

Ultrasound Skill and Application of Knowledge Assessment using an Innovative OSCE Competition-Based Simulation Approach

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Abstract

Background: Despite Point-of Care Ultrasound (PoC US) rapidly becoming an important tool in perioperative medicine structured education, PoC US is currently rarely integrated into the anesthesiology residency curriculum. The aim of this project was to assess the current ultrasound skills of anesthesiology residents at one institution and evaluate the needs for development of a formal ultrasound curriculum.

Methods: A event containing 6 different OSCE PoC US stations was developed with following stations: vascular, peripheral nerve block, lung ultrasound, transthoracic echocardiography (TTE) human model, pathologic TTE (simulator), and inferior vena cava (IVC) evaluation (simulator). The ability to obtain an US image or to interpret the US information was evaluated using a checklist and global rating scale. After IRB approval, anesthesiology residents participated in this event (n=30; PGY 2-4).

Results: All residents were able to identify vascular structures and demonstrated sufficient ultrasound skill for lung anatomy IVC assessment. The lowest scores were observed for performing and interpreting TTE. There were no differences in resident ultrasound skills for all OSCE stations except minor differences between PGY 2 and PGY 4 in TTE pathology station. While more advanced residents had more clinical exposure to ultrasound for procedures and point-of-care diagnosis, we did not find growth in ultrasound skill level. Despite performing sufficient ultrasound guided peripheral nerve blocks, PGY 4 residents were not able to consistently identify common nerve block targets.

Conclusions: Our findings indicate that exposure and clinical use of ultrasound for procedures and point-of-care diagnosis is not sufficient for developing competency in PoC US and that a formal curriculum throughout the entire anesthesiology residency is needed to ensure PoC US competency.

Key words: Resident Education, Objective Assessment, Ultrasound, Objective Structured Clinical Examination, Invasive Procedures, Transthoracic Ultrasound

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Introduction

Training in point-of-care ultrasound (PoC US) or bedside ultrasound is increasingly being introduced into medical school and residency program curriculum¹⁻³. Anesthesiologists commonly use ultrasound (US) to guide placement of central venous catheters and for performance of peripheral nerve blocks. Subspecialty trained anesthesiologists (e.g. Critical Care Medicine, Cardiothoracic Anesthesiology) often extend the use of PoC US to cardiac imaging (TEE; transesophageal echocardiography, TTE; transthoracic echocardiography) or other uses such as lung ultrasound^{4,5}.

Transesophageal echocardiography training is commonly provided during anesthesiology residency and there is increased interest in anesthesiologists obtaining perioperative echocardiography certification (PTEexam)⁴⁻⁶. However, it has only recently been proposed that PoC US skills, beyond cardiac US imaging, be included in the training of anesthesiology residents^{1,3,7}. Ramsingh et al proposed that a complete PoC US curriculum be implemented into anesthesiology residency training⁸. While anesthesiology residencies do not routinely provide a formalized and complete education in PoC US, many US skills might be attained during clinical rotations where US is utilized (e.g. critical care, cardiothoracic anesthesiology, regional anesthesia).

The aim of the described objective structured clinical examination (OSCE) competitive simulation event was to assess the skill level of our residents in using procedural US and PoC US. We hypothesized that more advanced (PGY 4) residents would have a higher skill level in identifying procedure targets, performing PoC US exams and applying the information towards patient care than more junior level (PGY 2, PGY 3) residents. Since our residency training program is implementing a formalized US curriculum, this event reinforced the curriculum goals and development plan.

Methods

The project received IRB exempt status and all participating residents provided written consent. The purpose of the event was to assess resident skill level in procedural anatomy, ability to perform a targeted PoC US exam, and ability to use the PoC US information for making clinical decisions. The participating faculty had received ultrasound training during their subspecialty training (CCM/Regional/CT) and frequently use PoC US and/or US for procedures during routine practice. The OSCE stations were chosen by consensus of the participating faculty based on US competencies expected upon graduation from residency training. For each OSCE station, the resident received written instructions about what task to perform and document. Each task had to be completed in 10 minutes or less. The following 6 examination stations were included:

Exam Station 1-Human Model (Vascular):

The resident was asked to generate an image of the left internal jugular vein.

