Narrative Review

Perioperative crisis resource management simulation training in anaesthesia

Dinker R. Pai[1,2], VR Hemanth Kumar[3], Sobana R[4,5]

[1]Director, [5]Dy Director, Medical Simulation Centre, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth, Puducherry, Departments of [2]Surgery, [3]Anaesthesiology, [4]Physiology, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth, Puducherry, India

Address for correspondence: Dr. Dinker R. Pai, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth, Pillaiyarkuppam, Puducherry, India. E-mail: dinkerpai@gmail.com

Submitted: 27-Nov-2023
Revised: 05-Dec-2023
Accepted: 06-Dec-2023
Published: 18-Jan-2024

Access this article online
Website: https://journals.lww.com/ijaweb
DOI: 10.4103/ija.ija_1151_23
Quick response code

ABSTRACT

Simulation-based education is now recognised to be a valuable tool to impart both technical and non-technical skills to healthcare professionals of all levels. Simulation is an well accepted educational tool for cultivating teamwork skills among residents globally. Simulation-based education encompasses diverse modalities, ranging from task trainers and simulated patients to sophisticated high-fidelity patient simulators. Notably, anaesthesiologists globally were early advocates of integrating simulation into education, particularly to instruct anaesthesia residents about the intricacies of perioperative crisis resource management and collaborative interdisciplinary teamwork. Given the inherent high-risk nature of anaesthesia, where effective teamwork is pivotal to averting adverse patient outcomes, and also to improve overall outcome of the patient, simulation training becomes imperative. This narrative review delves into the contemporary landscape of simulation training in perioperative anaesthesia management, examining the pedagogical approaches, simulators, techniques and technologies employed to facilitate this training.

Key words: Anaesthesia, crisis resource management, perioperative care, simulation training, teamwork

INTRODUCTION

Simulation has gained widespread acceptance as an educational tool for cultivating teamwork skills among healthcare professionals. There are many advantages stated for simulation: it offers repetitive practice for deliberate skill enhancement, ensuring safety for both learners and patients. The scheduling flexibility accommodates facilitators and learners alike, while computer-based systems enable self-directed learning with performance feedback, eliminating the need for facilitator intervention. Globally, the recognition of simulation as a training method in various fields of medical sciences is gaining traction.

However, its widespread adoption for imparting non-technical or 'soft' skills, specifically teamwork training, is still evolving. The global acknowledgement of the importance of training healthcare learners in these skills, crucial for minimising medical errors linked to non-technical shortcomings, has elevated the significance of teaching these skills in resident training worldwide. Anaesthesiologists, pioneering this approach, recognised the aptness of simulation-based education (SBE) for anaesthesia training due to the high stakes in patient safety, replicable cardiovascular and respiratory scenarios in simulators, a finite set of common resident challenges and the prevalence of issues in the operation theatre, making *in situ* simulation highly effective.

How to cite this article: Pai DR, Kumar VR, Sobana R. Perioperative crisis resource management simulation training in anaesthesia. Indian J Anaesth 2024;68:36-44.

This review aspires to catalyse a broader adoption of simulation within the anaesthesia teaching community, fostering its integration into mainstream education.

METHODS

This narrative review was undertaken to investigate the application of SBE in anaesthesiology, specifically for the training of anaesthesia residents in managing perioperative challenges. This review focused on English literature, employing keywords such as simulation, anaesthesia, intraoperative, perioperative, postoperative, training, non-technical and crisis. Google Scholar and PubMed served as the primary platforms for this search. In addition, the authors manually scrutinised references from the selected articles, identifying those deemed pertinent to augment the discussion.

From the extensive pool of over 1000 articles, a judicious selection of 68 was made through purposive sampling, guided by relevance criteria. This technique was also applied to explore themes not covered in the initial search, such as medical errors, low-cost simulation in anaesthesia and virtual reality (VR) simulation. Subsequently, all identified articles underwent rigorous screening, resulting in the final compilation of papers incorporated into this review.

DISCUSSION

Patient safety stands as the linchpin in contemporary health care, with growing litigation, societal scrutiny and information accessibility necessitating heightened awareness among healthcare practitioners regarding the origins and prevention of medical errors. This imperative is particularly pronounced in the field of anaesthesia, where the repercussions of such errors can be severe. Before delving into strategies to address these challenges, it is essential to explore the nature of medical errors briefly. The National Coordinating Council for Medication Error Reporting and Prevention has catalogued various types of medical errors, [Table 1].

