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REVIEW ARTICLE

The role of simulation training in anesthesiology resident education

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Abstract

An increasing number of reports indicate the efficacy of simulation training in anesthesiology resident education. Simulation education helps learners to acquire clinical skills in a safe learning environment without putting real patients at risk. This useful tool allows anesthesiology residents to obtain medical knowledge and both technical and non-technical skills. For faculty members, simulation-based settings provide the valuable opportunity to evaluate residents' performance in scenarios including airway management and regional, cardiac, and obstetric anesthesiology. However, it is still unclear what types of simulators should be used or how to incorporate simulation education effectively into education curriculums. Whether simulation training improves patient outcomes has not been fully determined. The goal of this review is to provide an overview of the status of simulation in anesthesiology resident education, encourage more anesthesiologists to get involved in simulation education to propagate its influence, and stimulate future research directed toward improving resident education and patient outcomes.

Keywords Simulation education · Anesthesiology resident · Non-technical skill · Patient outcome

Introduction

Simulation in medical education refers to recreating or imitating clinical scenarios to teach trainees and assess their performance [1]. Simulation education in the form of standardized patients or full-body mannequins has been sporadically reported since the late 1960s [2]. Since then, its acceptance has grown, and today, it is recognized as an integral part of medical education due to the decreased availability/opportunity to practice on real patients and growing concern for patient safety [3]. Technological development with increasingly sophisticated simulation modalities has also contributed to the growing acceptance of simulation education.

Simulation as a teaching and training tool consists of three components: initial briefing, simulation experience, and debriefing. Initial briefing refers to pre-simulation explanation and guidance. The simulation experience is the main part of simulation education. Participants undergo simulated clinical scenarios; various clinical scenarios focusing on either technical skills or non-technical skills are available [4–6]. Debriefing is a core component of simulation-based education. Post-simulation debriefing provides learners with the important opportunity to reflect on various aspects of the simulation and improve their clinical practice.

Recently, many anesthesiologists have become involved in educational activities and an increasing number of reports have indicated the efficacy of simulation in anesthesiology [7–9].

The aim of this review is to provide an overview of the current status of simulation in anesthesiology resident education by highlighting some of the latest studies that have reported its utility in anesthesiology resident training.

Simulation education in anesthesiology

Role in resident training

Anesthesiology is a hands-on specialty. As such, anesthesiology residents should master diverse techniques such as tracheal intubation, lung isolation, difficult airway management, central venous catheter placement, and regional anesthesia. Although these technical skills are best mastered in

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the clinical setting, simulation introduces novice trainees to these skills in a safe learning environment without putting real patients at risk. In a simulation environment, anesthesiology residents gain experience with anesthetic emergencies or rare anesthetic complications in a reproducible and controlled manner.

Non-technical skills such as communication, leadership, team work, situation awareness, and decision-making are also indispensable skills for anesthesiology residents. Teaching these non-technical skills has also been a major focus of simulation education [10–13].

Simulation training is beneficial for resident training as well as for lifelong education for experienced anesthesiologists. The Maintenance of Certification in Anesthesiology (MOCA®) program redesigned by the American Board of Anesthesiology allows participation in a simulation course as one of the options to meet the requirements to maintain board certification. Compared with experienced anesthesiologists, anesthesiology residents may benefit more from simulation training, since they likely acquire more new skills and handle more new situations during their several years of residency.

Several studies have shown the effectiveness of simulation-based training in technical and non-technical skills for anesthesiology residents over the last decade. In the future, effort should be directed towards showing how to more effectively optimize this modality of learning and how to transfer knowledge from research findings to clinical practice in anesthesiology [1].

Evaluation of residents' performance

Simulation-based settings are also used to evaluate resident performance, which is a principal task in education [14–16]. Wetmore et al. showed the effectiveness of the Pre-Anesthetic Induction Patient Safety checklist in the simulation setting [17]. Blum and associates showed the validity of a simulation-based performance assessment system for identifying critical anesthesiology resident performance gaps [18]. Arzalier-Daret and colleagues evaluated the effect of sleep deprivation after night shift duty in a simulation setting and reported that sleep deprivation was associated with anesthesiology residents' impairment in managing crisis situations [19]. One merit of simulation-based assessment is that participants can be assessed in a safe and less stressful environment. Assessment in a clinical setting is desirable for the evaluation of competency, but stressors such as the fear of putting a patient at risk may prevent residents from showing their true competency. In addition, clinical settings vary, and evaluating several residents in the same environment is not feasible. Simulation-based settings can allow safe and uniform participant assessments.

