CONCEPT PAPER

Tools for Measuring Clinical Ultrasound Competency: Recommendations From the Ultrasound Competency Work Group

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ABSTRACT

Competency in clinical ultrasound is essential to ensuring safe patient care. Competency in clinical ultrasound includes identifying when to perform a clinical ultrasound, performing the technical skills required for ultrasound image acquisition, accurately interpreting ultrasound images, and incorporating sonographic findings into clinical practice. In this concept paper, we discuss the advantages and limitations of existing tools to measure ultrasound competency. We propose strategies and future directions for assessing competency in clinical ultrasound.

Defining Competency in Clinical Ultrasound

Clinical ultrasound is focused ultrasound performed and interpreted by a clinician, in the context of providing direct patient care. It is utilized as a diagnostic modality to investigate a specific clinical question, safely guide invasive procedures, and assess response to therapeutic interventions. The term "clinical ultrasound" is synonymous with other terms such as "bedside ultrasound," "emergency ultrasound," and "point-of care ultrasound," encompassing a broad spectrum of ultrasound examinations performed by various specialties in diverse situations.[1]

Competency is the ability of health care professionals to integrate knowledge, skills, values, and attitudes into encounters in their clinical practice.[2] As applied to clinical ultrasound, competency reflects clustered skills of medical knowledge and technical aptitude to employ clinical ultrasound for optimized patient care and clinical outcomes. One published model, with the acronym I-AIM, has defined four subcompetencies of clinical ultrasound: identifying when to perform a clinical ultrasound, performing the technical skills in image acquisition, interpreting images, and incorporating those ultrasound findings into medical decision making and clinical practice.[3]

An example of competent clinical ultrasound use can be illustrated by the evaluation and management of a patient with acute, undifferentiated shortness of breath. The initial task involves the understanding of the scope and utility of lung ultrasound for the etiologies of shortness of breath. The next skill requires obtaining and optimizing lung images. This is followed by the knowledge to correctly identify pathologic findings such as bilateral B-line patterns or pleural effusions and applying these findings in the context of history, examination, and other diagnostic findings. Finally, the information gleaned from ultrasound

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imaging guides successful management of a patient with an acute exacerbation of congestive heart failure.

Measuring Competency in Clinical Ultrasound

Measuring competence requires defining what is expected at different stages of the learning process. Bloom's revised taxonomy divides learning into cognitive, affective, and psychomotor domains, each of which have milestones that move from "novice" to "minimally trained" to "well trained" to "expert" on comparable levels of skill and knowledge.[4] In a similar way, the Next Accreditations System (NAS) milestones from the Accreditation Council for Graduate Medical Education (ACGME) seek to prepare physicians for clinical practice with assessments of competency.[5] These milestones assess learners on a spectrum from a baseline level of nonexpertise through mastery, with the goal of enhancing quality and patient safety. The ACGME emergency medicine (EM) residency milestones include a dedicated ultrasound milestone that uses a threshold number of scans (150 total) as a surrogate to determine proficiency for graduating EM residents.[6]

While the ACGME EM ultrasound milestone suggests that performing a minimum number of ultrasound examinations can be used as a surrogate for overall clinical ultrasound competency, studies have found that different clinical ultrasound applications demonstrated different learning curves.[7–10] Using a standard number of ultrasound examinations to determine competency may not be the most accurate means of measuring clinical ultrasound competency, as learners may not uniformly meet a level of mastery at a predefined number of performed ultrasound examinations. Clinical ultrasound competency encompasses more than the technical skill of acquiring images that is reflected in the assumption of competency solely by reaching a quantitative metric. These concerns led to a multiorganizational suggestion for a revised EM ultrasound milestone that more accurately reflected performance progression throughout EM residency.[11]

The EM ultrasound milestone has provided a general benchmark for resident assessment, but agreement on how best to utilize the milestones and suggestions for revision are still evolving.[12] More importantly, there has been little discussion of how to assess competency across the different learner groups that perform clinical ultrasound, such as medical students, ultrasound fellows, practicing physicians, and advanced practice providers. Even among EM residency programs, there is a wide variety of clinical ultrasound assessment tools utilized.[13] In addition to the variety of users, the broad spectrum of clinical ultrasound applications renders a single, focused, standardized competency assessment challenging. Based on review of available published guidelines and content expert insights, this article provides a description of these tools with recommendations for practical utilization and suggestions for future directions in clinical ultrasound competency assessment.

