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A novel interventional pain simulation-based education curriculum: Implementation to enhance procedural training

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ABSTRACT

Several studies have demonstrated the benefits of simulation-based education (SBE) across all trainee levels in various medical fields. These benefits include allowing trainees greater autonomy and the opportunity to learn from mistakes in bioethical and procedural scenarios without compromising patient safety. While much progress has been made, there is little research on the implementation of SBE in pain medicine. This study investigated the effects of interventional pain SBE on 37 pain medicine fellows at the Brigham and Women's Hospital Pain Medicine Fellowship. The study found that fellows' performance, knowledge, and comfort were enhanced by the implementation of this curriculum.

1. Introduction

Interventional spine procedure training is an integral part of pain medicine fellowships. Hands-on practice during fellowship is essential for gaining clinical competency and confidence. Simulation-based education (SBE) is a form of experiential learning in a safe environment which aims to mimic realistic patient interactions and/or procedures. SBE has become an important aspect of formative medical training over the past two decades [1]. SBE fosters interactive and immersive activity by recreating a clinical experience, giving trainees independence while eliminating risk to patients. SBE can be adapted to a wide variety of clinical content [2,3].

SBE offers trainees the opportunity to practice technical skills as well as manage dynamic, complex and rare, but critical events. It is becoming ever more integrated into all levels of medical training [1,4]. Task trainers, or partial task trainers, are simulators that represent a body part and are utilized to practice key elements of a procedure, such as IV placement or airway management [5,6]. As development of competence in procedure performance requires understanding of anatomy, comfort with the technical steps, as well as psychomotor skills, partial task trainers are helpful simulation modalities for procedure training [5,6]. Other simulation modalities include human patient simulators or full body manikins varying in levels of fidelity, standardized patients, and virtual reality and augmented reality environments [6].

With simulation training, studies have shown improved performance of various technical skills, such as vascular surgical residents demonstrating decreased time for completion of iliac artery angioplasty and stenting, as well as decreased use of contrast dye and fluoroscopy time [7]. In the field of pain medicine, SBE has been described for crisis resource management, addressing complications associated with interventional pain procedures, and bioethics, including practicing difficult conversations [8–10]. However, studies involving SBE in pain medicine have been sparse [10], and a formal SBE curriculum for fluoroscopic-guided spine procedures has not been previously described.

As SBE can help trainees learn advanced procedural skills without risk to patients and provides a safe learning environment for trainees to identify knowledge gaps, ask questions, and learn from mistakes [1,11], an SBE curriculum was developed for pain medicine fellows. The goal was to implement an SBE curriculum to enhance training of fluoroscopic-guided spine procedures during pain medicine fellowship, with the hypothesis that implementation of this curriculum for pain medicine fellows is feasible and acceptable to trainees and teaching faculty.

Additional aims were to increase fellows' comfort with performing

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various spine interventions and enhance their understanding and knowledge of fluoroanatomy and C-arm manipulation, spine anatomy, procedure techniques, and radiation safety, all in the context of a realistic procedural experience. Furthermore, with the known risks of radiation exposure to patients, physicians, and additional team members, and with consideration of mitigation strategies for radiation exposure governed by the principles of 'as low as reasonably achievable' (ALARA) [12], another goal was to help fellows improve their technique to reduce procedure time and radiation exposure.

2. Methods

The research protocol in this study was approved by the institutional review board at the institution where the research was conducted (IRB protocol 2020P003625). Written informed consent was obtained from all subjects.

2.1. Study population

The study population was a cohort of pain medicine fellows from three academic years between 2018 and 2021 in the Department of Anesthesiology, Perioperative and Pain Medicine at Brigham and Women's Hospital, affiliated with Harvard Medical School in Boston, MA. Participants in this study included pain medicine fellows from various specialty backgrounds, including anesthesiology, physical medicine and rehabilitation, psychiatry, and emergency medicine.

The Standards for Quality Improvement Reporting Excellence 2.0 guidelines were incorporated when preparing this manuscript [13].

2.2. SBE curriculum

The curriculum was initially developed by three of the authors (D.L.S., E.R.N., R.J.Y.), all board-certified in pain medicine and faculty members of Harvard Medical School. The curriculum was first integrated into the pain medicine fellowship educational program during the 2018–2019 academic year and has been implemented to the present time.

Three simulation sessions were implemented per academic year, teaching various interventional spine procedures. Each academic year, fellows simulated lumbar interlaminar epidural steroid injections (LESI) and lumbar transforaminal epidural steroid injections (L TFESI) at the first session, lumbar medial branch blocks (L MBB) and S1 TFESI at the second session, and cervical medial branch blocks (C MBB) at the third session.

