CLINICAL ANAESTHESIOLOGY

The Best Practice & Research series aims to provide a topical serial publication describing and integrating the results from the latest original research articles into practical, evidence-based review articles. These articles seek to address the key clinical issues of diagnosis, treatment and patient management. Each issue follows a problem-orientated approach which focuses on the key questions to be addressed, clearly defining what is known and not known. Management is described in practical terms so that it can be applied to the individual patient. The serial is aimed at the physician in both practice and training.

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Preface

It's not all about technology

Best Practice and Research Clinical Anaesthesiology for simulation-based training is a unique but overdue gathering associated with multiple challenges. Simulation-based training in the field of anesthesiology has gained wide acceptance over the last decade. A huge milestone in simulation history was the construction of the first patient simulator entitled “SimOne” at the end of the 1960s. “SimOne” represented a fascinating product from cooperation of engineering (Stephen Abrahamson) and medicine (Judson Denson) [1,2]. Despite this promising start and rapidly developing technical capabilities, it took more than 20 years to introduce the idea of simulation-based training for anesthesia into the first European university hospitals. Today, technical developments enable us to simulate the physiology and pathophysiology during anesthesia and emergencies with so-called “full-scale mannequins” in a setting close to reality at almost every place.

However, simulation-based training is not limited to anesthesiology. Due to more and more sophisticated simulators, a multitude of skills can be trained. As a consequence, a huge interdisciplinary scientific community evolved, focusing on this topic. Especially in surgery, large efforts were taken to promote simulation for training manual skills. Regardless of specialty and professional group, simulation-based training always tended to reduce mistakes in the clinical setting during the last decades. This important ethical dimension of simulation-based training was already pointed out by Amitai Ziv several years ago [3,4]. According to the first rule in medicine “First of all do not harm” (Hippocrates), we should not train skills in our patients if other options are available, even if these training opportunities are more expensive and time consuming. This applies to all of our medical activities.

Whereas engineering represents the prerequisite for successful simulation in medicine, aviation is a shining example, not only because of the technical concepts to design environments close to reality, but also because of strategies for effective and reliable communication in emergency situations. In our opinion, simulation was the door opener for bringing concepts of cockpit/crew/crisis resource management into the world of medicine. David Gaba was one of the masterminds in this context [5]. Aviation is still the archetype of safety and reliability, and simulation has been one cornerstone especially for training critical incidents. In the beginning of medical simulation, many concepts were just copy-pasted without considering the differences between aviation and medicine. The very affecting story of Elaine and Martin Bromiley, also mentioned by Rhona Flin in the chapter about the concepts for crew resource management and the training of nontechnical skills, underlines this similarity of aviation and medicine. Despite technical and scientific progress, both aviation and medicine still rely on humans with all the gaps and traps of thinking, behavior, and psychology. However, physicians do not fly airplanes – they directly treat people. Nevertheless, comparisons between
aviation and medicine are frequently made. Inspired by St. Pierre and Hofinger [6], we summarize some exemplary differences between aviation and medicine in Table 1:

Although many lessons have been learned from the experiences in aviation, it is mandatory to develop concepts adapted to the specific conditions in human health care for training, recertification, and patient safety programs.

Following optimization of simulation-based training in medicine with engineering and aviation, the next challenging approach will be the inclusion of scientific methods. For many years, simulation, regardless of which fidelity or subject, was often used without any pedagogical knowledge, for

Table 1
Comparison of aviation and medicine (modified from [6]).

<table>
<thead>
<tr>
<th>Characteristics and mission</th>
<th>Hospital/operation room/ medicine</th>
<th>Aviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risks are always present and have to be balanced against a potential benefit; different outcomes could be acceptable</td>
<td>No risk, a safe flight is the only acceptable outcome</td>
<td></td>
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<tr>
<td>Physical consequences concern only the patient</td>
<td>Physical consequences for crew and passengers</td>
<td></td>
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<tr>
<td>Patient care is done by different team members in different places with overlapping time periods. A handover of diagnostic and treatment history has to be done</td>
<td>A flight is done by a defined crew with a defined start and landing. Long flights done by “heavy crews” with handovers during the flight are rare.</td>
<td></td>
</tr>
<tr>
<td>Emergencies (e.g., operations) always have to be handled immediately without the chance of optimizing the patient condition before intervention</td>
<td>In case of bad weather or unexpected problems with the airplane before the start, the flight can be canceled</td>
<td></td>
</tr>
</tbody>
</table>

| Team | Large interdisciplinary, inhomogeneous, and interprofessional teams; daily changing and often new team constellations | Limited cockpit teams, relatively homogeneous, daily changing and often new team constellations |

| Communication | No standardized communication | Highly standardized communication in the cockpit and with air traffic control (ATC) |

| Emergencies | In emergencies sometimes unclear hierarchy and leadership | In emergencies clear hierarchy and leadership |

| Crew resource management (CRM) | At the end of the 1990s, first sporadic attempts to reduce influence of human factors on errors and mistakes in health care | At the end of the 1970s, structured research and more and more implementation of mandatory training programs |

| Selection | Selection for entering medical schools almost based on cognitive skills necessary | Radical selection combined with multiperspective, psychometric assessments |

| Supervision | Patient care often without adequate supervision or designated supervision does not take place | Permanent and structured supervision |

| Standardization | Process variability desired and sometimes necessary and in consequence part of physicians self-concepts | Process variability not desired and not part of pilots self-concepts |

| Checklists | Just implemented for some aspects of health care and for some emergencies | Widely used and implemented also for most of the emergencies |

| “Man and plane” | Humans are creatures, physiology is difficult to calculate out of physiological principles; people might be similar but never a copy | Planes are constructed by humans, flying is calculable out of physical principles; airplanes are built in series and in consequence similar or identical |

| Simulator training is still optional in most countries. | Simulator training is mandatory at least two times a year. |
example, as we would like to point out with this editorial “It’s not all about technology.” High-end environments and up-to-date mannequins do not necessarily guarantee that participants reach the learning goals or inevitably result in effective measurements. Technical options are only prerequisites. Of much more importance is how the technical acquirements are integrated and used as part of teaching concepts. The skills of the teacher are essential for the success and those teaching skills need to be achieved over years. The clinical experience just represents one aspect; a different aspect is how to pass on one’s experience. In particular, the article of Susan Pasquale enriches this topic from an educational and scientific point of view.

Several commitments have to be made to implement simulation-based training into a department. Once enthusiastic and willing colleagues have been identified, those need to gain pedagogic background. Master of medical education (MME) programs are one of the possibilities to cope with the increasing demands in education. They focus not only on simulation but also on curriculum development, cognitive psychology, assessment, evaluation, leadership, and educational research providing the educational tools for successful learning. However, the qualification and the absence of the upcoming teacher in the clinical setting are expensive and will not be reimbursed in most places. The establishment of a curriculum, part of it in a sheltered teaching environment during working hours, is a difficult and sometimes unsolvable task. Teachers and residents will not be available for clinical work during courses. As long as there is no specific financial support for the training of residents, such as in countries like Germany, it needs clear-sighted hospital managers and imagination of the departmental chairs to implement such a teaching environment.

Experts in simulation-based training are rare, as they often need to balance their clinical tasks and their educational entitlement. Against this background, we understand why it was unforeseeably difficult to get in contact with some experts in this field. Therefore, we would like to express our gratitude to all the authors of the present edition for their willingness to share their expertise and invest additional time.

Their contributions clearly demonstrate that it is not all about technology but about how we use those achievements in simulation-based training programs to make learning experiences more effective, eventually resulting in an improvement in patient safety.

References


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Educational science meets simulation

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Keywords: teaching with simulation, simulation education, learning with simulation

With the increased use of simulation to teach the knowledge and skills demanded of clinical practice, toward the achievement of optimal patient care outcomes, it becomes increasingly important that clinician educators have fundamental knowledge about educational science and its applications to teaching and learning. As the foremost goal of teaching is to facilitate learning, it is essential that the simulation experience be oriented to the learning process. In order for this to occur, it is necessary for the clinician educator to understand the fundamentals of educational science and theories of education such that they can apply them to teaching and learning in an environment focused on medical simulation. Underscoring the rationale for the fundamentals of educational science to be applied to the simulation environment, and to work in tandem with simulation, is the importance that accurate and appropriate information is retained and applied toward establishing competence in essential practice-based skills and procedures.

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Introduction

With the advanced use of simulation in health care, it becomes progressively important that clinicians have basic knowledge about educational science and its applications to teaching and learning with simulation. The importance of establishing competence in essential practice-based skills and procedures underscores the rationale for educational science to work in tandem with simulation. The integration of the two will provide a learning environment that best addresses and facilitates achievement of essential patient care outcomes. Although teaching and learning is central to the use of...
Simulation, the focus is all too often on the technology or equipment without adequate preparation for the teaching or adequate reflection about the learning. Simulation provides a tool for teaching, but it is how the information regarding the use of the tool is presented, how it is taught, that should lead in an educational experience. When used effectively, simulation provides an environment for experiential learning toward enhancing the learner’s critical thinking, problem solving, and decision-making skills. It provides opportunities to assimilate the basic and clinical sciences and to apply that knowledge in realistic, yet low-risk situations. It can also improve teamwork and reflection. To effectively perform in medical situations, the medical team must draw on the knowledge and skills learned. As such, it is essential that the manner in which those knowledge and skills are taught be based upon educational science, such that accurate and appropriate information is retained and put into practice in any given situation, and such that it improves learner competency in the practice-based skills of clinical medicine. In that the primary goal of teaching is to facilitate learning, it is essential that simulation experience be oriented toward the learning process, a point that will be emphasized in this article.

