The Journal of Education in Perioperative Medicine

Original Research

The Development of a Basic Procedural Skills Checklist for a Simulation-based Mastery Learning Curriculum for Ultrasound-guided Interscalene Peripheral Nerve Blocks for Novice Residents

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Introduction

The practice of regional anesthesia requires specialized technical skills, including needle guidance and ultrasound image acquisition. Nontechnical skills, such as patient communication and adequate monitoring, are also necessary.[1] Many regional anesthesia programs use the apprenticeship model of teaching graduate medical education, relying on didactic lectures and experiential learning. In this model, the experience levels of trainees at the beginning of their rotation are varied. These trainees often perform their first ultrasound-guided regional anesthetic on a patient without prior experience, and this may affect patient safety, trainee and supervisor comfort, and workflow efficiency.[1,2]

In 2009, the American Society of Regional Anesthesia and Pain Medicine (ASRA) and the European Society of Regional Anaesthesia and Pain Therapy (ESRA) published the recommendations of a joint committee on ultrasound-guided regional anesthesia (UGRA) education.[3] The committee identified common tasks associated with regional anesthesia, developed a list of core competencies, and recommended pathways for education, including simulation.[3] In a review of teaching concepts in UGRA in 2016, Kessler et al agreed that simulation is beneficial for teaching the regional anesthesia core competencies as defined by the ASRA/ESRA joint committee.[4] When teaching UGRA using simulation, trainees are removed from the time pressure and safety concerns associated with routine patient care.[2] In addition, the reflective practice, debriefing, and repeated attempts allowed in the simulation lab provide excellent opportunities for trainees to learn and practice the highly technical aspects of UGRA.

Simulation-based education has demonstrated benefits in teaching UGRA.[2,5] In a 2012 study, Niazi et al randomized novice residents to 2 groups, 1 receiving conventional instruction and 1 receiving simulation education. The authors concluded that the addition of simulation to curricula in regional anesthesia increased the success rate of peripheral nerve blocks.[6] In a 2016 study by Barrington et al, simulation was successfully used with novice medical students to develop skills in image acquisition and anatomical identification of the axillary brachial plexus. After fifteen sessions, participants' scores improved.[7] However, both studies used a time-based approach for curriculum completion as opposed to the competency-based approach of simulation-based mastery learning (SBML).

SBML is an approach that ensures all learners reach a predetermined level of skill before completing the curriculum. In this approach, the results of the education activity are consistent across learners, whereas the time required to complete the curriculum varies.[8] In SBML, learners undergo baseline testing using a skills checklist to evaluate their performance and then view lectures and videos that demonstrate the procedure and review relevant background information. Following this asynchronous education, learners engage in simulation-based deliberate practice with feedback and additional instruction until they can meet or exceed a minimum passing standard (MPS) at posttesting.[8] Learners who do not reach the MPS undergo further deliberate practice until they can be retested and meet this standard. SBML curricula are founded in the science of expertise.[9]

SBML is used to teach various procedures to residents and attendings, including those performed in anesthesia, such as central line insertion,[10] lumbar puncture,[11] ultrasound-guided IV insertion,[12] and ventilator management[13] with positive results.[8] SBML is linked to improved patient outcomes and may be superior to other instructional techniques for clinical skill acquisition, including simulation alone.[8] In addition, SBML is considered a best practice of simulation-based education.[14] However, no current studies

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describe the implementation and benefits of using SBML to teach UGRA to trainees.

Therefore, we created an ultrasound-guided interscalene peripheral nerve block SBML curriculum. The curriculum was designed to help prepare novice residents before the start of their regional anesthesia rotations. In this manuscript, we describe the process of creating our interscalene block skills assessment checklist to ensure it yields valid and reliable data regarding a trainee's readiness to perform these procedures on patients with faculty supervision. We also describe the establishment of an MPS to determine procedural mastery.

Methods

We created and pilot-tested an ultrasound-guided interscalene block skills assessment using checklist development guidelines for SBML as described by Klein et al.[15] We conducted pilot testing of the checklist with anesthesiology residents at Northwestern University Feinberg School of Medicine (NUFSM) from October 2023 to April 2024. The NUFSM Institutional Review Board (IRB) and Johns Hopkins University IRB approved this study. The IRB of the study institution and Johns Hopkins were consulted as this study was designed and conducted as part of a master of education program at Johns Hopkins University. Anesthesia residents were required to provide written informed consent before participating in the study.

