State-of-the-art usage of simulation in anesthesia: skills and teamwork

Ralf Krage and Micha Erwteman

Purpose of review
This review describes the level of evidence for the use of medical simulation in anesthesia. It also discusses the topic of realism in simulation and its use for assessment.

Recent findings
Medical simulation in anesthesia covers a variety of techniques used for training and assessment. The current level of evidence for the use of medical simulation strongly supports a shift from learning on patients to learning on simulators. Skill and multidisciplinary team training are effective modalities and improve (team) performance and patient outcome.

Well defined learning objectives, not a high level of realism should be the main focus of a simulation activity. Simulation centers should focus on faculty development as emphasis on simulation facilities and simulator fidelity alone does not guarantee effective training.

Formative and summative assessment can help identify the omissions in knowledge, skills, and the ability to work in a team for both residents and anesthesiologists. Not only does it help to obtain competence, it also helps to maintain it.

Summary
Simulation for skill and team training should be a mandatory component for anesthesia residency programs and continuous medical education. The ‘see one, do one, teach one’ approach is obsolete and should be abandoned.

Keywords
assessment, realism, simulation-based education, skill training, team training

INTRODUCTION
Medical simulation has been a part of anesthesia education for decades. In fact, anesthesiologists were the pioneers in developing and implementing simulation methodology in healthcare. Yet simulation activities in anesthesia curricula are still oftentimes based on local initiatives rather than national programs.

Simulation-based education is beyond doubt a powerful tool in healthcare [1,2]. It is superior to traditional education for teaching a wide range of medical skills, procedures [3], and teamwork [4*,5,6,7**]. However, there still is discussion in the current literature about how ‘realistic’ simulation should be in order to create ‘relevant’ educational activities [8]. Despite the fact that the efficacy of medical simulation has been proven on various levels, the debate surrounding topics such as realism, relevance, and validity among other reasons may be a cofactor threatening to slow down the process of implementation.

In this article, we present the current level of evidence for both skill and team training using medical simulation. Furthermore, we discuss the relationship of realism and relevance of simulation activities and their effect on educational outcomes. Finally, we summarize the current level of usage of medical simulation as an assessment tool as this will become increasingly a topic in the near future.

TERMINOLOGY AND HISTORY
The word simulation stems from the Latin word simulare, which can be translated as ‘to imitate/to
copy’. Simulation has been used for a long time. Knights would practice on a Quintain to learn the skill of lance fighting and soldiers would engage in ‘war games’ to learn the theory and technique of warfare without the dangers of the battlefield [9].

Also in other fields like aviation, simulation has been used to teach skills and prepare for high-risk situations and to study the processes and the behavior of those involved.

Medical simulation therefore is foremost an educational tool, offering the participant the opportunity to learn and practice, both as an individual or as a group in a safe environment without the risk of patient harm.

Medical simulation covers a wide spectrum of tools used for the goal of education and assessment. It is, as described by Gaba [10], an instructional process that substitutes real patient encounters. The goal of simulation is to replicate patient care scenarios in a realistic environment that is predictable, consistent, standardized, and reproducible for the purpose of feedback and assessment [11]. Gaba identifies verbal simulation (‘what if’ discussions), standardized patients (actors), task trainers, patient simulators (mannequins), and virtual reality [12]. The first three forms of medical simulation have been used for a long time, with Madame du Coudray’s birthing mannequin from 1759 as a prime example of an early task trainer [13]. To start working with the latter two, it took both appropriate computer power and willingness to start working with a system other than the classic apprenticeship model. Neither were present in 1969 when Denson and Abrahamson [14] did their pioneering work with Sim One, the first, for the purpose of anesthesia training, build mannequin [15]. It took until the late 1980s for the mannequin simulation to gain popularity when the idea arose that combining task training with the, then, new concept of Anesthesia Crisis Resource Management could reduce the rate of common errors and improve team performance [16–18].

**LEARNING OUTCOMES: KNOWLEDGE, SKILLS, AND ATTITUDES**

Achieving a level of expertise is a critical objective in every residency program. Performing on an expert level in anesthesia means delivering safe patient care, and is a result of learning on different levels.

There are three layers of learning outcomes described in the literature [19]. They apply to those relevant in anesthesia:

1. Cognitive outcome: Knowledge, basic and clinical science such as anatomy, (patho)physiology and pharmacology;
2. Skill-based (psychomotor) outcome: single skills such as airway management (e.g., mask ventilation, intubation), spinal/epidural anesthesia, central venous catheter insertion and procedures (e.g., difficult airway algorithm, cardiopulmonary resuscitation guidelines);
3. Affective (attitudinal) outcome: learning how to apply the knowledge, skills and procedures into effective patient care in a multidisciplinary team (nontechnical skills such as communication, situational awareness, task distribution, and leadership/followership).