2.3. Simulation modalities

For procedure simulation, fellows simulated the spine procedures on two spine training systems (BioTras, Dallas, TX) comprised of a full cadaveric spine and pelvis encased in a thermoplastic mold and covered with removable simulation skin.

2.4. Debriefing/feedback

After each procedure, the faculty member observing the simulation provided debriefing, verbal feedback, and review of the appropriate techniques. The fellows then went to the didactics station outside of the procedure room for further discussion, as described below. After the didactic session, the fellows attended a procedure demonstration by a faculty member utilizing the spine training system with fluoroscopic guidance. Starting in the 2019–2020 academic year, virtual reality videos were recorded during the sessions and videos of their individual procedure performance were provided to each fellow as video feedback. The fellows could review their technique as well as the verbal feedback received during the session in a virtual reality platform for enhanced learning post-simulation session.

2.5. Didactics

For each session, a didactics station was established, and teaching materials were created, including PowerPoint presentations highlighting relevant spine and fluoroanatomy, clinical indications for the procedures, evidence related to the procedures, and procedure techniques including needle placement, optimal fluoroscopic views, contrast patterns, and safety considerations. Didactics were based upon practice guidelines from the Spine Intervention Society [14] and content from the Atlas of Image-Guided Intervention in Regional Anesthesia and Pain Medicine, 2nd Edition [15], the Atlas of Image-Guided Spinal Procedures, 2nd Edition [16], and relevant studies. The didactics portion of the simulation session provided additional opportunities for the fellows to debrief about their simulation procedure experience and ask questions.

2.6. Surveys and questionnaires

Written surveys for pre- and post-simulation sessions were developed and administered anonymously, utilizing participant identification numbers. All surveys assessed the fellows' comfort with the procedure, fluoroanatomy, and directing the C-arm. The pre-session survey also assessed how many times they previously performed the procedure. In the post-session survey, fellows were asked how helpful they thought the course was, whether the session will change the way they perform fluoroscopic-guided spine procedures in the future, if the session provided them with a better understanding of fluoroanatomy, the likelihood that they would use the model again to practice fluoroscopic-guided spine procedures, and whether they felt the simulation provided a realistic procedural experience (Kirkpatrick Level 1/Reaction) [17]. Knowledge Check questionnaires related to the procedures (pre- and post-session) were included in the 2020–2021 academic year (Kirkpatrick Level 2/Learning) [17]. In 2021, a post-fellowship online survey (REDCap, Nashville, TN) was emailed to fellows who graduated from the program (Kirkpatrick Level 3/Behavior) [17] to assess if skills learned during the simulation sessions were utilized in their clinical practice after training.

2.7. Simulation sessions

Upon arrival at each session, fellows completed the written pre-session survey. In the academic year 2020–2021, fellows also completed Knowledge Check questionnaires. Initially, paper surveys were administered, with a transition to utilizing online surveys for the 2020–2021 academic year sessions.

Two procedure rooms were utilized concurrently, with one fellow and one simulation program faculty member in each room. The trainee was asked to perform a specific procedure without prior notice regarding which procedure they would perform. The trainee was asked to simulate a true patient interaction by donning gloves and doing the procedure as if the training system was a patient. The fluoroscopy machines were operated by resident volunteers.

During the procedure, resident volunteers collected data including time it took to perform the procedure (sec), number of fluoroscopic images taken, and total radiation dosage (mGy). Procedure time began the moment the fellow requested the first fluoroscopic image and ended once the fellow perceived the needle was in its final position (just before contrast or medication would be administered) and indicated the task was complete. Fellows were then given the chance to pull back the spine model skin to reveal their final needle position in the translucent spine model. Photos were taken of the final fluoroscopic images in multiple views for reviewing procedural accuracy.

2.8. Skills stations

Due to the nature of the simulation sessions, where only two trainees were performing the simulated procedures at any given time, there was some inherent downtime during each session. During this downtime, trainees engaged in skills stations, where they learned additional skills by participating in physical exam stations and industry-sponsored demonstrations of a variety of pain management devices and/or medications, including dorsal root ganglion stimulation, spinal cord stimulation, and Botox injection for migraines. The sequence of events for the simulation session is shown in Fig. 1.

2.9. Statistical analysis

Paired pre- and post-session procedure times, numbers of fluoroscopic images, radiation doses, knowledge about procedures, levels of comfort performing procedures, and levels of comfort with fluoroanatomy and directing the c-arm were compared using Wilcoxon signed-rank tests. Effect sizes were quantified as median post-vs. pre-session differences with 95% confidence intervals (CIs). All statistical hypothesis tests were two-sided with no correction for multiple testing. Statistical analyses were performed with SAS software version 9.4 (SAS Institute, Cary, NC) and R software version 3.5.2 (R Foundation for Statistical Computing, Vienna, Austria).