Table 1: Types of Medical Errors Adapted from National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP, 2001).© 2024 National Coordinating Council for Medication Error Reporting and Prevention

Category	Description
Category A	Circumstances or events that have the capacity to cause error
Category B	An error occurred, but the error did not reach the patient (an 'error of omission' does reach the patient)
Category C	An error occurred that reached the patient but did not cause the patient harm.
Category D	An error occurred that reached the patient and required monitoring to confirm that it resulted in no harm to the patient and/or required intervention to preclude harm.
Category E	An error occurred that may have contributed to or resulted in temporary harm to the patient and required intervention.
Category F	An error occurred that may have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalisation.
Category G	An error occurred that may have contributed to or resulted in permanent patient harm.
Category H	An error occurred that required the intervention necessary to sustain life.
Category I	An error occurred that may have contributed to or resulted in the patient's death.

No Error, Error, No Harm, Error, Death, Error, Harm

'To Err Is Human' was a landmark report by the Institute of Medicine (IOM) in 1999, which opened the eyes of the healthcare fraternity to the risk of medical errors. This report estimated that medical errors cause injury to approximately 3% of hospital patients and result in a minimum of 44,000 and perhaps as many as 98,000 deaths per year in the USA.[1] James Reason studied errors across industries and categorised them as 'slips', 'lapses' and 'mistakes'. A slip is when an action is not executed, for example, not putting in a drain when indicated. Lapses are caused by forgetting, for example, forgetting to order blood before surgery. In both slips and lapses, things do not go according to plan, but the plan itself is sound. Mistakes happen when a plan itself is faulty. An example would be not having a backup plan for difficult tracheal intubation, causing patient harm when primary intubation fails.[2]

Studies examining errors in anaesthesia practice reveal a complex interplay of factors, including communication lapses, negligence, medication errors and human-related mistakes. Consensus points to medication errors as the most prevalent, with frequencies ranging from 0.075% to 0.7%.[3] In India, a study pinpointed the pressure to expedite tasks as a significant contributor to medication errors in the operating room.[4] Human error emerges as a dominant factor, implicated in over 80% of critical incidents in anaesthesia.[5] Another study also underscores its importance, attributing 66% of incidents, many deemed critical, to human error. Acknowledging the ubiquity of errors in health care and exploring training-based solutions to reduce their occurrence is imperative.[6]

Teamwork and crisis resource management

Crisis resource management (CRM) involves the essential principles for navigating critical situations.[7] It encompasses leadership, communication, followership, mutual support, situational awareness and decision-making, collectively known as human factors or non-techncial skills (NTS). In the realm of health care, where the majority of errors stem from deficiencies in these skills, training in high-performance interdisciplinary teams is vital. Efficient teams, defined as groups working towards a common mission, enhance patient outcomes, emphasising the need for team training, especially in perioperative care.[8]

Interdisciplinary teams in perioperative settings, comprising anaesthesiologists, nursing staff, therapists and surgeons, necessitate collaborative training. Interdisciplinary team training, notably through SBE, enhances performance in various aspects of CRM skills.[9] SBE proves invaluable for postgraduate residents to internalise the management of common anaesthetic challenges like hypotension or bronchospasm and practice rare situations multiple times, ensuring preparedness for clinical occurrences like malignant hyperthermia or thyroid crises. Table 2 highlights many common and rare crises that anaesthesia trainees face in the perioperative period. These have been subclassified as preoperative, intraoperative and postoperative crises.

With the progress of simulator technology, there is a wide choice of simulators available to train anaesthesia residents in perioperative CRM scenarios. Variety of mannequins including Human Patient Simulator (HPS) are available. HPS is the only mannequin in the market with built-in gas recognition software, enabling it to recognise oxygen and volatile anaesthetics when administered through a face mask or endotracheal tube. The mannequin responds appropriately to the inhaled gases, just as a real patient would. It also exhales carbon dioxide with end-tidal values that adjust according to the clinical situation. The mannequin interfaces with real clinical monitors, not only for the electrocardiogram (ECG) trace (which all the other mannequins also do) but for other parameters like noninvasive blood pressure, central venous pressure, invasive arterial blood pressure, oxygen saturation, etc. This mannequin also has a drug recognition system, whereby it reads the bar-coded syringes for drug name and concentration, estimates the volume injected and produces an appropriate physiological response. This mannequin interfaces seamlessly with clinical ventilators and can even trigger the ventilator. Laerdal (SimMan 3G Plus) and Gaumard (HAL® S5301) are also capable mannequins widely used for anaesthesia training, though their features are more limited. They do not, for example, have a physical gas recognition capability and only recognise gases when delivered through the software. SimMan 3G Plus is interfaced with ASL 5000 Lung Solution to interact realistically with clinical ventilators. New technology also allows some of these mannequins to interface with software-driven virtual