The practice of most clinician educators is influenced by some framework that guides their teaching, even if they are not fully aware of its theoretical orientation or educational science. It is, therefore, the intent of this article to begin to connect the science of education, educational theory, with practice by presenting information that operationalizes aspects of educational science and theoretical perspectives into approaches that are immediately applicable to teaching and learning in an environment focused on medical simulation. This article will present information on how educational science can be optimally used to enhance the use of simulation in clinical medicine.

An overview of educational science

Though Mann presents a review of theoretical perspectives that have influenced teaching in medical education, knowledge of educational science alone will not build the bridges needed to enhance teaching and learning. Instead, it is how to operationalize the educational theory and how to put it into practice, which will make build those bridges and make those connections. Within educational science, there is a distinction between theories of learning and theories of teaching. While “theories of learning deal with the ways in which an [individual] learns, theories of teaching deal with the ways in which a teacher influences [learning behavior]” [2]. As such, it is presumed that “the learning theory subscribed to by a [clinician educator] will influence his or her teaching theory.” Knowles, Holton, and Swanson [3] make the distinction by noting that learning is defined as “the process of gaining knowledge and or expertise…and…emphasizes the person in whom the change is expected to occur, [while] education emphasizes the educator.”

Physicians and other clinician educators using simulation, working alongside professional educators, continue to develop educational practices that assure their learners are demonstrating competencies to meet the needs of their patients. When the focus of educational science is on how to optimally facilitate learning, clinical educators must determine what learners need to learn in order to assure they will develop the knowledge and skills needed necessary in the rapidly changing healthcare environment. As such, as noted previously, it is important for clinician educators to possess at least a fundamental understanding of elements of educational science, including learning theory.

Although there are many theoretical perspectives of learning, including behaviorist, cognitivist, and developmental, this article will highlight the learning theories of Dewey and Kolb’s experiential learning, Schon’s reflective practice theory, Bruner’s constructivist theory, and Lave and Wenger’s situated learning theory, which all intersect and overlap with each other, and their relationship to simulation.

Simulation and experiential learning

“Simulation is a ‘hands-on’ (experiential learning) educational modality, acknowledged by adult learning theories to be more effective” [4] than learning that is not experiential in nature. It offers the
learner opportunities to become engaged in the learning. In simulation, learning takes place between learners, between the educator and learner, between the learner and content, and between the learner and simulation environment.

Learning is facilitated through experience, activity, context, and construction of knowledge. Lave and Wenger’s situated learning theory notes that learning is situated within the specific learning environment and that creation of “knowledge is intimately connected to participation in activities” [5]. The context in which the learning occurs, such as in a simulation, enhances the relevance of the learning, and thus deep learning.

Simulation has the potential to provide this experience and learning if used in keeping with the basic principles of educational theory. Experiential learning enhances the learner’s critical thinking, problem-solving, and decision-making skills, all being aims of teaching with simulation. Experiential learning “involves reflective thought, and influences subsequent actions and personal development” [6]. In experiential learning, learners build knowledge through their interactions and experiences within an environment that engages the learner and supports construction of knowledge. In keeping with the tenets of experiential learning, Lave notes that learning is situated, that it is rooted in context, activity, and culture, and that “knowledge needs to be presented in…settings and situations that would normally involve that knowledge” [7]. Such is certainly the case with learning in a medical simulation environment. Experiential learning operates with the principle that experience imprints knowledge more readily than didactic or online presentations alone. Simulation has been shown to improve the acquisition and retention of new knowledge compared with didactic lectures. Participants in the 2005 Millennium Conference on Medical Simulation agreed that “simulation offers a conducive environment for focused reflection and critical thought” [8]. Harden et al. [9] remind us that “educators are becoming more aware of the need to develop forms of learning that are rooted in the learner’s practical experience and in the job they are to undertake as a professional on completion of training.” Further, “learning takes place through the active behavior of the learner; it is what he does that he learns, not what the educator does” [10]. As such, the development of critical reflection skills, key in the debriefing phase of simulation, is essential to effectiveness in clinical health care.

Dewey’s experiential learning theory purports that it is important for learners to be engaged in activities that stimulate them to apply the knowledge they are trying to learn so they have the ability to apply it in differing situations. Application of knowledge is an essential feature of simulation and the learner’s ability to apply the knowledge in various situations is crucial in clinical practice. Experiential learning offers the learner the opportunity to build knowledge and skills that are vital to their clinical practice. However, learning to apply previously acquired knowledge and skills to new situations requires practice and feedback. As noted in Kolb’s cycle of experiential learning, the learner progresses through a cycle consisting of four related phases: concrete experience (an event), reflective observation (what happened), abstract conceptualization (what was learned and future implications), and active experimentation (what will be done differently). The learner’s prior experiences have a direct relationship to future learning, thus reinforcing the importance of the four phases of the experiential learning process, in particular the aspects of what happened, what was learned, and future implications. Dewey emphasizes that opportunities for reflection are essential. They provide opportunities for the learner to make connections between the experience and the knowledge drawn from the experience. So that, as learners move through the phases of experiential learning, they strengthen their ability to internalize the process and learn how to become better learners. Schon’s “reflection on action” is “a process of thinking back on what happened in a past situation, what may have contributed to the…event, whether the actions taken were appropriate, and how this situation may affect future practice” [11]. As learners increasingly internalize this process of reflection on action, which takes place in simulation debriefings, it is expected that it will be supplemented by “reflection in action” [11], which occurs immediately, while the learning event is occurring.

**Self-reflection, learning, and educational science**

Reflection is “the process by which we examine our experiences in order to learn from them” [12]. As such, reflective learning is based on experience. As noted by Sandars [13], “Reflection is a metacognitive [thinking about thinking] process that occurs before, during and after a situation with the
purpose of developing greater understanding of both the self and the situation so that future encounters with the situation are informed from previous encounters.”

It is, therefore, essential that learners develop metacognitive skills. However, they may make metacognitive errors such as not recognizing when they need help in their learning. Such errors point to the need for regular feedback and reflection on learning experiences so as not to create a false sense of competence, but maintain the learner’s motivation and professional sense of self. “Without a culture that promotes reflection..., learners may not consider their progress systematically and may not articulate learning goals to identify gaps between their current and desired performance” [14]. Although “reflection on experience” was the aspect of reflection that Schon paid the most attention to, “reflection-in-action” is essential for self-assessment.

In Bruner’s constructivist learning theory, the learner constructs knowledge through active engagement in the learning environment and with the content, through experiences. As such, there is a direct relationship between experiential learning theory and constructivist learning theory. The learners construct knowledge as they learn, based on their experience and prior knowledge, which highlights an important relationship between a learner’s prior knowledge and experience and their process of constructing new knowledge. Within this constructivism paradigm, the learner is guided by the educator to establish meaningful connections with prior knowledge and thus begins the process of constructing new knowledge for themselves. Simulation commonly uses this educational framework, in which the learner constructs knowledge for application in real-world activities. This framework also gives the learner increased responsibility for reflection and self-assessment, a component of the Kolb framework noted earlier. Further, as the learner finds relevance in the learning task, intrinsic motivation is more likely to be activated, leading to deeper learning with more links to prior knowledge, resulting in greater conceptual understanding. Simulation holds the potential to operationalize the constructivist framework, in that it provides active engagement with the content, coupled with application to real-world activities. As stated by Schon, “effective education requires...a transaction with the situation in which knowing and doing are inseparable” [15]. Prior knowledge most effectively integrates new knowledge when the learner is required to apply the knowledge to a new situation. An associated ingredient that helps to facilitate this integration of prior and new knowledge is the social process of collaboration, which is inherent in simulation or clinical teams working together. Recognizing the role that the social process of discussion plays in the construction of knowledge, Isba and Boor [5] note that “people learn from other human beings and together construct new understandings of the world.”

The role of prior knowledge and motivation in learning

A goal of learning is to integrate new information into an existing system located within the learner’s memory. The more connections created between the new information and prior knowledge, the easier it will be for the learner to remember the new information, which will become part of, and strengthened by, the connections that already exist. Assuming this knowledge is learned accurately to begin with, it is important to build on this prior knowledge so that acquired new knowledge does not link to inaccurate or misconceived principles, creating an incorrect foundation of information. When new knowledge is linked with a learner’s accurate and well-organized prior knowledge, it is easier to learn in that it becomes a part of the connections that already exist. It is also important to recognize that, typical of adult learning behavior, learning outcomes will be influenced by the prior knowledge brought to a given simulation. Therefore, assessing what the learner brings to the simulation experience is essential in helping the learner build on prior knowledge and skills to more optimally advance learning outcomes.

In addition to the importance of the relevance of the learning task to motivation, research points to a relationship between the learner’s motivation and how they approach learning, such that intrinsic motivation links to a deep approach to learning, and extrinsic motivation links to a surface approach to learning. Entwistle [16] notes the differences of these three approaches to learning (Table 1). Motivation and learning are fundamentally linked. Learners value clinical relevance, situations that require problem solving, have clinical relevance, and call for integration of content. “A necessary element in encouraging the shift from extrinsic to intrinsic motivation appears to be the opportunity for learners
to practice a skill/task until they gain competence; satisfaction with accomplishments and competence is itself motivating, and encourages in the learner further practice and the confidence to undertake new tasks" [17], integral in simulation.