An a *priori* power analysis determined that for an outcome with standard deviation that is 10% as large as the mean, inclusion of at least 10 participants would provide 99% power at a two-sided alpha level of 0.5 to detect a 20% change post vs. pre-curriculum.

2.10. Kirkpatrick model

The curriculum was assessed by Kirkpatrick level 1, reaction and opinion; Kirkpatrick level 2, acquisition of knowledge and skills; and Kirkpatrick level 3, application of learning [17].

3. Results

The final cohort consisted of 37 pain medicine fellows at the Brigham and Women's Pain Medicine Fellowship in the Department of Anesthesiology, Perioperative, and Pain Medicine.

There were 11–14 fellows from multiple specialties per academic year. Most participating fellows completed anesthesiology residencies (n = 33), and some fellows completed physical medicine and rehabilitation (n = 2), psychiatry (n = 1), or emergency medicine (n = 1) residencies.

The number of procedures each fellow performed during the current year, stratified by procedure type, are reported in Table 1. A substantial percentage of participants had performed at least 10 LESI, L MBB, and Cerv MBB C2/3 or C3/4 procedures prior to the corresponding procedure's simulation session (46.7%, 75.8%, and 75.8%, respectively), whereas only a small percentage of fellows has performed at least 10 L TFESI or S1 TFESI procedures prior to receiving the corresponding curriculum (3.3% and 9.1%, respectively) (Table 1).

LESI = lumbar interlaminar epidural steroid injection; L TFESI = lumbar transforaminal epidural steroid injection; L MBB = lumbar medial branch block; S1 TFESI = S1 transforaminal epidural steroid injection; C MBB = cervical medial branch block.

A notable within-participant decrease in procedure time (median change [95% CI]: −62.0 [−77.0, −37.5] seconds; $P < 0.001$) was observed for the LESI procedure post- vs. pre-session (Table 2, Fig. 2). Within-participant changes in procedure time and number of fluoroscopic images were not detected for L TFESI, L MBB, S1 TFESI, or C MBB C2/3 or C3/4 (Table 2). Within-participant changes in radiation dose were not detected for any procedure (Table 2).

A minimum median 20% point increase in procedure knowledge was observed for all procedures post- vs. pre-session (Table 3, Fig. 3). The

Table 1
Fellows' baseline experiences with LESI, L TFESI, L MBB, S1 TFESI, and C MBB C2/3 or C3/4.

Procedure	Number of procedures performed this year, n (%)					
	N	<5	5–9	10–19	20–29	30+
LESI	30	9 (30)	7 (23.3)	7 (23.3)	5 (16.7)	2 (6.7)
L TFESI	30	19 (63.3)	10 (33.3)	1 (3.3)	0	0
L MBB	33	2 (6.1)	6 (18.2)	8 (24.2)	12 (36.4)	5 (15.2)
S1 TFESI	33	19 (57.6)	11 (33.3)	3 (9.1)	0	0
C MBB C2/3 or C3/4	33	3 (9.1)	5 (15.2)	10 (30.3)	12 (36.4)	3 (9.1)