It is the responsibility of the residency program directors, educators, and instructors to help their students to identify their personal knowledge gaps and limitations on all three different outcome levels. Medical simulation is a very suitable tool to achieve these goals on all three levels without putting patients at risk, especially on the skills and attitude level [11]. Although it is not the main focus of this review, there are data showing that simulation is a very effective educational tool for teaching basic science (cognitive outcome level) [20,21].

**SKILLS AND PROCEDURES: TEACHING DOING WITHOUT DOING HARM**

Every anesthesiologist needs to build up practical skills during residency. For decades, procedures and techniques were taught with direct patient contact
using the ‘see one, do one, teach one’ approach, which raises both patient comfort and safety issues. Volpp and Grande [22] demanded a decade ago that there is a need for standardized training programs so that residents at each hospital are taught to perform procedures for appropriate indications in the appropriate manner. It is a fact that in medical education, transition from theoretical knowledge into clinical practice is challenging [23]. Medical simulation can close this gap as it allows learners to become familiar with a specific technique before practicing it on a patient. McGaghie et al. [24**] analyzed the benefits of simulation on different levels of educational outcome:

(1) T1: improving performance in the simulation laboratory;
(2) T2: improved patient care practices;
(3) T3: improved patient outcome;
(4) T4: collateral educational effects such as cost savings and skill retention.

Simulation is effective on all four levels. Using the example of central line insertion, there are overwhelming data showing that a simulation-based training program improves success rate of trainees in real patients [23], enhances sterile technique performance in residents [25], and reduces central line-associated bloodstream infections [26]. Madenci et al. [23] showed in a recent meta-analysis that healthcare professionals who followed a simulation-based training program were more likely to complete the given procedure whereas the non-simulation group needed more than one attempt to achieve task completion.

In addition, these patient outcome improvements could also be linked to significant cost savings [27].

Similar results were found for other skills such as lumbar puncture [28,29], fiberoptic intubation [30], paracentesis [31], thoracocentesis [32], and procedures such as advanced cardiac life support [33].

These results can only lead to the conclusion that we are morally obliged to our patients to use simulation for the teaching of skills whenever possible. As Ziv states: ‘Patients are to be protected whenever possible and they are not commodities to be used as conveniences of training’ [34].

HUMANS AND TEAMS: TEACHING HUMAN FACTORS AND TEAMWORK

Human factors have significant impact on patient safety. This relationship is a known fact for more than 30 years [35]. In 2000, the Institute of Medicine report found that patient harm in healthcare was often a result of poor multidisciplinary teamwork and communication. They emphasized that healthcare organizations should establish team training programs for personnel in critical care areas (e.g. emergency department, ICU, and OR) using proven methods such as crew resource management techniques employed in aviation, including simulation.’ [36]. Since then several studies have confirmed these general findings also for the perioperative setting. Team processes do influence team performance and patient outcome [37–40]. The European Society of Anesthesiology published the Helsinki Patient Safety Declaration in 2010 [41]. The declaration states that human factors play a large part in the delivery of safe care to patients and that Operating Room teams, including surgeons, nurses, and other healthcare professionals, have to come together to reliably provide this. Also, it concludes that education plays a key role in improving patient safety and demanded that team training should be part of the curricula to enhance communication and teamwork.

However, implementation of these demands is usually based on local ‘bottom-up’ efforts rather than nationwide ‘top-down’ approaches. The aviation industry requires the use of simulation and crisis resource management (CRM) training by law [42]. Anesthesia and healthcare in general would benefit from regulations like in aviation. Only government regulations can provide funds that are necessary to establish a training culture beyond local initiatives [42].

CLOSING GAPS IN ANESTHESIA AND BEYOND! THE NEED FOR MULTIDISCIPLINARY TEAM TRAINING

Already 30 years ago, Gaba and co-workers [17,42–44] identified gaps within the curriculum of anesthesia residency programs concerning crisis management such as decision-making, leadership, situation awareness, and communication. These so-called nontechnical skills were not taught systematically during postgraduate education. Teaching nontechnical skills even without simulation is effective and shows a direct effect on complication rates and overall mortality in critical ill patients [45*]. In a recent systematic review, it could be shown that adding simulation to these efforts is beneficial [46]. It is fair to say that anesthesia has been the driving force in implementing human factors and simulation-based education, but it seems that such training has created a silo approach to training efforts [47**]. Already in 2001, Gaba et al. [42] mentioned the significant distinction between different OR crews (surgical, anesthesia) forming one OR team. Recent literature identified
the existence of such silos and interprofessional friction as significant barriers for effective teamwork [7**]. Although teaching anesthesia personnel non-technical skills is effective, the effects on the overall patient care may be limited because of the reasons mentioned above. Simulation-based training settings should be multidisciplinary reflecting the real patient care environment. This approach not only improves team performance [47,48–51] but may also contribute specifically to improved mutual understanding between different medical specialties [48].

