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RESEARCH ARTICLE

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# Critical care ultrasound: A national survey across specialties

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## Abstract

**Purpose:** Management of the critically ill patient requires rapid assessment and differentiation. Point-of-care ultrasound (POCUS) improves diagnostic accuracy and guides resuscitation. This study sought to describe the use of critical care related POCUS amongst different specialties.

**Methods:** This study was conducted as an online 18-question survey. Survey questions queried respondent demographics, preferences for POCUS use, and barriers to implementation.

**Results:** 2735 recipients received and viewed the survey with 416 (15.2%) responses. The majority of respondents were pulmonary and critical care medicine (62.5%) and emergency medicine (19.9%) providers. Respondents obtained training through educational courses (26.5%), fellowship (23.9%), residency (21.6%), or self-guided learning (17.2%). POCUS use was common for diagnostic and procedural guidance. Emergency medicine providers were more likely to utilize POCUS to evaluate undifferentiated hypotension (98.5%, $P < .001$), volume status and fluid responsiveness (88.2%, $P = .005$), and cardiopulmonary arrest (94.1%, $P < .001$) compared to other specialties. Limited training, competency, or credentialing were the most common barriers, in up to 39.4% of respondents.

**Conclusion:** Study respondents utilize POCUS in a variety of clinical applications. However, a disparity in utilization still exists among clinicians who care for critically ill patients. Overcoming barriers, such as a lack of formalized training, competency, or credentialing, may lead to increased utilization.

**KEYWORDS**
critical care, education, emergency medicine, ultrasound

## 1 | INTRODUCTION

Management of the critically ill requires efficient evaluation and differentiation to identify possible diagnoses, guide resuscitation, and improve outcomes.[1,2] Point-of-care ultrasound (POCUS) is a noninvasive tool used to answer specific clinical questions in real time. POCUS has been shown to improve diagnostic accuracy, decision-making, and physician confidence.[3–7] The usefulness of POCUS in the evaluation of undifferentiated hypotension and shock, cardiopulmonary arrest, dyspnea, resuscitation and procedural guidance is well described in the literature.[8–12] Moreover, POCUS training and competency guidelines have developed across specialties.[13–17]

In 2001, the American College of Emergency Physicians (ACEP) described POCUS as "a skill integral to the practice of emergency medicine," and published the first *Emergency Ultrasound Guidelines* defining the scope of practice.[18] These guidelines, updated in 2008 and 2016, recommend POCUS use in the management of the critically ill, including differentiation, physiologic monitoring, and procedural guidance.[13] Similarly, critical care organizations have developed recommendations regarding POCUS training and practice. The American College of Chest

  

Physicians (ACCP) with *the Société de Réanimation de Langue Française* (2009), and the Society of Critical Care Medicine (SCCM) (2013, 2015, and 2016) have each published guidelines detailing the evidence-based recommendations for critical care related POCUS applications, and physician training guidelines.[14–17]

However, barriers to critical care POCUS training and practice still exist. In 2010, Eisen et al. electronically surveyed critical care training programs regarding POCUS education. Ninety-two percent of responding programs felt POCUS education was important and 80% recommended incorporating training into their curriculum; however, few programs offered specific POCUS training curricula (such as lung and pleural [74%], cardiac [55%], vascular diagnostic [33%], and abdominal [37%]) due to the limited experience amongst faculty (41%).[19] In 2014, Mosier et al. again surveyed critical care training programs and found a similar lack of formal POCUS curricula (42%) or trained faculty (<33%) with most programs relying on informal bedside teaching (77%).[20]

Despite its potential benefits, it is unclear to what extent POCUS is currently incorporated into the management of the critically ill across specialties. A better understanding of current physician practices, preferences, and barriers to implementation will help guide the development of training curriculum and further establish POCUS amongst specialties. This study sought to describe the use of critical care related POCUS amongst physicians of different specialties.

## 2 | MATERIALS AND METHODS

The study protocol was reviewed and approved by the University of Colorado Multiple Institutional Review Board.

### 2.1 | Study design

This cross-sectional study was conducted as an online survey, which was mailed electronically to providers across specialties from May 2015 to June 2015. Survey questions were developed with regard to existing national guidelines and literature. Pilot testing was conducted amongst emergency medicine and critical care medicine providers and feedback and suggestions were incorporated into the final survey instrument to improve question clarity, reliability, relevance, and validity.

The survey instrument was divided into sections (Appendix). Section one included respondent demographics, such as level of training, specialty, institutional affiliation type (eg, academic, community practice), and prior POCUS training and experience. Section two described respondent annual frequency of use (none, 1–10 examinations, 11–25 examinations, 26–50 examinations, >50 examinations) for select diagnostic POCUS applications (abdominal, cardiac, pleural/pulmonary, and vascular [ie, deep venous thrombus identification]), and preferences for POCUS guidance (primary method, secondary for "rescue" method, or never) in specific procedures (central line placement by anatomic location, paracentesis, thoracentesis, pericardiocentesis). Lastly, respondents were asked to describe frequency of POCUS use (never, rarely, sometimes, often, always) in specific clinical scenarios (undifferentiated hypotension, volume status and fluid responsiveness, cardiopulmonary arrest, and undifferentiated dyspnea). Dependent on the frequency of use in each clinical scenario, respondents were then asked to describe either their preferred POCUS method(s) (if they used POCUS "sometimes," "often," or "always"), or potential barrier(s) to use (if they responded "never" or "rarely"). Response to each individual question was optional and not required to complete the survey.

