Using a Simulated Model and Mastery Learning Approach to Teach the Ultrasound-guided Serratus Anterior Plane Block to Emergency Medicine Residents: A Pilot Study

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ABSTRACT

Background: The serratus anterior plane block (SAPB) is a safe, single-injection alternative for pain control in patients with rib fractures. This pilot study aims to teach the ultrasound-guided SAPB to emergency medicine (EM) residents using a mastery learning approach.

Methods: A 19-item checklist was created and mastery was determined to be 17 of 19 items correct. This pass score was established using a Mastery Angoff standard-setting exercise with a group of EM experts. Learners participated in baseline testing on a simulated model and performance was assessed by two raters. Learners then watched an instructional video and participated in an individualized teaching session. Learners underwent deliberate practice followed by posttesting until mastery was achieved. Score differences in baseline testing and posttesting were analyzed using a paired t-test. Pre- and posttesting surveys were also completed by participants.

Results: Twenty-eight PGY-1 to -4 residents volunteered to participate in the study. The range of reported SAPBs seen previously was 0 to 5. The mean ($\pm$ SD) number of items correct on the checklist for initial testing was 8.5 of 19 ($\pm$ 2.7), while the mean ($\pm$ SD) final score was 18 of 19 ($\pm$ 0.6; $p < 0.001$). All participants met mastery standards after the curriculum intervention. Median self-reported procedural confidence was 2 out of 5 on a 5-point Likert scale before the session and 5 out of 5 after the session ($Z = -4.681$, $p < 0.001$).

Conclusions: Using a mastery learning approach and simulated model, we were able to successfully train EM residents to perform the SAPB at a level of mastery and increase their overall confidence in executing this procedure.

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Rib fractures are a frequently encountered injury in emergency department (ED) patients and represent the most common finding in blunt thoracic trauma.¹ Inadequate pain control in patients with rib fractures can lead to poor oxygenation and ventilation as well as complications such as atelectasis and pneumonia.^{2,3} A patient's respiratory status might be further compromised by the effects of traditional pain control with intravenous opioids. Regional anesthesia is a helpful alternative to opioids in the ED, especially in patients with severe pain, who are more than 65 years of age, or who have multiple rib fractures.⁴ There are well-described regional anesthesia techniques for pain associated with rib fractures, including the paravertebral block, intercostal block, and epidural analgesia, but each of these can be technically challenging.² The serratus anterior plane block (SAPB) is a myofascial plane block that was first described in 2013.⁵ Compared to other regional anesthesia techniques, the SAPB is a good option for emergency providers due to its safety profile and technical ease of the procedure.⁶ Given the relatively recent movement to treat rib fractures using the SAPB technique in the ED, there exists a lack of educational materials and competency testing standards.

The SAPB is a technique that blocks the lateral branches of the intercostal nerves via the myofascial plane surrounding the serratus anterior muscle, which lies deep to the latissimus dorsi in the thorax.^{7,8} Anesthetic introduced into the plane superficial or deep to the serratus anterior provides analgesia to the anterolateral hemithorax, allowing for pain relief for rib fractures in the anterior two-thirds of the chest wall.³ The SAPB involves a single injection and allows for flexibility in patient positioning. Additionally, it has been described for use in patients with higher risk of complications such as those with dementia, coagulopathy, and morbid obesity.^{9,10} The SAPB has been shown to be safe and effective in the anesthesia literature for thoracotomy pain and has been described in the ED setting as a feasible option for treating acute pain associated with rib fractures.^{6,11-13}

Mastery learning is an approach of ensuring learners attain a high level of procedural skills, but to date there is no standard checklist available for teaching or performing the SAPB in the ED. Compared to traditional teaching practices, mastery learning is associated with better learning outcomes.¹⁴ A simulation-based mastery learning (SBML) session is one in which participants use individualized, deliberate practice of a

particular skill until they demonstrate that they can perform to a predetermined mastery level. The amount of practice needed to achieve mastery may vary between providers, but the final determination of achieving mastery is uniform. Mastery learning is an effective method of teaching multiple emergency medicine (EM) skills and procedures including paracentesis,¹⁵ lumbar puncture,¹⁶ thoracentesis,¹⁷ central venous catheter insertion,^{18,19} and thoracotomy.²⁰ Mastery learning has also been shown to result in higher first success rates and lower adverse patient safety events such as reduction of catheter-related bloodstream infections.²¹ Given the success of mastery learning in teaching other procedures, we thought it appropriate to use a mastery learning approach to teach residents the SAPB.

