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Review Article

Anaesthesia Section

Simulation-based Training for Anaesthesiology Residents: A Boon

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ABSTRACT

Training in anaesthesiology necessitates exposure to diverse clinical situations, demanding quick thinking, decision-making, and intervention. Achieving expertise in this field traditionally requires years of clinical practice and exposure to various scenarios. Simulation-Based Medical Education (SBME) revolutionises anaesthesiology training by providing a controlled environment where trainees can acquire knowledge, refine clinical skills, and develop clinical and non clinical competencies. This approach includes training in soft skills, critical analysis of clinical scenarios, and receiving constructive feedback from qualified instructors. In alignment with industries like aviation and the military, various countries have incorporated SBME into medical curricula. The present scoping review explores the benefits, limitations, and diverse applications of SBME for anaesthesiology trainees. The historical progression of SBME, from basic procedural models to advanced simulations and virtual reality, underscores its transformative impact on medical education. Standards and accreditation for simulation laboratories ensure quality maintenance in training programs. SBME in anaesthesiology focuses on technical skill development and cultivating crucial non technical skills essential for patient safety. The review emphasises the need for a comprehensive curriculum, qualified instructors, reliable equipment, and ethical considerations to establish standards for simulation in anaesthesia. The versatility of simulation types, including low-fidelity task trainers, high-fidelity mannequins, and virtual simulations, enhances training opportunities. Anaesthesia simulation encompasses a spectrum of scenarios, from cardiothoracic anaesthesia to airway management, addressing technical and soft skills. While SBME offers advantages such as enhanced teamwork, regulated skill development, and exposure to rare situations, drawbacks include costs, ethical concerns, and replicating real-world complexity. Ongoing research is crucial to assess the effectiveness of SBME and its impact on patient outcomes. The evolving significance of SBME in anaesthesiology suggests its continued promise for breakthroughs in medical education.

Keywords: Education, Ethical, Simulation-based medical education, Virtual reality

INTRODUCTION

An essential aspect of the education of an anaesthesia trainee is gaining knowledge in administering anaesthesia to patients, rigorous monitoring throughout the procedure, and managing any unprecedented complications. SBME is a practical method of preparing trainees for this responsibility. SBME uses simulation to replicate clinical scenarios for educational purposes [1]. They are valuable for learners, especially anaesthesiology trainees, as there is complete control over a preselected scenario without distressing patients. SBME helps learners undergo a training module, practice and develop their skills, and learn from mistakes without potentially threatening their professional identity or putting patients at risk. In these activities, the learner is introduced to the particular scenario and then decides on the management of the specific scenario. This interactive nature of simulation helps the learner retain the skills better and thus potentially impacts future decision-making related to a similar encounter [2].

Since its inception, simulation has been used to evaluate personnel's performances in various fields. The aerospace, nuclear, and military industries have utilised simulation for learning, assessing skills, and research and development. Simulation may provide similar benefits in medical education, particularly in anaesthesia. Despite discussions on its benefits, efficacies, and the difficulty in assessing its effectiveness, simulation has become a mandatory part of training in various countries [3]. Simulation for anaesthesia trainees is most commonly done using high-fidelity simulation or virtual reality. The former uses mannequins that mimic different physiological responses and may respond to various interventions, allowing the trainee to practice multiple clinical scenarios. The latter uses a computer-generated virtual environment to replicate a clinical scenario, thus helping to train in complex procedures with high rates of complications. Numerous locations, including hospitals, medical schools, and simulation laboratories, are used for simulation training. These facilities are guided by experienced educators and anaesthesiologists who teach the trainees through various scenarios. The trainees can learn from their expertise, receive constructive feedback, and work on areas that require improvement [4].

The advantages, limitations, and numerous uses of SBME for anaesthesiology trainees are discussed in the present review. The evolution of SBME over time, from simple procedural models to sophisticated simulations and virtual reality, highlights how it impacts medical education. Training program quality is maintained through standards and accreditation for simulation labs. In anaesthesiology, SBME emphasises the development of critical non technical abilities vital to patient safety and technical skill development. The review highlights the requirements for establishing standards for simulation in anaesthesia, including a thorough curriculum, skilled teachers, dependable equipment, and ethical considerations.