Checklist Development

One author (JJW) developed an initial checklist (graded dichotomously as done correctly or not done/done incorrectly) after reviewing the literature for existing checklists and best practices for performing regional anesthesia procedures.[16–20] The checklist was designed to be complete, including steps on patient consent and monitoring, but brief and feasible for use in a 20-minute scenario. Subsequently, a sample of 13 anesthesia teaching faculty from various institutions throughout the United States was recruited to review the initial checklist draft electronically (via email). Recruited faculty were known to one or more of the authors to have expertise in regional anesthesia. We wanted to ensure that at least 10 panelists completed the entire Delphi process, so we recruited 13 to account for potential dropouts. Ten panelists are often adequate to achieve consensus using the Delphi process, and this number is used in other studies of SBML checklist design in which consensus is achieved.[21] We collected demographic and clinical information from the faculty members who agreed to serve on the panel. We used the modified Delphi process until an 80% consensus was reached on the checklist. We set 80% as the consensus goal in keeping with the recommendations of Humphrey-Murto et al.[22]

Standard Setting

Once the checklist was finalized, the 12 Delphi panelists were invited to serve as judges for the standard-setting process, and 5 agreed to serve. The rest of the panel consisted of authors (VGT, SMM, LC, JHB) and an additional faculty member from the principal investigator's home institution, making the final panel consist of 10 experts. The panel met virtually to discuss the standard setting. Holding the virtual session made it easier to bring together the faculty from locations across the United States. We collected demographic and clinical information from the panel of judges. An expert in SBML and standard setting led this discussion (JHB). For each checklist item, the judges used the Mastery Angoff technique. They were asked to express their opinion on the percentage of "well-prepared" learners they felt would correctly answer each checklist item after the simulation instruction at posttest.[23] A well-prepared learner was described as a learner who would perform the procedure on the simulator safely with minimal to no supervision after simulation instruction. Whereas the discussion was held as a group to facilitate discussion and questions, voting on each item was conducted via an anonymous survey. A final MPS was calculated by first averaging the percentage scores of the checklist items for each judge and then averaging the scores across judges.

Simulation Environment for Pilot Testing

The simulation sessions were held in the simulation lab using the Simulab Regional Anesthesia Trainer with SmartTissue (Simulab Corporation, Seattle, WA, USA). The participants were provided with an ultrasound machine, which included a linear high-frequency probe and an additional probe, either a phased array probe or a curvilinear probe. The trainees were responsible for selecting and preparing the appropriate probe but were allowed to ask for assistance with settings if they were unfamiliar with the ultrasound machine. In addition, a bucket of supplies was provided to the trainee, including chlorhexidine skin prep, ultrasound probe cover, ultrasound gel, 1-cc syringes labeled lidocaine 1% for skin local, 20-cc syringes labeled bupivacaine 0.5%, a stopcock, saline flushes, and 50-mm and 100-mm SonoPlex II (Pajunk GmbH, Geisingen, Germany) block needles. During the scenario, the trainee was responsible for selecting and assembling the supplies. At the beginning of the scenario, the instructor read an introduction to the simulation center and a brief case stem identifying the patient as a healthy 25-year-old male presenting for a shoulder arthroscopy. The trainee was then instructed to obtain informed consent for the procedure from the patient and then set up and perform the block. During the informed consent phase, the instructor played the part of the patient. During the procedure phase of the scenario, the instructor played the role of assistant, handing supplies to the participant as necessary. When the trainee was satisfied with the needle placement, the trainee asked the instructor to inject and gave instructions on the injection technique, continuous versus incremental. To simulate injection spread, the instructor would then tell the trainee where the instructor saw the spread of the injectate based on the position of the needle tip. The types of verbal feedback offered were "no spread identified, intramuscular spread, intra-plexus spread, intraneural spread, or peri-plexus spread." The scenarios were recorded using a camera trained on the simulator and a screen recording of the ultrasound.

