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REVIEW

Simulation in teaching regional anesthesia: current perspectives

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Abstract: The emerging subspecialty of regional anesthesiology and acute pain medicine represents an opportunity to evaluate critically the current methods of teaching regional anesthesia techniques and the practice of acute pain medicine. To date, there have been a wide variety of simulation applications in this field, and efficacy has largely been assumed. However, a thorough review of the literature reveals that effective teaching strategies, including simulation, in regional anesthesiology and acute pain medicine are not established completely yet. Future research should be directed toward comparative-effectiveness of simulation versus other accepted teaching methods, exploring the combination of procedural training with realistic clinical scenarios, and the application of simulation-based teaching curricula to a wider range of learner, from the student to the practicing physician.

Keywords: regional anesthesia, simulation, medical education, ultrasound, nerve block, simulator

Introduction

The list of teaching and learning methods in modern medical education is exhaustive. The age-old model of observation followed by attempt (ie, "see one, do one, teach one") still exists and is still considered common in residency and fellowship training.[1] Other modalities available to today's medical learner include formal didactic lectures and multimedia learning (eg, mobile devices, textbooks, and Internet).[2–4] Traditionally, teaching methods have been introduced with minimal studies of efficacy, if any. Today, new methods are often held to a higher standard and are required to demonstrate superiority over some existing comparator. Those methods with proven efficacy may be integrated into medical education curricula, either individually or in combination with other methods as appropriate.

Simulation can be defined as something that is made to look, feel, or behave like something else especially when applied to research or education.[5] The use of simulation to mimic real life in the educational setting has arguably many origins but is closely tied to Kolb's experiential learning theory.[6] The educational experience provided by simulation is often hands-on, practical, provides immediate feedback, and allows for repetition. Training with simulation does no harm to patients; errors can be allowed to occur, can even be scheduled, and can provide realistic experiences managing common and rare situations which differs to "training by chance" where exposure is limited to real life cases that may or may not occur for every trainee. In the medical education setting, simulation-based interventions are now mature with a wide variety of applications.[7] For procedural skills, deliberate practice in a simulated-setting is

one example of an effective teaching strategy that has been used for specific skills training in central venous catheter insertion, subarachnoid block placement, and laryngoscopy.[8] Medical residents trained to place central venous catheters in simulation improve their clinical performance in the intensive care unit.[9] The translation of knowledge, skills, and attitudes from the simulation-based classroom to clinical care is important to show effectiveness or efficacy and drive curricular change.[10]

Regional anesthesia inherently requires precise procedural performance due to target nerve locations near vital structures (eg, blood vessels, pleura, organs, and nerves themselves) and seems naturally suited for the incorporation of simulation within the training curricula. Further, the recent evolution of ultrasound guidance in the practice of regional anesthesia has created great demand for training in this imaging modality for physicians who completed training more than a decade ago and are still in clinical practice.[11] The American Society of Regional Anesthesia and Pain Medicine (ASRA) and European Society of Regional Anesthesia and Pain Therapy (ESRA) have published joint committee guidelines for training in ultrasound-guided regional anesthesia, and the ASRA–ESRA guidelines suggest that simulation play an important role.[12] Although there is widespread use of the modality, the evidence basis for simulation in regional anesthesia training is not completely established.[2] In this review, we provide an up-to-date summary of the literature related to the use of simulation in regional anesthesia education and assess its effectiveness.

Literature review

A search of the MEDLINE database (PubMed.gov; United States National Library of Medicine, National Institutes of Health, Bethesda, MD, USA) using "regional anesthesia", "simulation", "regional anesthesia simulator", "regional anesthesiology simulation", "regional anesthesiology simulator", "nerve block simulator", and "nerve block simulation", was conducted between January and March 2015, and resulted in 393 citations. Three of the authors (TK, AU, and EM) excluded non-English language, veterinary, nerve conduction (without nerve blockade), and magnetic resonance imaging articles and eliminated any duplicate citations based on the search terms and phrases; 64 articles remained. The reference lists of pertinent articles were also manually searched and revealed 15 additional articles not included in the original MEDLINE search. The final sample of 79 articles was critically reviewed for simulation-based educational interventions and their effectiveness.