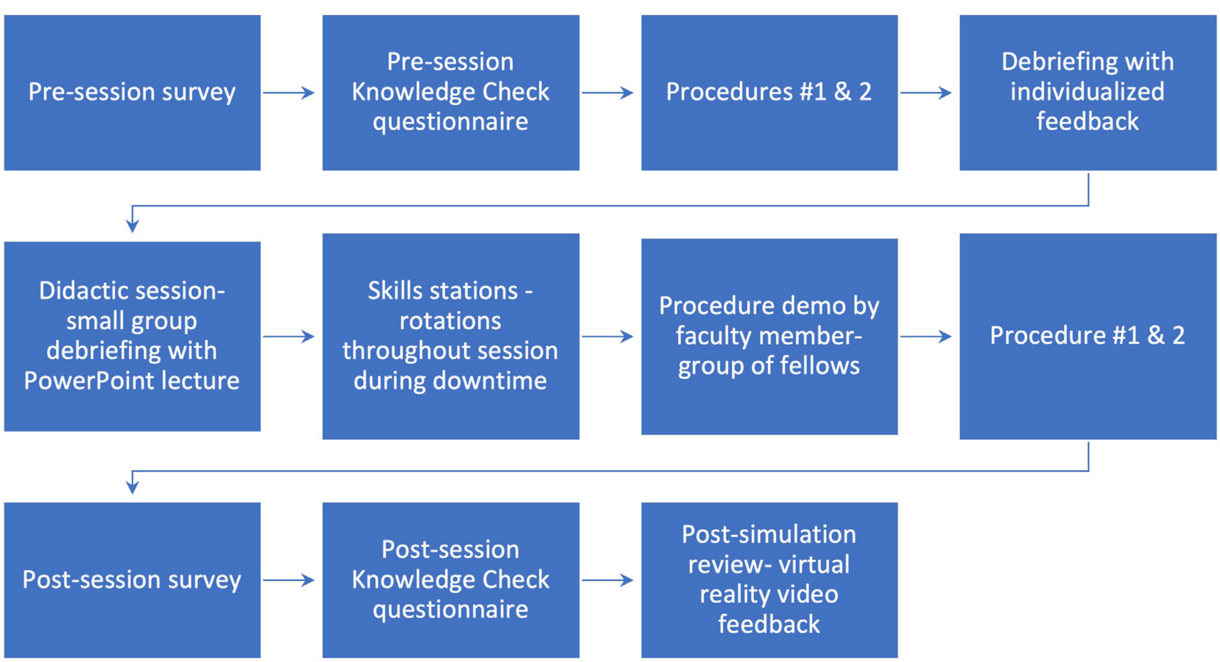

Fig. 1. Sequence of events for simulation session, from the 2018–2019 academic year to the 2020–2021 academic year. The pre-session knowledge check questionnaire and the post-simulation review with virtual reality video feedback were only conducted for the 2019–2020 academic year.

Table 2
Median within-participant changes in procedure time, number of fluoro images, and radiation dose post- vs. pre-session.

Procedure	N	Median change (95% CI)	P value[A]
LESI			
Procedure time (sec)	30	−62.0 (−77.00, −37.5)	<0.001
Number of fluoro images	30	−3.0 (−5.0, −1.5)	0.001
Radiation dose (mGy)	30	−0.08 (−0.16, 0.01)	0.075
L TFESI			
Procedure time (sec)	29	−24.0 (−103.5, 16.5)	0.289
Number of fluoro images	29	−2.0 (−7.5, 1.5)	0.223
Radiation dose (mGy)	29	−0.13 (−0.32, 0.02)	0.074
L MBB			
Procedure time (sec)	33	18.6 (−10.5, 41.0)	0.204
Number of fluoro images	33	0.5 (−2.5, 4.0)	0.739
Radiation dose (mGy)	33	0.06 (−0.09, 0.23)	0.411
S1 TFESI			
Procedure time (sec)	33	−27.5 (−65.5, 20.5)	0.249
Number of fluoro images	33	−2.0 (−4.5, 2.9)	0.078
Radiation dose (mGy)	33	−0.03 (−0.18, 0.14)	0.694
C MBB C2/3 or C3/4			
Procedure time (sec)	33	6.5 (−53.5, 70.5)	0.844
Number of fluoro images	33	1.5 (−3.5, 6.0)	0.480
Radiation dose (mGy)	33	0.03 (−0.09, 0.17)	0.701

LESI = lumbar interlaminar epidural steroid injection; L TFESI = lumbar transforaminal epidural steroid injection; L MBB = lumbar medial branch block; S1 TFESI = S1 transforaminal epidural steroid injection; C MBB = cervical medial branch block; CI = confidence interval.
A = Paired post-vs. pre-session measurements were compared using Wilcoxon signed-rank tests.

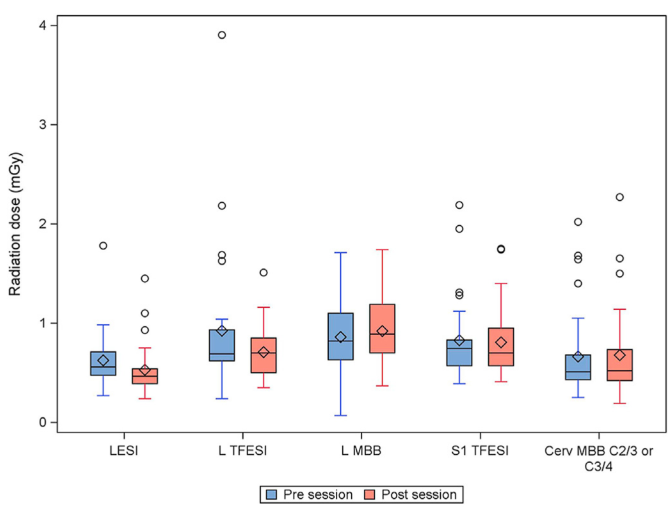

Fig. 2. Boxplots of pre- and post-session radiation dosages. Each box shows the first quartile, median, and third quartile. Whiskers extend to the most extreme values with 1.5 times the interquartile range above and below the third and first quartiles, respectively. Diamonds show the means, and the circles represent outliers. N ranged from 29 to 33.

greatest increase in knowledge was observed for L MBB and S1 TFESI (median change [95% CI]: 50 [20, 70]; P = 0.006) (Table 3).