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Pilot Procedure

Post-graduate year-2 resident anesthesiologists at NUFSM who had not started their regional anesthesia rotation participated in the pilot SBML curriculum to calibrate raters on checklist scoring. Pretests and posttests were video-recorded. After reviewing the pretests and posttests, a scoring rubric was developed by one author (JJW) with detailed instructions on how to grade each step, and it was then discussed among the NUFSM faculty responsible for rating the videos. This vital step helps to ensure consistency among raters. For example, if a trainee preps correctly but then contaminates the field, does the trainee lose points for the prep and aseptic technique or only the aseptic technique? Subsequently, the raters (JJW, LC, VGT, SMM) reviewed and scored the pretest and posttest videos using the checklist. One author (JJW) was established as the gold-standard rater because she would be primarily responsible for grading performance when the final SBML curriculum was initiated. Interrater reliability (IRR) was assessed using the kappa coefficient.[24] We also used the Fleiss' kappa (ƙ) to assess overall agreement among all 4 raters.[25]

Results

A 19-item checklist was developed and presented to the panel of 13 board-certified experts in Regional Anesthesiology and Acute Pain Medicine for the modified Delphi process. This panel of experts consisted of 54% (7 of 13) female members and had an average of 7.8 years of practice experience. Eighty-five percent (11 of 13) of the faculty members completed a fellowship in regional anesthesiology. The 2 faculty members who had not completed a regional anesthesia fellowship had each been in practice for more than 15 years. In the first round of the modified Delphi process, 12 of 13 expert panelists responded and achieved an 80% consensus on 12 of the 19 checklist items (Table 1). The remaining 7 items were edited based on the panel's recommendations and resubmitted to the panel for the second round of review. During this round, 11 of 12 panelists responded, and a consensus of at least 80% was reached on the remaining 7 items (Table 1). No items were added or omitted, resulting in a final checklist of 19 items that was graded dichotomously (done or not done/done incorrectly; Figure 1).

The standard-setting panel consisted of 10 expert judges, 9 of whom were practicing regional anesthesiologists, and 1 member was an expert in SBML and procedural skills (JHB). Five of the 9 practicing anesthesiologists had participated in the Delphi process during checklist development, and the other 4 consisted of authors (VGT, SMM, LC) and an additional member of the NUFSM regional anesthesia faculty. This panel of faculty members consisted of 40% females (4 out of 10) and had an average of 12.1 years of practice experience. The panel set the MPS at 95% items correct for the interscalene nerve block skills checklist, allowing trainees to miss 1 of 19 items.

Raters reviewed the 10 video-recorded pretests and 10 video-recorded posttests. All raters achieved substantial agreement when compared with the gold standard on the checklist (Cohen's ƙ between JW and LC was 0.73, JW and VGT was 0.73, and JW and SM was 0.73). Fleiss' kappa showed that there was substantial agreement between the 4 raters, ƙ=0.71 (95% confidence interval: 0.67–0.75, $p < .001$).

Discussion

This work developed a new ultrasound-guided interscalene nerve block SBML checklist. This checklist has content validity based on literature review and the modified Delphi process and exhibits significant IRR in a small, single-institutional pilot. Whereas existing checklists for UGRA have demonstrated excellent validity and reliability, they did not meet our needs due to their procedure type, development before the widespread use of ultrasound guidance, complexity, or references to local practices that may not be generalizable.[17–21] We established content and construct validity by referencing this previous work and using the Delphi panel of experts. The IRR was substantial based on the suggested classifications from McHugh.[24]

When creating this checklist, we sought to develop a tool that would not be overly cumbersome for a 20-minute scenario and could be graded in real time in the simulation center to allow for timely feedback and reliable rating (using dichotomous scoring). Most of our checklist focuses on behaviors that trainees must perform without direct supervision at the beginning of the rotation. The trainee often obtains informed consent, prepares supplies, and positions the patient before the supervising faculty member arrives. However, trainees may struggle without explicit instruction on how to execute these nontechnical skills. Additionally, certain essential behaviors are crucial to patient safety, including maintaining aseptic technique, maintaining continuous needle visualization, and ensuring the appropriate positioning of the blocked extremity. These items were intentionally included in the checklist to ensure trainees' awareness of these essential behaviors. The items that did not reach consensus in the first round of the Delphi panel reflected institutional variability in practice, such as the exact preparation and type of ultrasound and block equipment. In revising those items to reach consensus in the second round, our checklist became more generalizable outside our institution because it eliminated or minimized practices that were specific to our institution.

