Development of a multisystem point of care ultrasound skills assessment checklist

Nilam J. Soni1,2*, Robert Nathanson1,2, Mark Andreae3, Rahul Khosla4,5, Karthik Vadmalai6, Karthik Kode7, Jeremy S. Boyd8,9, Charles M. LoPresti10,11, Dana Resop12,13, Zahir Basrai14, Jason Williams15,16, Brian Bales8,9, Harald Sauthoff17,18, Erin Wetherbee19,20, Elizabeth K. Haro1,2, Natalie Smith1,2, Michael J. Mader21, Jacqueline Pugh2, Erin P. Finley2,14 and Christopher K. Schott3,22

Abstract

Background: Many institutions are training clinicians in point-of-care ultrasound (POCUS), but few POCUS skills checklists have been developed and validated. We developed a consensus-based multispecialty POCUS skills checklist with anchoring references for basic cardiac, lung, abdominal, and vascular ultrasound, and peripheral intravenous line (PIV) insertion.

Methods: A POCUS expert panel of 14 physicians specializing in emergency, critical care, and internal/hospital medicine participated in a modified-Delphi approach to develop a basic POCUS skills checklist by group consensus. Three rounds of voting were conducted, and consensus was defined by ≥80% agreement. Items achieving <80% consensus were discussed and considered for up to two additional rounds of voting.

Results: Thirteen POCUS experts (93%) completed all three rounds of voting. Cardiac, lung, abdominal, and vascular ultrasound checklists included probe location and control, basic machine setup, image quality and optimization, and identification of anatomical structures. PIV insertion included additional items for needle tip tracking. During the first round of voting, 136 (82%) items achieved consensus, and after revision and revoting, an additional 21 items achieved consensus. A total of 153 (92%) items were included in the final checklist.

Conclusions: We have developed a consensus-based, multispecialty POCUS checklist to evaluate skills in image acquisition and anatomy identification for basic cardiac, lung, abdominal, and vascular ultrasound, and PIV insertion.

Keywords: Education, Point of care, Ultrasound, Checklist

Background

Point-of-care ultrasound (POCUS) training is required for a growing list of specialties, including emergency medicine, critical care, and anesthesiology [1]. Physicians in-practice have been obtaining training through local and national continuing medical education courses that provide hands-on training and have been shown to be effective [2, 3].

Despite an increase in POCUS training, a critical gap remains in the ability to determine a physician’s competency in POCUS use due to variability in training standards and definitions of competency [4]. Several checklists and global rating scales have been published to evaluate POCUS skills [5–14]. Most published checklists are limited to a single organ system or specialty, and no multispecialty, multisystem checklists for evaluation of common POCUS applications of the lungs, heart, abdomen, and lower extremity veins have been published. Hospitals and healthcare systems are seeking validated multisystem POCUS checklists that can be applied across...
specialties to certify physician skills and maintain standards for POCUS use.

We describe the development of a multispecialty, multisystem POCUS skills checklist based on group consensus of national POCUS faculty from distinct institutions as the initial step toward creating a validated checklist.

**Methods**

We conducted a prospective observational study using consensus-based methods in two phases. The University of Pittsburgh Institutional Review Board approved this project (IRB # PRO18050302).

The initial POCUS skills checklist was developed by group consensus of POCUS experts from emergency medicine, critical care medicine, and hospital medicine during an in-person 3-day meeting dedicated toward developing a national POCUS training course for physicians practicing in the Department of Veterans Affairs (VA). Three diagnostic (heart, lungs, and abdomen) and one procedural application [peripheral intravenous line (PIV) insertion] were included in the checklist based on current evidence and applicability to multiple specialties. We piloted the initial checklist to evaluate novice learners from 2017 to 2019. Based on faculty feedback, the initial checklist was revised to include one additional diagnostic application (lower extremity deep venous thrombosis).

