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Simulation-Based Learning: Basics for Anaesthetists

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Abstract

Simulation training is useful to become familiar with new technology, to practice behaviours and strategies, to acquire routines for specific scenarios, and to reflect on one's behaviour. Processes that have to function almost automatically (e.g., resuscitation) have to be practised repeatedly until they can be reliably executed even under stress or fatigue. Simulators offer the opportunity to acquire these skills without endangering the patient. Various types of simulators (from pig liver to premature baby simulator) are already being used extensively for this purpose. Significant advantages of this learning environment include the freedom from risk in the event of errors, the repeatability of procedures, the possibility of varying conditions, and the possibility of practising processes with different complexities. Simulators are used in a variety of settings, providing valuable training in non-technical skills and creating awareness of other aspects of human factors. In addition, working with simulators through targeted testing of technology and work processes can help to structure work in hospitals more closely based on human factors.

Keywords: Anaesthesia, debriefing, human factors, simulation, simulated patients

Introduction

Over the past 40 years, the development of simulation has increased exponentially owing to significant societal, political, clinical, and educational influences. Patients remain important participants in healthcare education, and therefore, they increasingly question the process of their care and want to take part in the decisions made about their healthcare management.[1] It is, therefore, expected that learners and healthcare practitioners would be prepared for clinical practice before caring for patients.[2] This has led to significant changes in medical education globally, which recognise the need to incorporate all aspects of a doctor's practice, including knowledge, skills, and expected attitudes, within an outcome-based framework.[3-6]

The defined outcomes of competency-based curricula lend themselves to using a simulation approach. In addition, not only in Anaesthesiology but in most specialities, the current highly legislated working schedules further restrict opportunities for the traditional "apprenticeship" learning of medical skills.[7] This model appears to be no longer useful. Simulation offers a feasible alternative to learning procedural skills and also provides the opportunity to rehearse performance in complex integrated scenarios in a safe, protected, learner-centred simulated clinical setting.[8]

Simulation is a technique used to facilitate the learning of any kind, whether in the cognitive, psychomotor, or affective domains.[9, 10] It may involve a wide range of activities and approaches and applies to learners, from novice to expert–one of the major underlying drivers being to develop and maintain the safety of patients and healthcare practitioners.[8] In its definition, Simulation-based medical education (SBME) includes any educational activity that uses simulative tools and methods to create learning opportunities for participants.[11]

The rapid technological evolution has made it possible to develop tools to be used across all stages of professional development. Training approaches range from basic skill training to training of highly complex medical situations,

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like interprofessional critical care and complex scenarios addressing patient safety issues and human factors.

Simulation fidelity

How well a simulator replicates reality is a critical question in designing simulation-based education. Although there is a widespread assumption that the quality of a simulation experience equates to its level of replication of reality[12], simulation fidelity needs to be related to the learning outcomes of the learning event instead.[13]

Simulation is as a continuum that runs from low to high levels of fidelity and authenticity. Authors describe fidelity as "*the extent to which the appearance or/and behaviour of the simulation or simulator matches the appearance and behaviour of the real system*".[14] The best-known classification dichotomises simulation into high (hi) or low (lo) fidelity, traditionally related to the level of technical sophistication of the simulator. However, hi- or lo-fidelity relates to more than just technology, and simulation authenticity depends on the real world and community of practice. Another aspect of fidelity to be considered is contextual fidelity. This has both clinical and temporal components: the fidelity of simulation required for teaching a novice the technique of venepuncture is very different from that needed to recreate a multi-professional team during an operating theatre-based crisis.[14]

Classification of simulators

There are different types of simulation events and a broad range of simulators when it comes to medical education. We will explore the most common categories below:

Part-task trainers (physical component only)

Part-task trainers (PTTs) are currently trendy methods used to teach and develop mastery of technical, psychomotor, and procedural skills in educational settings. PTTs range from lo-fidelity trainers, like venipuncture arms, to highly sophisticated computerised human patient simulators.