Table 2: Perioperative crisis scenarios

Preoperative crisis

- Compromised airway
- Foreign body aspiration
- Cardiac events: Acute myocardial infarction, unstable angina or severe arrhythmias before surgery
- Respiratory distress: Sudden exacerbation of respiratory conditions (e.g. asthma, chronic obstructive pulmonary disease)
- Neurological emergencies: Stroke, seizures or neurological deterioration
- Haemodynamic instability: Rapid and severe changes in blood pressure or heart rate
- Medication errors
- Septic shock

Intraoperative crisis

- Anaesthesia machine failure
- High spinal/total spinal
- Uncontrolled bleeding: Excessive bleeding during surgery, leading to hypovolemic shock
- Anaesthetic-related issues: Malignant hyperthermia, anaphylaxis or inadequate reversal of neuromuscular blockade
- Cardiovascular events: Cardiac arrest, arrhythmias or hypertensive crises
- Airway and respiratory complications: Difficult intubation, airway obstruction, aspiration, desaturation, high airway pressure, bronchospasm, laryngospasm
- Intraoperative hypoglycaemia
- Delayed recovery
- Local anaesthetic systemic toxicity (LAST)

Postoperative crisis:

- Respiratory complications: Airway obstruction, respiratory distress
- Cardiovascular events: Myocardial infarction, arrhythmias
- Haemorrhage and shock: Post-tonsillectomy bleeding, hypovolemic shock or thyroid haematoma
- Neurological issues: Stroke, seizures
- Renal complications: Acute kidney injury
- Thromboembolic events: Deep vein thrombosis, pulmonary embolism, or disseminated intravascular coagulation
- Metabolic disturbances: Diabetic ketoacidosis, metabolic acidosis or electrolyte abnormalities
- Pain management issues: Inadequate pain control or adverse reactions to pain medications
- Psychological and behavioural reactions: Postoperative delirium, emergence delirium

defibrillators and ventilators, thus obviating the need for real clinical equipment.

Simulation extends beyond theoretical teaching, providing a safe environment for residents to learn from mistakes without consequences for real patients. The simulation environment allows residents to comprehend the repercussions of errors, fostering effective skills in managing critical conditions. Moreover, interprofessional training fosters collaboration and coordination among healthcare professionals, offering valuable benefits in patient care.[10]

Simulation-based learning is a potent tool for developing healthcare professionals' knowledge, skills and attitudes, offering a structured approach to teaching teamwork competencies, particularly for interdisciplinary teams. This method fosters a systematic decision-making process with opportunities for repeated practice until proficiency is attained, and it can assess the progression of these proficiencies. Teamwork training in simulated environments complements traditional didactic instruction, potentially enhancing performance and reducing errors.[11]

There is a growing understanding that most medical adverse events result from deficiencies in these skills rather than a lack of technical proficiency. The World Health Organization (WHO), in its patient safety document, has stated that 'common adverse events that may result in avoidable patient harm are medication errors, unsafe surgical procedures, healthcare-associated infections, diagnostic errors, patient falls, pressure ulcers, patient misidentification, unsafe blood transfusion and venous thromboembolism'.[12] Most items in this list pertain to non-technical rather than technical skills. Similarly, a Japanese study found that in a cohort of 73 fatal medical accidents, if the natural disease progression cases were excluded, 34 of the remaining 40 cases were due to NTSs.[13]

A transformative shift in the approach to anaesthesia education is imperative for the comprehensive adoption of the CRM approach. Emphasising this need, one study highlights the historical emphasis on technical proficiency over human interaction, espousing the critical role of information flow in high-acuity settings like operating rooms and emergency departments.[14]

The significance of NTS in anaesthesia has been underscored in an article, arguing that the postgraduate curriculum has traditionally focused on clinical knowledge and skills, neglecting NTS. The authors stress that NTSs play a pivotal role in ensuring team members' safe and efficient task performance, thereby mitigating the errors attributed to human factor issues during the perioperative period.[15]

Does simulation work?

It is unequivocally established that simulation significantly enhances learners' technical and teamwork skills, effectively identifying and rectifying errors in anaesthesia.[6] Numerous studies attest to its efficacy in teaching basic science, clinical knowledge, procedural skills, teamwork and communication across undergraduate and graduate medical education levels.[16] A training programme aimed at personal protective equipment (PPE) use significantly reduced the amount of self-contamination by study participants. The authors suggest that such training should be incorporated into the curriculum to reduce the risk of pathogen transmission.[17] In the international arena, simulation training is integral to the residency curriculum, prioritising clinical skills as a paramount learning outcome.[18] The majority of anaesthesia simulation training is targeted at the perioperative period. A notable example is Holzman's anaesthesia crisis resource management (ACRM) training course, conducted in a realistic operating theatre environment with various scenarios, garnering positive feedback for enhancing the safety of anaesthesia practice.[19] Scenarios included an overdose of inhalation anaesthetic, oxygen source failure, cardiac arrest, malignant hyperthermia, tension pneumothorax and complete power failure. Simulation, recognised as the cornerstone of CRM training, demonstrates results across Kirkpatrick levels 1–3 and, in some cases, even at Level 4, demonstrating its efficacy in imparting these skills through SBE.[20]