To gather formal consensus, an expert panel of 14 national POCUS faculty from emergency, critical care, and hospital medicine was convened which included the experts that developed the initial POCUS skills checklist. Experts were defined as individuals who regularly used POCUS in clinical practice; taught POCUS courses locally or nationally; and either had completed a dedicated POCUS fellowship, had a national professional society leadership role in POCUS, or had previously published on POCUS topics. All experts were required to disclose any conflicts of interest.

The checklist was divided into five sections (cardiac, lung, abdomen, lower extremity DVT, and PIV) and entered in an internet-based electronic data collection instrument (Research Electronic Data Capture [RED-Cap]) hosted on the server of the University of Texas Health Science Center in San Antonio, Texas. Expert panel members rated each item as a requirement for basic competency, and panel members were encouraged to provide feedback in free text boxes for each item.

A modified-Delphi approach was used to assess the level of agreement among experts. Three rounds of electronic voting followed by group discussion by videoconferencing were conducted between May 2020 and December 2020. Consensus was defined by ≥ 80% of experts agreeing to include an item. Items achieving < 80% consensus for inclusion were discussed, revised, and considered for an additional two rounds of voting.

To finalize the checklist, we pilot tested it on pre-recorded skill examinations of 18 learners who were categorized as novice, intermediate, or experienced POCUS users based on learners’ prior training and current use. Each POCUS expert reviewed a minimum of 40 videos that were randomized by learner and expert reviewer, and each video was rated by at least five different experts. Feedback from raters was incorporated into the checklist to add anchors and clarify wording. Formal validation of the checklist is planned for the future when the COVID-19 pandemic subsides and live in-person POCUS training events are permitted.

**Results**

Fourteen POCUS experts participated and 13 (93%) completed all three rounds of voting. Characteristics of the POCUS expert panel are displayed in Additional file 1: Table S1.

The original skills checklist included a total of 166 items for five different POCUS applications. The cardiac, lung, abdominal, and lower extremity DVT ultrasound checklists included sections for probe type, location, and control; basic machine setup; image quality and optimization; and identification of anatomical structures. The checklist for PIV insertion included additional items for needle-tip tracking.

After the first round of voting, 136 (82%) checklist items achieved consensus based on ≥ 80% agreement for inclusion (Additional file 2: Table S2). Thirty items did not achieve consensus from the cardiac (17), lung (6), PIV insertion (3), abdomen (2), and lower extremity DVT (2) checklists. A checklist item for speed and efficiency consistently did not achieve consensus for all applications and was removed after the follow-up panel discussion.

The second round of voting included 19 checklist items. Prior to voting, checklist items for optimization of image depth and gain were revised as, “Image depth (or gain) optimized appropriately.” Differences in convention of the screen marker and image orientation for the subcostal 4-chamber and inferior vena cava views were discussed and clarified on the checklist during the second round of voting. We chose to allow some flexibility and stated, “exam preset and orientation can vary based on specialty or local convention.” An additional 15 items reached consensus after the second round of voting.

The third round of voting focused on cardiac subcostal views. In emergency medicine, the subcostal views are often obtained as part of a focused assessment with
sonography in trauma (FAST) exam using a curvilinear probe and an abdominal exam preset, whereas in internal medicine and critical care, these views are most often obtained as part of a cardiac evaluation using a phased-array probe and cardiac exam preset. The group felt strongly not to remove these items and both probe types and exam settings were included in the revised checklist. All three items in the third round of voting achieved consensus. A total of 153 items were included in the final checklist (Tables 1, 2, 3 and 4).

The checklist was pilot tested using pre-recorded videos to identify unclear or ambiguous checklist items that could have varying interpretations. Anchors and explanatory statements were added to clarify certain checklist items based on group discussion (Additional file 3: Table S3).