Computer-based systems (no physical component)

In this case, instructors provide learners with interfaces that allow them to interact with materials relating to either basic sciences or decision-making, which can be staged and can progress at the learner's own pace. Several programmes, including sophisticated physiological models, have been produced. Some programmes also provide feedback on the decision-making ability and performance of the user; a famous example is the Laerdal's MicroSim suite, which is frequently used to reinforce an emergency care curriculum.

Main Points:

- Simulation-based training is an important tool for anaesthesia training.
- Different methods and tools are defined for simulation.
- Simulations enforce the acquirement of different skills as well as non-technical skills, without jeopardising the patient.

Integrated simulator models

Integrated simulators combine the two above-mentioned categories, and they usually consist of a whole- or part-body manikin coupled to a computer that controls the model's physiology and the desired output to "patient" monitors. The vital signs can be controlled and altered in response to interventions and therapies initiated by the user, who are interacting with the manikin. Modern integrated simulators have several attractive features. They include the life-like representation of body parts and functions, generate realistic monitoring data such as electrocardiography and pulse oximetry, and provide a hi-fidelity means of rehearsing procedures such as the insertion of a chest drain.

Virtual reality (VR) and haptic systems

Virtual reality simulators generate visual representations of objects or environments with which the user interacts. Haptic systems provide additional kinaesthetic and tactile sensation. These two approaches may be combined to provide training in basic skills such as venipuncture, or more sophisticated skills such as laparoscopic or endoscopic procedures.

Simulated patients

Simulated patients are laypersons or actors trained to portray specific medical roles or symptoms. These highly trained non-physicians can take on the roles of patients and assessors to realistically replicate patient encounters; they have been used in the past in anaesthesiology clerkships.[7] Simulated patients may be usefully involved in the teaching of many domains, including communication and consultation skills, physical examination, non-invasive procedural skills, and the assessment of professionalism. These lay people (sometimes actors) are trained and give the learners feedback on all aspects of their performance.

Simulated environments

The development of simulation centres provides students with varying degrees of recreation of the clinical setting in a protected environment. Within these venues, the application of contextual fidelity facilitates transfer to the real world. One could argue that real clinical settings are better places for learning and that simulation scenarios are increasingly being recreated in the workplace (see in-situ simulation, below). However, the disruption of regular clinical activity and the distraction of peripheral events may be a hindrance to in-situ simulations. In addition, a dedicated facility provides access to additional educational and audio-visual resources.

History of simulation

Simulation for medical education is a centuries-old tradition, and contrary to the popular belief, simulators existed even before the modern era. These simulators were used to teach everything from anatomy and physiology to obstetric care or surgical procedures.[15]

However, patient simulation, as we understand it today has its origins in the second half of the last century. In 1961, Abrahamson, Carter, and Denson developed the first "SimOne",[16] but the concept was dormant for several years. Changes of medical education concepts in the mid-1980s and the advent of computer technology with the dissemination of personal computers (PC) at affordable prices then continued a development that became increasingly established and led to the indispensable role of simulation in many fields of medicine.

In the last half-century, roughly three movements led to the development and dissemination of advanced patient simulation[17]:

a) Cardiopulmonary Resuscitation (CPR): Before the appearance of the first high fidelity simulators, Asmund Laerdal created the first part-task trainer, the Resusci-Anne. In the decades that followed, extensive development of simulators followed. Students could suddenly train both the basic (BLS) and extended measures (ALS) for resuscitation.

b) Development of full-scale humanoid simulators that could map essential aspects of human physiology and clinical pharmacology. The impetus for developing the prototypes came from very different objectives: (1) training manual and diagnostic skills (SimOne and Harvey Cardiac patient simulator), (2) diagnosis of device malfunctions (Gainsville Anesthesia Simulator (GAS), Leiden Anaesthesia Simulator (LAS)), and (3) study of human factors and team training: Comprehensive Anaesthesia Simulation Environment (CASE).

c) Due to a shift to competency-based curricula[3, 4, 18], there was an increased prevalence of skills labs, which provided students with a wide range of diagnostic and practical skills that could be taught with simulators.