Although the reliability and validity of simulation-based assessment have been widely accepted [18, 35], developments are slower than those in the use of simulation for training purposes [1]. More work is needed to demonstrate that simulation-based assessment can predict future performance in clinical settings.

Airway management

Airway management is one of the anesthesiologist's primary tasks and all junior anesthesiology residents should quickly become familiar with airway anatomy and proficient in airway management techniques. As a part of teaching airway anatomy and one of the modalities used to identify the position of an endotracheal tube in the airway, airway sonography simulation training with a hands-on gel phantom as well as instructional video training helps residents to improve their knowledge of airway sonoanatomy [20]. Simulation-based airway management makes the clinical learning experience more comfortable for the trainee. Kennedy et al. showed in their systematic review and meta-analysis that simulation was associated with higher learner satisfaction compared with non-simulation interventions [21].

Endotracheal intubation with bronchoscopy, an indispensable skill for anesthesiologists, is frequently performed to manage difficult airways or perform lung isolation. Although it entails complex technical and psychomotor skills [22], opportunities for anesthesiology residents to practice this task on real patients are limited. Simulation education can help anesthesiology residents to learn this technique safely and effectively [23], and several studies have highlighted the benefit of simulation curriculums for teaching bronchoscopy [24–26]. Various simulators are available for the placement of a bronchial blocker under bronchoscopy guidance, such as virtual reality-based simulation devices [27] and the *AirSim® Bronchi* simulator (Trucorp, Belfast, Northern Ireland) [28]. Usually, novice practitioners find it challenging to complete bronchoscopic intubation in a timely manner; such a delay would hamper an efficient turnaround of a busy operating room (OR). Teaching fiber optic intubation outside the OR beforehand would reduce time pressure on practitioners and may reduce the actual time required to complete intubation in the OR [29].

Difficult airway management is one of the leading factors associated with anesthetic deaths and remains a primary challenge for most anesthesiologists. Anesthesiology residents, however, may not have sufficient clinical exposure to difficult airway management [30]. According to American Society of Anesthesiologists difficult airway algorithms [31], surgical airway intervention is the final option in "can't intubate, can't ventilate" cases. Despite the rarity of this critical situation, anesthesiology residents should be trained for surgical airway techniques such as cricothyrotomy. Hubert and colleagues assessed the impact of simulation training on anesthesiology residents' ability to adhere to difficult airway management guidelines, and showed that simulation training improved resident compliance with the guidelines and their performance of cricothyrotomy [32]. Simulation-based cricothyroidotomy training is also beneficial for attending anesthesiologists in charge of resident education. Boet and associates showed the benefit of high-fidelity simulation training for attending anesthesiologists to retain cricothyroidotomy procedural skills [33]. Anesthesiologists must sometimes manage difficult airway situations outside the OR. Rochlen and colleagues evaluated anesthesiology resident out-of-OR emergent airway management and showed improved familiarity with the content of and adherence to difficult airway algorisms after simulation training [34].

Schebesta et al. concluded in a randomized-control study that simulators are not a valid alternative to human patients for performing scientific evaluations of supraglottic airway (SGA) management techniques [35]. However, because of the limited number of publications on this topic, whether simulation-based training can contribute to improved SGA management skills remains unclear. Further research is needed to evaluate the efficacy of simulation education in SGA management.

Several review articles on simulation-based airway training have been published [36–38]. Simulation education may have the advantage of improving learner behavior and performance and increasing learner interest and satisfaction, but whether simulation education leads to improved learner performance and patient outcomes in a clinical setting remains unclear. Yang and associates assert that experienced instructors and the best curriculum design are important in optimizing the benefits of simulation training [39].

Regional anesthesia

Regional anesthesia techniques have become some of the most basic and indispensable skills in clinical anesthesiology over the past few decades with the development of portable ultrasonography (US) devices [40], with which anesthesiology residents should become familiar.