### Cardiac POCUS checklist for basic competency in image acquisition and anatomy identification

| Cardiac parasternal | Cardiac subxiphoid |
|---------------------|--------------------|
| Selects PHASED-ARRAY transducer | Selects PHASED-ARRAY transducer |
| Selects CARDIAC EXAM | Selects CARDIAC EXAM |
| Correct probe LOCATION | Correct Probe LOCATION |
| Correct probe ORIENTATION | Correct Probe ORIENTATION |
| Probe CONTROL | Probe CONTROL |
| Obtains a quality Parasternal Long Axis view (Required structures = RV, LV, LA, AV, MV, LVOT, aortic root, descending thoracic aorta) | Obtains quality subxiphoid 4-chamber VIEW (Required structures = Liver, RV, RA, TV, LV, LA, MV) |
| Points to RIGHT VENTRICLE | Points to PERICARDIUM |
| Points to LEFT VENTRICLE | Points to LARGE |
| Points to LEFT ATRIUM | Points to RIGHT VENTRICLE |
| Points to AORTIC VALVE | Points to LEFT VENTRICLE |
| Points to MITRAL VALVE | Points to LEFT ATRIUM |
| Points to LEFT VENTRICULAR OUTFLOW TRACK | Points to MITRAL VALVE |
| Points to DESCENDING THORACIC AORTA | Points to TRICUSPID Valve |
| Points to PERICARDIUM | Image DEPTH optimized appropriately |
| Image DEPTH optimized appropriately | Image GAIN optimized appropriately |

| Cardiac apical | Inferior vena cava |
|----------------|-------------------|
| Selects PHASED-ARRAY transducer | Selects PHASED-ARRAY or CURVILINEAR transducer |
| Selects CARDIAC EXAM | Selects CARDIAC or ABDOMINAL EXAM preset |
| Correct Probe LOCATION | Correct Probe LOCATION |
| Correct Probe ORIENTATION | Correct Probe ORIENTATION |
| Probe CONTROL | Probe CONTROL |
| Obtains a quality 4-chamber cardiac VIEW (a 5-chamber view is acceptable) (Required structures = RV, LV, RA, LA, TV, MV) | Obtains quality IVC VIEW (Required structures = RA, IVC, a hepatic vein, liver) |
| Points to RIGHT VENTRICLE | Points to LIVER |
| Points to LEFT VENTRICLE | Points to IVC |
| Points to RIGHT ATRIUM | Points to HEPATIC VEIN |
| Points to LEFT ATRIUM | Points to RIGHT ATRIUM |
| Points to MITRAL VALVE | Points to site to assess for RESPIRATORY VARIATION |
| Points to TRICUSPID VALVE | – |
| Image DEPTH optimized appropriately | Image DEPTH optimized appropriately |
| Image GAIN optimized appropriately | Image GAIN optimized appropriately |

Based on the overall performance of this learner through all the views obtained and identification of anatomic structures during this hands-on skills evaluation, do you consider this learner to have the minimum skills to be considered COMPETENT in image acquisition and anatomy identification to perform CARDIAC POCUS exams of patients?

AV = aortic valve, IVC = inferior vena cava, LA = left atrium, LV = left ventricle, LVOT = left ventricular outflow tract, MV = mitral valve, POCUS = point-of-care ultrasound, RA = right atrium, RV = right ventricle, TV = tricuspid valve
Discussion

We have developed a consensus-based multisystem POCUS skills checklist to assess basic competency in image acquisition and anatomy identification. The checklist includes 153 items to evaluate skills to perform basic cardiac, lung, abdominal, and vascular ultrasound applications, including PIV insertion, that are commonly used in emergency medicine, critical care, and hospital medicine.

Our POCUS skills assessment checklist has noteworthy differences from other checklists. Most published POCUS skills checklists focus on assessing image acquisition and basic anatomy identification, whereas our checklist includes additional items to evaluate skills necessary for performing PIV insertion.