The 18-question survey was distributed electronically via the electronic mailing lists of the ACEP Critical Care Medicine section and the American Thoracic Society-Critical Care Assembly on two separate occasions. The selected professional societies reflect a broad group of practitioners across multiple specialties. Study data were collected and managed using the REDCap (Research Electronic Data Capture) tool (Vanderbilt University, Nashville, TN).[21]

### 2.2 | Data analysis

Unopened and blank survey responses were removed prior to analysis. Specialties with a limited number of respondents (eg, anesthesiology and anesthesia critical care) were grouped, where appropriate. "Other" responses, which could not be logically placed within the existing specialty groups, were added into a "other critical care" group for analysis. The remaining responses which could not be grouped as intended were removed prior to analysis. Partially completed surveys were analyzed, where appropriate, which resulted in different response totals for each question.

For each POCUS application, average annual use was compared across specialties as percentages for each response option (none, 1–10 examinations, 11–25 examinations, 26–50 examinations, >50 examinations). For preferences in procedural guidance, respondents were also compared as percentages across specialties for each response option (primary method, secondary or "rescue" method, or never).

In evaluating POCUS preferences and barriers for specific clinical scenarios, Likert-scale responses were dichotomized. Respondents who reported using POCUS "sometimes," "often," or "always" were collapsed as one group for preference analysis. Similarly, "rarely" or "never" respondents were collapsed together for analysis of barriers. Results are reported as totals and percentages, where appropriate.

POCUS preferences for each clinical presentation were compared by application and specialty. Total frequencies for each application were compared by specialty for statistical significance within each clinical scenario using chi-square tests. A $P < .05$ was considered statistically significant. Data were processed and analyzed using SPSS® (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY).

## 3 | RESULTS

The survey was distributed electronically to 5712 providers using the ACEP-Critical Care Medicine Section ($n = 782$) and the American Thoracic Society-Critical Care Assembly ($n = 4930$) electronic mail lists. Of those invitations, 2735 (55%) were viewed. A total of 416 (15.2%) anonymous responses were received. Seventy-five (18%) blank responses were removed prior to analysis.

**TABLE 1** Survey respondent demographic characteristics across specialties

| | | Specialties | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Anesthesia/ anesthesia critical care | Cardiac critical care | Emergency medicine | Internal medicine | Pulmonary and critical care medicine | "Other" critical care[a] | Total |
| What is your level of experience? | Faculty | 7 (87.5) | 6 (66.7) | 34 (50.0) | 7 (25.9) | 165 (77.5) | 12 (75.0) | 231 (67.7) |
| | Fellow | 1 (12.5) | 2 (22.2) | 9 (13.2) | 6 (22.2) | 46 (21.6) | 4 (25.0) | 68 (19.9) |
| | Resident | 0 | 1 (11.1) | 25 (36.8) | 14 (51.8) | 2 (0.9) | 0 | 42 (12.3) |
| | *Total* | 8 | 9 | 68 | 27 | 213 | 16 | 341 |
| What is your primary institutional affiliation? | Academic or University setting | 5 (62.5) | 7 (77.8) | 50 (73.5) | 15 (55.6) | 143 (67.5) | 12 (70.6) | 232 (68.0) |
| | Community setting, non-teaching | 1 (12.5) | 1 (11.1) | 2 (2.9) | 2 (7.4) | 26 (12.3) | 1 (5.9) | 33 (9.7) |
| | Community setting, teaching | 2 (25.0) | 1 (11.1) | 16 (23.5) | 10 (37.0) | 43 (20.3) | 4 (23.5) | 76 (22.3) |
| | *Total* | 8 | 9 | 68 | 27 | 212 | 17 | 341 |
| How did you primarily obtain training in point-of-care ultrasound? | Critical Care Fellowship | 2 (25.0) | 2 (22.2) | 7 (10.3) | 8 (29.6) | 58 (27.1) | 5 (29.4) | 82 (23.9) |
| | Not trained in the use of point-of-care ultrasound | 0 | 0 | 0 | 2 (7.4) | 23 (10.75) | 1 (5.9) | 26 (7.6) |
| | Post-training institutional credentialing program | 0 | 0 | 1 (1.5) | 0 | 4 (1.9) | 1 (5.9) | 6 (1.7) |
| | Residency training | 1 (12.5) | 3 (33.3) | 50 (73.5) | 8 (29.6) | 8 (3.7) | 4 (23.5) | 74 (21.6) |
| | Self-guided learning | 3 (37.5) | 2 (22.2) | 1 (1.5) | 6 (22.2) | 45 (21.0) | 2 (11.8) | 59 (17.2) |
| | Ultrasound Fellowship | 0 | 1 (11.1) | 3 (4.4) | 0 | 0 | 1 (5.9) | 5 (1.5) |
| | Ultrasound training course | 2 (25.0) | 1 (11.1) | 6 (8.8) | 3 (11.1) | 76 (35.5) | 3 (17.6) | 91 (26.5) |
| | *Total* | 8 | 9 | 68 | 27 | 214 | 17 | 343 |

[a]Includes surgical critical care, internal medicine critical care, "other" critical care, pediatric critical care, and emergency medicine critical care. Percentages are represented in parenthesis.