The objectives of this pilot study were to: 1) create the first checklist on performance of a SAPB based on EM expert consensus and define the minimum passing score (MPS) for achieving mastery and 2) determine if a mastery learning session could increase EM resident procedural competence as well as confidence in performing the SAPB.

METHODS

Study Design

This was a quasi-experimental pilot study of SBML training session for EM residents at a single university. Institutional research board approval was obtained through Stanford University (Protocol # 53620).

Study Setting and Population

All EM residents ($n = 58$) across all training levels of training (i.e., postgraduate year (PGY)-1 through -4) within Stanford University's EM residency program were invited to participate. Consent was obtained prior to participation. A low-cost model was developed specifically for this study to provide an opportunity for simulated practice. The model was created to represent the identifiable muscle layers on an actual patient using synthetic skin, ballistic gel, plastic wrap with petroleum jelly, and rawhide bones. Components were selected that were reusable, were nonperishable, and allowed for needle visualization under ultrasound guidance. In addition to the simulated model, during most sessions landmarks were also identified on a human, usually an EM physician or volunteer who agreed to be an ultrasound model specifically for that session; otherwise the SBML instructor assumed this role.

Study Protocol: Mastery Learning Checklist Development

Four EM faculty credentialed in ultrasound and trained in medical education initially developed a checklist based on clinical experience and empirical evidence collected in a literature review. This checklist was later presented and edited using a larger group of faculty experts. Experts were defined as fellowship-trained ultrasound faculty with experience in the SAPB (8) and medical education faculty (4). There were six women and six men. To increase representation of ultrasound and education experts, the checklist was debated over a video conference by EM ultrasound fellowship-trained faculty from two local institutions with EM training programs, two from Highland Hospital, Alameda Health System, and three from University of California San Francisco–Zuckerberg San Francisco General Hospital. Consensus on the final checklist was reached in two rounds.

Once the checklist was developed, a standard-setting exercise was performed using a Mastery Angoff method.²² A PhD expert trained in measurement and assessment helped moderate the standard-setting session to ensure scientific rigor. Eight of the experts who volunteered for the checklist development also served as judges during the standard setting to determine a MPS, including four women and four men. The MPS upon completion of the standard-setting exercise was 17 of 19 items correct.

Study Protocol: Measurements

All 58 residents were offered the opportunity to receive SAPB training. Participation in the study was voluntary. After providing informed consent, participants were assigned a number to deidentify their performance scores and survey data. Participants completed a brief four-question presurvey developed specifically for this study with questions about PGY year, prior SAPBs observed, overall confidence level, and barriers to performing the SAPB procedure (please see Data Supplement S1, Appendix S1, available as supporting information in the online version of this paper, which is available at <http://onlinelibrary.wiley.com/doi/10.1002/aet2.10525/full>). The primary goal of the survey was to collect data on self-reported confidence level before and after the training. After completing this survey, participants were given a standard prompt and asked to perform the procedure from start to finish on the simulated model. This

attempt was scored as the baseline assessment by two raters who were physically present to observe and score participants in real time using a paper checklist. Each rater was involved in the development of the checklist and was familiar with the criteria to fulfill each step. One primary rater was present during all sessions. A start and end time for each procedure attempt was also documented.

Once participants performed their baseline assessment, they were given the opportunity to ask questions. They then watched a 6-minute standardized instructional video. After the video, additional teaching was tailored to the learners' needs and checklist omissions. The appropriate landmarks were visualized with ultrasound on a human as well as the simulated model. Each participant was able to practice the procedure on a simulated task-trainer model as many times as desired to reach procedural comfort. Participants did not directly review the checklist during the session.

Once deliberate practice was completed, a posttest was performed. The same prompt was given to complete the procedure from start to finish, followed by a test out using the checklist that was completed by the same two raters. The participant achieved mastery if the MPS of 17 of 19 items or more were correctly performed. If mastery was not achieved, the participant went through additional teaching and deliberate practice prior to repeating the assessment. After the session the participant completed a three-question postsurvey that asked about PGY level of training, self-reported confidence in the procedure, and model realism. In addition, there were two open-ended questions for feedback on the session not included in the analysis, including what participants found helpful about the mastery learning session and what they would change. Data from all three paper sources (presurvey, checklists, and postsurvey) were deidentified and entered into a secure password protected spreadsheet using the assigned participant number.