History of Simulation

The SBME began early in the 20th century when trainees learned procedures like lumbar puncture and venipuncture on basic models. The use of SBME started to achieve broad acceptance in the 1960s. Harvey, a cardiopulmonary patient simulator, was created in the 1960s for medical students to identify and treat various pathologies of the cardiovascular system. This simulator was considered a significant advancement in medical simulation as it allowed the students to hone their clinical skills and decision-making abilities using a simulator [5]. Sim-one, a computer-controlled patient simulator, was introduced

in 1960 at the University of California. The utilisation of simulation in medical education continued to progress throughout the 1970s with new simulation technologies such as high-fidelity mannequins. These advances permitted the students to perform various clinical competencies ranging from simple tasks to complicated decision-making [6]. Medical curricula were incorporated with SBME programs in the 1980s and 1990s. The students received an integrated approach to clinical education, combining classroom teaching with SBME [7]. During the 2000s, simulation grew by leaps and bounds with the advent of virtual reality and dedicated simulation laboratories. These advances have made medical simulations more accurate and have allowed medical students to improve their skills in a controlled setting. Simulator-based medical education is now a crucial component of medical education worldwide. It is employed to educate a variety of medical competencies and to foster the growth of collaborative, communicative, and analytical abilities. It has been demonstrated that SBME improves student outcomes, lowers medical errors, and enhances patient safety. It will probably continue to be crucial for many years to come in training healthcare workers [8].

Standards for Simulation in Anaesthesia

A comprehensive curriculum that describes the learning objectives, materials, and evaluation methods should serve as the foundation for SBME in anaesthesia. The curriculum should be continuously evaluated and updated to represent the most recent developments in anaesthesia practice [3]. Instructors in educational simulations and simulation technologies should receive training. Additionally, they must be knowledgeable about anaesthesia practice and capable of giving trainees helpful criticism [9]. The tools used in anaesthesia training should be dependable, realistic, and fit for purpose. Regular maintenance and testing should be performed to ensure the equipment is operating correctly. SBME should incorporate reliable, valid, and congruent assessments of the learning objectives. Formative and summative assessments should both be a part of assessment strategies. Debriefing by subject experts and the use of video review after a simulation can be used to assess the trainees' performance during simulation. The debriefing process needs to be organised, assisted, and goal-oriented. It should also have a helpful and non threatening approach to feedback [10]. Simulation-based anaesthesia training should follow ethical guidelines, such as informed consent, patient confidentiality, and respect for the patient's dignity. Research is crucial in SBME to ensure that the training is efficient and that the teaching strategies are based on sound educational principles. Research should be conducted to evaluate the outcomes of different teaching modalities on learners and the effects of simulation-based training on clinical outcomes [11]. Accreditation of simulation laboratories has been undertaken by the Society for Simulation in Healthcare (SSH) since 2010. According to the SSH, accreditation has to be a peer-reviewed, custom evaluation of a simulation laboratory [12].

Types of Simulation

High-fidelity simulations: A sophisticated and advanced form of SBME, high-fidelity simulation closely mimics real-world medical scenarios with high realism. High-fidelity simulation in anaesthesiology training uses sophisticated mannequins that closely resemble human physiological responses and reactions to medical procedures. Features like sensitive vital signs, realistic anatomy, and the capacity to replicate a range of medical situations and emergencies are all included in these life-like patient simulators. Mannequins capable of simulating physiological reactions like heart rate, respiration, and blood pressure are used in high-fidelity simulations such as the Human Patient Simulator (HPS). These immersive simulators allow trainees to practice complicated situations like managing airways, crises, and team coordination [13]. Multiple trainees can collaborate to manage a simulated patient in team training situations, which frequently involve high-fidelity simulations. High-fidelity simulation provides a realistic and immersive learning environment essential for anaesthesiology training. Its capacity to imitate intricate clinical situations, deliver interactive instructions, and provide helpful criticism helps anaesthesia trainees acquire critical skills that improve patient safety and the general standard of anaesthesia care [14].

Low-fidelity simulations: Simplified and economic models are employed in low-fidelity simulations in medical education, such as anaesthesia training, to mimic specific components of real-world clinical situations. In an elementary setting, low-fidelity simulations emphasise practicing specific skills and procedures. These simulations give trainees practical learning experiences through primary resources, models, and task trainers [15]. In low-fidelity simulations, task trainers allow trainees to practice specific tasks, including managing an airway or emergency crisis, inserting an IV, and placing an epidural. These simulations are frequently less expensive and engaging than high-fidelity simulations, yet they help practice specific competencies [16]. Using computer software to recreate patient scenarios, virtual simulations like the virtual anaesthesiology training simulation system created by Computer-aided Engineering (CAE)-Link Corporation enable trainees to hone their skills in a controlled setting [17]. These simulations may not offer the same level of immersion as high-fidelity simulations, but they can be incredibly flexible and accessible from anywhere with an internet connection.