Evidence highlights the benefits of repeated simulation training for novice anaesthesia trainees, enhancing intrapersonal factors and communication performance. Notably, focused teaching fosters the development of assertive behaviours.[21] The perioperative setting, too, witnessed improved NTSs following simulation-based training.[22] Gaba, in an editorial in the British Journal of Anaesthesia, makes a strong case for anaesthesia team training after noting the success of such training in other fields like aviation.[23]

This wealth of evidence has spurred the establishment of simulation centres globally, catering to healthcare professionals at all experience levels, particularly anaesthesiologists.

Imparting simulation-based training

Integrating SBE into existing residency curricula is paramount to conducting simulation-based sessions effectively. Without this integration, teaching NTSs becomes inconsistent, risking unequal experiential learning and potential educational gaps. Curriculum development helps by providing a clear course structure, specifying learning outcomes as per the learners' needs, engaging the learners and enhancing teaching effectiveness; for the facilitators, a structured curriculum helps teachers organise and present learning effectively and keeps educators updated with educational trends.[24] Interprofessional simulations are crucial for CRM training, especially in anaesthesia, where teamwork is integral.[7]

It is very much possible to implement SBE in the existing curriculum for the Indian anaesthesia postgraduate programme. Kazior *et al*.[25] demonstrated that it is feasible to implement such a curriculum, and it is rewarding for trainees.

Alongside integration, allocating specific time for deliberate practice is essential for NTS acquisition. Deliberate practice involves a planned repetitive performance with a clear-cut outcome in mind and with focused feedback at each step.[26]

When designing teamwork skills sessions, adhering to sound educational theory and assessing the teamwork process and outcomes with reliability and validity standards is crucial.[27] It has also been shown that a brief team planning session before participating in a team training session improves performance[28], as does cognitive aids, which may potentially improve emergency care.[29]

Checklists have proven invaluable in the airline industry for improving performance in crises. Pilots have checklists for routine tasks like before, after, and before landing. Even though these tasks are routine, these checklists ensure that all the necessary steps are taken to ensure the safe operation of the flight. Pilots also have checklists for emergencies that happen rarely but can have disastrous consequences. These checklists act as a ready reference in case of in-flight emergencies, as it is humanly impossible to remember the steps for all the emergencies that can occur. Though checklists also occur in health care (e.g. the WHO operative checklists), they are not there for many common emergencies that anaesthesiologists are likely to face. Studies have shown that checklists are invaluable in improving patient outcomes.[30] An easy-to-remember 'Check CRISIS' tool, incorporating the anaesthesia practice's non-technical and technical skills, would help handle the crisis effortlessly in stressful situations.[31]

Shared mental models fostering situational awareness further improve team performance. Briefings before anticipated challenging patient management problems contribute to the shared mental model among the team members, facilitating successful patient outcomes during crises.[32]

Low-cost simulation solutions

Resistance to adopting SBE often stems from the misconception that simulation is inherently costly. It is crucial to dispel this notion, understanding that simulation is an educational modality that can be delivered in various formats, ranging from simulated patient actors to role plays and basic mannequins. Low-cost simulation solutions are emerging as a possibility in their own right across the world, and not just in developing countries. Examples include animal models,[33] low-cost task trainers[34] and team trainers employing basic mannequins paired with affordable or freely downloadable patient monitors, exemplified by platforms like Medsim Studio (https://medsimstudio.com/).

Innovative ideas have emerged to convert such low-cost systems into so-called high-fidelity systems.[35] Many of these innovations stem from the necessity of delivering SBE in low-resource settings.[36] Particularly in a country like ours, where funding for training often takes a backseat to patient care, the belief in the utility of SBE and the commitment to integrate it into the postgraduate curriculum can overcome financial constraints.