Exam Station 2-Human Model (Peripheral Nerve Block):

The exam station had two different scenarios assigned randomly to residents prior to the event. The resident was asked to generate either an image of the a) right interscalene nerve bundle, or b) right popliteal sciatic nerve.

Exam Station 3-Human Model (Transthoracic Ultrasound [TTE anatomy]):

The resident was asked to obtain two images for this station: a) the parasternal short axis view (PSAx) and mark the aortic valve, and b) the apical view (A4C) and mark the left ventricle.

Exam Station 4-Human Model (Lung Ultrasound):

The resident was asked to generate a video loop to demonstrate lung sliding.

Exam Station 5-US Task Trainer (Inferior vena cava evaluation):

In this station the resident was asked to perform a limited ultrasound exam of the upper abdomen on a laptop-based ultrasound simulator (SonoSim, Santa Monica, CA), specifically to identify the inferior vena cava (IVC) and to interpret the volume status based on the IVC findings. Two different scenarios were used for this project: a) high IVC respiratory variability, and b) low IVC respiratory variability. The scenarios were assigned randomly to each resident prior to the event. The complexity and difficulty of each scenario were similar. A faculty mentor was present during the encounter to facilitate the station.

Exam Station 6-US Task Trainer (Transthoracic echocardiography interpretation [TTE pathology]):

In this station the resident was asked to perform a transthoracic echocardiographic exam on an echocardiography simulator (HeartWorks Simulator System, Inventive Medical Ltd, London, United Kingdom). At the beginning of the scenario, the resident received written instructions about the simulated patient situation, and was asked to perform a TTE exam and generate a treatment plan based on the identified pathology. Three different scenarios from the simulator case bank were selected with similar complexity (Aortic Stenosis, Global Hyperdynamic Function due to hypovolemia, Cardiac Tamponade) and were assigned randomly to each resident prior to the event. A faculty mentor was present during the encounter to facilitate the station.

Standardized Patients (SP) were used for Exam Station 1-4 as human models. The SPs received training prior to the event and were instructed not to provide any verbal or non-verbal assistance to the participants. The SP for each Exam Station was identical for each event day. Ultrasound task trainers were used for Exam Station 5 and 6.

OSCE Competitive Simulation Event:

Prior to the event all participants watched a video-based instruction session including an outline of the event, expectations, assessment tools and directions for equipment use. The ultrasound equipment used in the event was similar to the ultrasound equipment commonly used in the operating room and in critical care.

The event was conducted on two separate days to allow a large group of residents to participate with minimal impact on clinical responsibilities. Each resident received a personalized schedule prior to the event. The event duration was 3 hours each day, allowing sufficient time for station turnover in between each encounter.

After IRB exemption was obtained, we recruited PGY 2-4 (CA1-3) anesthesiology residents from a single institution. The event was held March 2016 on two separate days but with identical configuration (e.g. location, equipment, facilitators and standardized patients). Prior to this event, the residents had not received any formal training in PoC US or US for procedural use except instructions for clinical use during rotations such as critical care medicine, cardiothoracic anesthesiology, regional anesthesia, and the postoperative care unit. Senior residents (PGY 4) had previously received training in transesophageal echocardiography (TEE). To ensure adequate equipment availability for the event without creating strain on patient care, the event was supported by SonoSite (Sonosite Inc, Bothell, WA) by providing non-clinical ultrasound equipment.

A total of 30 residents participated in the event (n=30: 10 PGY 4, 8 PGY 3, and 12 PGY 2 residents). All participants watched a 15min video-based instruction session on the used ultrasound devices 2-3 days prior to the event.

Assessment:

Prior to the event (video-based) and immediately before entering the OSCE station (written), the resident received instructions that the objective in Exam Station 1-4 was to obtain the best image of the requested structure. The residents received written task instructions prior to starting the encounter at OSCE station 5 and 6, emphasizing the encounter goal was to obtain diagnostic information using PoC US and to apply the information towards simulated patient care.