Simulation-based educational interventions

Fourteen articles published to date study the effect on learners who underwent a simulation-based educational intervention in regional anesthesia (Table 1).[13–26] Out of the 14, only studies by Niazi et al,[15] Baranauskas et al,[20] and Udani et al[14] tested a simulation-based teaching strategy against an equivalent control group not receiving simulation; all three studies enrolled anesthesiology trainees.[14,15,20] Based on the results of Niazi et al, residents in anesthesiology who received 1 hour of simulation training on needling and proper hand–eye coordination using ultrasound were more successful than a control group receiving no simulation, as assessed by blocks performed on real patients.[15] Baranauskas et al studied different durations of simulation training and the potential effect on learners, including 0 hours of simulation.[20] Students with 2 hours of simulation training in needling with ultrasound performed faster and with fewer technical flaws than students with 1 hour of simulation training. Additionally, those with 1 hour of training performed better than those with 0 hours of simulation training. Udani et al presented a randomized study in which residents are assigned to receive simulation-based deliberate practice teaching or a base curriculum without simulation to learn subarachnoid blocks.[14] In this study, performance scores using a task checklist improved in the participants receiving simulation-based teaching. However, there may not be a translational benefit as there is no difference between groups in the time required for participants to place subarachnoid blocks in actual patients.

Table 1 includes other studies that on some level assess effectiveness of simulation-based educational interventions, but the ability to discern the impact of simulation alone in these studies is limited by methodology. Woodworth et al, Gasko et al, Friedman et al, and Liu et al describe controlled studies.[13,17,19,22] However, the interventions under study are more complex than just incremental simulation-based teaching compared to a control group without simulation. For example, Woodworth et al include a teaching video in addition to simulation training, which is then compared to a control group.[13] Gasko et al compare a combination of CD-ROM teaching material with simulation versus CD-ROM teaching alone versus simulation teaching alone.[17] Friedman et al compare a high-fidelity simulator versus a low-fidelity epidural simulator without a comparison to no simulator.[19] Although these studies demonstrate the benefits of enhanced and more rigorous training, the results cannot be attributed entirely to the introduction of simulation. Liu et al evaluate three different types of simulators for regional anesthesia and conclude

Table 1 Simulation-based educational interventions

Study	Subjects	Intervention	Control group	Performance measure	Intervention sample	Control sample	Comparison of control versus intervention	Significance
Woodworth et al[13]	Residents and consultant anesthesiologists	Teaching video with interactive simulation	Sham video	Written test, live model scanning, and identification of sciatic nerve	16	7	Mean post-intervention written test scores in intervention group greater than control group	$P<0.01$
							No difference in posttest live-model scanning	
							Intervention group improved confidence	$P<0.05$
							No difference in time to perform ultrasound scan of sciatic nerve	
Udani et al[14]	Resident anesthesiologists	Deliberate practice training in simulation	Conventional training excluding simulation	Block performance in simulation and time to place clinical block	11	10	Greater increase in checklist score in intervention group versus control group	$P<0.03$
							No difference in time performing block in clinical setting	
Niazi et al[15]	Resident anesthesiologists	1 hour simulation training on needling and proper hand–eye coordination	Conventional training excluding simulation	Clinical block success	10	10	Intervention group had more successful blocks than control group	$P=0.02$
							Intervention group reached proficiency more than control group (80% versus 40%)	$P=0.08$
Moore et al[16]	Resident pediatric anesthesiologists	Comprehensive curriculum (ie, didactics, apprenticeship, and simulations)	None	Written test and block performance in simulation	9	N/A	Written test score improvement over 12 months	$P<0.01$
							No improvement in block accuracy	$P=0.08$
							No improvement in block efficiency	$P=0.12$
Gasko et al[17]	Student nurse anesthetists	Combination of CD-ROM and simulation teaching	Simulation or CD-ROM teaching alone	Ultrasound scan of cadaver in simulation	7	11 (simulation alone), 11 (CD-ROM alone)	Combination teaching better at increasing scanning performance than CD-ROM or simulation alone	$P<0.05$
							No difference in scanning between CD-ROM and simulation alone groups	$P>0.05$
Garcia-Tomas et al[18]	Resident anesthesiologists	Comprehensive curriculum (ie, anatomy workshop, live model scanning, simulated scenarios, and didactics)	None	Written test and objective structured clinical examination (OSCE)	56	None	Post-intervention written test scores improved	$P<0.01$
							Post-intervention OSCE scores improved	$P<0.01$
Friedman et al[19]	Resident anesthesiologists	High-fidelity epidural simulator use	Low-fidelity model use	Clinical epidural block assessed by checklist and global rating scale	12	12	No difference in checklist score	$P=0.29$
							No difference in global rating score	$P=0.09$