Here, it is important to visit the concept of fidelity. In simple terms, fidelity is the degree to which the simulation mimics reality. There has been a lot of debate in simulation circles around the concept of fidelity. Task alignment to resemble the actions required in a real task (functional fidelity) is more important than physical fidelity. For example, the skills involved in a laparoscopic procedure can be imparted using a fruit like clementine, compared to costly virtual reality (VR) laparoscopic simulators. This is because the skills involved in peeling and resuturing the fruit are akin to those required for dissection and suturing in actual patient laparoscopic surgeries.[37] Likewise, suppose participants in a simulation session believe that what they are doing is real (psychological fidelity). This can compensate for the lack of realism in the equipment (including the simulator) and the environment. The software-controlled mannequins (so-called high-fidelity mannequins) may have lesser fidelity for tasks not designed for, like tracheal intubation, starting intravenous lines, examination of heart and lung sounds, etc., compared to task trainers explicitly manufactured for these purposes. The simulation world is moving away from the term 'high fidelity' to describe these mannequins. These terms are still in common use, and so, for the purpose of this article, we will continue to use these terms for ease of understanding. Much more important than the equipment is the pedagogy underpinning simulation education. Trained facilitators with minimal resources can provide trainees with experiences equalling those provided in fancy, highly realistic simulation environments. Understanding the resources available and advocating for protected educator time is essential to implementing a successful simulation curriculum.[38] It has been shown that for novice learners, a higher level of fidelity may increase the cognitive load on the learner to the point of overwhelming them, effectively decreasing learning. Hence, beginners would be better off starting with low-fidelity simulation and moving up as they gain experience. Low-fidelity simulation may also be preferred when training on skills that call for repeated practice.[39] Another study demonstrated no added benefit from training on a costly VR model concerning transferring skills to intraoperative patient care. The authors suggested that low-fidelity models for training are an alternative for programmes with budgetary constraints.[40] A study comparing the use of either a high- or a low-fidelity simulated Advanced Life Support training demonstrated that the use of high-fidelity simulation led to equal or even worse performance and growth in knowledge compared to low-fidelity simulation while also inducing undesirable effects such as overconfidence.[41] In another study, there was no significant difference between residents trained on high- versus low-fidelity mannequins for neonatal intubation at baseline, immediately after training and 6–9 months after training.[42] Low-cost simulators can make the simulation more accessible, allow transport to different sites, and reduce repair and maintenance costs. Various props can be used to improve the realism when using such mannequins. These include using moulage, downloadable patient monitor software, designing realistic scenarios, and good pre-brief and debriefing. Hill *et al.* demonstrated that low-fidelity simulation proved beneficial for preoperative and postoperative scenarios as there was less distraction from the high-tech element of high-fidelity simulators. This facilitated the thought process and action for decision-making.[43]

The main benefit of high-fidelity simulators is the realism they inject into the simulation. More experienced learners need to suspend disbelief and get the most out of the session. It has been suggested that reasoning or analytical judgement for professional trainees is better with high-fidelity simulators as the cues provided by such simulators make it easier to obtain more information and arrive at a better action plan.[44]

Anaesthesia NTSs

No discourse on simulation in anaesthesia is complete without delving into the Anaesthesia Non-Technical Skills (ANTS) programme. Jointly crafted by the University of Aberdeen Industrial Psychology Research Centre and the Scottish Clinical Simulation Centre, the ANTS handbook delineates the essential NTSs for anaesthesia trainees. It elucidates teamwork, task management, decision-making and situational awareness as the primary components, further breaking down each skill into specific elements. Emphasising the continuum from undergraduate to postgraduate levels, the handbook serves as a globally utilised resource by anaesthesiologists for imparting NTSs.[45] This handbook outlines the set of NTSs imperative for anaesthesia trainees to achieve competency in patient management during the perioperative period. Research affirms that the ANTS system exhibits satisfactory validity, reliability and usability in experimental settings, contingent upon users receiving adequate training in its application.[46]

Remote Simulation in Anaesthesia

The coronavirus disease 2019 (COVID-19) pandemic presented unprecedented challenges to healthcare delivery and training methodologies. Amidst these challenges, innovative teaching and learning methods, notably in SBE, emerged as invaluable tools. SBE, in the form of telesimulation, proved instrumental in addressing the training needs during the pandemic. This approach mitigated the risk of patient exposure for trainees and provided a secure learning environment.[47]

The simulation adaptation to online platforms gained widespread acceptance among simulationists, prompting many to consider its continued use even in the post-pandemic era.[48] The anaesthesia community embraced this shift, deploying novel team and skills training techniques.[49-51] The efficacy of these innovative approaches was substantiated by the demonstrated acquisition of knowledge and skills through this modality.[52]

VR training in anaesthesia

The terminology associated with VR, augmented reality (AR) and mixed reality (MR) has evolved. Initially, any computer-based simulation environment, immersive or not, fell under the umbrella of VR simulators. Examples include interactive laparoscopic surgery or intubation simulators and screen-based simulation programmes. However, these terms will specifically refer to immersive environments for this review.