Simulation education seems to be suitable for teaching the US-guided regional anesthesia techniques. Ramsingh et al. suggested that anesthesiology residents who were trained using simulation showed higher post-lecture test scores and greater interest in perioperative US than those trained via didactic lecture [41]. Woodworth and colleagues reported that a short educational video with interactive simulation significantly improved knowledge of sonoanatomy [42]. Simulation has proven helpful for residents to acquire regional anesthesia technical skills. In an experimental model, Baranauskas et al. reported that longer US-guided peripheral nerve block training improved the learning curve of the technique [43]. Chen and associates reported that simulation training improved both trainees' comfort level and competency with needle driving in a simulation model [44]. Simulation training helped novices to acquire the skills necessary to perform US-guided lumbar facet joint injections and medial branch block [45]. Several publications show the benefit of simulation education in the clinical setting. Anesthesiology residents showed a better success rate in US-guided performance of regional anesthesia with an extra hour training session on needling and proper hand–eye coordination [46].

Simulation education is also helpful for pediatric anesthesia trainees. Moore et al. reported that pediatric anesthesia trainees' cognitive and technical US-guided regional anesthesia skills improved significantly through an instructional program with simulation [47]. Several publications also report the benefit of simulation training for learning spinal and epidural anesthesia, a primary technique for anesthesiologists. Resident performance of subarachnoid block can be improved by adding simulation-based deliberate practice to a base curriculum [48]. Spinal sonography is a useful technique for the evaluation of spinal anatomy of patients with obesity, pregnancy, and abnormal spinal anatomy. Simulation training with a hands-on gel phantom can improve anesthesiologists' knowledge of lumbar spine sonoanatomy [49]. A simulator that can recreate experts' perception during spinal anesthesia has also been introduced [50]. For epidural anesthesia, Magill and colleagues introduced a novel simulator that can approximately reproduce properties of complex multilayer tissue structures during epidural insertion [51]. Friedman and associates reported that a low-fidelity simulator can be as useful for learning how to place an epidural catheter as it is for placing a high-fidelity one [52]. Interestingly, Lim and her team showed that mental imagery was not different from low-fidelity simulation training for epidural anesthesia skill acquisition [53]. The role of simulation training in epidural anesthesia still needs to be discussed.

Although many publications have reported the benefit of simulation education in regional anesthesia, debates on its utility continue. Udani and associates showed no difference in acquisition and retention of skills in US-guided regional anesthesia between residents taught by either simulation-based practice or self-guided practice [54]. Competency-based curriculum with simulation training may be helpful for residents to learn regional anesthesia effectively [55]; however, effective educational strategies in regional anesthesia have not yet been established. Discussion about the roles of simulation in regional anesthesia training is still needed [56].

Cardiac anesthesia

Training in cardiothoracic and vascular anesthesia is a great challenge to anesthesiology residents. Usually, patients have life-threatening conditions, and anesthesiology residents should be familiar with cardiopulmonary pathology and intricate technical skills such as insertion of an arterial catheter, central venous catheter, or pulmonary artery catheter, and transesophageal echocardiography (TEE). In addition to this knowledge and these technical skills, communication and coordination between other medical staffs are important. Simulation education can be an effective tool for anesthesiology residents to learn these complex aspects of cardiac anesthesia [57] and various simulation devices to teach these skills have been introduced [58, 59].

For central catheter insertion, Diederich et al. reported that simulation education with low-fidelity equipment showed similar learning outcomes comparable with education with high-fidelity equipment [60]. Bruppacher and colleagues indicated that high-fidelity simulation-based training leads to improved patient care during weaning from cardiopulmonary bypass (CPB) when compared with the traditional teaching methods [61]. Morais and associates introduced simulation education with high-fidelity mannequins that can simulate CPB hemodynamics and received positive feedback from residents [62].