A minimum median 1-point increase in comfort level with performing the procedure and with fluoroanatomy and directing the c-arm was observed for all procedures post- vs. pre-session (Table 4, Fig. 4A and B). The greatest increase in comfort was observed in performing S1 TFESI (median change [95% CI]: 2 [1.5, 2]; P < 0.001) (Table 4).

After the LESI/L TFESI, L MBB/S1 TFESI, and C MBB C2/3 or C3/4 procedure sessions, 96.7%, 87.5%, and 89.7% of participants, respectively, reported that the course was "very helpful" (Fig. 5A). A minimum of 96.7% of participants reported that the simulation session gave them a better understanding of fluoroanatomy (Fig. 5B). Additionally, a minimum of 96.7% of participants felt that the session provided a realistic

Table 3
Median within-participant change in percentage of procedure knowledge questions answered correctly post- vs. pre-session.

Procedure	N	Median change (95% CI)	P value[A]
LESI and L TFESI	11	30 (20, 50)	0.034
L MBB and S1 TFESI	11	50 (20, 70)	0.006
C MBB C2/3 or C3/4	9	20 (20, 30)	0.018

LESI = lumbar interlaminar epidural steroid injection; L TFESI = lumbar transforaminal epidural steroid injection; L MBB = lumbar medial branch block; S1 TFESI = S1 transforaminal epidural steroid injection; C MBB = cervical medial branch block; CI = confidence interval.
A = Paired post-vs. pre-session percentages of procedure knowledge questions answered correctly were compared using Wilcoxon signed-rank tests.

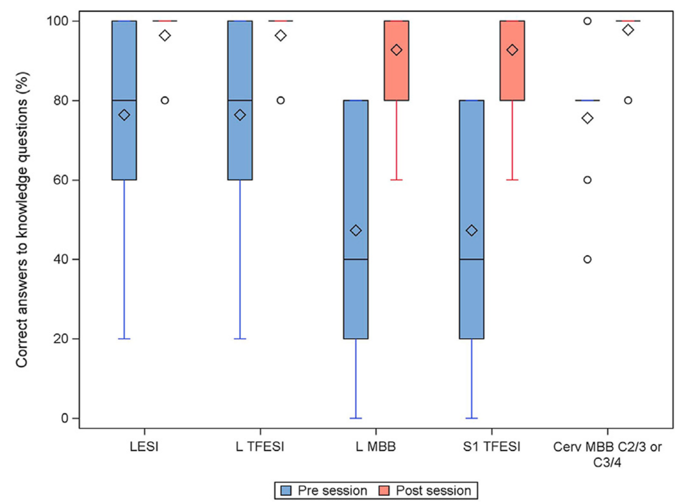

Fig. 3. Boxplots of pre- and post-session percentages of procedure knowledge questions answered correctly. Boxes show the first quartile, median, and third quartile. Whiskers extend to the most extreme values with 1.5 times the interquartile range above and below the third and first quartiles, respectively. Diamonds show the means, and the circles represent outliers. N ranged from 9 to 11.

procedural experience, a minimum of 93.3% of participants stated that this didactic session changed how they will perform fluoroscopic spine procedures, and a minimum 96.6% reported being likely or very likely to use the spine model again to practice/learn fluoroscopic-guided spine procedures (Fig. 5C 5D, 5E).

3.1. Application of skills learned in the curriculum (Kirkpatrick Level 3)

Nine out of 26 (35%) former fellows with at least one year in clinical practice responded to a post-graduation survey about application of skills learned in the curriculum. All respondents reported using skills learned from the simulation curriculum in their clinical practice frequently or very frequently (Table 5). Among LESI, L TFESI, S1 TFESI, and C MBB, respondents reported performing LESI and L TFESI the most frequently per year (Table 5).

4. Discussion

In this study, we examined the effects of implementing an interventional pain SBE curriculum for pain medicine fellows. The curriculum was established with 3–4 faculty members and 2–4 resident volunteers, implemented during non-clinic hours, utilized existing clinic space, and required little financial support from our institution. In this way, the interventional pain simulation curriculum was feasibly implemented. Our curriculum included skills training with a spine training system/model, debriefing, verbal feedback, didactics, virtual reality video

Table 4
Median within-participant changes in comfort level with performing procedures and with fluoroanatomy and directing the c-arm post vs. pre session.