“The relationship between the evolving professional identity of the learner and the receipt of feedback either confirms or questions that evolving identity in the form of information about the person’s competence” [18]. In that competence and identity are highly related, feedback on competence is interpreted as directly related to the learner’s sense of self and directly influences motivation. That being said, it becomes clear that the reflection phase of Kolb’s experiential learning cycle, and the feedback on performance inherent in that phase, is essential to developing intrinsic motivation for learning. Moreover, it is the reflection on what happened in the experience, what was learned, and what the implications are for future actions that facilitates the learner’s progression of understanding through the five stages of Miller’s triangle (i.e., knows what, knows how, shows how, does, and mastery), as well as through Bloom’s hierarchy of cognitive learning. Teaching and learning with simulation can use both the cognitive and psychomotor domains. Bloom’s hierarchy of learning in the cognitive domain has six levels of increasing difficulty or depth:

1. remembering (e.g., recalling or remembering the information)
2. understanding (e.g., explaining ideas or concepts)
3. applying (e.g., applying the information in a new way)
4. analyzing (e.g., calling upon relevant information or distinguishing between the different parts)
5. evaluating (e.g., comparing and evaluating plans, or justifying a stand or decision)
6. creating (e.g., creating a new point of view or product)

Table 1
The features of three approaches to learning.

<table>
<thead>
<tr>
<th>Deep approach</th>
<th>Surface approach</th>
<th>Strategic approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Intention to understand</td>
<td>• Intention to reproduce or memorize information needed for assessments</td>
<td>• Intention to obtain highest possible grades</td>
</tr>
<tr>
<td>• Motivated by intrinsic interest in learning</td>
<td>• Motivated by extrinsic concern about task requirement</td>
<td>• Motivated by hope for success</td>
</tr>
<tr>
<td>• Vigorous interaction with content</td>
<td>• Failure to distinguish principles from examples</td>
<td>• Organize time and distribute effort to greatest effect</td>
</tr>
<tr>
<td>• Versatile learning, involving both:</td>
<td>• Focus on discrete elements without integration</td>
<td>• Ensure conditions and materials for studying appropriately</td>
</tr>
<tr>
<td>○ Comprehension learning</td>
<td>• Unreflectiveness about purpose or strategies</td>
<td>• Use previous exam papers to predict questions</td>
</tr>
<tr>
<td>▪ Relate new ideas to previous knowledge</td>
<td>• Anxiety or time pressures</td>
<td>• Be alert to cues about marking schemes</td>
</tr>
<tr>
<td>○ Operational learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Relate evidence to conclusions</td>
<td></td>
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</tr>
<tr>
<td>▪ Examine the logic of the argument</td>
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The psychomotor domain lists behaviors from the simplest to the most complex:

1. imitation (e.g., patterning behavior after someone)
2. manipulation (e.g., performing actions with instructions)
3. precision (e.g., refining)
4. articulation (e.g., coordinating actions, achieving consistency)
5. naturalization (e.g., high level, natural performance)

**Considerations in designing the learning experience**

If the power of simulation is to be fully realized, it is vital that it be used in ways that are consistent with principles of educational science and effective teaching practice. The ever-advancing technology tools within simulation environments can be tempting to both the clinician educator and learner. However, it is crucial to the success of the learning experience to make sure that the educational rationale, not the technology, leads any decision to use simulation. As suggested previously, teaching needs to begin with an analysis of what the learners need, and learning outcomes one seeks to achieve, rather than merely what the technology can offer. Use of simulation based on the level and needs of the learner is key toward helping learners build on prior knowledge and skills.

As is always the case in teaching and learning, it is essential to establish goals and learning objectives; to determine how simulation will support the teaching and learning, and achievement of those goals and objectives; how simulation will be integrated into the teaching; and how its effectiveness (i.e., achievement of goals and objectives, demonstration of the knowledge or skill) will be evaluated. As noted throughout this article, it is not solely about what the learner should know, but what they should be able to do with the knowledge within the simulation and how the learner is expected to apply the knowledge in practice-based situations. When educational objectives focus on the learner's ability to apply knowledge to real and meaningful situations, case method teaching and student-centered learning can provide an effective, interactive environment. A case-based learning format harbors an active learning mode, challenges learners to accept responsibility for their own learning, and fosters a firsthand appreciation of the application of their knowledge to the practice of medicine. Simulation is in a unique position to make use of case-based learning in ways that reproduce real situations, and in ways that are rooted in clinical practice.

As stated earlier in this article, it is essential to the success of the learning experience, to ensure that the educational rationale, not the technology, leads any decision to use simulation. In order for a simulation experience to be oriented toward the process of learning, and for the process of learning to guide teaching practice, the clinician educator must address specific information that will guide design of the learning experience.

1. What knowledge, skills, and attitudes will the learner bring to the simulation?
2. How will the learning be designed for the number of learners?
3. If it is essential that knowledge be acquired and applied in a specific sequence of learning, then how will the content be organized and presented?

Objectives should be specific, observable, measurable, attainable, realistic, learner-oriented, and appropriate for the level of the learner. An objective is considered measurable when it describes something tangible. While a goal is a broad statement of the overall outcome you seek to achieve, objectives are specific statements of how you will get there and how you will know when you have achieved the objective. Generally, when each objective has been achieved the goal has been met. Thus, the objectives function as stepping-stones to meeting the overall goals. It is helpful if objectives are thought of as containing five elements:

1. Who
2. Will do
3. How much (or how well)
4. Of what  
5. By when

The following is another method of describing the elements:

- **Performance**: This describes what the learner is expected to be able to do  
- **Conditions**: This describes the conditions under which the performance is expected to occur  
- **Criterion**: This describes the level of competence that must be reached or surpassed

**Summary**

If the power of simulation is to be fully realized, it is vital that it be used in ways that are consistent with principles of educational science and effective teaching practices. It is expected that with the basic knowledge of educational science presented in this article, through selected education and learning theories and principles, the clinician educator will have an enhanced understanding of how to design educational simulation experiences such that they focus on the learning process and guide teaching practice. Further, this article presents the clinician educator with application-based information on key elements of the teaching and learning process, inextricable from educational science, which facilitate the motivation to learn, construction of knowledge, deep learning, and retention of accurate and appropriate information. The information herein also highlights the role that prior knowledge plays in the construction of new knowledge, the value and essential components experiential learning, reflection, the relationship between intrinsic motivation and deep learning, and situated learning. It is expected that the reader will apply the information to strengthen the impact of their teaching on the learning of those they teach and their subsequent competency in the required skills of clinical medicine to better facilitate achievement of patient care outcomes.

**Practice points**

- It is important for clinician educators to possess a fundamental understanding of principles of education science, including learning theory, to better ensure learners are acquiring the needed knowledge and skills.  
- Activities should engage learners in ways that stimulate them to apply the knowledge that they are trying to learn so they can build on the knowledge and apply it in different situations.  
- Prior knowledge most effectively integrates new knowledge when the learner is required to apply the knowledge to a new situation.  
- Opportunities for learners to reflect on the experience are essential in order to provide opportunities for them to create connections between the experience and the knowledge drawn from the experience. Without reflection, learners may not systematically identify gaps between their current and desired performance.  
- The opportunity to practice a skill until they achieve competence is motivating for learners, and it encourages further practice and the confidence to learn new skills.

**Research agenda**

- It will be beneficial to review the systems and processes in place that ensure clinician educators are receiving the professional development needed to acquire and apply principles of educational science to teaching and learning with simulation.
Conflict of interest statement

None.

References

Institutional needs and faculty development for simulation

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This review focuses on simulation in anaesthesiology as an educational intervention from a learning perspective. Simulation-based education in anaesthesiology has implications for both faculty development and institutional needs. However, in order to find evidence for the implications of these areas, it is necessary to turn to the literature on anaesthesiology simulations, health-care simulations and also the medical education and pedagogical literature. The most important factor for successful simulation-based education on an institutional level is curriculum integration of simulation, closely connected with defined learning outcomes. The corresponding factor concerning faculty development in simulation-based education is feedback. These three factors are closely interrelated, and to understand them and how to design high-quality simulation interventions from a learning perspective, it is important to look not only to the simulation literature but also to the pedagogical literature.

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Be aware of the fact that faculty may initially be threatened by a simulation intervention situation as there is a risk of a competency drop from (content) expert to simulation novice if the simulation context is a new experience. Curriculum integration, learning outcomes and feedback are factors closely linked together and all very important for a successful outcome for simulations from a learning perspective. A technical device (simulator) as such does not drive learning. Technology, faculty, learners and clinical context are all in interplay in order to foster high-quality learning; it is of significant importance to guarantee a high return of investment of time and money. Understanding this interplay and being able to master strategies to optimize learning are therefore essential.

Research agenda

- There is a great need for including the integration of educational theoretical frameworks in future research on simulation in health care
- There is a need for simulation in anaesthesiology to rely on evidence from not only the health-care simulation literature but also other parts of the medical education literature

Introduction

Defining simulation in health care and anaesthesiology

Simulation in health care, although originating from different specialties, is said to have its roots in the area of anaesthesiology [1]. However, simulation in health care has many faces and definitions; Aggarwal et al. [2] defines it as a technique, a technology or a process. Another way to describe simulation as a three-component phenomenon would be as follows: (a) a device for simulating a patient or a part of a patient, (b) used for technical and/or non-technical skills training or validation of equipment or technique and (c) interacts appropriately with actions taken by the clinician [3]. Yet a third way to make distinctions between different types of health-care simulations is between high-fidelity and low-fidelity simulations, depending on the degree to which the simulations is able to replicate reality. Within the field of fidelity, psychological fidelity is also discussed. Here, stressors are added into the simulation, trying to make the situation as ‘realistic as possible’ [4,5]. A third degree of fidelity is sociological fidelity, not very frequently addressed in the literature. Proponents of sociological fidelity claim that the traditional simulation literature overlooks hierarchies in a care team, power relations and issues on professional identity [4]. Further, simulation can also be an instrument for both formative and summative assessments. A review of simulation-based assessment in anaesthesiology [6] shows that it is used within the specialty, but that it needs to be developed further especially concerning scoring. In this review, simulation is viewed from a learning perspective.