For years, research on team training simulation was challenged by the question if improvements of performances of healthcare professionals in the simulation setting could be translated into improvements in the clinical setting. Recent literature shows that this is the case for Kirkpatrick level 3 and 4 [4**]. However, it needs to be stressed that exposing healthcare professionals to a single didactic session about human factors/CRM only has limited effect [52,53]. Instead, it should be a part of a culture change including a combination of classroom teaching and periodical simulation-based team training sessions [54].

**DOES SIMULATION-BASED TEAM TRAINING IMPROVE PATIENT OUTCOME?**

Measuring improved patient outcome based on the intervention ‘simulation-based team training’ is challenging. Only a few investigations were able to show a direct effect. Wayne et al. [55] presented data that the quality of patient care improved during actual cardiac arrests after a simulation-based training intervention. Draycott et al. [56] was able to show in a large investigation, including approximately 20,000 neonates, that simulation-based team training improves neonatal outcome significantly. Andreatta et al. [57] correlated simulation-based training to an improved pediatric survival rate after cardiopulmonary arrest.

Although the number of Kirkpatrick level 4 studies in simulation-based team training is limited, there are enough convincing data suggesting its efficacy. The challenging question is whether anesthesia/healthcare should wait for more convincing data. Gaba [58] stated: ‘no industry in which human lives depend on the skilled performance of responsible operators has waited for unequivocal proof of the benefits of simulation before embracing it... Neither should anesthesiology.’

**HOW REAL SHOULD WE FAKE IT?**

Despite the fact that there is overwhelming evidence that medical simulation is a powerful educational technique, implementation of simulation in existing curricula is often challenged by the argument that it is not ‘the real thing’.

Simulation is an activity that emulates real life and thus it is easy to assume that the quality of simulation improves when realism, or fidelity as it is often called, increases. However, there is no unequivocal proof for this statement [8].

Before answering the question to what extent one should strive for realism, it should be emphasized that, as Rettedal [59] states: ‘Simulators are not true to nature.’ However hard we try, the mannequin is not, and will not be real. The lessons learned are real though and are applicable in clinical practice. The real question is: where in the mind of the participant is the translation made from the ‘fake’ simulator to the real learning and what can the educator do to facilitate this process? It is important to realize that fidelity comes at different levels. Rehmann et al. [60] describes objective fidelity, the level at which the simulator mimics reality and perceptual fidelity, the perception of realism by the participant. It is worth noticing that a high level of objective fidelity does not necessarily result in a high level of perceived reality, nor is the opposite true [8].

Donoghue and his group conducted a study exposing pediatric residents to resuscitation scenarios with either a high-fidelity infant patient simulator or a standard mannequin without any pulsations, chest wall movements, breath/heart sounds, or vocal sounds. They found no significant difference in perceived realism. Participants experienced the educational activity as highly realistic in both groups [61].

Learning through simulation takes place by having an experience. Kolb [62] describes in his theory about experiential learning a cycle of experience, observation, formation of abstract concepts and generalizations, testing of concepts in new situations, and then having a renewed experience. This form of education is an effective way of teaching the adult learner. This said, the reality of the learning is directly related to the experience of the participant. The answer to the question to what extent one should strive for realism lies in the experience the educator wants the participant to have.

The perceptual fidelity is, for a large part, achieved by the participant, which is often described as to what extent the simulation experience relates to the comparable task in clinical practice [63]. To achieve a high level of perceived reality, the participant must be able to accept the shortcomings in objective fidelity. This process can be described as internal simulation [59]. It is at this level that the formation of abstract concepts and
generalizations takes place, closing the loop of experiential learning and bridging the gap between the ‘fake’ simulator and the real clinical lesson. In conclusion, we can say that the level of fidelity necessary to achieve effective simulation activity largely depends on the aim of that experience. The success of the quest for fidelity largely depends on the participant’s ability to see through its shortcomings. Impressive data from the ‘helping babies breathe’ project in developing countries show that simulation activities with very low fidelity can be highly effective teaching sessions [64,65]. Lastly, it is important to mention that simulators do not teach. They only become effective educational tools when they are used wisely and adequately by skilled educators [2]. An interesting question is actually when during a simulation course learning takes place. Savoldelli et al. [66] showed that exposing participants to a scenario without any form of feedback/debriefing had little effect on trainees whereas structured debriefing either with or without video assistance did. Just investing in simulators and facilities is not sufficient. Faculty development and maintenance programs are crucial for selecting and training of skilled educators to create sustainable learning [2,54].