Procedure	N	Median change (95% CI)	P value[A]
LESI			
Performing procedure	30	1 (0, 1)	0.035
Fluoroanatomy and directing the c-arm	30	1 (1, 1.5)	0.002
L TFESI			
Performing procedure	30	1 (1, 1.5)	<0.001
Fluoroanatomy and directing the c-arm	30	1 (1, 1.5)	0.002
L MBB			
Performing procedure	32	1.5 (1, 1.5)	<0.001
Fluoroanatomy and directing the c-arm	32	1 (1, 1)	<0.001
S1 TFESI			
Performing procedure	32	2 (1.5, 2)	<0.001
Fluoroanatomy and directing the c-arm	32	1 (1, 1)	<0.001
C MBB C2/3 or C3/4			
Performing procedure	31	1 (0, 1)	0.003
Fluoroanatomy and directing the c-arm	31	1 (1, 1.5)	0.009

LESI = lumbar interlaminar epidural steroid injection; L TFESI = lumbar transforaminal epidural steroid injection; L MBB = lumbar medial branch block; S1 TFESI = S1 transforaminal epidural steroid injection; C MBB = cervical medial branch block; CI = confidence interval.
A = Paired post- vs. pre-session comfort levels were compared using Wilcoxon signed-rank tests.

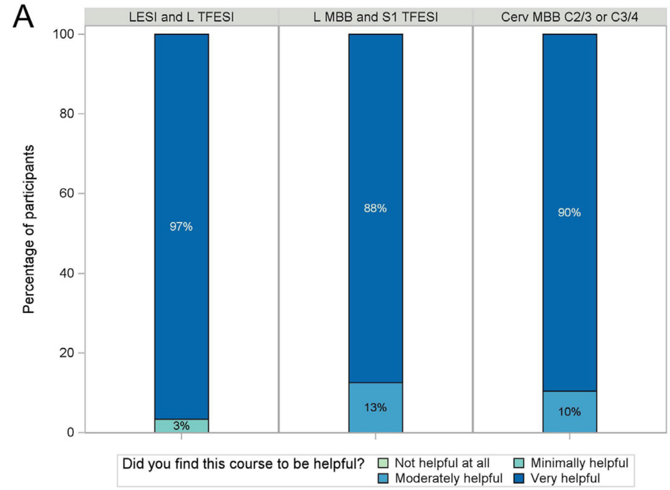

Fig. 5. Stacked bar charts of post-session feedback responses from fellows to the questions: "Did you find this course to be helpful?"(A), "Did the simulation session give you a better understanding of fluoroanatomy?"(B), "Do you feel that the simulation session provided a realistic procedural experience?"(C), "Did this didactic session change how you will perform fluoroscopic-guided spine procedures?"(D), and "How likely are you to use the spine model again to practice/learn fluoroscopic-guided spine procedures?"(E). Fellows were provided paper copies in the 2018–2019 and 2019–2020 academic years and received REDCap surveys in the 2020–2021 academic year. N ranged from 29 to 32.

feedback, and opportunities to practice procedure techniques in a psychologically safe, low-risk setting devoid of risk to patients.

Survey data compiled from three distinct didactic sessions per year from 2018 to 2021 demonstrated that the trainees universally found the sessions to be helpful, influential for their future practice, and realistic. All participants also stated that they are likely or very likely to use the spine training system again for such an educational experience in the future. Our data revealed favorable evaluation from the fellows (Kirkpatrick level 1) and increased perceived comfort level to perform the interventional spine procedures for all sessions. Additionally, our data demonstrated a statistically significant improvement in knowledge for each session (Kirkpatrick level 2). All respondents to our post-graduation survey reported using skills learned from the simulation curriculum in their clinical practice frequently or very frequently (Kirkpatrick level 3).

The improvement in comfort spanned the entire process of performing an intervention with set-up, fluoroscopy, radiation safety, and the actual positioning of the needle. During procedures performed in a clinical scenario, the attending physician and radiation technologist traditionally guide image optimization. The simulated environment allowed the trainees to learn how to optimize their views without the pressure of exposing a live patient to unnecessary radiation.

Objective data collected during the simulation curriculum showed a statistically significant reduction in fluoroscopic images taken and procedure time for LESI, whereas statistical significance was not detected for the other procedures, such as L TFESI, L MBB, and C MBB. For the L TFESI and S1 TFESI, the data showed a mean reduction in both radiation usage and procedure time. However, these were not statistically significant. This may be due to the large variability in fellow experience/performance with a relatively low sample size that was not powered to detect this difference. For C MBB, the number of fluoroscopic images, radiation dosage, and procedure time showed a mean increase, although this was also not statistically significant. This finding may be due to the nature of the higher risk, more advanced procedure, requiring more skill and thoughtfulness and fellows incorporating newer techniques into their post-intervention sessions.