(Continued)

Table I (*Continued*)

Study	Subjects	Intervention	Control group	Performance measure	Intervention sample	Control sample	Comparison of control versus intervention	Significance
Baranauskas et al[20]	Resident anesthesiologists	2 hours of simulation training	1 hour of simulation training or 0 hours of simulation training	Needling with ultrasound in simulation	3	3 (1 hour of simulation), 3 (0 hour of simulation)	Students with 2 hours of simulation training performed faster and with less technical flaws than students with 1 hour and 0 hours of simulation training	Not provided
Ouanes et al[21]	Resident anesthesiologists	Comprehensive curriculum (ie, anatomy lab, simulation on phantom models, high-fidelity scenarios, nerve stimulator techniques, oral board prep, journal club, PBLD, web-based lectures, clinical log, and lab research)	None	Written test and OSCE	Not reported	N/A	Post-intervention written test scores improved. Post-intervention scores improved	$P<0.05$. $P<0.05$
Liu et al[22]	Resident anesthesiologists	Opaque phantom model use	Clear phantom model or olive-in-chicken phantom model use	Block performance in simulation	12 Opaque model	12 clear model; 12 olive-in-chicken model	Decreased number of errors with each attempt in simulation. Decreased time to task completion with each attempt in simulation. All participants agreed or strongly agreed that model could be used for teaching and enhancing skill of UGRA	$P<0.05$
Kim et al[23]	Medical students	Phantom model use	None	Time to block in simulation	18	None	Reduction in time to perform block after fifth trial. Improved block quality after fifth trial	$P<0.01$. $P<0.01$
Cheung et al[24]	Undergraduate students	Simulation training	None	Needle targeting task in simulation	26	None	Less feedback was required after simulation training occurred. No difference in needle passes	$P<0.01$
Bretholz et al[25]	Pediatric emergency medicine consultants	Comprehensive curriculum (ie, web-based and simulation-based instruction)	None	Questionnaires documenting comfort level and intention to use ultrasound-guided nerve block techniques	11	None	Comfort with ultrasound-guided nerve block increased immediately after course. Intention to use ultrasound-guided nerve block increased immediately after course. No sustained increase in comfort nor intention to use ultrasound-guided nerve block 1 month after course	Only for ulnar block ($P=0.01$) but not femoral block ($P=0.16$)

Brenner et al[26]	Interdisciplinary (pain management consultants, fellows, residents, nurses, and technicians)	Crisis resource management course in pain medicine	None	Satisfaction survey	68 Physicians and four non-Physicians	None	Trainees recommended repeated course every 6 months Consultant physicians recommended repeating course every 1–2 years Interprofessional debriefings led to richer discussions

Abbreviations: N/A, not applicable; PBLD, Problem Based Learning Discussion; UGRA, Ultrasound-Guided Regional Anesthesia.

that novice practitioners decrease the number of errors in a simulated block with each additional practice attempt in simulation, regardless of the type of simulator used.[22]