While the development of patient simulation up to the end of the last millennium was still relatively straightforward, we expect the pace of growth and diversification to accelerate in the 21st century. With the advent of virtual reality, many new companies and numerous innovative projects have appeared on the market.

Simulation in Anaesthesia

Patient comfort and safety during a procedure is currently the standard practice expected from anaesthesiologists, by patients as well as surgeons. Competent professionals are needed to deliver a high quality and safe anaesthesia. Therefore, training young physicians to become competent anaesthesiologists is a core task of the specialty.

Training is a versatile concept with theoretical knowledge of the specialty to be acquired and the applied part to practice. The first aspect is more or less taken for granted with books, articles, and online materials. However, owing to the safety concerns, the practical aspect of training is still challenging. For long time now, training in the actual work environment is a well-accepted method. However, there are safety issues arising from this approach.

Simulation has become an indispensable tool for training as well as evaluating procedural skills. It improves performance as well as patients' outcomes.[19]

The combination of using drugs, complex devices, and performing invasive procedures is challenging the everyday practice of an anaesthesiologist in an operating room defined as a 'complex dynamic world'.

In contrast, the non-technical, decision-making part of the situation is even more puzzling most of the time. Sharing information, planning possible situations, and a good communication is fundamental for a safe anaesthesia management. Training those non-technical skills with simulation in a controlled environment increases the quality of the training and improves the professional development of our specialty.[20]

Airway Management: From a skill to a teamwork; an evolving area

Airway management is one of the fundamental skills for anaesthesiologists. It can be life-saving in emergency cases, however a failure in the airway management of a patient may be a major source of morbidity and mortality.[21] Therefore, teaching airway management is always an essential part of anaesthesia training. With limited and unexpected exposure to difficult airway and due to safety concerns, it is not always possible to teach different approaches to deal with such scenarios in real-time natural environment. It may be difficult to gain enough experience and to become an expert in airway management based solely on clinical experience. Therefore, simulation training, owing to its repeatability, is playing an essential role in airway training. Several studies have shown that simulation-based training improved the behaviour performance and learner's satisfaction and interest for airway management, but further studies are needed to establish a clear relationship with success rate in clinical settings.[22-27]

In light of these data, airway management education seems to be more effective via simulation, and it is also associated with a higher learner's satisfaction. It is also important to evaluate the performance and to compare different and newly designed methods and devices via simulation trials. Therefore, simulation should be a main part of the airway management training for skills as well as teamwork planning.

Simulation-based scenarios are ideal for training less common clinical requirements for managing a difficult airway situation. They ensure better preparedness for difficult situations and could potentially contribute to reducing morbidity and mortality; they can also effectively reduce costs by outsourcing time-consuming training content.[10] However, they are neither suitable for learning different techniques for securing the airway nor for comparing different airway tools, but should be used in combination with clinical training on patients to learn different procedures and work in a team.

Anaesthesia: a multidisciplinary practice-an interprofessional simulation

Anaesthesia practice can be defined as a 'multidisciplinary specialty' with different patients managed in different conditions by different team members. It is therefore important to be skilled for practical approaches as well as teamwork organizations. In order to achieve that, an interprofessional simulation is set to improve the awareness of different professionals' roles and responsibilities and to promote teamwork. This approach enriches the training of nontechnical skills of a team all-together.

One of the rare but devastating events for an anaesthesiologist is a perioperative cardiac arrest. If the care team is not prepared for crisis management, this can result in a poor patient outcome. Therefore, different simulation case scenarios are implemented in the training of multidisciplinary teams.[28]

Intensive care units are also areas where anaesthesiologists are exposed to various difficult scenarios. Simulation training is very important in these areas to promote the non-technical competencies as well as to reinforce the interprofessional collaboration in such settings.[10]

When an interprofessional simulation training is planned, the sociological (hierarchy, authority, conflicts) aspect, which can affect the communication as well as teamwork, should always be taken into the consideration. These aspects may also affect the course of learning. These obstacles can be managed with a well-planned debriefing.

