUS for targeted volume management compared with usual care without CCUS in acutely ill adult patients to improve clinical outcomes	Conditional recommendation, for; low quality of evidence
5) We suggest the use of CCUS compared with usual care without CCUS in adults with cardiogenic shock to improve clinical outcomes	Conditional recommendation, for; very low quality of evidence

CCUS = critical care ultrasonography.

17, 20, 21), three found that CCUS was associated with a shorter duration of pulse checks (12, 16, 22) and two found no difference (14, 18). There were no subgroup analyses performed due to lack of primary data.

Evidence to Recommendation

Many a priori selected patient outcomes for CCUS use during cardiac arrest had no data available and those that were available had very low quality. The summary

of evidence was inconclusive, as training programs, access to ultrasound equipment, and equipment costs vary widely between institutions. These variables result in an unknown balance of cost and benefit effects. It is possible that specific subgroups or specific institutions might favor CCUS, while others might favor usual care. Consequently, the panel suggested that either the use of CCUS or usual care is appropriate during adult cardiac arrest.

Special Considerations

If performed by a proficient operator, given the low risk of TTE and known diagnostic accuracy, the use of CCUS may be used as the preferred method to guide resuscitation during cardiac arrest. Both TTE and TEE require training and agreement about diagnosis and protocolized intervention. CCUS during cardiac arrest would be an acceptable intervention for pulse checks, to diagnose the underlying etiology of arrest, and to assess adequacy of chest compression location. This application of CCUS should be accompanied by proper training, credentialing, and quality assurance processes. In response to increasing interest in TEE training, the National Board of Echocardiography has added a certification of TEE within Critical Care Echocardiography.

Recommendation 2. We suggest using CCUS in the management of adults with septic shock to improve clinical outcomes (Conditional Recommendation, For; Low Quality of Evidence).

Remark

Although we observed a small benefit of mortality in these patients, it is possible that CCUS may offer more benefit in some patients compared with others. These studies used different CCUS protocols at different points in the patients' resuscitation. For example, patients in the most favorable study had received around 3 L less crystalloid than patients in the least favorable study (24, 25). CCUS can rapidly inform on alternative diagnoses and guidance of fluid administration (26, 27). Although fluid administration remains a cornerstone of sepsis management, CCUS might offer less benefit in patients who are already hemodynamically optimized at the time of imaging (24). In septic patients where volume responsiveness is in question, there may be greater value in CCUS (see Recommendation 4).

Evidence Summary

We identified 11 RCTs enrolling 931 patients that compared various ultrasound protocols for hemodynamic assessment compared with usual care (24, 25, 28–36). Compared with usual care, CCUS may reduce mortality at 1 month (RR, 0.86; 95% CI, 0.72–1.03; low certainty) and would probably result in a slight reduction in the volume of fluids received in the first 24 hours (MD, –0.7 L; 95% CI, –1.09 to –0.3; moderate certainty). The absolute risk ratio for mortality is five fewer deaths per 100 (95% CI, 10 fewer to 1 more). Overall, there may be no significant difference in receipt of renal replacement therapy (RR, 0.89; 95% CI, 0.67–1.18; low certainty), or ICU length of stay (LOS) (MD, 0.57 d; 95% CI, –0.21 to 1.34; low certainty). Similarly, CCUS had an uncertain effect on duration of invasive mechanical ventilation, duration of vasopressors and inotropes, and hospital LOS (all very low certainty).

Evidence to Recommendation

Despite the variation in clinical practices, our analysis suggests that CCUS confers a small mortality benefit in septic patients. We, therefore, recommend CCUS for initial and ongoing assessment and management of sepsis and septic shock in institutions that have access to ultrasound machines where users are appropriately trained and evaluated for competency.

Special Considerations

CCUS-guided management of volume responsiveness is relatively well established, both in sepsis and in other states. Less clear is the role in CCUS for guiding vasopressors and inotropes, although CCUS may offer value in patients without a definitive diagnosis or concomitant septic cardiomyopathy. At present, there is no consensus on thresholds for initiating or titrating inotropes, vasopressors, or other adjunctive therapies in sepsis based on echocardiographic or ultrasound findings.

Recommendation 3. We suggest using CCUS to aid with diagnoses and to guide the management of adults with acute dyspnea or acute respiratory failure to improve clinical outcomes (Conditional Recommendation, For; Low Quality of Evidence).