Moore et al, Garcia-Tomas et al, Ouanes et al, and Bretholz et al describe comprehensive regional anesthesia curricula and demonstrate their effectiveness.[16,18,21,25] These interventions all include simulation-based teaching but are combined with other teaching strategies (eg, web-based tutorials, journal clubs, anatomy labs, etc); thus it is not possible to identify the specific contribution of simulation. Furthermore, studies lack a control group. Kim et al, Cheung et al, and Brenner et al use a single simulation-based teaching intervention, not in the context of a comprehensive curriculum, but do not include a control group comparison.[23,24,26] Due to the nature of all participants' receiving some type of teaching, the reported effectiveness is mostly positive. Participants report feeling more comfortable with procedures, and post-intervention written test scores increase. The studies by Garcia-Tomas et al and Ouanes et al show post-intervention objective structured clinical examination (OSCE) scores also increase.[18,21] Brenner et al report that interprofessional debriefings in their crisis management course lead to richer discussions.[26] However, Moore et al show that although written test scores improve after implementation of their educational curriculum, there is no difference in block accuracy or efficiency as assessed in a simulator.[16] Bretholz et al also report that the initial increase in comfort after their educational intervention is not sustained one month later.[25]

Novel simulator design

To date, 18 articles describe the design of a novel regional anesthesia simulator (Table 2).[27–44] Simulators used for part-task training (eg, phantoms) in ultrasound-guided regional anesthesia vary based on the materials used and indications (ie, tasks to be taught). Inorganic materials are common in commercially available phantoms but often lack realistic tactile sensation and haptic feedback and do not allow for injection of liquid solutions as is common in regional anesthesia techniques (Figures 1 and 2). These phantoms are useful for teaching procedural steps, dexterity, target identification, and needle guidance. In contrast, organic phantoms (ie, meat) arguably produce the most realistic sonoanatomy and tactile sensation and do allow for injection and even catheter insertion, but they are not reusable and must be replaced for subsequent training sessions (Figure 3).
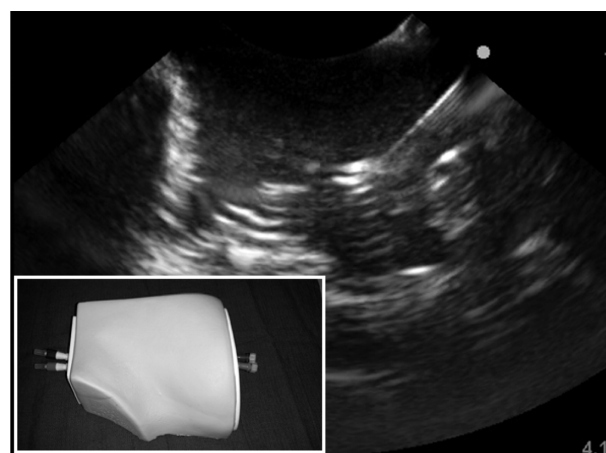
Since it is not possible to present every model used for regional anesthesia practice, for the purpose of this article

Table 2 Novel simulator design

Study	Design
Lee et al[28]	Phantom model
Morse et al[27]	Robot-assisted model
Ullrich et al[29]	Virtual reality model
Sparks et al[30]	Phantom model
Rosenberg et al[31]	Phantom model
Liu et al[33]	Phantom model
Niazi et al[32]	Phantom model
Lim et al[34]	Virtual reality model
Kessler et al[35]	Cadaver model
Inoue et al[36]	Phantom model
Hemmerling et al[37]	Robot-assisted model
Grottke et al[38]	Virtual reality model
Capogna et al[39]	Phantom model
Atallah et al[40]	Phantom model
Adhikary et al[41]	Environmental modification
Hocking et al[42]	Phantom model
Pollard[43]	Phantom model
Bellingham and Peng[44]	Phantom model

Figure 2 Sample sonogram of an anatomic inorganic phantom for ultrasound-guided regional anesthesia.
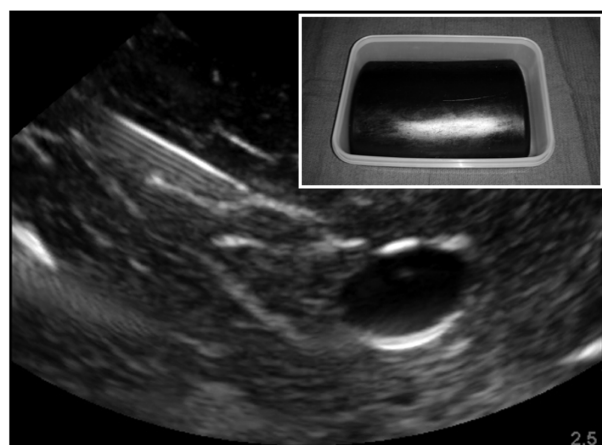**Note:** Inset box indicates external view of the model.