Faculty experts reviewed the archived images of OSCE station 1 through 4 after the event in a blinded fashion. A checklist was used and each exam component assessed using the global rating scale (GRS; 1=poor, 5=excellent)⁹. An example of this assessment tool is provided in Figure 1. OSCE Station 5 and 6 facilitators completed a scenario-specific checklist with GRS during the encounter. The checklists were developed by the participating faculty and validated prior to the event using non-participating junior faculty.

The assessment process was completed over 4 weeks after the event and performance data were summarized for individual resident debriefing. The expert faculty identified the top four performers for OSCE Station 2-6. The top performers and overall winners (1st / 2nd / and 3rd place) were announced in an Olympic-style medal ceremony at our departmental weekly conference. Gift cards (\$10-25) were provided with each award.

Statistical Analysis:

The OSCE station results were sorted into resident performance based on training level. Mean and standard deviation of scaled OSCE Station scores (Station 2 through 6) for each training year (PGY 2, PGY 3, and PGY 4) were calculated. Statistical assessment for significance was performed using one-way ANOVA. A p-value of 0.05 or less was considered statistically significant. Evaluation sheets were reviewed to identify the requested structure as a yes (success) or no (fail) answer. The success/fail frequency for each station based on training level was tested for statistical significance using the 3x2 Chi Square test with significance level at $p \leq 0.05$.

Survey:

After the event and but before the award ceremony, the participants received an anonymous electronic survey to investigate their perceptions of the event. The survey included questions about the learner's opinion of the event's value for personal development and allowed open-ended feedback. The de-identified survey responses were analyzed.

Results

Eighteen residents (60%) participated in the survey and the responses are shown in Table 1. Based on the survey, >80% of the respondents agreed or strongly agreed that, a) the skills and expected knowledge level for the event was appropriate for their training level, and b) the event allowed them to demonstrate competency in ultrasound skill and knowledge. The participants provided several comments and recommendations indicating that: a) the combination of human models with task simulators was helpful and made the event interesting, b) there was some uncertainty and unfamiliarity with how to use and optimize the provided equipment, and c) there is a desire for more structured education and incorporation of PoC US with high-fidelity simulation into their training.

The scaled score for each resident year (PGY 2-4) is shown in Figure 2. OSCE Station 1 was not used for quantitative analysis. All residents were able to demonstrate basic vascular anatomy (internal jugular vein for central line placement). The results of OSCE station 1 suggested that all participants were able to use the ultrasound equipment and understood the encounter tasks as the station outline of Exam Station 1 was very similar to OSCE Station 2-4.

Participants indicated sufficient ultrasound skill for demonstrating lung anatomy and using PoC US to assess inferior vena cava (IVC) respiratory pattern for fluid status assessment. The lowest scores were observed for performing a targeted transthoracic exam on a human model. There were no differences in participant performance related to training level, except in the TTE pathology exam station. Although our residents perform regional nerve blocks frequently and complete a minimum of 2 months on the acute pain service, senior residents (PGY 4) did not demonstrate the ability to obtain an ultrasound image of a common peripheral nerve block target. In the TTE pathology exam station (Station 6) PGY 2 residents had a significantly lower score than more advanced residents (PGY 2 0.41 ± 0.09 vs PGY 3 0.56 ± 0.12 and PGY 4 0.55 ± 0.12 , $p=0.02$ for PGY 2 vs PGY 4). PGY 3 and above have had exposure to subspecialty cardiothoracic anesthesia at the time of the event and had been exposed to transesophageal echocardiography (TEE). All but 2 PGY 4 residents have completed a TEE month (4 week exclusive training in TEE exam performance and interpretation)¹⁰.