Table 2: Lung POCUS checklist for basic competency in image acquisition and anatomy identification

| Lung—anterior chest | Lung—costophrenic recess |
|---------------------|-------------------------|
| Selects phased-array or curvilinear probe | Selects phased-array or curvilinear probe |
| Selects ABDOMINAL or LUNG EXAM | Selects ABDOMINAL or LUNG EXAM |
| Correct Probe LOCATION | Correct Probe LOCATION |
| Correct Probe ORIENTATION | Correct Probe ORIENTATION |
| Probe CONTROL | Probe CONTROL |
| Obtains quality Anterior Lung VIEW | Obtains quality Costophrenic VIEW |
| (Required structures = Ribs, pleural line, A-lines) | (Required structures = Diaphragm, liver or spleen, lung parenchyma descending with respirations) |

Points to RIBS
Points to RIB SHADOW
Points to PLEURAL LINE
Recognizes PLEURAL SLIDING
Points to A-LINES
Demonstrates normal pattern using M-mode (seashore)
Image DEPTH optimized appropriately
Image GAIN optimized appropriately

Based on the overall performance of this learner through all the views obtained and identification of anatomic structures during this hands-on skills evaluation, do you consider this learner to have the minimum skills to be considered COMPETENT in image acquisition and anatomy identification to perform LUNG and PLEURAL POCUS exams of patients?

Table 3: Abdominal and pelvic POCUS checklists for basic competency in image acquisition and anatomy identification

| Abdominal skills | Pelvic skills |
|------------------|--------------|
| Selects curvilinear or phased-array probe | Selects curvilinear or phased-array probe |
| Selects ABDOMINAL EXAM | Selects ABDOMINAL EXAM |
| Correct Probe LOCATION | Correct Probe LOCATION |
| Correct Probe ORIENTATION | Correct Probe ORIENTATION |
| Probe CONTROL | Probe CONTROL |
| Obtains quality right upper quadrant FAST VIEW | Obtains quality transverse BLADDER VIEW |
| (Required structures = liver, kidney (including inferior pole of kidney), hepatorenal recess) | with either the prostate or uterus in view |
| (Required structures = bladder, prostate/uterus) |
| Points to DIAPHRAGM | Points to BLADDER WALL |
| Points to LIVER | Points to PROSTATE or UTERUS |
| Points to KIDNEY | Points to URINE WITHIN THE BLADDER |
| Points to HEPATORENAL RECESS (Morison’s Pouch) | Points to area to assess for PELVIC FREE FLUID |
| Points to RENAL PELVIS | – |
| Image DEPTH optimized appropriately | Image DEPTH optimized appropriately |
| Image GAIN optimized appropriately | Image GAIN optimized appropriately |

Based on the overall performance of this learner through all the views obtained and identification of anatomic structures during this hands-on skills evaluation, do you consider this learner to have the minimum skills to be considered COMPETENT in image acquisition and anatomy identification to perform ABDOMINAL and PELVIC POCUS exams of patients?
acquisition skills of a single organ system, such as cardiac [5–8], thoracic [12–14], FAST exam [9–11], vascular [5], neuromuscular [15], musculoskeletal [16], or procedures [17]; or assessing skills of clinicians from a single specialty, such as emergency medicine [10], surgery [9], or critical care [5]. In contrast, our checklist was based on consensus from 14 POCUS experts from emergency (5), critical care (5), and hospital medicine (4), who practice at different medical centers across the United States. The value of our consolidated checklist is it establishes a common standard for assessing skills in image acquisition and anatomy identification for basic, common POCUS applications across specialties. Institutions seeking tools to assess POCUS skills prior to granting privileges to use POCUS for clinical decision-making can use our checklist to efficiently evaluate POCUS skills of physicians from different specialties.

Our multisystem POCUS skills checklist combines the use of both checklist items and global rating scales. Checklists use task-specific items that can provide both evaluative scoring with cutoff levels for “passing” as well as formative feedback. Checklists are perceived as being easier to use, especially for non-expert assessors, and having better interrater reliability [17]. However, checklists may focus more on thoroughness rather than overall competency and may not capture a summative assessment of one’s performance [18, 19]. One approach to overcome this limitation is increasing the point-value of critical checklist items, or identifying checklist items that result in immediate disqualification from competency if performed incorrectly [18, 20]. By comparison, global rating scales provide an overall assessment of a learner’s skills and can differentiate learner levels with high reliability and sensitivity, particularly when performed by content experts [21–23]. For these reasons, a final global rating question was included to determine whether the learner has demonstrated minimum skills to be considered competent in image acquisition and anatomy identification for basic, common POCUS applications across specialties.