METHODS

Currently, there are a number of national EM organizations with sections that focus on clinical ultrasound training, including the Society of Academic Emergency Medicine (SAEM)'s Academy of Emergency Ultrasound, the American College of Emergency Physician (ACEP)'s Ultrasound Section, and the Society of Clinical Ultrasound Fellowships (SCUF). In 2016, members from SCUF coordinating a working group focused on clinical ultrasound competency, drawing from the membership of the aforementioned three organizations. Members of this working group were identified as subject matter experts in the field of clinical ultrasound education. The working group's goal was to identify and describe the tools used to assess competency in clinical ultrasound.

To identify the current state of clinical ultrasound competency assessment, published guidelines and policy documents describing assessment in clinical ultrasound were reviewed. Documents reviewed include those from the American Board of Emergency Medicine,[14] ACEP,[15] Council of Emergency Medicine Residency Directors,[16,17] SAEM,[17] the American Institute of Ultrasound in Medicine,[18] and the ACGME.[19] A subset of the working group reviewed these documents and performed a textual analysis. A list of tools for measuring clinical ultrasound competency was identified from these published documents.

The investigators performed iterative content analysis and discussed their clinical practice, educational experiences, and assumptions about clinical ultrasound competency assessment tools. This ensured that unrecognized assumptions relevant to the results were discovered and supported through group consensus. Institutional ethics review and approval were not required as this investigation consisted of review of

published documents and voluntary participation of discussions performed with the working group regarding assessment techniques. There was no external financial support for the investigation or manuscript development.

RESULTS

Despite published documents suggesting a standard means of clinical ultrasound training, there is no universally accepted means of measuring clinical ultrasound competency. Our document review found six documents; two were excluded because they did not explicitly describe means of measuring competency. The documents ranged from six to 46 pages in length, and the time span of these policy documents were from 2009 to 2016. A listing of these documents is found in Data Supplement S1 (available as supporting information in the online version of this paper, which is available at http://onlinelibrary.wiley.com/doi/10.1002/aet2.10368/full). Our iterative process resulted in a listing of five different assessment methods for measuring clinical ultrasound competency. In the following section we provide our analysis and expert commentary on these modalities.

Written Examination

Description. Traditional written examinations can be utilized to assess the trainee's knowledge of indications and contraindications, interpretation of images, and medical decision making in clinical scenarios specifically created for the test. Written examinations with multiple-choice questions are widely used to assess medical knowledge, including the tests created by the National Board of Medical Examiners.[20]

Benefits. A wide breadth of content can be assessed, and the questions can be standardized across a large group of learners. Once the examination is created, execution requires much less time and resources than other assessment modalities.

Limitations. Written examinations are limited to the demonstration of tacit knowledge and fail to assess the technical skills required to obtain and optimize ultrasound images. Moreover, while written tests can assess if the application of clinical ultrasound is appropriate for specific clinical scenarios, it may not translate to how the examinee would actually incorporate clinical ultrasound into daily practice. Additionally, creation of a written test involves evaluative strategies to ensure that the test is fair and reliable.

Practical Utilization. In summary, a written examination is insufficient to measure all aspects of competency in clinical ultrasound and should be supported by additional assessments of psychomotor proficiency. An alternative method to written testing would be to ask examination-type questions during image review sessions or hands-on sessions. This could be in addition to, or instead of, a formal written examination. Oral questioning allows the learner to explain his or her thought process and allows the evaluator to target follow-up questions tailored to the learner's knowledge base. As with written testing, it is important to track learners' progress toward competency and set benchmarks for acceptable scores.

Image Review

Description. Review of recorded ultrasound images assesses learners' image quality and interpretation skills, after an ultrasound examination has been performed.

Benefits. Image review provides insight into the learner's performance in scanning actual patients. Timely asynchronous review of recorded ultrasound images can provide longitudinal feedback to learners, highlighting those areas which the learner needs to focus on improvement and those areas that the learner demonstrates proficiency. Sequential image review provides a longitudinal assessment of a learner's evolving skills and provides a documentation of a learner's progress.

Limitations. The disadvantage of this approach is that it is performed after the examination was completed, so it may not be clear if the provider has missed relevant findings on their ultrasound examination at the time of clinical evaluation. For example, if the learner provides an image of Morrison's pouch with no visible fluid, it may be difficult for the assessor to determine if fluid was truly absent or if the learner missed fluid on the recorded images due to incomplete visualization of the area. Additionally, feedback to the learner is likely not as impactful when delayed from real-time scanning. This approach does not consistently assess application into clinical practice. There must be available faculty to review images on a regular basis. Image archiving systems can facilitate image review to be performed on a broad scale of learners; however, this incurs cost if utilizing a commercially available option.