Simulation and learning — review rationale

Looking at simulation from a learning perspective, it is evident that it requires and stimulates active learning, as shown by Murray [7] through his review on current trends in simulation training in anaesthesia. Hence, the process of learning through simulation is quite different from many traditional methodologies; in simulation, the learner learns through observation, participation and debriefing [8]. A review of simulation studies in anaesthesia journals from 2001 to 2010 also points toward the fact that the key to effective simulation training is often not the actual simulation scenario, but instead the debriefing phase [3], which has also been confirmed by Dieckmann et al. [5] and LeBlanc [9]. Le Blanc [9] further shows through her review that although simulation is an established tool for training and assessment in anaesthesiology it has become even more important to focus on issues of learning; how are simulations being implemented and used to their full potential? Walton et al. [10] describes a lacking perspective of pedagogy when thinking about how learning occurs in connection to health
science simulation, a lack of faculty working with evidence-based learning theories in connection to simulation. Within the field of nursing, it has been pointed out how institutions often invest in simulators without preparing faculty pedagogically through faculty development [11–14]. Hence, simulation and the active type of learning it stimulates require awareness of pedagogical issues on an institutional level and qualitative faculty development to increase pedagogical awareness among faculty, the quality of simulations and, in the long run, learning.

In this review, we will focus on simulation as an educational intervention [15]. We will also derive from the view that a technical device (simulator) as such does not drive learning. Technology, faculty, learners and clinical context are all in interplay in order to foster high-quality learning; it is of significant importance to guarantee a high return of investment of time and money. Understanding this interplay and being able to master strategies to optimize learning are therefore essential. Faculty development and institutional needs will hence be explored from an educational design and learning perspective, and the review will focus on literature from the research field of medical education. As pointed out by Schaefer et al. in their review of instructional design and pedagogy science in healthcare simulation [15], there is a great need for including the integration of educational theoretical frameworks in future research on simulation in health care.

In the 2010 follow-up to the Flexner report, research clearly questions the current state of progression of learning in medicine [16]. However, simulation in health care is used at all stages of medical education: undergraduate, postgraduate and in continued medical education. This whole educational continuum is also reflected in the rationale for this review. Issenberg et al. show in their 2005 systematic review on high-fidelity medical simulation and learning [17] that five factors have contributed to the rise of the use of simulation in medical education in the continuum: problems with clinical teaching, new technologies for diagnosis and management, assessing professional competence, medical errors/patient safety/medical errors and the role of deliberate practice [17].

This review includes literature from medical education research on simulation-based education in health care overall as well as in anaesthesiology, specifically.

Mapping

Institutional needs

Simulation-based education from a learning perspective is neither a device nor just a technology. From an institutional perspective, it is critical for success to provide a frame for the simulation-based learning module(s). This review shows how curriculum integration including defined outcomes is crucial for successful outcomes, and they are also clearly institutional responsibilities and proper attention has to be given to them. Moreover, questions about faculty development for instructors or facilitators are an institutional responsibility and that content subject will be more closely referred to under the headline ‘Faculty development’.

Curriculum integration

Defined outcomes

In the systematic review conducted by Issenberg and colleagues in 2005 on high-fidelity medical simulations that lead to effective learning, curriculum integration of simulation exercises is considered to be an important feature of their effective use. The review shows that simulations should be integrated into the learners’ normal schedule and combined with patient care to obtain the most effective results. Further, Issenberg et al. highlight the importance of defined and appropriate outcomes for the level of training; learners are more likely to master important skills when having defined outcomes to strive towards [17]. McGahie’s review and critical evaluation [18] also brings forward the fact that reliable simulation-based education should be about simulation activities integrated with other educational events such as, for example, clinical experience or laboratory work. However, the importance of learning objectives is once again highlighted in this context: learning outcomes bring transparency to how simulation can complement clinical education and real patient care. The review
also shows the importance of making the case for the importance of simulation in competition with a busy clinical schedule as well as the importance of introducing its importance to faculty [19]. In a synthesizing review, McGahie and colleagues report [18] that the issue of learning outcomes in simulation-based education is focused on more specifically; it shows that there is a strong association between standardized learning outcomes and hours of practice in simulations. More frequent practice in simulations leads to better results and achievement of learning outcomes, and it applies to all levels of learners from medical students to specialists [19]. The best evidence guide formulated by Motola et al. on simulation in health-care education [20] also confirms the importance of reviewing curricula for how different learning activities support learning outcomes, simulation being one of these learning activities. It is advised that a cross-competency team (faculty, content experts and simulation technicians) evaluates the curriculum and decides where and how simulation is most properly integrated. It is also reported to be important that both the senior administration on an institutional level as well as faculty are committed to the usage of simulation activities in order to make the initiative successful; for example, is usage of faculty time likely to increase when conducting the simulation interventions?20 In a systematic review and meta-analysis of mastery learning for health professionals using simulations by Cook and colleagues [21], it is shown how an outcome-focused learning methodology (mastery learning) leads to better learning outcomes among learners using the methodology in simulation interventions, compared to those using no specific methodology. However, the outcome-focused methodology clearly took longer time than non-mastery learning [21].

Faculty development

Faculty development interventions are designed with the increased knowledge, skills and attitudes of the faculty in mind, thus also in the case of simulation training and education. Steinert et al. [22] show in their systematic review of faculty development initiatives designed to improve teaching effectiveness in medical education, that participants most often report changes of learning and behaviour after taking part in the initiatives. Still, they also report that there is a need for use of theories of learning within faculty development initiatives in medicine [22]. However, McGahie et al. [18] show how the role of faculty in simulation-based medical education is not researched properly from an evaluation point of view and that there is a need for uniform faculty development for faculty involved in simulation in health-care education. Clinical experience alone is not a guarantee for success in the role of faculty promoting learning [18]. This review identifies feedback as the number one most important feature for effective simulation-based education and therefore it should be a central part of the content in faculty development initiatives for simulation faculty, preferably viewed from a learning perspective.

Feedback

In a systematic review from 2005, Issenberg and colleagues showed that although educational feedback is the most important feature in simulation-based education, the source of feedback is of much less importance than its presence. The sources of feedback can hence be of different types such as, for example, given by faculty during a session, built in to the simulator or given afterwards in connection to watching the recording of the simulation [17]. The review and critical evaluation conducted by McGahie et al. [18] of research on simulation-based medical education from 1969 to 2009 also shows that feedback is the number one feature and best practice that simulation-based medical education should focus on. The review further shows that contemporary research on feedback emphasizes three important core elements to shape learning: varieties, sources and impact. The best evidence practical guide formulated by Motola et al. in simulation in health-care education [20] points in the same direction: feedback to learners is a critical component to ensure effective learning. Motola et al. [20] also bring up the importance of letting the learning outcomes steer the design of the type of feedback given within a simulation, from different sources (faculty, peers or simulator) and at different times (immediate, real-time or post event). They also point towards the importance of feedback to ensure that the learning objectives are met and that a learning process without feedback is at risk of being a missed opportunity for further learning. When implementing feedback, Motola et al. [20]
identify three important stages: planning, pre-briefing and providing the feedback. The planning phase is conducted in connection to the development of the scenario and feedback should be planned to be in consistency with the learning outcomes, the pre-briefing phase where learners are prepared in a non-threatening environment about expectations and finally the provision of feedback where feedback from the simulator guides the learner when meeting the learning objectives. The Motola et al. guide finally concludes that feedback is critical to effective learning in simulation, that is, it should always be planned and that faculty development initiatives in feedback techniques are central for simulation faculty and their effective use of simulation [20]. However, problems have been identified by Mainhart et al. [23] in the literature within the area of the faculty's skills in giving feedback to learners in simulation learning situations: understanding the learners' frame of reference as well as overcoming concerns about the faculty–learner relationship. These questions about the faculty's readiness to handle feedback to learners in simulation settings were highlighted in a randomized controlled trial in an anaesthesiology residency training environment, which showed that the quality of faculty feedback was improved after a short educational intervention. The improvements were made within the areas of identifying performance gaps, maintaining a psychologically safe environment and overcoming discomfort in discussing professional over lapses with the residents [23].

Discussion

This review shows how curriculum integration and defined learning outcomes are closely related when it comes to being success factors for promoting high-quality simulation interventions from a learning perspective. Curriculum integration and definition of learning objectives clearly is something that is engaging and should engage faculty involved in simulation interventions. However, the responsibility for these factors really lies on a senior administration/institutional level. However, the most important feature creating circumstances for high-quality simulation interventions from a learning perspective on a faculty level is feedback. At the faculty level, it is also important to remember that although faculty members are content experts and experts within their specific specialties, they sometimes lose this expert status when entering the simulation environment. There, they are sometimes surrounded by technical equipment that they may not be used to, and in engaging in the simulation intervention they are then risking their expert status in front of the learners. One way of illustrating this could be by using the Dreyfuss and Dreyfuss model [24] where the faculty are risking stepping down from an expert level, all the way down to a novice level [24] (Fig. 1). This phenomenon could create some resistance from some faculty in the implementation phase.