Table 4  Vascular POCUS checklist for basic competency in image acquisition and anatomy identification

| Lower extremity deep venous thrombosis (DVT) | Peripheral IV insertion (transverse approach) |
|---------------------------------------------|-----------------------------------------------|
| Selects high freq linear transducer         | Selects high freq linear transducer            |
| Selects vascular, venous, or arterial EXAM  | Select vascular, venous, or arterial EXAM      |
| Correct probe LOCATION                      | Correct probe LOCATION                         |
| Correct probe ORIENTATION                   | Correct probe ORIENTATION                      |
| Probe CONTROL                               | Probe CONTROL                                  |
| Obtains quality COMMON FEMORAL VEIN VIEW    | Tracks needle tip as needle advances toward vein |
| (Vein should appear oval/triangular in the center of screen; avoid oblique, off-axis views) | Successfully uses transverse approach to insert peripheral IV |
| Points to common femoral vein               | Image DEPTH optimized appropriately            |
| Points to common femoral artery             | Image GAIN optimized appropriately             |
| Points to common femoral vein/greater saphenous vein junction |                                |
| Demonstrates femoral vein COMPRESSION       |                                |
| Obtains quality POPLITEAL VEIN VIEW         |                                |
| (Both popliteal vein and artery should be seen clearly in center of screen) |                                |
| Points to popliteal artery                  |                                |
| Points to popliteal vein                    |                                |
| Demonstrates popliteal venous COMPRESSION   |                                |
| Image DEPTH optimized appropriately         |                                |
| Image GAIN optimized appropriately          |                                |

Based on the overall performance of this learner through all the views obtained and identification of anatomic structures during this hands-on skills evaluation, do you consider this learner to have the minimum skills to be considered COMPETENT in image acquisition and anatomy identification to perform LOWER EXTREMITY DVT POCUS exams of patients?

Based on the overall performance of this learner through all the views obtained and identification of anatomic structures during this hands-on skills evaluation, do you consider this learner to have the minimum skills to be considered COMPETENT to perform ultrasound-guided PERIPHERAL IV INSERTION on patients?

IV intravenous
identification to perform the specified POCUS exam on patients.

A rigorous multi-step process was conducted to develop our checklist from 2017 to 2021. Initially, speed and efficiency of image acquisition were included in the checklist. However, after pilot testing the initial version of our checklist with novices, we noted substantial variability in interpretation and application of these checklist items among expert faculty and removed them, because consensus could not be achieved on the specific wording, anchoring, and scoring of these items. In the final phase of checklist development, a standardized set of recorded skills exams of novice, experienced, and expert learners were reviewed and scored by the expert panel members independently which led to insertion of additional anchors to clarify some checklist items.

Our consensus-based multisystem checklist has limitations. First, POCUS competency requires mastery of image acquisition and interpretation, and integration of findings into clinical decision-making, which include the cognitive, psychomotor, and affective domains of learning [24, 25]. Our POCUS checklist assesses image acquisition skills and identification of normal structures, while additional assessment is needed for the cognitive domain. Second, we were unable to assess interrater reliability of our checklist due to the cancellation of live-in-person courses during the COVID-19 pandemic. We plan to validate our checklist with learners after resumption of live-in-person POCUS courses in the future. Third, we had to balance completeness versus efficiency when selecting views to include in a multisystem POCUS skills checklist, and although important, certain views, such as the left upper quadrant, were not included based on group consensus. Finally, we have postponed weighting of critical checklist items until validation of our checklist prospectively. We anticipate greater weighting of the final global rating question on competency for granting privileges.