"In-Situ" simulation - getting in!

Different approaches have been described recently to 'move into' the natural environments; aiming to enhance the multidisciplinary training and to assess institutional response to several rare and maybe unexpected situations.

The 'Mega-Sim' model defined by Bradley et al.[29] was a one-day in situ event with a scenario of trauma in pregnancy. The patient needed to be transferred to the operating room for an emergency case. This complex clinical scenario was involving multiple disciplines and departments. This simulation session positively affected the perceptions of institutional teamwork and communication. This in situ model was a good example for multidisciplinary training and institutional assessment.

In situ simulation allows teams to review their practices in their actual environment and to identify their weaknesses. This leads to an organizational learning, which is an important benefit of this approach. In contrast, high fidelity is an important issue for simulation training. Another benefit of in situ simulation training is the improvement of the fidelity via the natural environment and therefore, reliability in high stress environments such as operating rooms and intensive cares. It may also be an attractive alternative for interdisciplinary simulations for trainees who do not have access to fully equipped simulation centres.

Anaesthesia training relies on the duration, the quality, the environment, and the continuity of a clinical experience. Therefore, simulation training is a very important tool with its different aspects.

Simulation of Human Factors

Human Factors is an interdisciplinary science that investigates the relationship between people and technology and intervenes with people in (work) systems.[30]

In recent years, there has been increasing talk of human factors when it comes to patient safety, errors in medicine, and simulator training. Human factors are the cause of 60–80% of all accidents.[31, 32] The term "human factors" is used to describe the reasons for errors at various levels of a working system; this is not necessarily blaming it on a specific person. The awareness that a patient accident has many causes is connected with striving for a safety culture that wants to avoid blaming. Instead of exposing and punishing individuals, the aim is to prevent mistakes, and this can be achieved through training.[10, 14]

Since the beginning of human factors research over ten years ago, optimising the relationship between people and work activities has always had two goals: on the one hand, work systems should become more efficient and safer. On the other hand, we should strive to promote the health and well-being of working people. Therefore, Human Factors emphasise the importance of system design: work tasks, work processes, and the design of organisational structures should adapt to the characteristics, capabilities, and weaknesses of people.[33] The known concept of the chain of errors ["Swiss cheese model"[34]] examines the causes of errors at various levels of the system. However, the "Swiss cheese model" offers another message in reverse: if the individual barriers have few or no holes, people can make mistakes without accidents occurring. That is the fundamental concern of Human Factors: to design work systems in such a way that many errors cannot happen in the first place ("design-out") or that mistakes do not lead to accidents.

Crisis Resource Management (CRM)

An important finding that found its way from psychology via aviation into medicine (and Anaesthesia) is that interpersonal behaviour and cognitive skills are essential for safe action. Communication, teamwork, leadership, stress management, and attention control are some of these factors, and they are known as "non-technical skills".[35] Non-technical competencies are not equal to human factors; instead, they are an integral part of it.

We can define non-technical skills as "behaviours (in the operating theatre environment) not directly related to the use of medical expertise, drugs, or equipment".[36] One of the main drivers for the widespread adoption of non-technical skills training [called initially cockpit resource management (CRM)[37]] was the 1977 Tenerife air disaster when two airworthy Boeing 747s collided on the runway after some non-technical skills lapses. After that, individual airlines developed their in-house CRM training and assessment and since then, aviation personnel train non-technical skills broadly and frequently. This concept was later adapted to medicine[38], including Anaesthesia.[39] But in contrast to aviation, the focus of non-technical skills in medicine is mostly on the management of incidents. In 2003, Flin et al.[36] developed the ANTS (Anaesthetists' Non-Technical Skills), the first non-technical skills framework for anaesthetists. Since 2003, there has been a significant increase in non-technical skills frameworks for other specialities, including surgeons (NOTTS), scrub practitioners (SPLINTS), and anaesthetic assistants.[40]