This checklist maps to some of the skills assessed in Anesthesiology Milestone, Patient Care 10: Regional (Peripheral and Neuraxial) Anesthesia.[26] This project can be used by program directors to help make Milestone scoring decisions for residents who reach the MPS on the checklist. The MPS correlates with Level 3 to 4 criteria (on simulators, not patients) for performance of an interscalene nerve block. As part of SBML, participants must reach an MPS on posttesting to complete the curriculum. The passing standard aims to establish the point at which the learner has developed an adequate level of skill on the simulator to perform the procedure safely on patients under faculty supervision. However, residents will still require additional clinical instruction and assessment on actual patients to ensure simulation education translates to patient care.

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Our study has several limitations. First, we cannot determine if checklist reliability can be established at other institutions due to the nature of our single-institution pilot. Additionally, SBML is resource-intensive, and other institutions may not have the faculty and simulation resources required to implement the checklist within an SBML curriculum. Significant time away from clinical duties may be required for faculty and trainees to participate in the curriculum. Future work will attempt to quantify the resources needed and whether this is feasible for programs. Second, our checklist focuses on one type of block. We attempted to design the checklist so that many of the skills measured could be translated to other UGRA procedures as this would allow a more streamlined development of similar checklists for different procedures. We also aim to assess skills that are transferable to other procedures, hoping that the interscalene can be used as representative block, but we did not intend for the simulation curriculum to replace the additional learning required to gain skills in all UGRA procedures. Additionally, some items on the checklist may not be universally practiced at all institutions (eg, saline injection, skin wheal). However, these items can be edited or excluded by individual institutions to fit their own practices. Third, the use of video-recordings likely affected the IRR for items that were difficult to assess via video, such as aseptic technique and hand hygiene. However, our average IRR for all items was substantial, indicating that most of the variability in performance was due to the participants' skills rather than variations among raters.

Conclusion

Our ultrasound-guided interscalene block SBML checklist aimed to assess the knowledge and skills of novice anesthesia residents for an interscalene peripheral nerve block. We chose an SBML approach given its previous success in other procedures, such as lumbar puncture and central venous catheter insertion.[11,12] We created a regional anesthesia checklist with early evidence of content validity (literature review and modified Delphi) and substantial IRR. Future research is needed to assess the validity and reliability of the checklist further when evaluating learners as they complete the SBML curriculum at our institution and others. By providing our novices with simulation education before they perform these procedures on patients, we aim to enhance trainee comfort and experience while also improving patient safety. In addition, given that this tool was designed to teach novice residents a single block before their rotation, future work to develop assessment tools directed at other procedures and more advanced skills required for practicing regional anesthesia on patients may provide trainees with valuable feedback and opportunities to improve before independent practice.

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Abstract

Background: Simulation-based medical education is a well-established tool for teaching technical skills to trainees. Simulation-based mastery learning (SBML) consists of pretesting, independent content review, deliberate practice, and posttesting to reach a minimum passing standard (MPS). If the MPS is not reached, the learner repeats the deliberate practice and retakes the test. SBML may be a beneficial approach for teaching regional anesthesia skills to novice residents. To implement such a curriculum, a skills assessment checklist that yields valid and reliable data must be developed for testing trainees.

Methods: A checklist was developed for ultrasound-guided interscalene nerve blocks, adapted from available checklists in the literature. The checklist was designed to assess the initial knowledge and skills of novice trainees for the interscalene peripheral nerve block. This checklist was then distributed to an expert panel of regional anesthesiologists who used a modified Delphi technique to reach consensus on content. An MPS was set for the skills checklist using the Mastery Angoff standard-setting technique. Finally, the checklist was piloted; novice anesthesia residents participated in the curriculum and performed video-recorded simulated ultrasound-guided interscalene blocks before beginning their regional anesthesia rotation. Four trained raters scored videos to evaluate interrater reliability.