Simulation in Anaesthesia

Role of the teacher: Skilled teachers play a crucial role in creating successful and impactful simulation-based training. They possess extensive clinical experience and expertise in anaesthesia practice, ensuring that simulation scenarios are realistic, relevant, and aligned with actual clinical situations. Moreover, they can execute simulation scenarios that closely mimic the complexities of real-life anaesthesia situations. Better debriefing sessions help learners reflect on their performance, identify areas for improvement, and discuss strategies for enhancing patient care. Teachers also promote interprofessional education by designing simulation scenarios that require effective teamwork and communication among anaesthesiologists, nurses, surgeons, and other team members.

Airway management: Anaesthesiologists must have an in-depth knowledge of airway management as it is vital to provide oxygen and mechanical ventilation for individuals unable to breathe correctly.

Various airway training courses are available, including courses by the Difficult Airway Society and the Hong Kong College of Anaesthesiologists, among others. Multiple scenarios can be included in simulation-based training for airway management, ranging from simple airway management techniques like bag-valve-mask ventilation to more complicated airway interventions like intubation and surgical airway management. Various patient demonstrations, including restricted airways and emergency conditions, can be modeled in simulation scenarios [18]. Multiple mannequins such as the Laerdal airway management trainer and Ambu airway management trainer are available [19]. Hubert V et al., conducted a study to evaluate the ability of anaesthesiology residents to comply with guidelines on complex airway management and performing a cricothyroidotomy. A total of 27 anaesthesiology residents were enrolled in the study and assessed using simulation in a "cannot intubate, cannot ventilate" scenario before training and three, six, or 12 months after the training. Post-training, all residents were found to comply with the complex airway guidelines, compared to 17 residents before the activity on cricothyroidotomy. It was also found that the mean duration taken to perform a cricothyroidotomy was comparatively less in the post-test period [20]. Nilsson PM et al., conducted a randomised controlled study to assess the effectiveness of simulation in fiberoptic intubation in 23 anaesthesia residents. These residents received part-time or whole-task training in fiberoptic intubation using simulators and were compared with anaesthesiologists with no prior training. They

concluded that both groups had a positive learning effect regarding fiberoptic intubation compared to the anaesthesiologists who did not receive such training [21].

Regional Anaesthesia

Regional anaesthesia involves administering anaesthetic drugs to block sensory and motor nerves in specific body parts to relieve pain and avoid the need for general anaesthesia. It is frequently employed for procedures such as abdominal surgery, limb surgery, and joint replacements. Regional anaesthesia simulation-based training can cover a variety of situations, from conventional nerve block techniques to more intricate ultrasound-guided regional anaesthesia. Various patient presentations, including challenging anatomical landmarks, obesity, and concurrent medical disorders, can be simulated using simulation scenarios. Simulators like Blocksim and ScanNav are available to simulate peripheral nerve blocks [22].

Obstetric Anaesthesia

Obstetric anaesthesia involves administering anaesthetic agents to pregnant women to relieve pain and manage pregnancy-related problems. It is a crucial area of practice that calls for a high level of proficiency. Basic spinal and epidural anaesthesia procedures to more complicated ones, such as managing high-risk pregnancies or rare complications, can all be included in simulation-based training for obstetric anaesthesia. Various patient presentations, including those of obese or high-risk patients and emergencies such as foetal cardiac arrest, can be simulated in simulations. Courses like Multidisciplinary Obstetric Midwifery and Anaesthetic Simulation (MOMAS), Eastern Airway Skills Training (EAST), and Vital Anaesthesia Simulation Training (VAST) are available [23]. The mega sim model introduced by Bradley NL et al., included a scenario of a pregnant female subjected to trauma and needing surgery. It involved simulation for a multidisciplinary team, resulting in a positive perception of teamwork and communication. It was divided into two parts, which included care between departments, and was subdivided into sections and stages. Debriefing occurred after each part, involving communication, resource utilisation, and situational awareness [24].