AR involves a real-world view overlaid with digital elements. Notable examples include Microsoft's HoloLens and Google Lens, which are now integrated into mobile phones. CAE Healthcare's mannequins and ultrasound simulators incorporate AR, allowing learners to visualise organ systems or a foetus within the mannequin to understand ultrasound images or the childbirth process better. MR combines real-world and digital elements, enabling interaction between physical and virtual components. In MR, learners can physically interact with virtual objects within the natural environment. For instance, arthroscopic simulators integrate physical structures with virtual elements, providing a tactile experience for learners.

VR immerses users in a fully digital environment through a headset that isolates them from the external world. This technology can recreate an entire operating theatre environment with virtual patients, surgeons and nurses, who can interact verbally and physically with the learner. Although not yet widespread in anaesthesia, VR is anticipated to grow, as evidenced by existing studies. For example, one study recreated an operating room fire to train nursing students to manage such emergencies, revealing the modality's usefulness despite technical limitations.[53] Another study focused on VR-based peripheral nerve block simulation incorporating anatomical variations.[54] A prospective study with dental students explored AR simulation for training in infiltrative anaesthesia. The authors found that AR improved syringe manipulation and control in students administering their first anaesthesia injection to paediatric patients, although it may not reduce acute stress.[55]

CONCLUSION

Simulation-based education encompasses diverse modalities, ranging from task trainers and simulated patients to sophisticated high-fidelity patient simulators. The integration of virtual reality and augmented reality simulators has further enriched this spectrum. The implementation of simulation-based education demands a significant investment of time and effort, coupled with essential faculty training, to ensure its efficacy. However, adopting a simulation-based curriculum yields substantial rewards, catalysing a noteworthy transformation in resident knowledge, skills and attitudes. This is particularly pronounced in cultivating non-technical teamwork skills during the perioperative period.

Given the inherent high-risk nature of anaesthesia, where effective teamwork is pivotal to averting adverse patient outcomes, simulation training becomes imperative. It is a collective responsibility for all anaesthesia faculty members to acknowledge the intrinsic value of simulation-based education and leverage its potential to hone the capabilities of their residents.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

ORCID

Dinker R Pai: https://orcid.org/0000-0001-9204-5721
VR Hemanth Kumar: https://orcid.org/0000-0003-1229-7975
Sobana R: https://orcid.org/0000-0002-6350-4172

REFERENCES

1. Kohn LT, Corrigan JM, Donaldson MS. To Err is Human: Building a safer health system. Washington DC: National Academy Press; 1999.
2. Reason J. Human Error. Cambridge University Press; 1990.
3. Rayan AA, Hemdan SE, Shetaia AM. Root cause analysis of blunders in anaesthesia. Anesth Essays Res 2019;13:193-8.
4. Annie SJ, Thirilogasundary MR, Hemanth Kumar VR. Drug administration errors among anesthesiologists: The burden