we define a novel simulator design as a new, previously undescribed product employing innovative technology to represent the realistic scenario of performing a regional anesthesia procedure. The novel simulator design takes one of the following forms: 1) a physical model (ie, phantom); 2) virtual reality model; 3) robot-assisted model; or 4) environmental modification. Only Niazi et al,[32] Lim et al,[34] Lee et al,[28] and Morse et al[27] report an effect on learners attributable to the use of their novel simulators. The other 14 articles are solely descriptions of simulator design. None of the studies that report an effect on learners include a control group against which simulation-based teaching is compared. Rather, these studies focus on before and after test comparisons and show positive results associated

with training on the novel simulators described. Lim et al demonstrate that after using their virtual reality simulator, participants' skills in identifying surface landmarks for block placement improve.[34] Lee et al demonstrate that participants' time performing an epidural block decreases with 20 repetitions on their simulator.[28] Morse et al use a crossover study design to show that performance is more consistent and that learning is quicker using a robot-assisted regional anesthesia technique in simulation when compared to a traditional, manual technique using practitioner's hands.[27]

Use of a simulated environment as an experimental setting

Eleven articles present a new medical device or evaluate an established nerve block technique in a simulated environment (Table 3).[45–55] Examples include primarily case reports on

Figure 1 Sample sonogram of a nonanatomic inorganic phantom for ultrasound-guided regional anesthesia.
Note: Inset box indicates external view of the model.
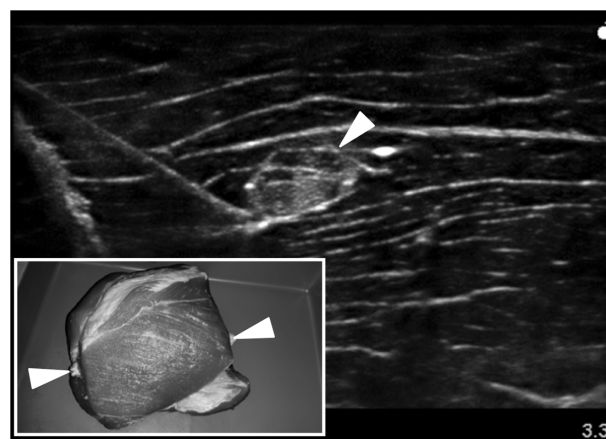
Figure 3 Sample sonogram of an organic phantom for ultrasound-guided regional anesthesia using a porcine meat specimen with inserted bovine tendon to represent the target "nerve" (arrowheads identify the tendon).
Note: Inset box indicates external view of the model.

Table 3 Use of a simulated environment as an experimental setting

Study	Medical device or technique
Whittaker et al[45]	Use of needle-guide device
Neal et al[46]	Use of treatment checklist device for local anesthetic systemic toxicity
Johnson et al[47]	Hand-on-syringe technique
Gupta et al[48]	Use of multi-angle needle-guide device
Cook et al[50]	Use of Luer and non-Luer connector devices
Kilicaslan et al[49]	Evaluation of echogenic needle device
Brinkmann et al[51]	Use of single operator, real-time, ultrasound-guided epidural needle device
Mariano et al[54]	Comparison of echogenicity for multiple perineural catheters
Kan et al[53]	Air test technique for inferring perineural catheter tip location by an expert
Johns et al[52]	Air test technique for inferring perineural catheter tip location by a novice
van Geffen et al[55]	Use of needle-guide device