Cardiothoracic Anaesthesia

Cardiothoracic anaesthesia involves administering anaesthesia during cardiothoracic surgeries such as coronary artery bypass grafting, valve replacements, and heart transplants. Various simulation-based training situations can be used for cardiothoracic anaesthesia, ranging from straightforward airway management techniques to complex operations like Extracorporeal Membrane Oxygenation (ECMO) and heart-lung bypass. Various patient presentations, including those of high-risk patients and emergencies such as cardiac arrest, can be replicated in simulation scenarios. Courses like Cardiac Anaesthesia Simulation Training (CAST) are available [25]. Thirteen residents undergoing a cardiothoracic anaesthesia rotation were instructed on seven tasks using the simulator AirSim Bronchi, including the use of fiberoptic bronchoscope, placement of bronchial blockers, lung isolation techniques, and application of continuous positive airway pressure to the unventilated lung in a study conducted by Failor E et al., [26]. The residents used a 5-point Likert scale to rate their confidence after the course. It was observed that the residents' confidence in each lung isolation technique increased after the simulation session [26]. Neelankavil J et al., conducted a prospective randomised study using 61 anaesthesiology residents to demonstrate that training in transthoracic echocardiography using simulation-based training was more effective than lecture-based methods. A pretest was conducted before the training. The residents were trained using lecture- or simulation-based methods and then given a post-test. It was found that residents in the simulation group had a better post-test results in all criteria compared to the other group [27].

Soft Skills

The safe and efficient practice of anaesthesia increasingly emphasises non technical skills, commonly referred to as 'soft skills.' SBME is the best way to teach and evaluate these abilities in anaesthesia trainees [28]. Critical non technical skills can be taught and assessed through simulation, including communication, collaboration, decision-making, and other relevant competencies. Communication is crucial for safe and effective anaesthesia care. The ability to provide clear and precise instructions, listen attentively, and communicate effectively with other healthcare team members are all communication skills that can be evaluated in simulation scenarios. Simulator-based training enables trainees to practice their communication skills, empathy, and cultural sensitivity. Designing simulations representing diverse patient groups allows trainees to practice communication with patients from various backgrounds and cultures, enhancing their understanding of different patient populations' needs and perspectives and the skills required to provide culturally sensitive care. As anaesthesia is a team-based practice, trainees must collaborate effectively with other medical specialists. The ability of trainees to work well with other members of the healthcare team, such as surgeons, nurses, and other anaesthesiologists, can be assessed through the creation of simulation scenarios. Safe and high-quality care administration relies on effective teamwork, and simulation-based training enables healthcare professionals to practice collaboration in a realistic and controlled environment. Situational awareness involves recognising, understanding, and anticipating circumstances. Simulated scenarios can be designed to evaluate a trainee's situational awareness, including their ability to identify potential issues and take necessary preventive actions. Anaesthesia trainees must be able to make quick and informed decisions based on available information. Simulation scenarios can be used to assess a trainee's decision-making skills, including their ability to prioritise tasks and act decisively under pressure. To provide safe and effective care, trainees must manage stress in the highly demanding anaesthesia setting. Simulation scenarios can be designed to evaluate a trainee's stress management and composure under pressure [29].

Benefits of Simulation-Based Medical Training

Simulation training provides a controlled environment for anaesthesia trainees to develop their skills without risking patient safety. This helps them learn complex scenarios such as airway management, critical care management, and regional anaesthesia. Trainees can experience many scenarios that may not be possible during their clinical training, including rare complications and emergencies, which are crucial for developing decision-making skills in high-stress situations [15].

Given that anaesthesiology is a high-risk specialty with exposure to various emergencies, simulation allows trainees to practice and learn from their mistakes without compromising patient safety. Trainees are trained in decision-making skills and critical analysis. In a simulations, trainees must make time-constrained decisions effectively and learn to manage multiple tasks simultaneously with the information available. All clinical scenarios can be customised based on the trainee's needs and repeated as necessary [30].

Simulation ensures that anaesthesia trainees establish a solid foundation regardless of their backgrounds and primary education disparities. It improves the communication skills and teamwork of trainees. In scenarios, trainees must collaborate with other healthcare team members to achieve the best outcomes. It also requires them to communicate effectively with patients and their families, enhancing the quality of patient care. Simulation is also utilised to teach about recent advances and new equipment types. Therefore, trainees can become familiar with these techniques before applying them in patient care. Ultimately, simulation can enhance patient safety in anaesthesiology and critical care. Competent staff with knowledge of recent technical advancements and new equipment can significantly reduce iatrogenic errors and enhance

patient outcomes. Additionally, identifying areas for improvement in anaesthesiology during simulation can lead to changes in protocols and procedures, ultimately enhancing patient safety [31].