LEARN, PASS, OR FAIL: SIMULATION AS AN ASSESSMENT TOOL

In aviation, simulation has been imbedded in assessment for decades. Most airliners make it mandatory for their pilots to have a yearly assessment of competence with the consequence for failing the test. During medical school and residency programs, assessments through simulation, in all its forms, is common practice. The Objective Structured Clinical Examination using either standardized patients or task trainers is used for assessment of skills and certification around the world [67]. However, for medical specialists, even though continuing medical education is mandatory in many countries, only a few countries use medical simulation to assess competence (knowledge, skills, and teamwork).

Epstein [68] states ‘competence is not an achievement but rather a habit of lifelong learning’, emphasizing that competence should not only be obtained but also maintained.

Earlier in the article we described the three layers of learning outcomes such as cognitive (knowledge, theory), skill-based (skills, procedures/ algorithms), and affective (team skills) [19]. For the anesthesiologist, a high level of knowledge and skill competency does not automatically lead to effective patient care without adequate team skills. In other words, to safely work in the challenging environment of anesthesiology, one must be competent at all levels. Assessment of competence helps in identifying the omissions in any of these layers [68]. For this, simulation could start playing a pivotal role [69].

ASSESSMENT TERMINOLOGY: ARE WE TALKING ABOUT THE SAME?

In general, assessment is divided up in formative and summative assessment.

Formative: assessment for learning

In medical simulation, this form of assessment is in widespread use. The goal of a debriefing is to identify strengths and weaknesses of learners and to help in closing performance gaps. This is formative assessment and stresses again the need for skilled educators in medical simulation who are capable of creating learning experiences during debriefing [70].

Summative: assessment of learning

The goal of summative assessment is to assess student learning at the end of an instructional unit by comparing it against some standard [71] and means that they can either pass or fail. For an assessment to be summative, it must be both reliable (meaning that the test represents the true abilities of the person) and valid (the test must accurately represent the nature of what is intended to be measured) [72,73].

THE MEDICAL SPECIALIST: MAINTAINING AND ASSESSING COMPETENCE

Although there is literature reflecting on the need and effectiveness for mandatory simulation-based courses for medical specialists for continuing medical education [11], for example, to enhance nontechnical skills [74] or airway management skills [75], assessment in general, summative assessment in particular, is met with significant skepticism. As Holmboe et al. [76] notes: ‘There is a deep culture of conservatism around testing which contrasts with the accelerating pace of innovation in education and practice, creating a widening gap between current approaches to assessment and what healthcare providers actually do in practice’. Causes for this skepticism are multifactorial. They most likely consist of costs, reliability/validity issues [11], and last but not least ‘change in practice’ in general [76].

The use of both formative and summative assessment using simulation mandatory for the medical specialist would imply a remarkable culture change
CONCLUSION

Ever since its introduction about 30 years ago, medical simulation in anesthesia has gone through a rapid development from basic skill trainers to highly interactive mannequins enabling learning of both skills and teamwork. With the current level of evidence about its efficacy, there is no ground to challenge the implementation of simulation medical education [1]. Government regulations mandating the use of simulation in anesthesia and healthcare in general could further help to speed up its implementation so that the obsolete and inadequate educational technique of ‘see one, do one, teach one’ can be abandoned.

Medical simulation will never be able to completely replace clinical teaching and experience but it allows learners to be better prepared for the real clinical environment by practicing skills and teamwork in a simulation beforehand and is effective in maintaining competence. It ideally complements medical education in patient care settings [54,80].

Human factors play a crucial role in patient safety [41]. Teaching nontechnical skills can be highly effective and leads to improved team performance and patient outcome [45*]. Whenever possible, human factor/CRM training should be simulation-based [46] and multidisciplinary [47**,49,50].

Increasing fidelity of the simulator and adding ‘realism’ to a scenario per se does not necessarily produce more learning [61,64,65]. It is therefore paramount to precisely determine the learning objectives of the simulation activity and adjust the necessary level of realism accordingly [2]. Lack of realism in simulation should no longer be an excuse to further delay its implementation. Simulation centers should invest not only in facilities and simulators but also in faculty development. Only in the hands of skilled simulation educators, a simulator becomes an effective educational tool [66].

The use of both formative and summative assessment strategies can help the medical specialist to identify omissions in knowledge, skills, and the ability to work in a team and thereby may help in maintaining or even boosting competence needed to work in the challenging world of anesthesia [67,77].

Anesthesia, healthcare in general, needs to redesign its curricula for both residency programs and medical specialists to react to changes (e.g., work hour regulations [22], increasing public pressure on physician performance [11]) and to implement evidence that is there. To paraphrase Ziv et al. [34], we owe it to those we serve, as an ethical imperative.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest

- of outstanding interest


An outstanding review on the transfer of learning of simulation-based skill training showing cost savings on patient outcomes and cost savings.