Data Analysis

Score differences on the baseline performance and postcurriculum intervention were analyzed by using a paired t-test (Microsoft Excel, 2019). Inter-rater reliability was calculated using Cohen's kappa (κ) coefficient (IBM SPSS Statistics for Windows Version 24.0, 2019). The presession and postsession surveys were analyzed using descriptive statistics and a Wilcoxon signed-rank test.

RESULTS

A total of 28 (48%) residents participated in the pilot study (for the breakdown by PGY; please see Table 1). In presession survey data, 12 of 28 participants (43%) had previously seen a SAPB performed in the clinical environment. The average number of SAPBs seen ranged from 0 to 5 blocks and was variable across levels of training. However, the most frequently reported number of blocks previously seen was 0. Prior to the session, participants' overall self-reported confidence in the procedure had a median rating of 2 (interquartile range [IQR] = 1–2) on a 5-point Likert scale, which corresponded to “slightly uncomfortable.” The median (IQR) confidence ratings were similar across PGY level (PGY-1 = 2 [1.5–2.5]; PGY-2 = 1 [1–2]; PGY-3 = 2 [2–4]; PGY 4 = 2 [1.75–2]). Participants were asked to select the greatest barriers to performing the SAPB in the ED from options including not knowing where materials are located, no time on shift, confidence in procedure, attending not comfortable with procedure, procedure not indicated for rib fracture location, and patient declines. The most commonly reported barrier was learner confidence in the procedure. The least

commonly reported barrier by participants was the patient declining the procedure.

Twenty-eight participants completed baseline testing and posttesting until mastery was reached. None of the study participants met the MPS at baseline. After completion of the session, all participants reached the MPS (see Figure 1). Twenty-four participants (86%) achieved the MPS on initial posttesting and the additional four (14%) reached MPS after one session of additional deliberate practice. Comparison of mean ($\pm$ SD) scores from baseline testing to final posttesting were significant with 8.5 of 19 ($\pm$ 2.7) items correct to 18 of 19 ($\pm$ 0.6) items correct ($t(28) = 16.9$, $p = <0.001$; Table 2).

Content validity for the checklist came from a literature review and expert contribution to checklist items to best represent the content domain of interest. Internal consistency was determined using interrater reliability, which highlights the agreement between checklist scores for the two raters that scored each resident. There were seven rater-pair combinations, each with a Cohen's kappa ranging from 0.44 to 1.00. The overall Cohen's kappa was calculated to be 0.74, suggesting an overall moderate agreement among raters (see Table 3).

A Wilcoxon signed-rank test showed that the mastery learning session on SAPB yielded a statistically significant increase in participants' confidence levels upon completing the SAPB procedure ($Z = -4.681$, $p < 0.001$). The overall median (IQR) confidence rating was 5 (4–5) out of a 5-point Likert scale post-session, which corresponded to “very comfortable” performing the procedure. Similar increases in self-rated confidence were seen across PGY levels

Table 1
Demographic Data for EM Resident Participants by PGY

Year in Training	Participants (N = 28)
PGY-1	7 (25)
PGY-2	8 (29)
PGY-3	5 (18)
PGY-4	8 (29)

Data are reported as *n* (%).

Figure 1. Baseline assessment score versus test-out score.

Table 2
Baseline and Test-out Scores for Participants

Participant Number	Baseline Score (%)	Test-out Score (%)
1	45	89
2	63	95
3	58	95
4	37	92
5	37	95
6	47	95
7	66	100
8	32	95
9	21	95
10	34	92
11	42	89
12	32	100
13	50	95
14	37	95
15	68	95
16	68	95
17	47	89
18	58	95
19	53	95
20	37	89
21	32	100
22	74	89
23	26	95
24	21	89
25	34	95
26	58	89
27	50	95
28	47	95
Mean	46	94

Table 3
Kappa (κ) Statistic and Standard Errors for Rater Pairs

Rater Pair	Kappa (κ)	Standard Error
1	0.525	0.141
2	0.438	0.201
3	0.619	0.197
4	1.00	0.000
5	1.00	0.000
6	1.00	0.000
7	0.600	0.187
Overall	0.740	0.103

(PGY-1 = 5 [4.5–5.0]; PGY-2 = 5 [4–5]; PGY-3 = 4 [4–5]; PGY = 4 [4–5]).