This review is based on findings from literature on health-care simulation more broadly, but also from literature more specifically on anaesthesiology simulation. Lorello et al. [25] believe that until there more robust evidence is developed in simulation-based education in anaesthesiology, we need to rely on evidence from the health-care simulation literature but also other parts of the medical education literature [25]. Viewing curriculum integration, learning outcomes and feedback from an overarching perspective, it is clear that they are all closely related in the realm of pedagogy. Hence, as learning theories often are a missing piece of the health care and/or anaesthesiology simulation

![Fig. 1. Model of competence (Dreyfuss & Dreyfuss, 1980)](image-url)
intervention puzzle, we believe it to be important not to reinvent the wheel in the world of simulation-based education. Instead, we should take a closer look at what pedagogical research and learning theories have to offer on these issues, which might also be helpful for the realm of simulation-based education.

Regarding feedback, perhaps the strongest evidence from outside the world of health professions for its effectiveness on learning is Hattie’s synthesis of 800 meta-studies on factors contributing to high-quality learning in all sectors of education, from primary school to continuous professional education [26]. Hattie points out that when faculty give feedback to learners and vice versa teaching and learning can be synchronized and powerful, and his meta-analysis shows that feedback makes learning visible.

Determining learning outcomes and communicating learning objectives are shown to be of significant importance in several of the reviews, which are the basis for this review [17,19–21]. The SOLO taxonomy [27] is a validated instrument that will help in further formulating learning objectives — the key for successful learning (Fig. 2).

Once an overview is established on the overall aim of a simulation-based training session, a detailed learning objective must be produced. It is of significant importance to keep in mind that simulations (independent of fidelity, level of difficulty, etc.) are only a means to foster learning in specific domains. The simulation as such does not have an intrinsic value; it is just an instrument to foster learning. Therefore, proper attention must be put into formulating these key learning objectives.

A first distinction must be made between technical/procedural and non-technical skills. To formulate learning objectives effective to learning requires specific competence and a valuable instrument to assist this process is the SOLO taxonomy [27]. The taxonomy has different levels of cognition, from low to high, and the taxonomy is hierarchical meaning that higher levels presuppose foundations in lower levels. In any normal simulation setting, level 4 of the taxonomy is relevant and learning objectives should be based on this level. The way the taxonomy works is to use active verbs to formulate what the expected learning outcomes are for each individual. Learning objectives should be known to the learner prior to attending a session, as well as for all faculty involved. The knowledge of the learning objectives will drive learning [27] in the intended direction and it will also be the basis for the debriefing and individual feedback that is proven to be a very important factor for successful simulation-based education.

Closely related to this is another important issue that sometimes may cause problems — the lack of, or gap in, relevant basic knowledge on, that is, physiology, pharmacology, local anatomy or different algorithms. Understanding is not a fixed state but a continuum from low to high levels of understanding. Simulations often operate on a SOLO level 4, which is equal to “application, integration, evaluation, problem-solving, medical reasoning etc.” However, level 4 requires basic knowledge, which is sometimes lacking in medical simulation. This can be handled quite easily once aware of the problem.

![Fig. 2. The SOLO-taxonomy (Biggs & Tang, 2007)](image-url)
Conclusion

This paper is based on the mapping of results mainly from review articles highlighting features and factors contributing to effective simulation-based medical education. The results are presented from a learning perspective and are mainly focused on institutional needs and faculty development in simulation.

On an overall level, it is important to reemphasize that simulations as such do not drive learning. A proper educational design must be in place and well-suited educational methods must be used. The evidence suggests that curriculum integration is one key factor by which simulation-based education is seen and placed in a wider educational context. The explicit learning objective and the overall learning aim with a simulation are equally important. From an individual perspective, each instructor/facilitator/teacher has to master the skill of providing feedback based on the explicit learning objectives.

Today, there are several different forms of simulations, from human-based standardized patients to high-tech, high-fidelity simulators. Considerable effort has been put into developing more and more sophisticated simulators and scenarios are being developed containing training in technical and procedural skills as well as non-technical skills as communication and leadership. In addition to this, we have a strong impetus to include psychological fidelity to even further replicate reality plus the emerging discussion on sociological fidelity. It is now due time to also start addressing the complex issue of educational design and learning perspectives. Simulation, independently of its format and sophistication, must be put into a proper, evidence-based educational context in order to reach its maximal and optimal learning potential. This article has outlined some of the features identified in the literature and recommendations based on this evidence have been provided for institutional needs and faculty development in simulation.

Conflict of interest statement

None.

References


The matter of ‘fidelity’: Keep it simple or complex?

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simulation
realism
learning success
medical education

Simulation often relies on a case-based learning approach and is used as a teaching tool for a variety of audiences. The knowledge transmission goes beyond the mere exchange of soft skills and practical abilities, including practical knowledge and decision-making behaviour as well. As it seems, simulation requirements largely depend on the skills, abilities or competences to be conveyed. Unfortunately, we lack any scientific evidence as to how much learners should be stressed to achieve a positive learning outcome. As regards learning and practising purely technical skills, however, it can be generally assumed that simulations should be as anatomically/physiologically close to reality as possible. On the other hand, teaching soft or decision-making skills and sharing practical knowledge poses less stringent requirements on simulation realism. For simulation-based learning, learning outcomes depend not only on knowledge, practical skills and motivational variables, but also on the onset of negative emotions, perception of own ability and personality profile. ‘Simulation’ training alone does not appear to guarantee learning success. Rather, it seems necessary to establish a simulation setting suitable for the education level, needs and personality characteristics of the students. Thus, it is fair to conclude that there is no evidence correlating the realism of a simulation scenario with the learning success of students.

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Introduction

Technological progress introduces permanent changes in all spheres of life. This is particularly evident in medicine. In the last 20 years, simulators and physiological models have reached unprecedented development levels. Nowadays, simulators in the field of medical education and continued training allow representing and simulating even the most complex scenarios and diseases, with a hitherto unseen level of realism. On the other hand, we need no longer leverage in full all features and capabilities provided by modern simulators. Furthermore, simulator classrooms depict real situations with increasing accuracy by means of appropriate equipment and design. However, technical and spatial equipment alone no longer guarantee optimal learning, because: ‘Simulators don’t teach!’ Not surprisingly, teachers remain paramount in the learning process. As implementing simulation scenarios is a highly complex and costly endeavour, questions regarding the efficient use of resources inevitably arise: How much realism must be sought to achieve a particular learning outcome? This article attempts to portray the current state of knowledge on this topic.

Simulation often relies on a case-based learning approach and is used as a teaching tool for a variety of audiences. Knowledge transmission goes beyond the mere exchange of soft skills and practical abilities, including practical knowledge and decision-making behaviour as well. Learning success has been measured successfully in the past [3]. Such an assessment also included the subjective impression of participants regarding their learning through simulation scenarios [4]. However, we lack a precise understanding of the factors or the interaction thereof through simulation — leading to this positive learning experience. There is only consensus that simulator learning must be of a multifactorial nature. In addition, the nature of simulation-based learning is also relevant. Simulation realism requirements largely depend on the skills, abilities or competences to be conveyed. In this context, simulation shall be construed as a technique to attain specific learning objectives [5]. Simulation can thus be seen as a means to an end rather than as a fixed, unchangeable variable. The degree of realism seems to be an important control variable, bearing major influence on the learning conveyed by the model. Accordingly, the degree of realism must be commensurate to the learning goals. In the simulation area, such learning goals are primarily connected to the integration of technical skills in a more complex overall situation, or to the so-called nontechnical skills (communication skills), which allow better dealing with usually dynamic situations [6]. In the following section, we describe the current state of knowledge in conveying different learning objectives and the associated realism.

Simulation for hard skills teaching

Miller’s learning pyramid distinguishes four competence levels [7]:

1. Knows
2. Knows how
3. Shows how
4. Does.

Each competence level demands its own teaching method. For example, hard skills are particularly suited to the teaching of Miller’s competence level 2 (i.e., Knows how). Hard skills of such nature are taught using human-like phantoms (e.g., vein puncture arm). In this case, the degree of realism usually rests on highly realistic depiction of anatomical structures or functional relationships rather than on embedding simulators in a realistic environment. Even today, however, this approach presents certain limitations. For example, airway management, anatomy abnormalities or pathophysiology (cough, secretion, bleeding, aspiration) cannot be adequately represented in this way. Despite some limitations, the benefits of simulator-based teaching are still significant, as these tools offer outstanding training options for teaching technical skills [6].

In this respect, the development and implementation of simulation techniques in medicine tend towards an expansion beyond the necessary transmission of technical skills, focussing as well on the implementation of such skills in complex working environments. Ultimately, the approach is strongly
dependent on the intended audience. As it happens, the above trend refers primarily to experienced participants. New technical skills, therefore, must be conveyed first in a larger overall setting, deferring implementation to a later stage.

**Simulation for communication skills teaching**

Useful simulator-based training influences future behaviour in an effective fashion [8,9]. Thus, this learning approach seems fit for teaching teamwork and communication skills. On the other hand, exposing trainees to certain stress situations seems to drive training effectiveness. In this regard, we might refer to a few studies covering the induction of stress effects through simulation [10,11]. Realistic simulations can produce stress reactions identical to those experienced in the operating room under real conditions [10]. Consequently, the teaching of communication skills might benefit from scenarios depicting largely realistic situations to trigger appropriate stress responses. Current research also addresses the following issue: Does the high stress induced by a realistic simulation dampen the educational efforts of knowledge transfer? This raises the question as to the relative placement and extent of stress stimuli throughout the learning process.

Students’ training and experience levels seem to play an important role as to the claim to realism and, thus, the stress level.

Unfortunately, we lack any scientific evidence as to how much learners should be stressed to achieve a positive learning outcome [1].