in India - A questionnaire-based survey. J Anaesthesiol Clin Pharmacol 2019;35:220-6.
5. Cooper JB, Newbower RS, Long CD, McPeek B. Preventable anesthesia mishaps: A study of human factors. Anesthesiology 1978;49:399-406.
6. DeAnda A, Gaba DM. Unplanned incidents during comprehensive anesthesia simulation. Anesth Analg 1990;71:77-82.
7. Ladkany D, Pastorino A. Curriculum development in medical simulation. In: StatPearls. StatPearls Publishing; 2022.
8. What is a team? Available from: https://asq.org/qualityresources/teams#:~:text=A%20team%20is%20defined%20as,to%20solve%20a%20particular%20problem. [Last accessed on 2023 Nov 22].
9. Paull DE, De Leeuw LD, Wolk S, Paige JT, Neily J, Mills PD. The effect of simulation-based crew resource management training on measurable teamwork and communication among interprofessional teams caring for postoperative patients. J Contin Educ Nurs 2013;44:516-24.
10. Gaba DM, DeAnda A. A comprehensive anesthesia simulation environment: Re-creating the operating room for research and training. Anesthesiology 1988;69:387-94.
11. Lateef F. Simulation-based learning: Just like the real thing. J Emerg Trauma Shock 2010;3:348-52.
12. Available from: https://www.who.int/news-room/fact-sheets/detail/patient-safety. [Last accessed on 2023 Dec 02].
13. Uramatsu M, Fujisawa Y, Mizuno S, Souma T, Komatsubara A, Miki T. Do failures in non-technical skills contribute to fatal medical accidents in Japan? A review of the 2010–2013 national accident reports. BMJ Open 2017;7:e013678.
14. Pizzi L, Neil PD, Goldfarb I, Nash DB. Crew Resource Management and its Applications in Medicine. In: Shojania KG, Duncan BW, McDonald KM, Wachter RM, Markowitz AJ, editors. Making Health Care Safer: A Critical Analysis of Patient Safety Practices. Evidence Report/Technology Assessment No. 43. 2001. p. i-x.
15. Radhakrishnan B, Katikar MD, Myatra SN, Gautam PL, Vinayagam S, Saroa R. Importance of non-technical skills in anaesthesia education. Indian J Anaesth 2022;66:64-9.
16. Okuda Y, Bryson EO, DeMaria S Jr, Jacobson L, Quinones J, Shen B, *et al*. The utility of simulation in medical education: What is the evidence? Mt Sinai J Med 2009;76:330-43.
17. Andonian J, Kazi S, Therkorn J, Benishek L, Billman C, Schiffhauer M, *et al*. Effect of an intervention package and teamwork training to prevent healthcare personnel self-contamination during personal protective equipment doffing. Clin Infect Dis 2019;69(Supplement3):S248-55.
18. Al-Elq AH. Simulation-based medical teaching and learning. J Family Community Med 2010;17:35-40.
19. Holzman RS, Cooper JB, Gaba DM, Philip JH, Small SD, Feinstem D. Anesthesia crisis resource management: Real-life simulation training in operating room crises. J Clin Anesth 1995;7:675-87.
20. Buljac-Samardžić M, Dekker-van Doorn CM, Maynard MT. What do we really know about crew resource management in healthcare?: An umbrella review on crew resource management and its effectiveness. J Patient Saf 2021;17:e929-58. doi: 10.1097/PTS.0000000000000816.
21. Guris RJ, Duarte SS, Miller CR, Schiavi A, Toy S. Training novice anaesthesiology trainees to speak up for patient safety. Br J Anaesth 2019;122:767-75.
22. Kolawole H, Guttormsen AB, Hepner DL, Kroigaard M, Marshall S. Use of simulation to improve management of perioperative anaphylaxis: A narrative review. Br J Anaesth 2019;123:104-9.
23. Gaba DM. Crisis resource management and teamwork training in anaesthesia. Br J Anaesth 2010;105:3-6.
24. Available from: https://www.hurix.com/the-importance-of-curriculum-development-in-enhancing-teaching-and-learning/#:~:text=Curriculum%20development%20benefits%20students%20by,the%20pace%20for%20learning%20progress. [Last accessed on 2023 Nov 16].
25. Kazior MR, Ianchulev S, Nguyen J, Trainer-Albright B, Shah P. Creation of simulation-based curriculum of perioperative emergencies for residents in anesthesiology. Cureus 2021;13:e15509.
26. Issenberg SB, Gordon MS, Gordon Dl, Safford RE, Hart IR. Simulation and new learning technologies. Med Teach 2001;16:16–23.
27. Entin EB, Lai F, Barach P. Training teams for the perioperative environment: A research agenda. Surg Innov 2006;13:170-8.
28. Evain JN, Perrot A, Vincent A, Cejka JC, Bauer C, Duclos A, *et al*. Team planning discussion and clinical performance: A prospective, randomised, controlled simulation trial. Anaesthesia 2019;74:488-96.
29. Sellmann T, Alchab S, Wetzchewald D, Meyer J, Rassaf T, Thal SC, *et al*. Simulation-based randomized trial of medical emergency cognitive aids. Scand J Trauma Resusc Emerg Med 2022;30:45.
30. Jaulin F, Lopes T, Martin F. Standardised handover process with checklist improves quality and safety of care in the postanaesthesia care unit: The Postanaesthesia Team Handover trial. Br J Anaesth 2021;127:962-70.
31. Kumar VRH, Nag K, Rani P, Ravishankar M, Pai D. Evolution, development, and simulation-based testing of 'Check CRISIS' – A unique cognitive tool in perioperative crisis management. J Clin Sci Res 2021;10:256-62.
32. Neuhaus C, Schäfer J, Weigand MA, Lichtenstern C. Impact of a semi-structured briefing on the management of adverse events in anesthesiology: A randomized pilot study. BMC Anesthesiol 2019;19:232.
33. Park SJ, Kim HJ, Yang HM, Yoon KB, Lee KY, Ha T, *et al*. Impact of simulation-based anesthesiology training using an anesthetized porcine model for ultrasound-guided transversus abdominis plane block. J Int Med Res 2020;48:300060519896909. doi: 10.1177/0300060519896909.
34. Eyre A, Dobiesz V. A low-cost facial and dental regional anesthesia task trainer. J Educ Teach Emerg Med 2021;6:I1-9. doi: 10.21980/J8RP9Q.
35. Hartwell DA, Grayling M, Kennedy RR. Low-cost high-fidelity anaesthetic simulation. Anaesth Intensive Care 2014;42:371-7.
36. Skelton T, Nshimyumuremyi I, Mukwesi C, Whynot S, Zolpys L, Livingston P. Low-cost simulation to teach anesthetists' non-technical skills in Rwanda. Anesth Analg 2016;123:474-80.
37. Andreatta P, Marzano DA, Curran DS, Klotz JJ, Gamble CR, Reynolds RK. Low-hanging fruit: A clementine as a simulation model for advanced laparoscopy. Simul Healthc 2014;9:234-40.
38. Sawaya RD, Mrad S, Rajha E, Saleh R, Rice J. Simulation-based curriculum development: Lessons learnt in Global Health education. BMC Med Educ 2021;21:33.
39. Green M, Tariq R, Green P. Improving patient safety through simulation training in anesthesiology: Where are we? Anesthesiol Res Pract 2016;2016:4237523.
40. Chandra DB, Savoldelli GL, Joo HS, Weiss ID, Naik VN. Fiberoptic oral intubation: The effect of model fidelity on training for transfer to patient care. Anesthesiology 2008;109:1007-13.
41. Massoth C, Röder H, Ohlenburg H, Hessler M, Zarbock A, Pöpping DM, *et al*. High-fidelity is not superior to low-fidelity simulation but leads to overconfidence in medical students. BMC Med Educ 2019;19:1-8.
42. Al-Wassia H, Bamehriz M, Atta G, Saltah H, Arab A, Boker A. Effect of training using high-versus low-fidelity simulator mannequins on neonatal intubation skills of pediatric residents: A randomized controlled trial. BMC Med Educ 2022;22:1-7.
43. Hill K, Schumann M, Farren L, Clerkin R. An evaluation of the use of low-fidelity and high-fidelity mannequins in clinical simulations in a module preparing final year children's and