The results of the analysis based on success/fail for ultrasound demonstration of the requested target are shown in Table 2. All residents were able to demonstrate the vascular target. Despite extensive exposure to ultrasound guided peripheral nerve block training and the number of peripheral nerve blocks performed increasing with training level, the results of exam station did not indicate an increasing ability of ultrasound identification of peripheral nerve block target based on training year. Based on a current procedure log up to and including the month of the event, following peripheral nerve block frequencies have been reported: PGY 2 average of 37.5 ± 21.0 , PGY 3 104.9 ± 48.8 , and PGY 4 127.6 ± 66.3 . However, the success rate in PGY 2 was not significantly lower than in senior and more experienced residents. The lowest rate of success

to identify the requested structure was observed in the TTE stations (exam station 3 [anatomy] and 6 [pathology]). High success rates were observed in the lung anatomy station (exam station 4) and identification of IVC on a simulator (exam station 5). For both examination targets, the residents had not received formal training prior to the event, and ability reflected clinical exposure.

Discussion

The described OSCE Competition-based simulation event was able to assess resident competency in a wide variety of ultrasound skills expected of anesthesiologists. The event data was valuable in assessing the baseline quality of our current residency curriculum in teaching the use of PoC US. We found that: 1) despite increasing clinical procedure frequency, the ability to demonstrate peripheral nerve block target with ultrasound did not improve, 2) the ability to perform a transthoracic echocardiography exam and use the information is currently not sufficient, and 3) a basic understanding of lung and IVC ultrasound is present despite the lack of structured clinical training.

Recent publications defined the scope of perioperative ultrasound and what the expectations for the future anesthesiologist will be^{1,3,7}. An international group of anesthesiologists recommended that anesthesiology residency programs should include structured, continuous training in perioperative ultrasound, and that skill competency should be verified during residency¹. Ramsingh et al published a comprehensive perioperative PoC US curriculum implemented at the University of California/Irvine, demonstrating a broad variety of PoC US applications for anesthesiologists (FORESIGHT Comprehensive Perioperative Ultrasound Examination)⁸. Since the described curriculum requires significant departmental resources (equipment/time), we designed this event to provide guidance and an assessment of needs. We assumed, based on our residents' procedure numbers for vascular access and peripheral nerve block placement, that they receive sufficient exposure to ultrasound use for these procedures. We found that all residents, independent of training level, had adequate skills to identify a vascular structure with ultrasound. However, more than one third of experienced residents (PGY 4) were not able to identify a common peripheral nerve block target. Ultrasound competency and quality was not dependent upon clinical experience. This finding supports a more structured approach to ultrasound training and inclusion of skill assessment into residency training. In clinical practice, most invasive procedures are performed in attending presence. The inability of residents to identify the target independently may be masked by the attending input. A true skill assessment as demonstrated in this project may be an objective way to ensure competency and provide constructive feedback.

The belief that structured ultrasound instruction can wait until subspecialty training or fellowship appears obsolete¹¹. The American Board of Anesthesiology (ABA) included certain concepts of perioperative ultrasound in the Milestone project¹². However, the value of being able to use PoC US for the perioperative patient care goes above the expectations outlined in the ABA Milestones^{7,8,13}. Skilled anesthesiologists using advanced US technology for more procedures will hopefully improve patient care quality and safety. The perioperative availability and use of ultrasound will give our specialty increasing credibility in perioperative care. The findings of this project demonstrate that clinical exposure alone is not sufficient to learn PoC US. Despite the significant requirements for equipment and personnel (task simulators, ultrasound equipment,

and instructor time), anesthesiology residencies should strongly consider developing structured instruction and assessment options for anesthesiology relevant ultrasound skills^{8,14}.

Our current residency curriculum exposes PGY 3 and PGY 4 residents to transesophageal echocardiography (TEE)¹⁰. PGY 3 residents on the cardiothoracic anesthesia rotations are present during the TEE exam performed by the PGY 4 resident and are exposed to the TEE instructions the PGY 4 resident receives. Additionally, the PGY 4 residents have a dedicated 4 week TEE rotation in which they personally perform 30-40 TEE exams and interpret stored TEE exams daily with an experienced TEE trained attending. Despite the intense TEE training we did not observe any 'cross-pollination' of TEE skills towards TTE skills. Without having any formal education in TTE, only a small fraction of residents were able to perform a TTE exam. While residents with CT/TEE exposure performed marginally better on the TTE task simulator, the results indicated insufficient skill level and ability to interpret the information for all resident groups.