Conclusions
We have developed a consensus-based multispecialty, multisystem POCUS checklist to assess basic competency in image acquisition and anatomy identification of cardiac, lung, abdominal, and vascular ultrasound, and PIV insertion. This checklist was designed to assess the skills of novice POCUS users from a wide range of specialties. Future steps include validating our checklist with learners during live-in-person POCUS courses and determining its interrater reliability.

Abbreviations
ACGME: Accreditation Council for Graduate Medical Education; DVT: Deep vein thrombosis; FAST: Focused assessment with sonography in trauma; PIV: Peripheral intravenous line; POCUS: Point-of-care ultrasound.

Supplementary Information
The online version contains supplementary material available at https://doi.org/10.1186/s13089-022-00268-4.

Acknowledgements
The authors would like to thank the faculty and staff of The Winter Institute for Simulation, Education, and Research (WISER) center (Pittsburgh, PA) for their time, space, and resources to conduct this study.

Author contributions
NJS, CKS, MM, MA, JSB, JP, EPF, and CLM conceived and designed the study including the initial skills checklist. NJS, RN, MA, RK, KV, KK, JSB, CLM, DR, ZB, JW, BB, HS, EW and CKS piloted the checklist, served on the expert voting panel, collected data, and finalized the checklist. MM, EKH, NS, JP, and EPF performed data cleaning and analysis followed by preparation of tables/figures for the manuscript. NJS, RN, MA, RK, KV, KK, JSB, CLM, DR, ZB, JW, BB, HS, EW, and CKS contributed to drafting the manuscript, and all authors contributed substantially to revisions and finalization. NJS and CKS take primary responsibility for the data presented in this manuscript. NJS takes responsibility as the corresponding author and manuscript as a whole. All authors read and approved the final manuscript.

Funding
Dr. Schott and LoPresti received funding for this work from an Innovation Grant by the Alliance for Academic Medicine. Dr. Soni receives funding from the Department of Veterans Affairs Quality Enhancement Research Initiative (QUERI) Partnered Evaluation Initiative (I50 HX002263-01A1) and National Center for Patient Safety. None of the funding agencies supporting this work were involved with the study design; collection, analysis, and interpretation of data; writing of the report; or the decision to submit the article for publication. The contents of this publication do not represent the views of the U.S. Department of Veterans Affairs or the United States Government.

Availability of data and materials
Data is available upon request.

Declarations
Ethics approval and consent to participate
The University of Pittsburgh Institutional Review Board approved this project (IRB # PRO18050302).

Consent for publication
All authors agree to publication of the manuscript in The Ultrasound Journal.

Competing interests
All authors report no competing or conflicting interests related to this manuscript.

Author details
1 Medicine Service, South Texas Veterans Health Care System, San Antonio, TX, USA. 2 Department of Medicine, University of Texas Health San Antonio,
References

1. AC Geme. http://www.acgeme.org. Accessed 11 Apr 2021.

2. Greenstein Y, Littauer R, Narasimhan M, Mayo PH, Koenig SJ (2016) Effectiveness of a critical care ultrasonography course. Chest 148:459A.

3. Schott CK, LoPresti M, Boyd JS et al (2021) Retention of point-of-care ultrasound skills among practicing physicians: findings of the VA national point-of-care ultrasound training program. J Am Med 134:391–399.

4. Wong A, Galarza L, Duska F (2019) Critical care ultrasound: a systematic review of international training competencies and program. Crit Care Med 47(3):e256–e262.

5. Patrawalla P, Eisen LA, Shiloh A et al (2015) Development and validation of an assessment tool for competency in critical care ultrasound. J Grad Med Edu 7(4):567–573.

6. Gaudet J, Waechter J, McLaughlin K et al (2016) Focused critical care echocardiography: development and evaluation of an image acquisition assessment tool. Crit Care Med 44(6):e329–335.