Echocardiography has become indispensable for cardiothoracic and vascular anesthesia, and several papers have reported the benefits of simulation training for teaching basic transthoracic echocardiography (TTE) and TEE skills. Simulation training can be beneficial for teaching basic TEE concepts including anatomic correlation, structure identification, and image acquisition [63, 64]. TEE simulation training can also improve knowledge of normal echocardiographic anatomy [65]. In the critical care setting, simulation-based TEE training improves the ability of novice operators to perform focused critical care TEE [66]. TEE simulation can also serve as a tool to assess the sonographer's evaluation skills [67]. For TTE, Neelankavil and associates reported in their prospective randomized study that anesthesiology residents trained with simulation showed better TTE image acquisition/anatomy identification skills on volunteer subjects [68]. Since these simulation devices are generally expensive, cost-effectiveness in simulation training in cardiac anesthesia remains an issue.

Obstetric anesthesia

Simulation education has played an important role in training technical, cognitive, and teamwork skills in obstetric anesthesiology [69]; and can be used to effectively assess and teach anesthesiology resident teamwork and behaviors [70]. The volume of cesarean delivery under general anesthesia has decreased, potentially limiting training experiences for anesthesiology residents. Therefore, educators have recommended the increased use of surrogate training modalities such as simulation-based training to teach these skills. Scavone and associates introduced a scoring tool to measure resident performance of general anesthesia for emergency cesarean delivery on a patient simulator and found it to be reliable and valid [71]. They also reported that anesthesiology residents who underwent focused simulation training of general anesthetic management for emergency cesarean deliveries demonstrated improved performance during a subsequent simulated anesthetic scenario compared with trainees who did not undergo such instruction [72]. Simulation training is effective not only for learning, but also long-time retention of acquired skills. Anesthesia residents remained competent in performing general anesthesia for emergent cesarean delivery even 8 months after simulation-enhanced training [73].

Simulation education gives residents a good surrogate opportunity to prepare for rare obstetric emergencies. Daniels and associates introduced simulation team training for the management of epidural-induced hypotension followed by an amniotic fluid embolism, and concluded that simulation-based obstetric crises training offered a good opportunity for educators to identify their residents' specific performance deficits [74]. Obstetric bleeding is also life-threatening event that may occur in obstetric anesthesia and simulation training may also be effective in training the estimation of blood loss volume [75, 76].

Several reviews on simulation education in obstetric anesthesia have been published [69, 70, 77]. Despite the potential benefits and advantages of simulation training, it is still unclear whether simulation training leads to residents' improved behaviors or better care in the clinical setting, or whether simulation improves patient outcomes in obstetric anesthesiology. Further research is certainly needed.

Other fields

The rewards of simulation education have been introduced in other fields of anesthesiology. Liver transplant anesthesia requires extensive preparation and rapid recognition of changing clinical conditions. Aggarwal and associates introduced a simulation course combining didactic sessions and mannequin-based simulation. They reported that residents felt improvements in their preparedness, confidence, anticipation, and understanding of the importance of communication skills in liver transplant anesthesia [78]. Katz and colleagues showed in their randomized-controlled trial that adding a serious game, an interactive application created for imparting knowledge or skills, to an existing educational curriculum for liver transplant anesthesia resulted in significant learning gains for residents [79]. In the field of neuroanesthesiology, Rebel et al. introduced a computer-based somatosensory evoked potential simulator and indicated that session with this simulator was an effective teaching method [80]. Although screen-based simulators have not proven more effective than problem-based learning discussions for education during anesthesiology residents' neuroanesthesia rotation, resident satisfaction with the simulation training showed subjective evidence of a positive impact [81].

The clinical benefit of point-of-care (POC) ultrasound for perioperative whole-body assessment has been advocated. Ramsingh and associates introduced a simulation-based integrated whole-body POC ultrasound curriculum for anesthesiology residents. They reported that their curriculum contributed to improved learner satisfaction, knowledge, examination skills, and, what's more, led to changes in clinical management in some cases. [82]. The benefits of simulation education are also found in the "medical handoff", or the transfer of patient care responsibility and information [83]. Simulation-based practice resulted in improved intraoperative handoff communication and retention of skills at 1 year [84]. Simulation education may be beneficial in the training of endoscopic sedation [85] and evaluation of pediatric anaphylaxis management in the OR [86].