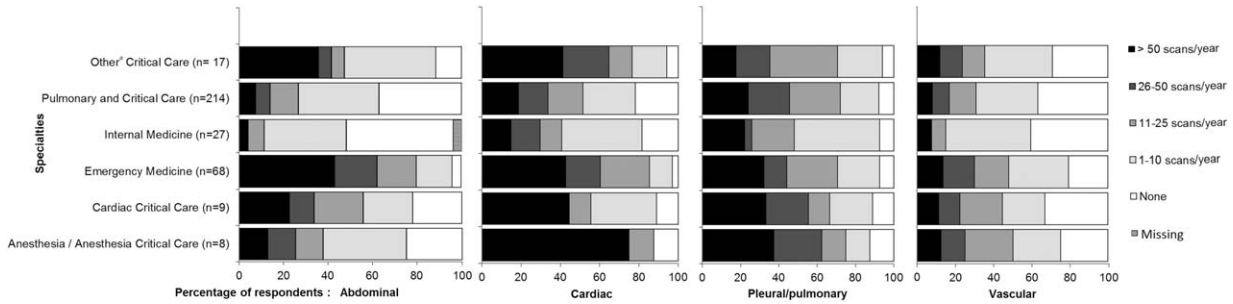


**FIGURE 1** Frequencies of POCUS applications used by survey respondents across specialties

Respondent demographics, including level of experience, institutional affiliation, and POCUS training, across specialties are presented in Table 1. The majority of respondents were pulmonary and critical care medicine (213/341, 62.5%) and emergency medicine (68/341, 19.9%) providers. Respondents were most commonly faculty members (231/341, 67.7%), and worked in an academic or university setting (232/341, 68.0%). Emergency medicine providers were more likely to have obtained POCUS training during residency (50/68, 73.5%, $P =< .001$) as compared to other specialties (24/275, 8.7%). The remaining specialties most commonly obtained POCUS training through a POCUS educational course (91/343, 26.5%), critical care fellowship (82/343, 23.9%), or self-guided learning (59/343, 17.2%).

The average number of annual POCUS examinations (none, 1–10 examinations, 11–25 examinations, 26–50 examinations, >50 examinations) for each diagnostic application (abdominal, cardiac, pleural/pulmonary, and vascular) and preferences for procedural guidance (primary method, secondary or "rescue" method, or never) are demonstrated as percentages by specialty in Figures 1 and 2. Overall, POCUS use was more common (all but "none" respondents) for cardiac (83.5%) and pleural/pulmonary applications (92.4%) than abdominal (70.4%) and vascular (66.7%) applications. Frequencies of respondents across specialties who preferred POCUS procedural guidance were for central vascular access (femoral 211/342 [61.7%], internal jugular 299/343 [87.2%], subclavian 79/341 [23.2%]), paracentesis (277/341 [81.2%]), pericardiocentesis (185/317 [58.4%]), and thoracentesis (312/343 [91.0%]).

Figure 3 shows POCUS application preferences for specific clinical presentations as frequencies across specialties. Frequency of POCUS use for undifferentiated hypotension was "sometimes" (76/343 [22.2%]), "often" (100/343 [29.2%]), and "always" (101/343 [29.4%]). Of respondents who used POCUS to evaluate undifferentiated hypotension (277/343, 80.8%), frequencies of use across specialties were: anesthesia/anesthesia critical care (7/8 [87.5%]), cardiac critical care