Table 1. Anaesthetists' Non-Technical Skills (ANTS) Framework, According to Flin et al. (36)

Skill Group	Skill Category	Skill Element
Cognitive (mental)	Situation Awareness	Gathering information
		Recognising & understanding
		Anticipating
	Decision-making	Identifying options
		Balancing risks & selecting options
		Re-evaluating
Social (interpersonal)	Task Management	Planning & preparing
		Prioritising
		Providing & maintaining standards
		Identifying and utilising resources
	Team working	Coordinating activities with team
		Exchanging information
		Using authority & assertiveness
		Assessing capabilities
		Supporting others

The Anaesthetists' Non-Technical Skills (ANTS) framework identifies the following non-technical skills, dividing them into four skills categories and 15 skill elements (Table 1).

The ANTS framework does not aim to be all-encompassing; its authors say, "The ANTS System is not intended to provide an exhaustive list of all non-technical skills used by anaesthetists. It is limited to the principal skills that one can identify through observable behaviour".[36]

A few researchers have looked at non-technical skills in the operating theatre and found that errors and operation length are related to the non-technical skills of the surgeons, anaesthetists, and nurses.[41]

The training of non-technical skills can occur at the level of an individual, the group, or the team. That being said, CRM training courses are not equal to team training. Both areas can be addressed in simulator settings or using other training methods.[10]

Debriefing

In a simulation, we use the term "debriefing" as an evaluation of simulation scenarios after their implementation.[42, 43] After the simulation, debriefing is an indispensable component of simulation training and has the most apparent potential to contribute to reflective learning.[44] However, studies also suggest that different forms of debriefing can have varying effects. A long debriefing at the end of the scenario is not always better than briefly reviewing the scenario several times and interrupting for direct feedback.[45,46] Research on debriefing is still in its early stages.

Debriefing represents a possible framework for self-reflection and the creation of learning-relevant impulses.[44] In the context of a debriefing, the participants themselves analyse their strengths and weaknesses and think about alternative courses of action with the help and guidance of the debriefer. It is a moderator-led discussion of the events in a scenario, which intends to reflect and integrate activities and thus enable long-term learning. Debriefing is a social practice, which means that those involved must adhere to specific, explicit, and implicit rules to be able to participate successfully and in a learning-relevant manner.[10] The particular design of this social practice and the regulations applied differ significantly between countries and their cultures, between medical disciplines, between different simulation centres, between individual instructors, over time, and also concerning different target groups and learning objectives.

Steinwachs[47] described three debriefing phases: the first phase relates to a reconstruction of the event; the second relates to a more in-depth analysis of the event; and the third relates to the significance of the event for the everyday practice of the participants. We can find these phases in many of the newly developed debriefing approaches.[43, 45, 46]

Depending on the setting, debriefings can have significantly different lengths, but they usually range from 20 to 40 minutes. Various techniques are used within a debriefing[43, 45, 46]: for example, moderating a discussion can alternate with giving verbal feedback and watching a video recording of the scenario.

What does the future hold?

Simulation is not intended to be a replacement for authentic experiential learning. It can, however, prepare practitioners for the real world and can provide a structure for deliberate practice.

There are several issues that still need to be further explored. It is still not clear how well clinical skills taught during a simulation intervention transfer into practice. In addition, there are significant costs associated with establishing simulation-based learning, related to both the technological aspects and the physical infrastructure, personnel, and the ongoing costs associated with a simulation programme; however, this needs to be an offset against the potential gain in terms of patient safety.

Another relevant issue is that simulation needs more supportive evidence; despite an almost exponential boom in the simulation literature, more well-designed studies are required to link educational theory with changes in workplace behaviour that impact patient outcomes, occurring as a direct result of simulated interventions.

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