Saiboon IM et al., conducted a study to examine the confidence students developed and their understanding of managing primary incident responses following simulation using a questionnaire-based study. The results indicated that using SBME improved the students' understanding levels in terms of knowledge and managing direct incident responses. The students also reported that their confidence had increased following the simulation session [32]. Sanchez N et al., conducted an observational study in which 24 students were enrolled to learn basic procedural skills using simulation after their medical school graduation to integrate into anaesthesia training. The study included five skills essential for anaesthetic management: inserting a peripheral intravenous cannula, hand washing sterilely and preparing the workstation, face-mask ventilation, and tracheal intubation. A total of 20 were observed to be competent in all procedures during the final assessments based on task-specific checklists and global rating scales. There was a statistical significance for all skills between the baseline and post-workshop assessment scores, except for tracheal intubation, and for all skills between stages 2 and 3, except for hand washing and gowning [33].

The SBME should be an essential component of anaesthesia training, enabling trainees to acquire the skills and information necessary to administer anaesthesia to patients to enhance safety and efficiency. The ability to design controlled scenarios that allow focused learning without risking patient or trainee safety is one of the benefits of simulation over conventional training techniques as emphasised in the introduction [34].

While other industries like the military and aerospace have long used simulation for learning and assessment, simulation in anaesthesia training is not an entirely new concept. The advancement of SBME provides an equal opportunity to deliver safe, efficient training, and evaluation in a supervised setting [35]. Despite the benefits of SBME, it comes with limitations, including the cost and maintenance of equipment, supplies, and labour costs for efficient simulation training [36]. Additionally, evaluating the effectiveness of SBME and its impact on patient outcomes poses challenges. Ongoing research and development in this area are crucial to ensure that SBME is beneficial for training and assessment. SBME is increasingly utilised in anaesthesia, and several countries now mandate it as part of the training curriculum. Guidelines and standards are in place to effectively administer and assess SBME. Undoubtedly, simulation in anaesthesia training will continue to evolve and play a more significant and prominent role in anaesthesia [31]. Reproducible situations and assessments are crucial for successful simulation training, but this may restrict the capacity to tailor training to specific patient populations or individual learners [37].

Limitation(s)

Simulation training requires specialised technology, a dedicated area, and qualified employees; it may prove costly to establish and maintain. This could make simulation-based training programs less accessible, especially in environments with limited resources. Simulations cannot replicate the complexity and unpredictability of real-world situations, limiting the ability to apply simulation-based skills in real-world settings. Simulation-based training often focuses on specific techniques or skills and may not cover extensive clinical decision-making or patient management competencies. Trainees may need additional instruction and practical experience outside the simulation to develop these skills.

While simulation provides a safe environment for trainees to practice their abilities, there may be ethical concerns about exposing trainees to high-risk scenarios that could harm actual patients. For example, if the simulation accurately represents real-world scenarios, it may lead to the development of skills that are not applicable in practical situations, potentially misleading and harmful, especially in professions where precision is critical. Furthermore, simulations designed to mimic high-stress or emotionally charged situations can significantly impact trainees' emotions and mental well-being. If trainees perceive simulation-based training as monotonous or irrelevant to their clinical practice, they may lose interest, reducing the training's ability to enhance clinical judgment and decision-making. Despite ongoing advancements in simulation technology, there are still limits to what simulators can replicate. For instance, simulators may not accurately reproduce the way tissue feels or the variations in patient reactions that can occur in clinical situations. Additionally, non verbal cues in communication, which are significant in team-based treatment settings, may not always be captured by simulators. While simulation can be a useful tool for practice and learning, it should not be overused in place of practical experience. The complexity and unpredictability of real-world clinical settings cannot be entirely replicated through simulation, necessitating learners to interact with actual patients to develop essential experience and expertise. The creation and use of simulation scenarios may be biased; for instance, scenarios may be more applicable to specific patient populations or medical problems, unintentionally disadvantaging particular trainee populations [36].

CONCLUSION(S)

The SBME in anaesthesiology training has become essential, providing a safe and authentic learning environment. The evolution of SBME over time-from simple procedural models to sophisticated high-fidelity simulations and virtual reality-demonstrates how it has influenced medical education. Despite the numerous benefits of SBME, it is crucial to acknowledge its drawbacks, which include the need for specialised technology, associated costs, and the challenge of accurately simulating the complexity of real-world situations. SBME enhances patient safety, reduces medical errors, and prepares anaesthesia trainees for challenges they may encounter in their clinical practice by offering a safe and authentic learning environment. The review raises concerns about the time allocated for such training, emphasising the potential need for increased exposure to curricula that integrate medical management with non technical skills. It also stresses that, despite the many advantages of simulation, real-world experience remains the primary source of learning. Instead, simulation serves as a tool for practitioners to prepare by providing a structured environment for focused practice.

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