Practical Utilization. In summary, image review is an important and integral part of competency assessment in clinical ultrasound but should be performed in a timely manner to provide meaningful feedback. Video clips demonstrate a more thorough visualization of the area scanned, yet still images document that the learner recognizes the key anatomy. Concurrent review of other imaging tests as well as the hospital course provides additional formative feedback, illustrates additional findings, and provides information on limited quality scans.

Objective Structured Clinical Examinations

Description. Objective structured clinical examinations (OSCEs) can assess various aspects of competencies related to clinical ultrasound.[21] OSCEs are typically structured with multiple stations or scenarios, each designed to test specific learning objectives.[21] OSCEs have become widely utilized in graduate and postgraduate medical training and have been endorsed as a tool for assessing clinical ultrasound competency by major emergency ultrasound national organizations.[16,17,22–25]

Benefits. Objective structured clinical examinations provide a more realistic patient care scenario than would be possible with a written test, assessing both the technical skill of image acquisition and the knowledge for image interpretation as well as theoretical clinical application. The evaluator can observe an entire simulated encounter, which provides information on the learner's knowledge and skill base beyond reviewing the eventually acquired images, and further education can be customized for individual learners. The simulated clinical scenario can be designed to ensure that important but less common clinical presentations are regularly assessed.

Limitations. A major disadvantage of the OSCE is the time and cost involved, which can include proctor availability, equipment organization, development of the test, and recruitment of standardized patient models. Another limitation is that the reliability of an OSCE requires multiple samples across several stations to ensure that there is adequate sampling. In addition, the use of most standardized patient models can create a situation where pathology is lacking. Although an OSCE is designed to simulate a clinical encounter, it remains a simulated, testing environment and may not fully measure a learner's true behavior in a clinical situation.

Practical Utilization. An OSCE is useful in assessing baseline ultrasound skills in beginners prior to initiating a training regimen or following training to determine the effect of the training. Given the available resources, repetitive OSCEs can serve as longitudinal competency assessments to monitor skill maintenance or progression over time. If available, high- and low-fidelity ultrasound simulation products are well suited to provide a breadth of repeatable, normal, and pathologic standardized source of images for OSCEs.[26]

Standardized Direct Observational Tool

Description. The Standardized Direct Observational Tool (SDOT) is a uniform predefined checklist to evaluate a learner's performance in performing proctored examinations.[27,28] This checklist can be used during a clinical patient encounter or applied in a simulated setting.

Benefits. A series of standard objectives can be tested, allowing for uniformity among grading, often with a predefined minimum passing score to declare competency. SDOT can be designed to assess technical skill and interpretative ability.

Limitations. Similar to the OSCE, the SDOT requires the availability of a trained examiner and the time to perform the examination.

Practical Utilization. The Council of Emergency Medicine Residency Directors have developed SDOTs to help evaluate residents across all of the EM Milestones, including the ultrasound milestone: https://www.cordem.org/globalassets/files/sdots/milestones-version-patient-care-specific-sdot-pc1-14.doc. Repetitive SDOT examinations can be used to monitor an individual learner's longitudinal progress and can easily be applied to both simulated and clinical scanning sessions, or an SDOT can be performed at the end of a training period to ensure that specific metrics have been met.

In-Situ Live Clinical Observation

Description. In situ live clinical observation, as a means of measuring clinical ultrasound competency, involves observing a learner perform, interpret, and apply findings while in the clinical environment.

Benefits. Clinical observation can assess how a learner applies ultrasound in real clinical practice

across all four subcompetencies, including identification the indications and limitations of clinical ultrasound, performance the technical skills in image acquisition, interpretation images, and incorporation those ultrasound findings into medical decision making and clinical practice. This allows for appreciation of actual pathology, more challenging patient examinations, and a realistic testing environment, while avoiding time outside of clinical shifts needed to execute other testing. Additionally, the learner can be assessed using a variety of patients and pathology. Direct observation allows the evaluator to confirm findings and degree of imaging difficulty by repeating aspects of the clinical ultrasound themselves.

Limitations. Clinical observation can be limited by available time on shift and the unpredictability of patient factors presenting in the clinical environment. For example, for a learner to be evaluated on their use of biliary ultrasound, there must be a patient with a gallbladder, ideally with a clinical presentation necessitating a biliary ultrasound examination. Additionally, it requires evaluator time to observe a learner in clinical practice, which may not be feasible given volume and/or acuity of the clinical environment. It may not be practical to use for simultaneous assessment of a large groups of learners, and it may not comprehensively assess a learner's ultrasound knowledge.