7. Millington SJ, Arnfield RT, Hewak M et al (2016) The rapid assessment of competency in echocardiography scale: validation of a tool for point-of-care ultrasound. J Ultrasound Med 35(7):1457–1463.

8. Adamson R, Morris AE, Sun Woan J, Ma IWY, Schnobrich D, Soni NJ (2020) Development of a focused cardiac ultrasound image acquisition assessment tool. ATS Sch 3(1):260–277.

9. Ziesmann MT, Park J, Unger BJ et al (2015) Validation of the quality of ultrasound imaging and competence (QUICK) score as an objective assessment tool for the FAST examination. J Trauma Acute Care Surg 78(5):1008–1013.

10. Bell CR, McKainey CJ, Holdren M, Fichtinger G, Rang L (2017) Sono- graphic accuracy as a novel tool for point-of-care ultrasound competency assessment. AEM Educ Train 1(4):316–324.

11. Russell L, Østergaard ML, Nielsen MB, Konge L, Nielsen KR (2018) Standardised assessment of competence in focused assessment with sonography for trauma. Acta Anaesthesiol Scand 62:1154–1160.

12. Skaarup SH, Laursen CB, Bjerrem AS, Hilberg O (2017) Objective and structured assessment of lung ultrasound competence. A multispecialty delphi consensus and construct validity study. Ann Am Thorac Soc 14(4):555–560.

13. Millington SJ, Arnfield RT, Guo RJ et al (2017) The Assessment of Competency in Thoracic Sonography (ACTS) scale: validation of a tool for point-of-care ultrasound. Crit Ultrasound J 9(1):25.

14. Di Pietro S, Mascolo M, Falaschi F et al (2021) Lung-ultrasound objective structured assessment of technical skills (LUS-OSATS): utility in the assessment of lung-ultrasound trained medical undergraduates. J Ultrasound Med 32(1):57–65.

15. Tawfik EA, Gartwright MS, Grimm A et al (2021) Neuromuscular ultrasound competency assessment: consensus-based survey. Muscle Nerve 63(5):651–656.

16. Kissin EY, Niu J, Balint P et al (2013) Musculoskeletal ultrasound training and competency assessment program for rheumatology fellows. J Ultrasound Med 32(10):1735–1743.

17. Kahr Rasmussen N, Niajarhanj L, Carlsen J et al (2021) Evaluation of competence in ultrasound-guided procedures-a generic assessment tool developed through the Delphi method. Eur Radiol 31(6):4203–4211.

18. Desy J, Noble VE, Woo MY, Walsh M, Kirkpatrick AW, Ma IWY (2021) Use of critical items in determining point-of-care ultrasound competence. Eval Health Prof 44(3):220–225.

19. Waltz A, Baccus M, Schaefer JP et al (2015) Diagnosing technical competence in six bedside procedures: comparing checklists and a global rating scale in the assessment of resident performance. Acad Med 90(8):1100–1108.

20. Payne NJ, Bradley EB, Heald EB et al (2008) Sharpening the eye of the OSCE with critical action analysis. Acad Med 83(10):900–905.

21. Hodges B, McIroy JH (2003) Analytic global OSCE ratings are sensitive to level of training. Med Educ 37(11):1012–1016.

22. Hodges B, Regehr G, McNaughton N, Tiberius R, Hanson M (1999) OSCE checklists do not capture increasing levels of expertise. Acad Med 74(10):1129–1134.

23. Regehr G, MacRae H, Reznick RK, Szalay D (1998) Comparing the psychometric properties of checklists and global rating scales for assessing performance on an OSCE-format examination. Acad Med 73(9):993–997.

24. Soni NJ, Tierney DM, Jensen TP, Lucas BP (2017) Certification of point-of-care ultrasound competency. J Hosp Med 12(9):775–776.

25. Menix KD (1996) Domains of learning: interdependent components of achievable learning outcomes. J Contin Educ Nurs 27(5):200–208.

Publisher’s Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.