devices or techniques such as Luer connectors, echogenic needles, needle guides, "air test" for inferring perineural catheter tip location, and a hand-on-syringe technique.[47–50,52,53] Only Kilicaslan et al,[49] Whittaker et al,[45] Neal et al,[46] Johnson et al,[47] and Gupta et al[48] provide effectiveness data. Simulation itself is not evaluated for efficacy, and studies that include a control group expose both the control and intervention groups to the simulated environment. Reported outcomes include improvements in knowledge, skills, and/or behaviors with the use of the new device or technique. Neal et al[46] evaluate the use of a treatment checklist for the management of local anesthetic systemic toxicity (LAST). The authors describe creating a simulated, clinical environment utilizing a mannequin to represent a clinical patient who receives an inadvertent toxic dose of intravascular local anesthetic. The learners, anesthesiology residents, and fellows, are inserted into the simulated crisis with or without a LAST treatment checklist. In their findings, the authors demonstrate that physician trainees using a treatment checklist make better medical decisions related to the critical management of LAST than trainees who do not use a checklist.

Other published topics related to simulation and regional anesthesia

The remaining articles span a broad range of topics, and none test the effectiveness or efficacy of simulation-based teaching in regional anesthesia. Some authors collect the needs of training regional anesthesiologists and establish metrics to assess performance, using simulators.[56–60] Others use a simulated environment to calculate procedural learning curves and observe practitioner ergonomics.[61–67] Although these articles touch on the topic of medical education in regional anesthesia, we consider them outside the scope of the present review on simulation-based educational interventions and their effectiveness.

Discussion

Although simulation-based medical education has been shown to be effective for specific applications, our review reveals that similar evidence in regional anesthesia training is limited. We especially note a lack of comparative evidence studying the effectiveness of a simulation-based teaching strategy versus a proper control: participants' receiving identical teaching as the intervention group less simulation-based instruction. This would mean that control group participants should have an equal amount of time in an educational setting even when they are not receiving simulation-based instruction. Medical education research is expected to show efficacy or comparative-effectiveness against an established method, or else educators may presume "if you teach [students], they will learn".[68] We know that the addition of simulation-based instruction automatically means extra training, but we cannot assume that this extra training automatically leads to the acquisition of new knowledge or skills.

We encourage the development, implementation, and scientific investigation of comprehensive regional anesthesia training curricula. From the work published to date, we are unable to deduce the incremental effectiveness (or ineffectiveness) of simulation-based regional anesthesia education, although we acknowledge that it has face validity. The description of novel simulators and development of new regional anesthesia techniques in a simulated environment represent just the first step to fully assess the role of simulation in teaching the knowledge, skills, and behaviors necessary for regional anesthesia competency.

Recently, regional anesthesia has been evolving further into the medical subspecialty of regional anesthesiology and acute pain medicine (RAAPM), and guidelines have been established for fellowship training.[69] However, teaching strategies are not clearly recommended or identified. Learners are taught using various techniques, most commonly as observers who transition to active participants in the apprenticeship model. A mix of didactic, multimedia, and simulation-based learning would augment this apprenticeship. The effectiveness of the variations in the RAAPM curricula is largely unknown, and curricula may very well be institution-specific for many reasons (eg, faculty and resources available).[70,71]

We see many advantages to simulation-based education in RAAPM. The key elements of simulation-based

education, namely repetitive practice, targeted feedback, self-reflection, and avoiding harm to patients make it a useful teaching strategy. The simulated environment is well-suited for providing learners with the time and means to gain effective feedback and reflect on their performance; something that is difficult to obtain when taking care of real patients as time in the clinical setting is often limited and rushed. Many aspects of RAAPM are procedure based, and practice in simulation can recreate a realistic experience. We believe RAAPM may be the ideal specialty to embrace "hybrid" simulation (Figure 4), a combination of part-task training and mannequin-based simulation to facilitate procedural practice in the context of life-like scenarios (eg, the anxious patient, a vasovagal response, or even LAST). Repetitive practice in a controlled, simulated environment has been shown to lead to better procedural performance in the clinical setting.[9] This is one of the tenets of deliberate practice, an effective use of simulation-based medical education.[14] As educators, we hope that a student's mistakes will be made in the simulated environment, and corrected prior to actual patient care. Another advantage of simulation-based education is that it exemplifies principles of adult learning and Kolb's experiential learning theory. In our review of published articles, it is clear that learners of all stages in medical school, residency, fellowship, and clinical practice react and enjoy participating in simulation-based education even though it may initially cause some anxiety.[72,73]