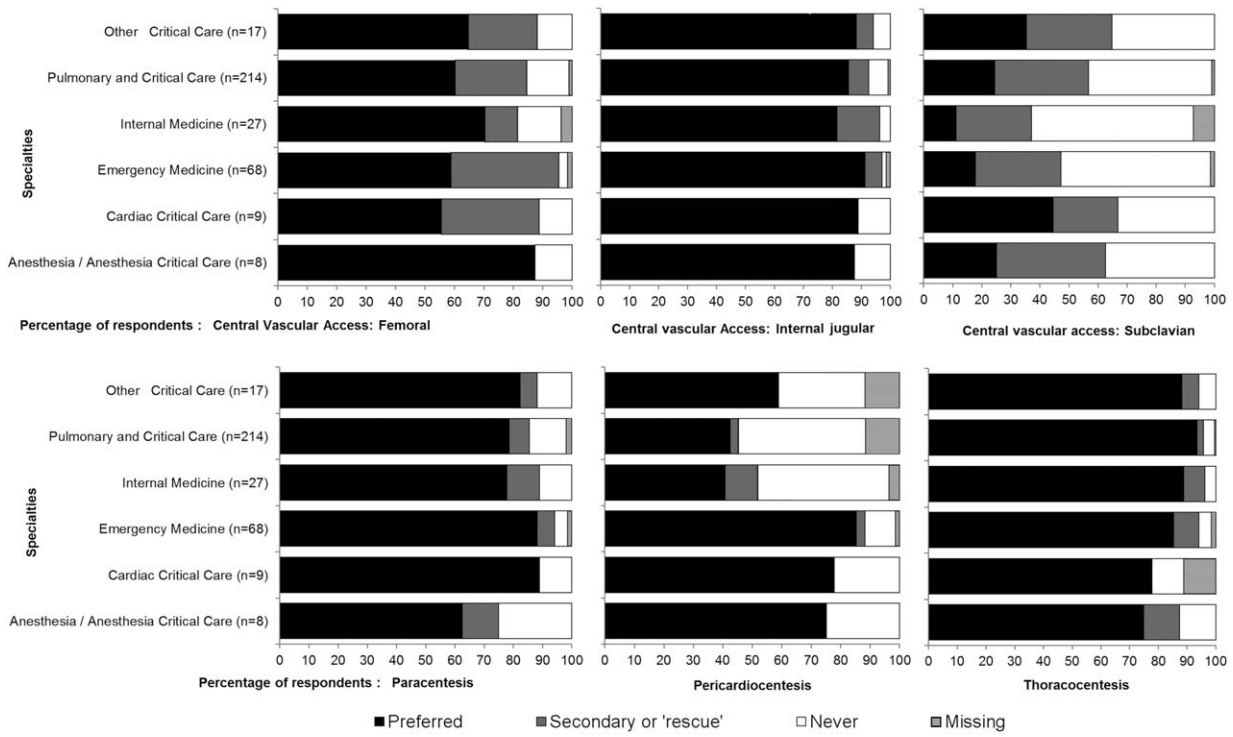


**FIGURE 2** Frequencies of POCUS procedural applications used by survey respondents across specialties

(6/9 [66.7%]), emergency medicine (67/68 [98.5%]), internal medicine (21/27 [77.8%]), pulmonary and critical care medicine (163/214 [76.1%]), and "other" critical care (13/17 [76.0%]). Within the group of respondents who utilize POCUS to evaluate undifferentiated hypotension, a focused cardiac evaluation (eg, evaluation of cardiac structure and contractility, pericardial effusion and cardiac tamponade, right ventricle strain, etc, was more common (94.6%, $P = < .001$) than each of the other applications, apart from central venous vasculature evaluation such as evaluation of inferior vena cava or internal jugular diameter (91.7%, $P = .179$). Emergency medicine providers were more likely to use POCUS to evaluate undifferentiated hypotension (67/68, 98.5%) as compared to all other specialties combined (210/275, 76.4%) ($P < .001$).

Frequencies of POCUS use to evaluate volume status and fluid responsiveness were: "sometimes" (91/343 [26.5%]), "often" (112/343 [32.6%]), and "always" (55/343 [16.0%]). Of respondents who used POCUS to evaluate volume status and fluid responsiveness (258/343, 75.2%), frequencies of use across specialties were: anesthesia/anesthesia critical care (7/8, [87.5%]), cardiac critical care 7/9 (77.8%), emergency medicine 60/68 (88.2%), internal medicine 20/27 (74.1%), pulmonary and critical care medicine 151/214 (70.1%), and "other" critical care 13/17 (76.5%). Within the group of respondents who utilize POCUS to evaluate volume status and fluid responsiveness, the most commonly selected POCUS application was central venous dynamic analysis (eg, inferior vena cava or internal jugular respirophasic variation) in both spontaneously breathing (203/258, 78.7%, $P < .001$) and