Elaborate, realistically designed simulations should therefore rather be used to convey communication skills, as opposed to the hard skills above, which are suitable to teach technical skills.

**Impact of simulation on long-term retention**

The positive influence of simulation on learning is no longer an issue [4]. This also holds true for learning technical skills, soft skills, practical knowledge and decision-making behaviours. However, can we assume the same for other learning dimensions, namely knowledge, understanding, competence and transfer effectiveness? To answer this question, we examined the teaching of commercial resuscitation courses of the European Resuscitation Council (ERC). While overall teaching is deemed to be good, two learning dimensions, namely transfer effectiveness and competence, seem insufficiently conveyed [12]. Numerous studies have analysed the influence of realistic simulations on cognitive learning. These concluded that ‘transfer effectiveness’ was optimally conveyed through simulations [13]. In addition, Breuer identified a significant connection between cognitive knowledge tests and simulation, even without addressing the issue of realism [14]. Nevertheless, as a rule, studies on simulation-based training yield extremely positive results [15]. The question of how much simulated reality a scenario must deliver to achieve successful knowledge transfer or sufficient preparation for patient care seems insufficiently clarified from a scientific standpoint, especially concerning the integration of technical skills in a meaningful storyline [16]. A recent study shows that, while realistic simulation design provides a significant knowledge increase immediately after the simulation, even with less experienced participants, this has no effect whatsoever on the cognitive long-term retention of students. On the other hand, there is general agreement that simulated clinical cases must be realistic enough for students to enjoy a meaningful experience and learn. Again, scientific evidence is wanting.

‘Psychological fidelity’

Until recently, psychological fidelity has been largely ignored as a simulation factor in human medicine. This term does not refer to stress generated by the realistic simulation, but, for example, to the realistic depiction of interprofessional interactions (e.g., surgeon—anaesthesiologist). Up to now, however, only the aviation industry has explored this topic [17]. These results still require transmission to and verification in the field of medical simulation.
Conclusion

While simulation has made a huge technological leap in the last 20 years, medical teaching is hard
to conceive without it nowadays and we know very little about the exact processes governing
simulation-based learning. Indeed, there is scant evidence in this domain. As regards learning and
practising purely technical skills, however, it can generally be assumed that simulations should be as
anatomically/physiologically close to reality as possible. On the other hand, teaching soft or decision-
making skills and sharing practical knowledge poses less stringent requirements on simulation real-
isim. The selected scenario must be realistic, and the simulation and simulator technical features must
be adequately aligned \[6\]. Simulator usage must also be considered from a financial point of view. For
example, using a ‘high-fidelity’ simulator to convey hard skills is hardly cost-effective. For successful
learning, a well-presented scenario with properly trained teachers using a simple resuscitation doll
appears to fare better than a highly complex, albeit unrealistic and non-professional simulation sce-

For simulation-based learning, learning outcomes depend not only on knowledge, practical skills
and motivational variables, but also on the onset of negative emotions, perception of own ability and
personality profile \[2\].

‘Simulation’ training alone does not appear to guarantee learning success. Rather, it seems neces-
sary to establish a simulation setting suitable for the education level, needs and personality charac-
teristics of the students.

Result

In spite of the widespread use of simulators for medical education and training, there is no evidence
correlating the realism of a simulation scenario to the learning effectiveness for students.

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<th>Practice points</th>
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<td>• Simulation is the most suitable tool for conveying complex relationships.</td>
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<td>• Simulation does not lend itself well to the conveying of purely factual knowledge.</td>
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<td>• Human’ reality is suitable for teaching technical skills.</td>
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<td>• Realistic simulations are suitable for teaching nontechnical skills.</td>
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<td>• The higher the desired proficiency level, the greater is the realism required.</td>
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<td>• Good’ simulation seems to demand a simulation setting suitable for the education level, needs and personality profile of learners.</td>
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<td>• Good’ simulation planning should answer the following questions: Who is the intended audience of our simulation?’.</td>
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<th>Research agenda</th>
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<td>• Unfortunately, we lack any scientific evidence as to how much learners should be stressed to achieve a positive learning outcome.</td>
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<td>• There is insufficient evidence to properly correlate degree of realism and knowledge transfer effectiveness.</td>
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<td>• Transferring scientific data collected on the mannequin to patient care may be difficult.</td>
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<td>• Further research on simulator-base learning is highly advisable.</td>
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References


Basic concepts for crew resource management and non-technical skills

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training
assessment

In this paper, we explain the conceptual background to non-technical skills and show how they can influence job performance in anaesthesia. We then describe the taxonomy of anaesthetists’ non-technical skills (ANTS) and related systems, such as ANTS-AP for anaesthetic practitioners. We discuss the training courses that have been designed to teach these non-technical skills, which are called crew resource management (CRM), crisis resource management (CRM) or crisis avoidance resource management (CARMA). Finally, we discuss the application of non-technical skills assessment systems.

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Introduction

Notwithstanding clinical and technical advances in anaesthesia, there are still risks for patients. One notable example is the English case of Mrs Elaine Bromiley, a 37-year-old mother of two young children, who died in April 2005 as a result of a problem in maintaining her airway during elective endoscopic sinus surgery, in a private clinic. Analyses in industry have indicated that human error can
be a significant component of accident causation [1], and sometimes a key component is a deficiency in the non-technical skill (NTS) of operational staff. What is relevant about Elaine Bromiley’s case is what occurred in the UK as a result of her death. Martin Bromiley, who was her husband, is an airline pilot. In his world of aviation, accidents are taken very seriously and that means they are carefully and systematically investigated by experts to discover not only the technical but also the non-technical causes. He assumed that his wife’s unexpected and tragic death would be subjected to this level of scrutiny but he was told unless he pursued a legal case, that would not normally occur. He managed to instigate an independent inquiry by a senior anaesthetist, which revealed a number of deficiencies in NTS during the accident trajectory [2]. He then asked if there was a national clinical human factors group that can advise health-care organisations on the latest developments for NTS training and other human factors interventions. However, in the world of health care, no such group existed. Moreover, very little training in human factors or NTS was provided to health-care staff, unlike the other safety-critical industries.

Therefore, Martin Bromiley set about addressing these deficiencies, by establishing in 2007 the first Clinical Human Factors Group for clinicians and human factors specialists (www.chfg.org). His efforts are now leading to an enhanced awareness of the importance of the role of human factors in health care and patient safety. Human factors science essentially studies the variables that can influence human behaviour in relation to task execution. In a work context, this means the environmental, organisational and job factors, as well as the physiological and psychological characteristics that influence behaviour at work. The largest of the professional organisations is the Human Factors and Ergonomics Society, based in the USA (www.hfes.org), and its members come from various disciplines, such as ergonomics, psychology and engineering, and it hosts specialist meetings on health care. There are similar organisations in other countries.

There are many important applications of human factors science in anaesthesia [3]. One important relevant area concerns the behaviour of anaesthetists in relation to their NTS. In this paper, we explain the conceptual background to non-technical skills and show how they can influence job performance in anaesthesia. We describe the taxonomy of anaesthetists’ non-technical skills (ANTS) and ANTS-AP for anaesthetic practitioners, as well as the training courses that have been designed to teach these skills. This type of course can be labelled crew resource management (CRM), crisis resource management (CRM) or crisis avoidance resource management (CARMA). Finally, we discuss the development and application of NTS assessment systems.

**Non-technical skills**

The term ‘non-technical skills’ was first used by the European civil aviation regulator in relation to airline pilots’ behaviour on the flight deck. NTS can be defined as “the cognitive, social and personal resource skills that complement technical skills, and contribute to safe and efficient task performance” (p. 1) [4]. In essence, they enhance workers’ technical skills. Poor NTS can increase the chance of error, which in turn can increase the chance of an adverse event. Good NTS (e.g., high vigilance, clear communication and team coordination) can reduce the likelihood of error and consequently of accidents. Analysis of incidents, as well as studies of behaviour during routine work (task analysis), can reveal which workplace behaviours positively or negatively influence job performance and adverse events. A recent study of difficult airway management cases showed how a human factors interview protocol can help to extract additional information from anaesthetists who have experienced these cases [5]. The findings underline the importance of situation awareness, as well as some of the social factors that can impede effective performance. This type of knowledge can help to inform the design of NTS training and competence assessment systems.

**Airline pilots, human factors, CRM and NTS**

The aviation industry had realised by 1980, from a series of accidents with no primary technical failure, that maintaining high standards of safety was going to require attention to the pilots’ NTS and their relation to safe and unsafe behaviours during flight operations [6]. Experienced pilots were interviewed to discover which behaviours constituted ‘good airmanship’. The aviation psychologists
conducted experiments in flight deck simulators and reanalysed accident reports, in order to determine which skill components either contributed to accidents or were effective in preventing adverse events. Having identified these skills, crew resource management (CRM) training courses were designed for pilots to increase understanding of the importance of particular behaviours for safety and to provide opportunities to practise the skills in exercises and simulated flights. In 1989, a British Midland plane crashed at Kegworth after the pilots mistakenly shut off the working engine when the other was on fire. This was such a strong demonstration that human error and teamwork failures were contributing to fatal accidents that the UK Civil Aviation Authority took the view that CRM had to be introduced, even though at the time there were only a few scientific studies on its effectiveness. By the 1990s, CRM training for pilots had been widely introduced in aviation, driven by national regulators and the influence of the International Civil Aviation Organisation.

In aviation, pilots are taught and examined in the psychological and physiological factors influencing task performance from the start of their training (human performance limitations courses). They then undertake crew resource management training provided by their employing airline on a regular basis. Consequently, they are very familiar with the cognitive and social skills required for safe and efficient flight operations, as well as how these skills can be influenced by stress and fatigue.