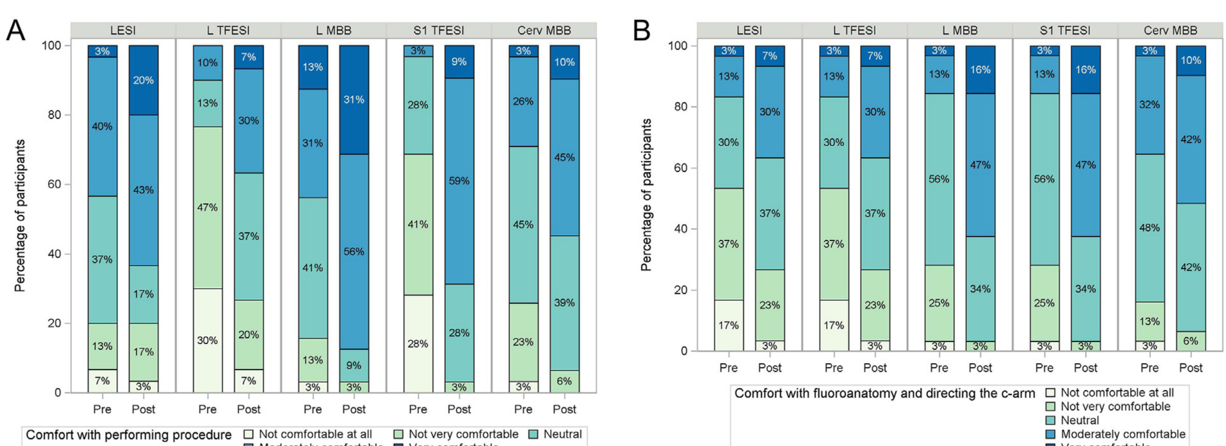

Fig. 4. Stacked bar charts of pre- and post-session level of comfort with performing procedures (A) and with fluoroanatomy and directing the c-arm (B). N ranged from 30 to 32.

Table 5
Post-graduation survey of fellows graduating in 2019 and 2020 gauging their learning and number of procedures performed per year. N = 9.

Graduation year	n (%)
2019	5 (55.6)
2020	4 (44.4)
Since graduation, how often have you applied the information learned from the simulation curriculum in your clinical practice?	
Never	0
Very rarely	0
Rarely	0
Occasionally	0
Frequently	3 (33.3)
Very frequently	6 (66.7)
LESI performed per year	
0	0
1–25	0
25–50	1 (11.1)
50–100	3 (33.3)
100–150	2 (22.2)
>150	3 (33.3)
L TFESI performed per year	
0	0
1–25	0
25–50	1 (11.1)
50–100	4 (44.4)
100–150	2 (22.2)
>150	2 (22.2)
S1 TFESI performed per year	
0	0
1–25	2 (22.2)
25–50	2 (22.2)
50–100	5 (55.6)
100–150	0
>150	0
C MBB performed per year	
0	0
1–25	0
25–50	3 (33.3)
50–100	3 (33.3)
100–150	2 (22.2)
>150	1 (11.1)

LESI = lumbar interlaminar epidural steroid injection; L TFESI = lumbar transforaminal epidural steroid injection; L MBB = lumbar medial branch block; S1 TFESI = S1 transforaminal epidural steroid injection; C MBB = cervical medial branch block.

One major limitation of this study was the small sample size, which was determined by fellowship program size. This reduced our ability to detect small, yet clinically relevant changes in performance metrics. Furthermore, although the resident volunteers were trained on the specific views required for the procedures and had opportunity to practice prior to the session, the use of resident volunteers to operate the C-arm may have contributed to longer procedure and fluoroscopy times. In addition, as the C-arm was not operated by the same person for all procedures, a confounding variable may have been introduced. Another limitation was the lack of a randomized control group. However, the primary goal of this study was to assess the feasibility and implementation of this curriculum.

Simulation programs are widely reported to be expensive and time intensive. Potential barriers of creating a simulation program include the cost of spine injection models, needles, gloves, any procedure related materials, space, C-arm, and faculty and trainee time. Our curriculum limited these costs by having dedicated faculty members and residents who volunteered their time outside of clinical hours in existing clinical space. Utilizing feedback from faculty members and fellows, the curriculum has evolved over the years to improve efficiency and the flow of the sessions.

As medical simulation becomes increasingly incorporated into medical training, educators should continue to refine and advance the simulation-based medical curricula. Factors attributed to the most effective models for learning with SBE are repetitive performance, feedback, and assessment [18]. Simulation-based scenarios also can provide a mechanism to identify knowledge and performance gaps [19] and facilitate the creation of simulation sessions designed to target these deficiencies. The role of simulation in medical education has expanded greatly over the past twenty years and has moved from an area of research and education to include performance evaluation [20]. With more data presented from a variety of specialty-based simulations, SBE as a performance assessment tool has become more valid [21].

Our simulation program included the features of simulation which have been shown to best facilitate learning, including the ability to provide feedback, repetitive practice, curriculum integration, and the ability to range difficulty levels [22,23]. Given the educational benefits of our SBE curriculum, including deliberate practice with feedback, reproducibility, opportunity for assessment of learners, and the absence of risks to patients, which match the benefits described in the literature [4], there may be broader implementation of this SBE curriculum across other pain medicine training programs.