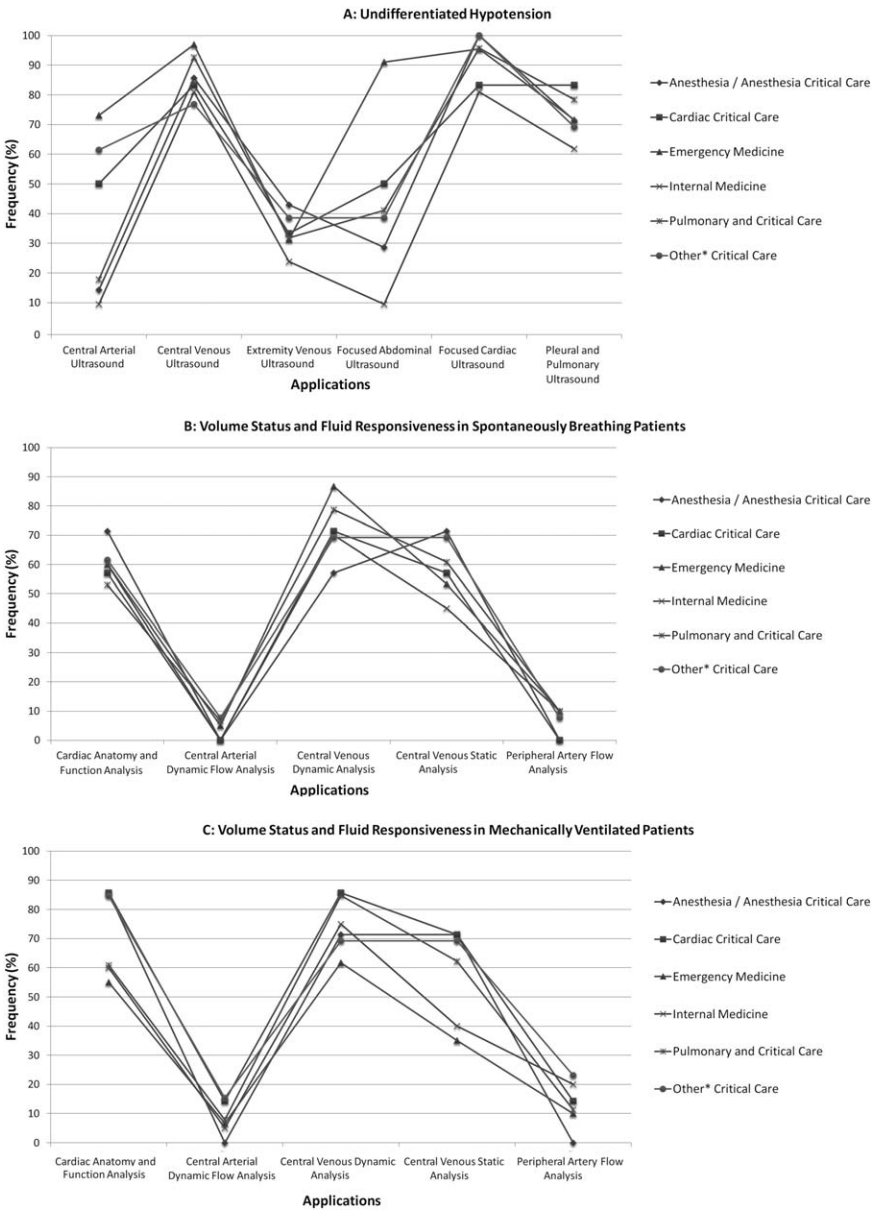


**FIGURE 3** Preferences of survey respondents for specific POCUS clinical presentations across specialties: A, Undifferentiated hypotension. B, Volume status and fluid responsiveness in spontaneously breathing patients. C, Volume status and fluid responsiveness in mechanically ventilated patients. D, Cardiopulmonary arrest. E, Undifferentiated dyspnea

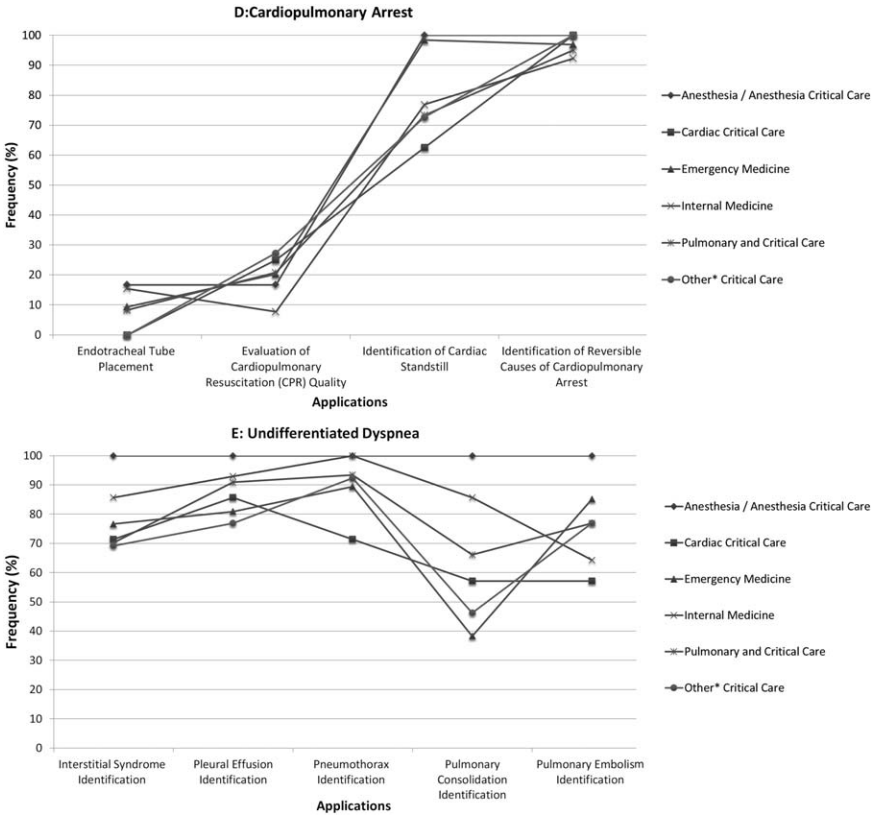


**FIGURE 3** Continued

mechanically ventilated patients (200/258, 77.5%, $P < .001$). Emergency medicine providers were more likely to use POCUS to evaluate volume status and fluid responsiveness (60/68, 88.2%), as compared to all other specialties combined (198/275, 72%) ($P = 0.005$).

Frequencies of POCUS use for evaluating cardiopulmonary arrest were "sometimes" (77/343 [22.4%]), "often" 72/343 (21.0%), and "always" 73/343 (21.2%). Of the 222 respondents who used POCUS to evaluate cardiopulmonary arrest, frequencies of use across specialties were: anesthesia/anesthesia critical care (6/8 [75%]), cardiac critical care 8/9 (88.9%), emergency medicine 64/68 (94.1%), internal medicine 13/27 (48.1%), pulmonary and critical care medicine 120/214 (56.1%), and "other" critical care 11/17 (64.7%). Within the group of respondents who utilize POCUS to evaluate cardiopulmonary arrest, the most common POCUS application was identification of reversible causes of arrest (213/222, 95.9%, $P < .001$). Emergency medicine providers were more likely to utilize POCUS to evaluate cardiopulmonary arrest (64/68, 94.1%), as compared to all other specialties combined (158/275, 57.5%) ($P < .001$).

Frequencies of POCUS use for evaluating undifferentiated dyspnea were: "sometimes" 103/342 (30.1%), "often" 72/342 (21.1%), and