It was not only in aviation where cognitive and social skills were found to contribute to workplace safety; studies of accidents in many other sectors of industry began to reveal the same patterns [4]. Today, CRM (i.e., NTS) training is now widely used for different occupations as a form of safety management and skills development, as a recent report by the Energy Institute (2014) describes [7]. Ab initio courses in medical schools are beginning to introduce the concept of NTS and explain their importance for patient safety. At a number of Scottish medical schools, there are now psychologists employed to lecture on human factors and patient safety and these topics are being embedded throughout the 5-year curriculum [8].

The main categories of NTS are as follows:

- Situation awareness
- Decision-making
- Teamwork
- Leadership
- Coping with stress
- Managing fatigue

These skills are not unfamiliar to anaesthetists but they have not traditionally been taught as part of clinical training. An increasing body of evidence suggests that they are required by anaesthetists to maintain safe performance [9]. Human error cannot be eliminated, but efforts can be made to minimise, catch and mitigate errors by ensuring that people have appropriate NTS to cope with the risks and demands of their work. In the next section, the main categories of NTS and their application to anaesthesia are briefly described.

Categories of NTS for anaesthetists

**Situation awareness**

Situation awareness is essentially a continuous monitoring of the task, noticing what is going on and detecting any changes in the environment. Almost all aspects of the anaesthetists' intraoperative tasks rely heavily on their vigilance and situation awareness skills. The critical role of situation awareness for anaesthetists has recently been reviewed with implications examined for practice, training, measurement and equipment design [10]. Fioratou et al. [11] pointed out that the anaesthetist needs to distribute their attention across many sources of information and that situation awareness is also shared within the team. This cognitive skill is primarily about gathering and processing information from the anaesthetic work environment and using stored memories and mental models to make sense of it. Research studies have indicated how interruptions and
distractions, both of which are common in operating theatres [12], can disrupt situation awareness [13] and can present risks for prospective memory, that is, remembering to do things in future (e.g., re-administer a drug in 10 min) [14].

Decision-making

Decision-making during work tasks, sometimes called dynamic decision-making, is a cognitive process for reaching a judgement, selecting an option and choosing which action to take to meet the needs of a given situation. In anaesthesia, there is a continuous cycle of monitoring and re-evaluating the task environment, and then taking the appropriate action. Decision-making usually involves more than one method, depending on circumstances. The main types of decision-making are recognition primed (a pattern recognition/intuitive process), rule based, analytical (i.e., comparing optional courses of action) and creative. Conditions for decision-making can vary in relation to time pressure, task demands, feasibility of options and what level of constraint, support and resource exists for the decision-maker. There is surprisingly limited literature on the decision-making skills of anaesthetists, with some notable exceptions [15] given the importance of cognition for safe anaesthesia. There is now a growing literature for on-task decision-making in emergency medicine, especially by Croskerry [16], and also for surgeons’ intraoperative decision-making [17].

Teamwork

There is no shortage of evidence that teamwork in operating theatres is very important and that this has a major impact on patient safety. The team skills relate to effective communication, task coordination, supporting other team members, negotiating and resolving conflicts. A recent review of what can improve teamwork in the operating theatre by Weller and Boyd [18] identified three main types of intervention that have been shown to be effective. These were structured methods of sharing information within the team (e.g., checklists), team training and organisational adjustments. Anaesthetists can play a significant role in the maintenance of team harmony and performance using both verbal and non-verbal communication. This is an area where there have been a number of research studies into coordination and communication in anaesthesia crews [19], as well as into specific situations such as handovers by anaesthetists to recovery rooms [20] or in anaesthetic emergencies [21].

Leadership

While there is an emerging literature on the intraoperative leadership role of surgeons and how this impacts on task performance in the operating theatre [22], there has been less research on the specific leadership role of the anaesthetist during surgery, although it is clear that they can perform critical leadership tasks, not only in emergencies but also during routine operating conditions. In fact, there can be ambiguity about who should take the leadership role in a theatre team between the senior anaesthetist, the senior surgeon and the senior nurse. This can result in multiple leaders or other equally hazardous situations where apparently no one is fully in charge. While some surgeons assume they have the leadership role, in fact, task leadership is partly about monitoring, managing and supporting the team, so this may be difficult for surgeons when they have total visual focus on the surgical site. In the ANTS system, leadership behaviours for anaesthetists are contained within the element of teamwork. Reader et al. [23] examined leadership in the intensive care unit and found more emphasis on functional behaviours than on behaviours concerned with developing the teams.

Coping with stress

There are two types of work stress and both have implications for worker and patient safety [24]. Occupational or chronic stress relates to ongoing conditions and pressures from the job, co-workers, bosses and the organisation. This type of stress has been extensively studied in a whole range of occupations and is certainly experienced by anaesthetists. In almost all organisations, workers need to
have skills to recognise the causes and effects of occupational stress and to have techniques for dealing with these, as well as knowing what sources of support are available from their employer. In non-technical (CRM) skills training courses, the focus tends to be more on the second type of stress, namely acute stress, which is experienced by workers who have to deal with very high-demand situations, such as emergencies. This is particularly relevant to anaesthetists because of the risks of the patient becoming critically ill, as the case of Elaine Bromiley demonstrated.

Managing fatigue

Anaesthetists need to be able to cope with working at night, working shifts and concentrating for long periods of time with no rest breaks. Fatigue is common in these types of work settings and it is well known to be a pervasive contributing factor to industrial accidents. Hence, the skills for managing fatigue are also required by anaesthetists [25]. The Association of Anaesthetists of Great Britain & Ireland recently published an updated edition of its guidelines, ‘Fatigue and Anaesthetists’ [26]. It describes current issues relating to fatigue and provides recommendations relating to rest facilities, the management of on-call work (with particular emphasis on the older anaesthetist) and education on fatigue. A key aspect of fatigue management is recognising when one is fatigued, understanding how this impacts cognitive skills such as decision-making and adapting behaviour accordingly. When intercontinental pilots are fatigued after a long flight, they adapt their team coordination behaviours such as using more read-back and checking and taking decisions more systematically [27].

Identifying ANTS

The specific NTS required for a particular occupation need to be determined by a systematic process of identification based on task analysis. While the main skill categories (e.g., decision-making or leadership) are similar across professions, the component elements and examples of good and poor behaviours need to be carefully specified for a given profession and task set. These can be distinctive and clearly vary from one technical setting to another. This is why it is inadvisable to use an NTS set devised for one domain (e.g., aviation) in a different work setting (e.g., health care). In essence, a two-stage process should be employed: first, to identify the skills and related behaviours deemed to influence safe and efficient performance, and, second, to refine the resulting list and to organise it into a concise, hierarchical structure or taxonomy. This skill set can then form the basis not only of NTS training but also of related assessment systems. Gaba and colleagues [28] used a behaviour rating tool as part of their assessments of anaesthetists’ performance in crisis management simulations. In Scotland, a research project was started in 1998 to identify anaesthetists’ NTS for routine activities, as well as in more challenging situations. The aim was to design a method of rating these skills from observations of behaviour in the anaesthetic room or operating theatre: The resulting ANTS system [29] is shown in Fig. 1.

The ANTS system was developed using a similar design and evaluation process as was used to produce a NTS rating tool (NOTECHS, Non-Technical Skills (for airline pilots)) for European airline pilots [30]. The skill set was derived from data on anaesthetists’ behaviour gathered from a literature review, observations, interviews, surveys and incident analysis [10,31,32]. The ANTS rating tool was formulated to meet a set of design criteria, similar to those of NOTECHS, such as suitability for practical use in the operating theatre or a simulation setting. (For detailed reports and papers, see www.abdn.ac.uk/iprc/ants.)

As shown in Fig. 1, the ANTS skills framework has four categories: situation awareness, decision-making, task management and team working, with component elements and examples of good and poor behaviour for each element. Managing stress and coping with fatigue were not included as explicit categories in ANTS, due to the difficulty of judging these states, which can be concealed unless extreme; moreover, they influence other behaviours that can be rated. However, the skills to cope with fatigue and stress should be covered in a CRM/NTS course for anaesthetists. Leadership was not set as a separate category but incorporated into team working, because there are times where the anaesthetist may lead the theatre team.
Having identified the basic set of NTS for the practice of safe delivery of anaesthesia (ANTS) and having structured these into a taxonomy, the next stage was to design and test a behavioural rating tool. A four-point scale for ANTS was devised for rating observed behaviours with regard to the elements and categories. The descriptors on the rating scale not only reflect performance levels but also emphasise their relevance for patient safety. The ANTS ratings can be made where anaesthesia is delivered, normally, in the operating room, or the anaesthetic room (or in simulator facilities). The tool was designed to be used by experienced anaesthetists to rate the NTS of another anaesthetist who has achieved basic technical competence.

The first evaluation of the ANTS behaviour-rating method was undertaken with 50 consultant anaesthetists who were given 4 h of training on the system and subsequently rated the NTS of consultant anaesthetists in eight videotaped scenarios. While the amount of training was minimal, the levels of rater accuracy were acceptable and inter-rater reliability approached an acceptable level [29]. The raters had experience in giving feedback on technical skills, but they had no previous experience of behaviour rating and they were given only introductory training in the ANTS system. Therefore, given their limited familiarity and practice with the system, it was concluded that these findings were sufficient to move on to usability trials. The first measures of usability and acceptability from consultants and trainees were promising [32], and so the system was released in 2004 and made available free of charge via the website to anaesthetists for non-commercial use. From the requests we receive for copies and an emerging set of publications, it is apparent that there are anaesthetists in many countries now using or considering use of the ANTS tool. The system has been translated into several languages, including German and Hebrew, and it has been used to evaluate simulator training for anaesthetists in Canada [33] and in Denmark [34]. It is also being used in African countries, such as Rwanda [35].