general nursing students for internship placement. Compr Child Adolesc Nurs 2023;46:295-308.
44. Havighurst LC, Fields LE, Fields CL. High versus low fidelity simulations: Does the type of format affect candidates performance or perceptions. In: Proceedings from the 27th Annual IPMAAC Conference on Personnel Assessment; 2003.
45. Flin R, Fletcher G, Glavin R, Maran N, Patey R. Anaesthetists' Non-Technical Skills (ANTS) System Handbook. UK: University of Aberdeen; 2003.
46. Fletcher G, Flin R, McGeorge P, Glavin R, Maran N, Patey R. Anaesthetists' Non-Technical Skills (ANTS): Evaluation of a behavioural marker system. Br J Anaesth 2003;90:580-8.
47. Büyük S, Bermede O, Erkoç S, Alkış N, Lilot M, Meço B. Use of simulation to teach in the operating room-Don't let the COVID-19 pandemic interrupt education: An observational clinical trial. Braz J Anesthesiol 2022;72:185-8.
48. Buléon C, Caton J, Park YS, Eller S, Buyck M, Kardong-Edgren S, *et al*. The state of distance healthcare simulation during the COVID-19 pandemic: Results of an international survey. Adv Simul (Lond) 2022;7:10. doi: 10.1186/s41077-022-00202-7.
49. Ahmed OMA, Belkhair AO, Ganaw AEA, ElKersh MM, Adiga J. Anaesthesia simulation training during coronavirus pandemic: An experience to share. BMJ Simul Technol Enhanc Learn 2020;7:58-9.
50. Hong BE, Myo Bui CC, Huang YM, Grogan T, Duval VF, Cannesson M. Implementing COVID-19 simulation training for anesthesiology residents. MedEdPortal 2022;18:11215. doi: 10.15766/mep_2374-8265.11215.
51. Van Wyk R, Turton EW. Anaesthesia skills and simulation training during the COVID-19 pandemic. Afr J Health Prof Educ 2021;13:196-7.
52. Tremosa L. Beyond AR vs. VR: What is the difference between AR vs. MR vs. VR vs. XR. Interaction Design Foundation. Available from: https://www.Interactiondesign.org/literature/article/beyond-ar-vs-vr-what-is-the-difference-between-ar-vs-mrvs-vr-vs-xr.2022.
53. Wunder L, Gomez NA, Gonzalez JE, Mitzova-Vladinov G, Cacchione M, Mato J, *et al*. Fire in the operating room: Use of mixed reality simulation with nurse anesthesia students. Informatics 2020;7:40.
54. Grottke O, Ntouba A, Ullrich S, Liao W, Fried E, Prescher A, *et al*. Virtual reality-based simulator for training in regional anaesthesia. Br J Anaesth 2009;103:594-600.
55. Mladenovic R, Dakovic D, Pereira L, Matvijenko V, Mladenovic K. Effect of augmented reality simulation on administration of local anaesthesia in paediatric patients. Eur J Dent Educ 2020;24:507-12.