Status of simulation in anesthesiology resident education

While simulation education has been gaining interest and acceptance among anesthesiologists, the optimal use of simulation education in anesthesiology resident education programs is still unclear. In the United States, the Accreditation Council for Graduate Medical Education Program requirements for Graduate Medical Education in Anesthesiology stipulates that residents must participate in at least one simulated clinical experience each year [87]. In the Japanese board certification program, anesthesiology residents must participate in the American Heart Association's Basic Life Support and Advanced Cardiovascular Life Support course during their residency; these courses have simulation training settings.

Although a significant amount of research about the use of simulation training in anesthesiology has been conducted and has shown its advantages and benefits, some remaining problems should be discussed.

First, the best type of simulator has not been determined. Recent technology has made high-fidelity mannequins replicate real clinical conditions; however, several authors have reported no significant difference between groups trained with high-fidelity simulators and those trained with low-fidelity simulators [52, 88]. Cheng and associates reported in their systematic review and meta-analysis that the use of high-fidelity manikins in comparison to low-fidelity ones showed no benefit in knowledge or skill performance at the conclusion of the course or at 1 year after the course [89]. Given budget constraints, it seems reasonable to make the most of conventional low-fidelity simulators to achieve comparable benefit. High-fidelity simulators should be critically evaluated as to whether they would provide additional educational benefits over low-fidelity models.

The second question is whether simulation education can contribute to better patient outcomes. The Kirkpatrick classification is widely used to evaluate education intervention outcomes [90]. This classification has four levels of educational intervention outcomes (Table 1). Numerous publications have shown that simulation education can improve residents' knowledge, skills, and behaviors. However, a little evidence shows that simulation training improves patient outcomes, which corresponds to Kirkpatrick level 4 [91–93]. We classified educational outcomes from the original publications cited in this article into each Kirkpatrick level (Table 2). Recognizing the potential advantages and benefits of simulation education in anesthesiology, further research should be directed toward patient outcomes.

Finally, the scarcity of the number of simulation specialists in anesthesiology is a practical issue. The field of anesthesiology has been a pioneer of simulation education for resident training [94], but the number of anesthesiologists versed in simulation education seems to be still limited, especially in Japan. Several courses have been designed to cover fundamental skills for the creation and delivery of high-quality simulation-based healthcare education. "Improving Simulation Instructional Methods" (iSIM) offered by the Peter M. Winter Institute for Simulation, Education and Research (WISER) at the University of Pittsburgh and "Fundamental Simulation Instructional Methods" (FunSim) offered by SimTiki Simulation Center, John A. Burns School of Medicine in Hawaii are well-known simulation instructional courses. Being a good clinical teacher requires special skills and training [95], and training anesthesiologists to become good simulation teachers is critical.

Conclusion

A growing number of reports indicate the efficacy of simulation in anesthesiology resident education in teaching knowledge and both technical and non-technical skills. More anesthesiologists should get involved in simulation education to spread its influence and use in resident education.

Table 1 Kirkpatrick classification

	Level	Details
Level 1	Reaction	Improved leaner's satisfaction and confidence
Level 2	Learning	The learning of skills and knowledge
Level 3	Behavior	Behavioral change of healthcare providers in the clinical setting
Level 4	Organization	Improved patient outcome

Table 2 Educational outcomes of original articles cited in this paper

	Topics	Kirkpatrick level			
		Level 1	Level 2	Level 3	Level 4
Airway	Airway sonography		20		
	Flexible fibreoptic intubation	26, 28	23, 26, 27, 28	24, 25, 29, 88	
	Difficult airway management		32, 33, 34		
Regional	Nerve block	44	41, 42, 43, 44, 45, 47, 54	46	
	Spinal and epidural anesthesia		49	48, 89	
Cardiac	CVC insertion		60		
	CPB	62	62	61	
	TEE		63, 65	64, 66	
	TTE		68		
Obstetric	Emergent CS		72, 73,		
	Obstetric emergency		74, 75, 76		
Others	Non-technical skills		5,	4,	
	Liver transplantation	78	78, 79		
	Neuroanesthesia		80, 81		
	Point-of-care ultrasound	82	82	82	82
	Handoff			83, 84	

CVC central venous catheter, *CPB* cardiopulmonary bypass, *TEE* transesophageal echocardiography, *TTE* transthoracic echocardiography, *CS* cesarean section

Future research efforts should be directed toward evaluating improvement in patient outcomes.

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