DISCUSSION

The application of SAPB regional anesthesia is increasing in popularity within ED settings,^{6,23} yet research

around teaching this procedure has been underexplored. Our single-institution pilot study contributes to the literature through the creation of a procedural checklist for the SAPB and implementation of a simulation training session using a mastery learning approach.^{15–19,21,24–26} Through this preliminary study, we demonstrated that a SBML technique can be used to achieve mastery standards as defined by a panel of experts as well as improve overall confidence in performing the SAPB. We theorize that this type of educational intervention can help facilitate procedural teaching and improve clinical care.^{17–19,22,25,26} Given the relatively recent introduction of the SAPB into ED care, it is important to establish evidence behind methods to teaching this procedure.

Participation in skills training can increase both confidence and competence.²⁷ Prior to the educational intervention, none of the participants achieved the MPS or reported feeling “very comfortable” with the procedure. Despite this, the majority of the participants (24/28, 86%) were able to achieve the MPS on their first attempt after viewing the educational video and engaging in deliberate practice with the simulated model. After the intervention, all of the participants self-reported a statistically significant increase in confidence when performing the procedure. This increase in confidence may facilitate the willingness to perform the procedure in the ED setting, which is particularly important given that participants reported seeing few SAPB prior to the training.

Participants reported a few barriers to performing the SAPB during clinical practice, the most common of which was learner confidence. By increasing learner confidence in the procedure through this educational intervention and standardized evaluation, we effectively addressed the most significant barrier to performing the procedure. In a similar vein, “attending not comfortable with the procedure” was noted to be a barrier for participants. Given the increase in resident confidence, and the fact that residents and attendings work so closely together, future research could explore attending physicians’ comfort and competence in performing the SAPB procedure.

Further investigation will be important to assess long-term retention of the SAPB procedural skill. In addition, it will be necessary to study the transfer of demonstrated procedural competence in the simulated setting to successful performance of the SAPB in clinical practice. This may incorporate clinical data to determine how frequently residents and attending

physicians are performing the SAPB and if those who participated in the SBML training perform the procedure more often, with greater efficacy, or with fewer complications. Finally, ultrasound images should be reviewed for quality improvement purposes to correlate needle guidance and anesthetic deposition with achievement of analgesia for the patient. This requires further investigation with clinical studies.

LIMITATIONS

Our study has some limitations. First, this pilot study was held at a single EM residency program equipped with five ultrasound fellowship-trained faculty, one ultrasound fellow, and additional faculty members who have experience performing the SAPB. This expertise may limit the reproducibility across other sites and nonacademic centers. Furthermore, during development of the checklist, the same experts involved in vetting of checklist items were also involved in setting the MPS. Some of the raters involved in the baseline and posttesting were also involved in the checklist creation and standard setting. This could have introduced bias into the perceived achievable MPS and actual performance of resident participants.

Second, the overall small size of the study population at a single institution limits generalizability to all trainees in EM. If they did not volunteer to participate during the designated conference day, residents joined the session on their own time, which was challenging to coordinate in the context of a busy clinical schedule. Given that slightly less than half of all residents elected to participate, there exists the possibility of a selection bias. Although we offered some sessions during resident conference to make participation easily accessible for all residents, there exists the possibility that those who chose to participate may have been more interested in learning ultrasound-guided regional anesthesia or were perhaps more confident in their procedural skills. We did not assess resident competence or previous experience performing regional anesthesia prior to this intervention nor did we collect demographic data apart from PGY level to determine if these were associated with baseline assessment scores. Both of these are areas for future research and investigation. Viewed comprehensively, these factors limit the generalizability to all residents regarding attainment of the MPS. Of note, recruitment of additional participants was halted by new regulations for social

distancing that started in early March 2020; it is likely that more residents would have participated if enrollment had continued. Finally, and perhaps most importantly, despite participants demonstrating the ability to perform the necessary steps to complete the mastery learning module with competence, it is unclear how well this correlates with clinical proficiency or longitudinal maintenance of procedural skills. Future studies should aim to address these limitations by incorporating multiple study sites with greater numbers of participants and raters. When possible, raters should ideally be independent and not associated with the checklist development group. It would be beneficial to assess whether there are any factors that predict performance of baseline testing to better cater to the individualized learning needs. Longitudinal skill assessments could help assess for knowledge retention. Finally, research is needed on the clinical implications of mastery learning to perform this block and how it relates to patient outcomes in the ED setting.

CONCLUSION

This pilot study demonstrates the successful application of a simulation-based mastery learning framework to teaching the serratus anterior plane block to emergency medicine residents. This approach allowed resident participants to demonstrate high procedural competency and increase confidence in the procedure. This work has implications for how we determine standards and educate residents about approaching pain management using regional anesthesia in patients with rib fractures.

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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/aet2.10525/full>

Data Supplement S1. Supplemental material.