Evidence Summary

We found 18 trials with a total of 3673 enrolled patients that compared various CCUS protocols to usual care (37–54). CCUS may reduce the time to a correct diagnosis (MD, –1.23 hr; 95% CI, –1.62 to –0.85 hr; low certainty), time to correct treatment (MD, –20.67 hr; 95% CI, –27.18 to –14.15 hr; low certainty), duration of mechanical ventilation (MD, –3.26 d; 95% CI, –4.68 to –1.84 hr; low certainty), and it may slightly increase the proportion of patients with a correct final diagnosis after initial assessment (RR, 1.14; 95% CI, 0.99–1.31; low certainty). CCUS may result in no difference in hospital LOS (MD, –0.77 d; 95% CI, –1.61 to 0.07; low certainty) or the proportion of people that receive noninvasive ventilation (RR, 1.12; 95% CI, 0.74–1.69; low certainty). CCUS has an uncertain effect on 30-day mortality, ICU LOS, and the proportion of patients that require additional tests (all very low certainty). Furthermore, CCUS may have no effect on adverse events (RR, 0.63; 95% CI, 0.23–1.77; low certainty) and had an uncertain effect on cost (very low certainty).

Evidence to Recommendation

The reduction in duration of mechanical ventilation, reduced time to reach correct diagnosis and treatment, and the absence of increased adverse outcomes supported our suggestion to use CCUS in these patients, albeit with low certainty. CCUS may be more valuable in settings with limited access to radiographs or CTs, such as during the COVID-19 pandemic or in resource-limited settings, although further study is needed to evaluate the potential benefit in resource-limited settings (55, 56). In addition to diagnosis, CCUS can guide management of patients with respiratory failure, both with diuresis and with ventilator management (50, 52). This must be weighed against the feasibility of purchasing ultrasound machines and the time and financial burden of training ultrasound providers.

Special Considerations

At present, there is insufficient evidence to recommend using a particular CCUS protocol in these patients, as several widely different protocols demonstrated that CCUS was associated with a shorter duration of mechanical ventilation. For example, Salem et al (52) used lung ultrasound to titrate positive end-expiratory pressure compared with the Acute Respiratory Distress Syndrome Network standard protocol and demonstrated improved mortality and reduced duration of mechanical ventilation. Xia et al (54) assessed lung and diaphragm to gauge appropriateness for liberation from mechanical ventilation, while Pradhan et al (49) used CCUS to monitor patients for ventilator associated pneumonia.

Recommendation 4. We suggest the use of CCUS for targeted volume management compared with usual care without CCUS in acutely ill adult patients to improve clinical outcomes (Conditional Recommendation, For; Low Quality of Evidence).

Evidence Summary

Eighteen RCTs were found, enrolling 1765 patients comparing CCUS and usual care without CCUS for volume management (24, 25, 28–33, 35, 36, 57–64). Most studies used thoracic (cardiac, lung) and/or abdominal ultrasound and focused on dynamic assessments. These studies suggest that CCUS may reduce mortality when compared with usual care (RR, 0.80; 95% CI, 0.68–0.94; low certainty) and may reduce fluid balance at up to 72 hours after admission (MD, 0.72 L; 95% CI, 1.5 L lower to 0.06 L higher; low certainty). Other outcomes such as duration of mechanical ventilation, ICU LOS, need for renal replacement therapy, need for vasopressors, and acute kidney injury were inconclusive with very low certainty. Subgroup analyses found improved mortality with CCUS use in ICU patients compared with emergency department patients and improved fluid balance in patients with sepsis or those with a medical cause for their admission.

Evidence to Recommendation

CCUS for targeted volume management may offer desirable effects with an observed decrease in mortality. This evidence may have been limited by indirectness, given the varied designs and use of ultrasound by the individual studies, and imprecision. Although our systematic review found that CCUS may reduce fluid balance, this finding should be interpreted contextually. With the publication of the CLASSIC and CLOVERS trials (65, 66), it is evident that an isolated measure of fluid balance is not sufficient to make overarching

conclusions. Some patients may benefit from more fluids and some from less (67, 68). Our recommendation is informed by a combination of these findings, the indirect evidence that a personalized approach to fluid management may be beneficial, and the overall lack of data regarding the undesirable effects of using CCUS by an experienced provider.