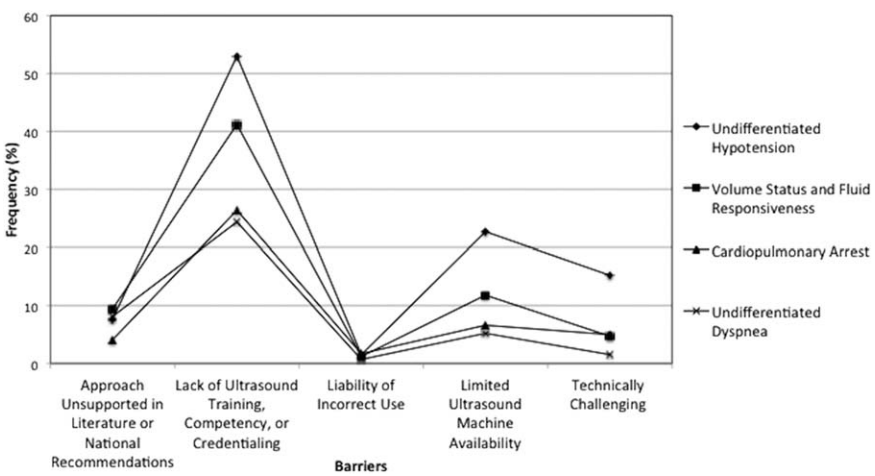


**FIGURE 4** Barriers to implementation of POCUS mentioned by survey respondents for specific clinical presentations

"always" 32/342 (9.4%). Of the 207 respondents who used POCUS to evaluate undifferentiated dyspnea, frequencies of use across specialties were: anesthesia/anesthesia critical care (5/8 [62.5%]), cardiac critical care 7/9 (77.8%), emergency medicine 47/68 (69.1%), internal medicine 14/27 (51.9%), pulmonary and critical care medicine 121/213 (56.8%), and "other" critical care 13/17 (76.5%). Within the group of respondents who utilize POCUS to evaluate undifferentiated dyspnea, the most commonly selected POCUS application for evaluating undifferentiated dyspnea was pneumothorax identification (191/207, 92.3%, $P < .001$).

Barriers to POCUS implementation for specific clinical presentations are demonstrated as frequencies in Figure 4. Frequencies of respondents who stated they "rarely" or "never" use POCUS for each clinical presentation were respectively 35/343 (10.2%) and 32/343 (9.2%) for undifferentiated hypotension, 45/343 (13.1%) and 41/343 (12.0%) for volume status and fluid responsiveness, 60/343 (17.5%) and 62/343 (18.1%) for cardiopulmonary arrest, and 58/343 (16.9%) and 77/343 (22.4%) for undifferentiated dyspnea. For each clinical presentation, respondents most commonly identified a lack of ultrasound training, competency, or credentialing, as compared to other barriers (35/66, [53%] for undifferentiated hypotension, 35/85 [41.2%] for volume status and fluid responsiveness, 32/121 [26.4%] for cardiopulmonary arrest, and 33/135 [24.4%] for undifferentiated dyspnea).

## 4 | DISCUSSION

Multiple professional organizations recommend POCUS use in the management of the critically ill. Despite this, POCUS is not universally integrated within residency and fellowship training curricula.[19,20] An understanding of current POCUS use, preferences, and barriers may help further expand training curricula and promote use and collaboration across specialties. To our knowledge, this is the first study to describe individual practitioners' POCUS use in the management of the critically ill across different specialties.

ACEP, ACCP, and SCCM each recommend POCUS use to aid in diagnostic evaluation and procedural guidance.[13–15] Furthermore, SCCM guidelines contain evidence-based recommendations for specific POCUS applications and clinical presentations.[16,17] Overall, amongst study respondents, annual POCUS use was more common for the cardiac (SCCM recommendation: 1B-2C, 83.5%) and pleural/pulmonary diagnostic applications (1A-2B, 92.4%), as compared to abdominal (1B-2C, 70.4%) and vascular (1B, 66.7%). Similarly, respondents preferred POCUS procedural guidance for central vascular access (femoral [1A, 61.7%], internal jugular [1A, 87.2%], subclavian [2C, 23.2%]), paracentesis (1B, 81.2%), pericardiocentesis (58.4%), and thoracentesis (1B, 91.0%). Despite recommendations, across multiple national organizations, POCUS utilization was not universal amongst study respondents. Currently, potential exists for the continued expansion of POCUS use in common applications, such as peripheral or central venous access guidance.

In each clinical scenario surveyed, respondents utilized an assortment of POCUS applications. For patients presenting with undifferentiated hypotension (1B), POCUS was utilized across specialties (80.8%), with emergency medicine providers reporting the highest use (98.5%). Amongst study respondents, a focused evaluation of the heart (94.6%) and central venous vasculature (91.7%), were the most commonly utilized applications. Numerous POCUS-guided approaches for hypotension and shock differentiation currently exist.[8,22,23] Each is performed through a sequential visual assessment of multiple organ systems in order to identify potential causes of hypotension. While each utilizes a variety of different applications, evaluation of the heart and inferior vena cava is common. Study respondents' POCUS use in undifferentiated hypotension was consistent with guideline and literature recommendations.

POCUS use for evaluating volume status and fluid responsiveness (1B) was less common amongst study respondents (75.2%). The most commonly selected POCUS application was central venous analysis (static and dynamic caval index measurement) in both spontaneously breathing (no recommendation, 78.7%) and mechanically ventilated patients (1B, 77.5%). Moreover, techniques beyond the scope of current POCUS guidelines, such as left ventricle outflow tract velocity–time integral (LVOT-VTI) measurements, were also utilized (62%). Recent literature suggests that central venous pressure (CVP) is insufficient to predict fluid responsiveness.[24] Additionally, as many as 50% of hemodynamically unstable patients may not respond to empiric fluid loading, with over-resuscitation resulting in potentially worsened outcomes.[25,26] POCUS assessment of volume status and preload responsiveness, specifically in septic shock (1C), allows providers to more precisely resuscitate critically ill patients. As providers embrace critical care-related POCUS, novel applications, such as LVOT-VTI, are likely to continue to develop.[27]