Practical Utilization. In summary, clinical observation assessment is relatively easy to incorporate into a clinical shift or clinical imaging session. However, the clinical environment itself may limit the feasibility of this competency assessment tool. Incorporating an SDOT on a scheduled basis ensures consistency of the evaluation across learners. A recent study demonstrated that measuring clinical ultrasound competency via in situ clinical observation as measured by SDOT correlated well with assessment via asynchronous image review.[29]

DISCUSSION

There is no currently established consensus on which assessment tools are best to measure clinical ultrasound competency. Therefore, educators must weigh the benefits and limitations of each tool, summarized in Table 1.

Revisiting the example of applying clinical ultrasound to a patient with undifferentiated dyspnea, there are a variety of strategies that could be employed to assess the subcompetency in clinical ultrasound, as illustrated in Table 2. Using a combination of techniques ensures a reliable assessment of all four subcompetencies in clinical ultrasound. One assessment strategy would be to use a written test to assess the learner's subcompetencies of clinical ultrasound knowledge and image interpretation and use scheduled direct observation to assess how the learner incorporates clinical ultrasound into medical decision making and clinical practice.

Another assessment strategy would be to first perform an OSCE to determine initial skill level, followed

Table 1
Summary of Clinical Ultrasound Competency Assessment Methods

Assessment Modality	Benefits	Limitations
Written examination	Easily standardized Less time-intensive than other assessment methods May be easily repeated to evaluate knowledge retention	Does not assess image acquisition or application of findings Insufficient to use as a holistic method of assessment
Image review	Assess subcompetencies without faculty presence in real time Natural longitudinal assessment of trainee's progression	Requires a robust quality assurance structure Review is delayed, so missed findings will not be discovered or acted on contemporaneously
OSCE	Real-time evaluation of image acquisition technique and image interpretation Can create realistic clinical scenario	Faculty and time-intensive May require hiring standardized patients May incur resource costs Creation and scoring of tool requires additional faculty training
SDOT	Standardized means of evaluation Real-time evaluation of image acquisition technique and image interpretation	Faculty and time-intensive May require hiring standardized patients or incorporating in unpredictable clinical environment
Direct observation	May be performed during a clinical shift May reduce need for multiple faculty Can assess all four areas of competency simultaneously Naturally repeatable over the duration of training	Difficult to standardize due to unpredictable clinical environment Requires faculty facile in all core clinical ultrasound applications to evaluate

OSCE = objective structured clinical examination; SDOT = standardized direct observation tool.

Table 2
Example of Clinical Ultrasound Subcompetencies Applied to a Clinical Presentation of Undifferentiated Dyspnea

Subcompetency	Potential Assessment Modalities	Practical Example
Identify indications for clinical ultrasound	Written examination, oral examination, in situ observation	Query the indications and limitations of clinical ultrasound for the evaluation of undifferentiated shortness of breath
Acquire clinical ultrasound images	OSCE, SDOT, in situ observation	Directly observe the provider performing a lung ultrasound examination on a patient with shortness of breath
Interpret clinical ultrasound images	Written examination, oral examination, quality assurance session, in situ observation	Assess the provider's interpretation of the lung ultrasound examination
Incorporate findings into medical decision making and clinical practice	Quality assurance sessions, in situ observation	Examine the provider's appropriate application of lung ultrasound in clinical practice

OSCE = objective structured clinical examination; SDOT = standardized direct observation tool.

by scheduled SDOTs during the training period with weekly image review and structured feedback, followed by a final written test. The approach of combining assessment techniques to better measure competency in medical education has been suggested by other authors.[30] Van Der Vluten and Schuwirth[31] advocate that assessments in medical education address complex competencies and thus require quantitative and qualitative information from different sources, as well as professional judgment.

Given the broad spectrum of subcompetencies in clinical ultrasound, combining multiple assessment techniques is necessary to create a comprehensive picture of a learner's progression to competency. Research is needed to establish which modalities or combinations of modalities are most effective for establishing competency, with consideration for different learner groups and varied educational environments. Additionally, efforts should be directed in generating validity evidence and gathering psychometric evidence for new clinical ultrasound assessment tools.

As with other clinical skills, measuring competency in clinical ultrasound is essential to ensuring safe patient care. In this concept paper, we discussed the advantages and limitations of a variety of existing clinical ultrasound competency assessment tools. In doing so, we propose strategies for utilization and future directions for assessing clinical ultrasound competency.

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Supporting Information

The following supporting information is available in the online version of this paper available at http://onlinelibrary.wiley.com/doi/10.1002/aet2.10368/full

Data Supplement S1. Documents and Policy Statements Reviewed.