Future objective data collection may include use of technical checklists for each procedure [24] as well as utilizing "gold standard" reference points (new attendings and more experienced attendings) for comparison with the trainees. In addition, larger studies may show statistically significant decreases in radiation exposure for simulated procedures, whereas our relatively smaller study did not find statistically significant reductions for procedures other than LESI. Additional next steps include analyses of the virtual reality feedback videos and procedural accuracy data, utilizing the following proposed grading system:

A = safe and acceptable needle position
B = safe, but unacceptable needle position
C = unsafe and unacceptable needle position

Continued research is needed to help educators justify the considerable time, effort, and financial cost required to create and run a sustainable simulation program [23], in addition to validating the benefits of using such a model as it relates to outcomes-based education.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.inpm.2022.100167.

Appendix. - Knowledge Check questionnaires (with answers in bold)

Session #1: LESI and L TFESI

1) While performing an interlaminar epidural steroid injection, in the contralateral oblique view, which landmark is visualized to access the epidural space?

a. Spinolaminar line
b. **Ventral interlaminar line**
c. Posterior interlaminar line
d. Superior laminar line

2) While performing an interlaminar epidural steroid injection, in the lateral view, which landmark is visualized to access the epidural space?
a. **Spinolaminar line**
b. Ventral interlaminar line
c. Posterior interlaminar line
d. Superior laminar line

3) While performing a transforaminal epidural steroid injection, in the AP view, it is important to “square off” the _______.
a. Inferior articular process
b. Inferior end plate
c. **Superior endplate**
d. Superior articular process

4) Reinforcing medullary arteries enter the intervertebral foramina ventral to the spinal nerve and accompany the intra-dural ventral nerve rootlets to supply regional blood flow to the anterior spinal cord via the anterior spinal artery. The largest of these reinforcing medullary arteries is the _________.
a. Vertebral artery
b. **Artery of Adamkiewicz**
c. Spinal radicular artery
d. Hypogastric radicular artery

5) While performing a transforaminal epidural steroid injection, in which view do you ensure that your needle tip is not positioned medially to the 6:00 position of the pedicle?
a. Lateral
b. Contralateral oblique
c. Ipsilateral oblique
d. **AP**

Session #2: L MBB and S1 TFESI

1) For lumbar medial branch blocks, what is the landmark for placement of the needle tip?
a. Intersection of the transverse process and the inferior articular process
b. Underneath the “chin” of the scotty dog
c. **Intersection of the transverse process and the superior articular process**
d. Intersection of the spinous process and the superior articular process

2) The L3-4 facet joint is innervated by
a. L3 and L4 medial branches
b. **L2 and L3 medial branches**
c. L4 and L5 medial branches
d. L4 medial branch only

3) The L5-S1 facet joint is innervated by
a. L5 medial branch and S1 lateral branch
b. L3 and L4 medial branches
c. L5 dorsal ramus only
d. **L4 medial branch and L5 dorsal ramus**

4) For an S1 TFESI, advance in the lateral position _____.
a. To the sacral canal floor
b. **Just beyond ventral epidural space**
c. Just beyond the dorsal epidural space
d. To the ganglion impar

5) An L5-S1 right paracentral disc herniation will most likely impinge
a. **The traversing/descending right S1 nerve root**
b. The exiting right L5 nerve root
c. The L5 medial branch
d. The S1 lateral branch

Session #3: C MBB C2/3 or C3/4

1) The C5-C6 zygapophysial joint is innervated by articular branches from:
a. C6-7
b. C4-5
c. **C5-6**
d. C3-4

2) The typical cervical medial branches run around the
a. **Ipsisegmental articular pillar**
b. Ventral interlaminar line
c. Spinolaminar line
d. Uncinate articular process

3) The third occipital nerve (TON) innervates which joint?
a. C3-4
b. **C2-3**
c. C4-5
d. C1-2

4) The greater occipital nerve (GON) is derived from the __________.
a. Ventral ramus of the C1 spinal nerve
b. Ventral ramus of the C2 spinal nerve
c. Dorsal ramus of the C1 spinal nerve
d. **Dorsal ramus of the C2 spinal nerve**

5) In the true lateral view, to avoid contacting the spinal nerve and vertebral artery, the needle tip should not be positioned
a. More dorsal than the dorsal margin of the articular pillar
b. **More ventral than the ventral margin of the articular pillar**
c. Middle of the articular pillar
d. At the superior aspect of the articular pillar

LESI = lumbar interlaminar epidural steroid injection; L TFESI = lumbar transforaminal epidural steroid injection; L MBB = lumbar medial branch block; S1 TFESI = S1 transforaminal epidural steroid injection; C MBB = cervical medial branch block.

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