In the evaluation of cardiopulmonary arrest (1B-2C), emergency medicine providers (94.1%) were significantly more likely to perform POCUS as compared to the other specialties (57.5%). Amongst study respondents, POCUS was most commonly utilized to identify the potentially reversible causes of arrest (2C, 95.9%). Physicians traditionally employ the Advanced Cardiovascular Life Support (ACLS) algorithm to guide resuscitation in cardiopulmonary arrest and manage potentially reversible causes. POCUS offers providers the opportunity to predict resuscitation outcomes, efficiently differentiate pulseless electrical activity (PEA) from profound hypotension, and identify treatable etiologies of cardiac arrest such as severe left ventricular dysfunction (1C), pericardial effusion and tamponade (1B), pulmonary embolism (1C), hypovolemia (1B), and tension pneumothorax (1A).[10] Further incorporation of POCUS-guided interventions within cardiopulmonary resuscitation guidelines may expand use amongst non-emergency medicine specialties.

As compared to the clinical scenarios mentioned above, POCUS evaluation of undifferentiated dyspnea (1A-2B) was more evenly performed across specialties (60.5%), with pneumothorax identification (1A, 92.3%) being the most commonly utilized application. The potential etiologies associated with undifferentiated dyspnea are numerous. The sensitivity and specificity of POCUS for identification of pneumothorax (1A), pleural effusion (1A), and interstitial and parenchymal disease (2B) has been demonstrated to be comparable to those of plain film radiography.[28–30] Furthermore, POCUS allows for real-time and

serial evaluations, while avoiding radiation exposure. Study results indicate the potential for further expansion of POCUS use in undifferentiated dyspnea.

However, amongst study respondents, barriers to POCUS use still exist. A lack of formal training, competency, and credentialing were most commonly cited. Survey respondents obtained POCUS training in a variety of formats, including educational courses (26.5%), critical care fellowships (23.9%), and residency training (21.6%). POCUS training and competency guidelines exist for multiple specialties.[13–15] Emergency medicine providers are required to obtain POCUS experience during residency training.[31] Amongst study respondents, emergency medicine respondents were more likely to obtain POCUS experience during training (73.5%) as compared to the other disciplines (23.9%). These findings are consistent with previous studies, which demonstrated limited formal POCUS curricula amongst critical care programs.[20] Further development and implementation of formal training curricula during residency and fellowship may increase POCUS use.

In 1999, the American Medical Association (AMA) recommended that the requirements for POCUS competency and credentialing should be defined by the individual practitioner's specialty.[32] Emergency departments employ departmental ultrasound directors to help develop institutional credentialing guidelines, and to ensure practitioners meet and maintain these requirements. Unlike emergency medicine providers, who more commonly obtain experience during residency training, critical care providers may be encouraged to obtain post-graduate external certification, such as the Examination of Special Competence in Adult Echocardiography (ASCeXAM), in order to demonstrate competency.[15] Such additional requirements may further discourage POCUS use. Specialties may consider the continued development of POCUS leadership positions within departments to ensure that providers meet institutional training, competency, and credentialing standards, without external certification requirements.

We recognize the limitations to this survey study. First, a lower-than-expected number of responses were obtained. Further non-responder follow-up beyond the initial distributions was not available. Second, while respondents represented a variety of specialties, levels of experience and institutional affiliations, the majority of them were pulmonary and critical care medicine and emergency medicine practitioners in academic or university settings. Despite attempts to appropriately condense respondent groups, multiple specialties may be underrepresented. While this may limit generalization, we feel that these results have significance and meet study objectives. Third, we recognize the potential for selection bias in the study respondents, as those with POCUS experience and interest may have been more likely to complete the survey. Furthermore, survey responses are self-reported. The potential impact of this selection and non-response bias could not be fully assessed, as further information regarding non-responders was not available. As a result, study findings may overestimate POCUS use and preference, which limits further interpretation. Conversely, the challenges and barriers of ultrasound adoption may be underrepresented. Increased emphasis on POCUS training and resource investment may overcome persistent barriers to implementation.

In summary, POCUS is an important tool in the evaluation and management of the critically ill patients. Study respondents across specialties utilized POCUS in a variety of clinical applications. However, a lack of formal POCUS training, competency, and credentialing is still a common barrier.

## FINANCIAL DISCLOSURE AND CONFLICTS OF INTEREST

The study authors have disclosed that they do not have any conflicts of interest.

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## APPENDIX A: SURVEY INSTRUMENT

1. What is your level of experience?
   - Medical Student
   - Resident
   - Fellow
   - Faculty

2. What is your primary specialty?
   - Anesthesiology
   - Anesthesia critical care
   - Cardiac critical care
   - Cardiology
   - Emergency medicine
   - Internal medicine
   - Neuro critical care
   - Pulmonary and critical care
   - General surgery or surgical subspecialty
   - Surgical/trauma critical care
   - Other, please specify:

3. What is your primary institutional affiliation?
   - Academic or University setting
   - Community setting, non-teaching
   - Community setting, teaching

4. How did you primarily obtain training in point-of-care ultrasound?
   - Critical care fellowship
   - Post-training institutional credentialing program

- Residency training
- Self-guided learning
- Ultrasound fellowship
- Ultrasound training course
- Not trained in the use of point-of-care ultrasound
- Other, please specify:

5. How many of each of the following did you perform and interpret in the last year?

None 1–10 11–25 26–50 >50

- Focused abdominal ultrasound:
- Focused cardiac ultrasound:
- Focused Pleural/pulmonary ultrasound:
- Focused Vascular ultrasound (e.g. deep venous thrombosis):

6. How do you utilize ultrasound guidance for the following procedures?

Preferred method Alternative or "Rescue" method Never

- Central venous access guidance:
- Femoral
- Internal jugular
- Subclavian
- Paracentesis
- Pericardiocentesis
- Thoracentesis

7. How often to you utilize point-of-care ultrasound to evaluate undifferentiated hypotension?

- Never (proceed to question #7b)
- Rarely (proceed to question #7b)
- Sometimes
- Often
- Always

7a Which point-of-care ultrasound application(s) do you utilize to evaluate undifferentiated hypotension (please select all that apply)? (Once completed, proceed to question #8)

- Central arterial ultrasound (eg, identification of abdominal aortic aneurysm or dissection, etc.)
- Central venous ultrasound (eg, evaluation of inferior vena cava or internal jugular diameter, etc.)
- Extremity venous ultrasound (eg, identification of venous thrombosis)
- Focused abdominal ultrasound (eg, identification of peritoneal free fluid, etc.)
- Focused cardiac ultrasound (eg, evaluation of cardiac structure and contractility, pericardial effusion and cardiac tamponade, right ventricle strain, etc.)
- Pleural and pulmonary ultrasound (eg, identification of pneumothorax, interstitial syndrome, pleural fluid, etc.)
- Other, please specify:

7b Which best describes the reason you do not utilize point-of-care ultrasound to evaluate undifferentiated hypotension?

- Approach unsupported in literature or national recommendations
- Lack of ultrasound training, competency, or credentialing
- Liability of incorrect use
- Limited ultrasound machine availability
- Technically challenging (eg, time consuming, patient factors, need for serial exams, etc.)

8 How often to you utilize point-of-care ultrasound to evaluate volume status and fluid responsiveness?

- Never (proceed to question #8b)
- Rarely (proceed to question #8b)
- Sometimes
- Often
- Always

8a Which point-of-care ultrasound application(s) do you utilize to evaluate volume status and fluid responsiveness for spontaneously breathing and mechanically ventilated patients (please select all that apply)? (Once completed, proceed to question #9)

Spontaneously Breathing/ Mechanical Ventilation

- Cardiac anatomy and dynamic function evaluation (eg, Left ventricular end-diastolic area (LVEDA) or Left ventricle outflow tract (LVOT) velocity-time integral (VTI) measurement, etc.)
- Central arterial dynamic flow analysis (eg, Carotid artery, descending Aorta, etc.)
- Central venous dynamic analysis (eg, Inferior vena cava or Internal jugular respirophasic variation, etc.)
- Central venous static analysis (eg, Inferior vena cava or Internal jugular diameter, etc.)
- Peripheral artery dynamic flow analysis (eg, Brachial, radial, femoral artery, etc.)
- Other, please specify:

8b Which best describes the reason you do not utilize point-of-care ultrasound to evaluate volume status and fluid responsiveness?

- Approach unsupported in literature or national recommendations
- Lack of ultrasound training, competency, or credentialing
- Liability of incorrect use
- Limited ultrasound machine availability
- Technically challenging (eg, time consuming, patient factors, need for serial exams, etc.)

9 How often to you utilize point-of-care ultrasound to evaluate cardiopulmonary arrest?

- Never (proceed to question #9b)
- Rarely (proceed to question #9b)
- Sometimes
- Often
- Always

9a Which point-of-care ultrasound application(s) do you utilize to evaluate cardiopulmonary arrest (please select all that apply)? (Once completed, proceed to question #10)

- Endotracheal tube placement confirmation
- Evaluation of cardiopulmonary resuscitation (CPR) quality
- Identification of cardiac standstill

- Identification of reversible causes of cardiopulmonary arrest (e.g. Pericardial tamponade, tension pneumothorax, thromboembolism, hypovolemia, etc.)
- Other, please specify:

9b Which best describes the reason you do not utilize point-of-care ultrasound to evaluate cardiopulmonary arrest?

- Approach unsupported in literature or national recommendations
- Lack of ultrasound training, competency, or credentialing
- Liability of incorrect use
- Limited ultrasound machine availability
- Technically challenging (e.g. time consuming, patient factors, need for serial exams, etc.)

10 How often to you utilize point-of-care ultrasound to evaluate undifferentiated dyspnea?

- Never (proceed to question #10b)
- Rarely (proceed to question #10b)
- Sometimes
- Often
- Always

10a Which point-of-care ultrasound application(s) do you utilize to evaluate undifferentiated dyspnea (please select all that apply)? (Once completed, survey complete)

- Interstitial syndrome identification (eg, evaluation for B-lines, "lung rockets," signs of heart failure on transthoracic echo, etc.)
- Pleural effusion identification (eg, evaluation for pleural fluid, "sinusoid" sign, etc.)
- Pneumothorax identification (eg, evaluation for lung slide/point, A-lines, "seashore sign," etc.)
- Pulmonary consolidation identification (eg, evaluation for pulmonary hepatization, air bronchograms, etc.)

10b Which best describes the reason you do not utilize point-of-care ultrasound to evaluate undifferentiated dyspnea?

- Approach unsupported in literature or national recommendations
- Lack of ultrasound training, competency, or credentialing
- Liability of incorrect use
- Limited ultrasound machine availability
- Technically challenging (eg, time consuming, patient factors, need for serial exams, etc.)