Special Considerations

CCUS is only one component of a multifaceted approach to determination of volume status. Much like clinical decision-making, CCUS is also prone to error, particularly in unskilled hands. The evidence shows that a variety of CCUS modalities can help target volume management; ultimately, the provider will need to make their decisions based upon their history, clinical examination, and the information CCUS provides with an understanding of its limitations.

Recommendation 5. We suggest the use of CCUS compared with usual care without CCUS in adults with cardiogenic shock to improve clinical outcomes (Conditional recommendation, For; Very Low Quality of Evidence).

Remark

Usual care in cardiogenic shock patients often involves the use of a pulmonary artery catheter (PAC). Although PAC and CCUS require proficiency in their utilization, CCUS provides comparable information to a PAC, which is portable, and has a better safety profile. However, some patients may benefit from both a PAC and CCUS for management, particularly for volume management and titration of inotropic support (D/E cardiogenic shock defined as patients in a critically deteriorating state with cardiogenic shock by the Society for Cardiovascular Angiography & Intervention, post-cardiotomy shock, and those requiring mechanical circulatory support [MCS]) (69).

Evidence Summary

The panel analyzed five studies with different designs and use of ultrasonography; the results could not be pooled due to lack of data and significant clinical heterogeneity (57, 70–74). Overall, CCUS was found to have an uncertain effect on mortality, time to resolution of hemodynamic instability, ICU LOS, hospital LOS, duration of mechanical ventilation, duration of renal replacement therapy, and rate of inotrope administration (all very low certainty). One RCT found no difference in mortality between TEE-guided management and usual care (74). Conversely, CCUS was found to have improved mortality in an observational study (73). Importantly, these studies had methodological limitations, including the absence of precision and stratification related to the assessment of patient ventricular systolic function or shock etiology classification (indirectness) (71, 74).

Evidence of Recommendation

Despite the lack of evidence showing a clear benefit of CCUS use for patients with cardiogenic shock, the panel made a conditional recommendation for its use due to the minimal adverse events with the use of CCUS and the undesirable effects of its alternatives (i.e., PAC). Furthermore, despite the lack of cost-effectiveness studies on this topic, literature shows that not using PACs routinely is cost-effective (75). There is a lack of robust data regarding harm with the use of CCUS and with respect to TEE; our systematic review was not able to find data on adverse events in our specific patient population. PACs can be associated with adverse events and data misinterpretation (23, 76, 77). Although CCUS is also susceptible to adverse advents and data misinterpretation, indirect evidence shows that overall TEE complication rates are low (78–82). Despite the superior safety of CCUS, observational studies show PACs can be beneficial for cardiogenic shock patients receiving MCS or following heart transplantation (83–85). Importantly, we suggest the use of CCUS compared with not using CCUS. However, many cardiogenic shock patients may likely benefit from both CCUS and PAC.

Special Considerations

CCUS is often used to diagnose cardiogenic shock and is part of the standard of care in the management of these patients. Yet, there is minimal evidence supporting its use. Future studies comparing CCUS to PACs for the management of cardiogenic shock patients will be useful.

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Research Agenda for Critical Care Ultrasonography (CCUS) and Patient-Important Outcomes: 1) Improving diagnostic accuracy in current CCUS applications via machine-based learning and developing interventions/protocols to address patient important outcomes; 2) Randomized trials comparing management of cardiogenic shock using CCUS and pulmonary artery catheter by appropriately trained practitioners; 3) The role of CCUS in safer weaning of mechanical circulatory support; 4) The role of CCUS in predicting outcomes in patients with intermediate and high-risk pulmonary embolism; 5) Randomized controlled trials in septic shock patients using protocoled CCUS care for accurate diagnosis of fluid status and management, including determination of appropriate thresholds for interventions; 6) Specific role of CCUS for acute respiratory distress syndrome diagnosis/recognition and management (including positive end-expiratory pressure titration and prone positioning initiation); 7) The role of CCUS in resourced-limited settings; 8) The role of CCUS in guiding vasoactive medications in cardiogenic shock; 9) The use of artificial intelligence to improve image acquisition, accuracy and reproducibility of CCUS between users to improve clinical outcomes; 10) Cost-effectiveness of CCUS-driven management of patients with acute respiratory insufficiency, sepsis, and septic shock; and 11) Patient/family views and involvement regarding the use of CCUS in critical illness, particularly in determining patient-important outcomes.

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