Results: After 2 rounds, expert consensus was reached for all items; the final dichotomous checklist (correct or incorrect/not done) consisted of 19 items. The MPS was set at 18 of 19 items correct. Ten pretests and 10 posttests were reviewed by 4 raters. The average interrater reliability was Kn = 0.73.

Conclusion: We developed an interscalene nerve block skills assessment checklist that was shown to produce valid and reliable data in our small pilot study. Future work will further contribute to the validity and reliability of the interscalene nerve block SBML checklist.

Keywords: Regional anesthesiology, medical education, simulation, checklist

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Figure

Figure 1. *Final ultrasound-guided interscalene block skills checklist.*

Checklist Item	Done	Not Done / Done Incorrectly
1. Decontaminates hands (must be done before physical contact with the patient)		
2. Obtain informed consent (must meet all 6 criteria) a. Explains steps of procedure: use of ultrasound, administration of local anesthetic around nerves (2 of 2) b. Risks: bleeding, infection, nerve injury (3 of 3) c. Side effects: diaphragmatic weakness, hoarseness, Horner's syndrome (2 of 3) d. Benefits: avoidance of general anesthesia, post-op pain control, and decreased opioid consumption (2 of 3) e. Offers alternatives: IV and PO analgesics (1 of 2) f. Patient gives consent		
3. Time out with 2 persons present (2 patient identifiers, allergies, anticoagulation, site marked, consent(s) verified)		
4. Properly sets up block apparatus with needle, +/-saline, local anesthetic		
5. Prepare a clean high-frequency ultrasound probe, +/- probe cover		
6. Appropriate ASA monitors are applied (SpO2, EKG, NIBP)		
7. Position patient supine and head up, turn head slightly to contralateral side, arm resting at side		
8. Don gloves		
9. Prep skin of the supraclavicular fossa and lower neck with chlorhexidine, scrub back and forth for 30 seconds		
10. Plexus scanned until identified in interscalene groove		
11. Performs survey scan and identifies structures pertinent to the procedure a. Upper trunk of brachial plexus (c5 and c6) b. Anterior and middle scalene muscles c. Evaluates for blood vessels in the image (visual scan or color doppler)		
12. Skin wheal with 1% lidocaine		
13. Keep needle visible when advancing, does not advance needle without visualization		
14. Aspirate before injection of local anesthetics		
15. Small (1- to 2-mL) initial injection saline or injectate to verify spread around plexus with ultrasound and confirm low injection pressure		
16. Confirmation of local anesthetic spread in relation to the nerve and adjusts needle position to optimize		
17. Ask for proper aspiration every 3- to 5-mL increment injection, up to 20 mL based on spread		
18. Provides padding to blocked extremity		
19. Maintained aseptic technique throughout entire procedure		
TOTAL	/19	

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Table

Table 1. *Modified Delphi Results*

	Round 1 (12 panelists)			Round 2 (11 panelists)		
Item	Include	Exclude	Edit	Include	Exclude	Edit
1. Hand decontamination	83.33%	16.67%	0			
2. Informed consent	66.67%	0	33.33%	90.9%	0	9.1%
3. Time out	75%	0	25%	90.9%	0	9.1%
4. Block apparatus	33.33%	25%	41.67%	81.81%	0	18.19%
5. Prepare probe	66.67%	8.33%	25%	100%	0	0
6. ASA monitors	100%	0	0			
7. Patient position	100%	0	0			
8. Gloves	83.33%	8.33%	8.33%			
9. Skin prep	91.67%	0	8.33%			
10. ID plexus	91.67%	8.33%	0			
11. Survey scan	75%	0	25%	90.9%	0	9.1%
12. Skin wheal	75%	8.33%	16.67%	81.81%	0	18.19%
13. Needle visibility	100%	0	0			
14. Aspirate before local	100%	0	0			
15. Test injection	8.33%	58.33%	33.33%	100%	0	0
16. Confirmation of spread	100%	0	0			
17. Incremental injection	91.67%	0	8.33%			
18. Padding to extremity	83.33%	16.67%	0			
19. Aseptic technique	1%	0	0			

Checklist items descriptions can be found in Figure 1.