Considering the absence of structured training for lung ultrasound or abdominal ultrasound prior to this event, the findings for lung anatomy and IVC pathology were surprising. More than two thirds of residents were able to 1) demonstrate lung sliding on human models and 2) identify IVC on a task simulator and interpret volume status based on IVC diameter patterns. Both examinations modes are rarely taught in the operating room. It is likely that the residents were exposed to PoC US during their Critical Care rotations. A recent study exploring different teaching strategies for lung ultrasound to anesthesiologists found that this application was learned relatively quickly¹⁵. While we are encouraged by these observations, there is still room for improvement and a structured, comprehensive PoC US curriculum should include instructions on all essential PoC US applications.

The survey results indicated that the learners understand the value of this technique and are motivated to participate in the acquisition of the PoC US knowledge and skills. Assessment of technical skills (OSCE) will soon be a part of the Applied Exam of Primary Certification Process of the ABA¹⁶. Some of the skill stations will include the use of ultrasound and ability to interpret ultrasound-generated information. Therefore, anesthesiology residencies have a sense of urgency to prepare current residents for this part of their primary certification. PoC US curriculum should keep the ABA expectations in mind. However, the clinical importance and value of PoC US exceeds the primary certification expectations. To train our residents for the future, the PoC US curriculum integration into the anesthesiology residency should address more than just milestone competency required³. The competitive component used in this event has proven helpful to motivate the learners^{17,18}.

In conclusion, we have demonstrated that a competition-based event using simulation can be used to objectively assess anesthesiology resident skills and provide formative feedback to learners. Future applications include modifying the event to apply to different specialties and creating similar events with training level specific workstations to assess higher level residents and their progress during training as a part of milestone level assessment.

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Figure 1

Ultrasound Olympics Exam Station 3 (TTE Anatomy)

Resident Name: _____ Evaluated by: _____
 Date: _____
 Training level: CA1 CA2 CA3

Task: Identify Aortic valve in Parasternal short axis view

US Task		Grade (GRS)	comments
Ultrasound Basic Setup	Selects appropriate orientation		
	Selects appropriate depth		
	Selects appropriate gain		
Ultrasound scanning	Picture shows parasternal short axis view		
	Picture shows left ventricular outflow tract		
	Overall picture quality		
Target Identification	Identifies target on Screen (marked with arrow) Arrow identifies Aortic valve		<input type="checkbox"/> Success <input type="checkbox"/> Fail
	Total points	/35	

Task: Identify Left Ventricle in apical view

US Task		Grade (GRS)	comments
Ultrasound Basic Setup	Selects appropriate orientation		
	Selects appropriate depth		
	Selects appropriate gain		
Ultrasound scanning	Picture shows apical view of the heart		
	Picture shows ventricular structures (right or left)		
	Overall picture quality		
Target Identification	Identifies target on Screen (marked with arrow) Arrow identifies Left ventricle		<input type="checkbox"/> Success <input type="checkbox"/> Fail
	Total points	/35	

Comments:

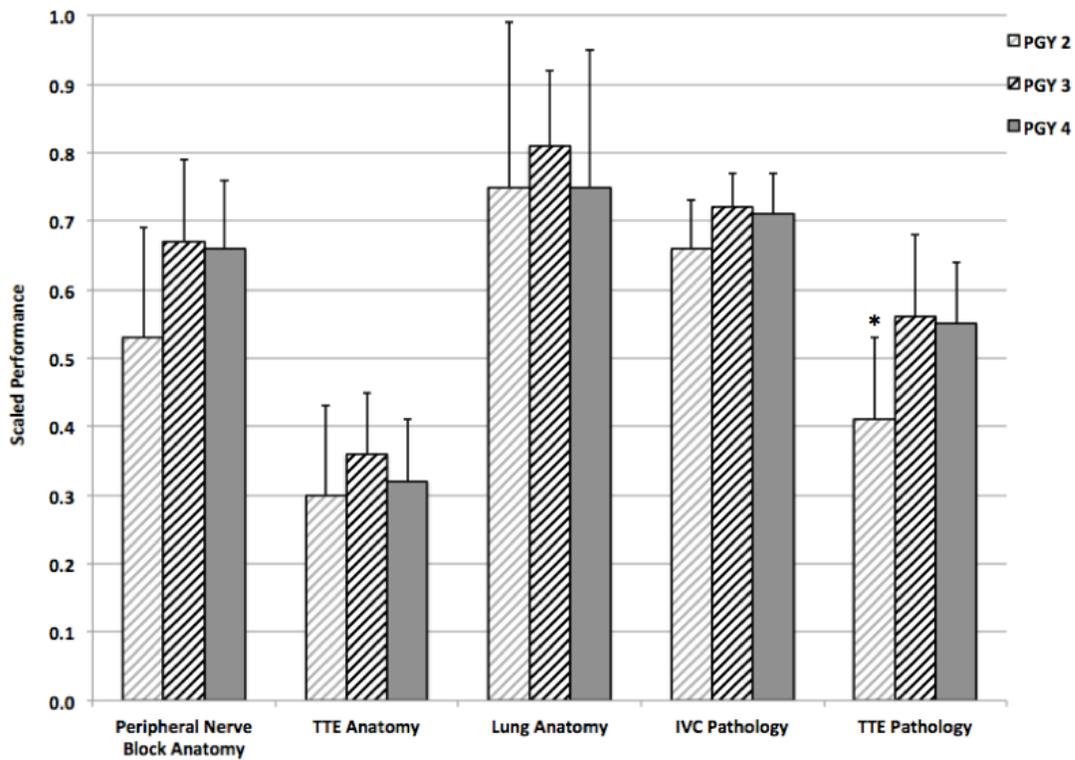
The figure demonstrates the evaluation tool for Exam Station 3 (transthoracic echocardiography [TTE] anatomy on human model). The station consisted of 2 tasks: aortic valve demonstration in the parasternal short axis view (PSAX), and left ventricle in the apical view (A4C). Grading occurred by Global Score Rating (GRS)-based scoring (1=poor, 5=excellent) for several exam components (probe orientation, depth, gain, image quality) and success/fail based scoring for task completion.

Table 1

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The skills and knowledge expected during the event were appropriately challenging for my level of training	22%	61%	0%	17%	0%
The event allowed me to demonstrate competency in ultrasound skill and knowledge	33%	50%	11%	6%	0%

Survey response from event participants (n=18; 60% response rate). Response rate per training year: PGY 2 58% (n=7 out of 12), PGY 3 100% (n=8 out of 8), PGY 4 30% (n=3 out of 10). Data are shown as percentages of responses for each survey statement.

Figure 2



The figure shows the scaled global rating score (GRS) scores for Exam Station 2 through 6 for all participants based on training year. Data are presented as mean \pm SD. P value was obtained using one-way ANOVA. * $p < 0.05$

Table 2

Table 1

		PGY 2 (n=12)		PGY 3 (n=8)		PGY 4 (N=10)		P value
		Success	Fail	Success	Fail	Success	Fail	
Station 1	Vascular (LIJ)	12 (100%)	0	8 (100%)	0	10 (100%)	0	
Station 2	Peripheral Nerve Block	5 (42%)	7	5 (63%)	3	6 (60%)	4	0.58
Station 3	Aortic valve (PSAX)	1 (8%)	11	1 (13%)	7	2 (20%)	8	0.72
	Left Ventricle (A4C)	1 (8%)	11	1 (13%)	7	1 (10%)	9	0.96
Station 4	Lung sliding	8 (67%)	4	5 (63%)	3	7 (70%)	3	0.95
Station 5	IVC demonstration	11 (92%)	1	8 (100%)	0	10 (100%)	0	0.46
Station 6	TTE exam for pathology	2 (17%)	8	4 (50%)	4	6 (60%)	4	0.09

The table shows the analysis of station evaluation for success/non-success in demonstrating the requested target.