Alternatively, there may be disadvantages to simulation-based education in RAAPM. First, one may assume that a large capital investment in equipment and time is required.[74] In our review, we find that this may not be true as many novel

Figure 4 Example of a "hybrid" simulator with the right lower extremity of the mannequin removed and replaced with a porcine-bovine meat phantom to allow for realistic procedural practice in ultrasound-guided regional anesthesia and perineural catheter insertion.

low-cost simulator designs have been described to help keep costs to a minimum while maintaining fidelity and achieving learning objectives.[30,33,36,75] Time in simulation is time away from clinical care. However, training guidelines established by the Accreditation Council for Graduate Medical Education for anesthesiology residents now require time in simulation annually, and simulation is included in the requirements for maintenance of board certification in anesthesiology. There is momentum to encourage novice physicians to practice in simulation prior to engaging in clinical care. The same may be said for physicians who have already completed their training and are trying to learn a new technique such as ultrasound-guided peripheral nerve blockade. Simulation may provide a more effective alternative to other methods currently available (eg, continuing medical education or industry-sponsored workshops), and self-teaching is still widespread in this population.[76] There may be costs involved for practicing physicians to participate in continuing education as well as loss of income. In our opinion, the time spent in simulation may be a solid investment since a complication prevented by practice in simulation may actually save time and decrease complications in clinical practice.

There are several limitations to our review. The search terms related to regional anesthesiology, regional anesthesia, simulation, and simulation-based education have many pseudonyms that may have resulted in an incomplete literature search and inability to evaluate every study exploring the effectiveness of simulation-based education in regional anesthesia. Each of the authors completed his own web-based and manual searches to generate as comprehensive a reference list as was feasible. We define simulation broadly in this review and have included published articles that describe any type of simulated environment or training, including as little as 5 minutes in simulated-training,[13] for the sake of completeness. In reality, we believe effective simulation-based education in RAAPM necessitates stricter criteria including personal feedback, repetitive practice, and student reflection. These are unique characteristics of simulation that have the potential to augment learning.

We as educators see additional benefits of simulation-based education. As anesthesiologists who specialize in RAAPM, the scope is not limited to just performance of nerve blocks. While achieving mastery in a new technical skill is a measurable and achievable result with simulation, this should not ever be a physician's final goal. Studies by Neal et al[46] investigating the use of emergency checklists during a simulated LAST crisis and Brenner et al[26] employing similar crisis management simulations for pain physicians

demonstrate the potential role of simulation in teaching professional practice far beyond mere technical skills. In RAAPM, the frontier for simulation-based education should evolve to include teaching difficult patient interactions (eg, demented elderly with hip fracture), ethical dilemmas (eg, wrong side blocks), interdisciplinary team-based care, safety culture, and more.

As technological advances in regional anesthesia and analgesia emerge, such as new robot-assisted procedures, medications, equipment, and techniques, they will require rigorous testing followed by an effective means to update training. The simulated environment is ideal for trialing these innovations, comparing them to current practices, and proving them effective prior to full implementation in clinical care. When there is sufficient evidence to support a change in clinical practice, simulation may even be able to facilitate dissemination and implementation.

In summary, the emerging subspecialty of RAAPM represents an opportunity to critically evaluate the current methods of teaching regional anesthesia techniques and the practice of acute pain medicine. To date, there have been a wide variety of simulation applications in this field, and efficacy has largely been assumed. However, a thorough review of the literature reveals that effective teaching strategies, including simulation, are not yet established completely, in RAAPM. Future research should be directed toward comparative-effectiveness of simulation versus other accepted teaching methods, exploring the combination of procedural training with realistic clinical scenarios, and the application of simulation-based teaching curricula to a wider range of learner from the student to the practicing physician.

Disclosure

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