**Fig. 1.** Anaesthetists’ non-technical skills (ANTS).
Tools for anaesthetic practitioners and nurse anaesthetists

Recently, a new tool, Anaesthetic Non-Technical Skills for Anaesthetic Practitioners (ANTS-AP), was developed by John Rutherford, a consultant anaesthetist in Scotland, for the assessment of the anaesthetic nurses and operating department practitioners (ODPs), who assist the anaesthetist. This group of practitioners plays an invaluable role in the safe delivery of anaesthesia. While there was no doubt that they too require cognitive and social skills for safe and effective practice, there is very limited literature on this topic [36]. The ANTS-AP taxonomy and behavioural rating system was designed using the available literature [36], interviews with anaesthetic practitioners (and also with consultant and trainee anaesthetists) [37] and an analysis of an anaesthetic event database. The extracted skills were developed into a structured taxonomy by the research team and a group of experienced anaesthetic practitioners. The prototype rating system was evaluated using video footage recorded in a simulation centre, with 48 anaesthetic practitioners who rated the scenarios using the new tool [38]. This was the design method used previously for ANTS, Non-Technical Skills for Surgeons (NOTSS) for surgeons [39] and Scrub Practitioners’ List of Intra-operative Non-Technical Skills (SPLINTS) for scrub practitioners [40]. As shown in Table 1, ANTS-AP has three categories and nine elements with associated behavioural markers for good and poor performance. Further details of ANTS-AP can be found on the website www.abdn.ac.uk/iprc/ants-ap.

A similar NTS behavioural rating system has recently been developed in Denmark for nurse anaesthetists by Lyk-Jensen and colleagues [41].

Training ANTS

Anaesthesia has been at the forefront of developments to train NTS in medicine with Gaba and colleagues designing the first anaesthesia crisis resource management (ACRM) courses based on aviation crew resource management [42]; see Lighthall for recent review [43]. In addition to introducing basic theories of human performance limitation, the original course focused on some ‘key principles’ including the following:

- Anticipate and plan
- Demonstrate leadership
- Utilise all available resources
- Use cognitive aids
- Distribute work appropriately
- Use all available information
- Re-evaluate regularly

There is now considerable interest in adapting CRM training for health-care practitioners [44,45], and there are now a range of NTS courses available, many of which are developed in collaboration with former airline pilots with experience of CRM training. It is evident that courses are sometimes imported from aviation or other industries without adequate training needs analysis or customisation.

<table>
<thead>
<tr>
<th>Category</th>
<th>Element</th>
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<tbody>
<tr>
<td>Situation awareness</td>
<td>Gathering information</td>
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<td></td>
<td>Recognising and understanding</td>
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<tr>
<td></td>
<td>Anticipating</td>
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<td>Teamwork and communication</td>
<td>Coordinating</td>
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<td>Asserting</td>
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<td>Task management</td>
<td>Planning and preparing</td>
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<td></td>
<td>Prioritising and problem solving</td>
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<td></td>
<td>Coping with pressure</td>
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Course design should optimally be tailored to pre-training needs analysis, although this is not always carried out [46]. Courses that focus on behavioural aspects of performance should allow the learner to reflect on their own behaviours and simulation offers a safe and realistic environment in which to achieve this. Weller et al. [47] recently showed that the communication patterns of anaesthesia teams in the simulator are similar to those in real cases. The use of video allows learners to reflect on the strengths and weaknesses of their own performance, and the use of effective debriefing helps learners to identify performance gaps and agree on a learning plan to address such deficiencies. Creating the opportunity for practice with further feedback and regular rehearsal thereafter allows learners to develop and maintain skills. Such regular and recurrent training is provided in the environment of civil and military aviation; unfortunately, this is still not common in health care.

The use of simulation in training is now increasing, particularly in a number of acute specialities, including anaesthesia. It is no longer considered acceptable to carry out practical procedures on patients without first developing those skills in a simulated environment and therefore the focus of simulation training is often on development of practical skills or rehearsal of management of uncommon but serious conditions such as malignant hyperpyrexia or anaphylaxis.

It is widely accepted that good scenario design should tailor each scenario to address two to three key learning objectives. These are often focussed on technical aspects of performance; however, scenarios designed to address behavioural aspects of performance should similarly be designed to address key behavioural skills. An event-based approach to training (EBAT) and measurement has been described for training and assessing teamwork skills in emergency medicine residents [48]. A similar technique has been applied to the development of a simulation-based course addressing NTS for anaesthetists (CARMA). The underpinning theory and concepts of cognitive (situation awareness and decision-making) and social (task management and team working) skills is first introduced using a formal presentation and small group exercises. Following this, participants undertake scenarios of varying length, which are designed to address key categories or elements within the framework. Scenarios are designed to highlight particular NTS categories. An example of a scenario addressing cognitive skills is illustrated in Box 1.

**Box 1**
Cognitive skills scenario.

The surgeon (played by confederate) causes damage to the aorta during laparoscopic procedure but is unable to see free blood in the peritoneum on laparoscopy as blood loss is contained in the retroperitoneal space. The patient displays clear physiological signs of hypovolaemia (falling BP and ETCO₂, increasing heart rate on monitor and increased capillary refill time). The anaesthetist must establish SA through information gathering, recognition and understanding and anticipation, and use appropriate authority and assertiveness to convey concern to the surgeon and develop a shared understanding of the possible diagnosis. This emphasises the importance of systematic information gathering and asking open questions to avoid fixation; thinking aloud helps to share one’s mental model with other members of the team and to consider alternative diagnoses.

Debriefing of scenarios is carried out using ANTS as a framework for discussion. This allows participants to identify effective and less effective behaviours at the element level within the scenario. Video replay is an essential component to allow participants to reflect on the effectiveness of their actions. At the conclusion of debriefing, each participant will have clearly identified what they consider to be effective behaviours, which they might try to test or develop during further scenarios. Participation in further scenarios allows comparison of effectiveness of different skills across varying ‘clinical’ contexts and allows individuals to develop and rehearse skills throughout the course. Participants will also develop familiarity with the ANTS taxonomy while watching performances of fellow participants and making behavioural observations using the framework. At the conclusion of the course, each participant will have developed insight into their personal strengths and weaknesses in NTS and have
produced a clear personal development plan of behaviours they wish to develop. The course is positively evaluated and participant follow-up indicates that most will continue to utilise the ANTS taxonomy for personal reflection and development; however, this has not been formally tested in Scotland.

Yee and colleagues [33] were able to demonstrate an improvement in NTS in anaesthetic trainees on repeat exposure to the simulator after they had been debriefed with feedback using the ANTS framework following their first exposure to the simulator. ANTS has been utilised in a number of other simulation studies, for example, Bruppacher et al. [49] who used ANTS to evaluate performance before and after training for weaning from cardiopulmonary bypass. Marshall and Mehra [50] recently reported an experimental study with a sample of 64 experienced clinicians (mainly anaesthetists), who were divided into a control group and an intervention group (who had a cognitive aid present). They were presented with a simulated ‘can’t intubate, can’t oxygenate’ crisis. Observers (blinded to the group) analysed each participant’s NTS using the ANTS rating system as well as technical performance. The results showed that there was no difference in technical scores but the group with the cognitive aid showed higher ANTS scores.

Whilst simulation clearly provides the optimal environment in which to develop an understanding of the effect of behavioural aspects of practice, it is through use in the clinical environment that non-technical behavioural marker systems are most likely to gain widespread acceptance. Early attempts to introduce ANTS into clinical practice proved challenging – not least because the concepts and terminology around cognitive skills (situation awareness and decision-making) in particular were unfamiliar to trainers and trainees alike [51]. However, a decade on from the development of ANTS, these concepts are more readily accepted. As colleges and universities begin to integrate the World Health Organization patient safety curriculum into undergraduate training [52], junior health-care professionals are likely to enter the clinical environment with a greater awareness of these concepts and need to develop these skills for safe practice. The promotion of patient safety as a priority, and endorsement of safety-related skills and training by professional bodies such as colleges and speciality associations, is vital to encouraging established health-care practitioners to engage with training and development. The widespread sharing of patient stories, such as that of the death of Elaine Bromiley due to failure of effective airway management [2], has highlighted the importance of NTS in safe anaesthetic practice and encouraged most anaesthetists to be more conversant with the key concepts of situation awareness, decision-making and team working.

Both the Royal College of Anaesthetists (RCoA) and The Royal College of Surgeons of Edinburgh (RCSEd) now run regular courses to equip professionals with the skills required to observe, rate and give feedback on NTS in the clinical environment using the ANTS and NOTSS tools. The Royal Australasian College of Surgeons incorporated NOTSS into its professional framework and also runs NTS training courses. Both courses use a similar methodology introducing psychological concepts through lectures and group sessions, followed by use of scripted videos to allow participants to observe and classify behaviours at the category and element levels. These courses are most commonly attended by educational facilitators who, in turn, are then equipped to utilise the framework to provide feedback to trainees in clinical practice. The first modules on NTS for surgical residents in the USA were released on November 2014 as part of the national curriculum for general surgery, implemented by the Surgical Council on Resident Education (SCORE, www.score.org). These are on cognitive skills (situation awareness, decision-making) and social skills (communication and teamwork, leadership) [53].

Assessing anaesthetists’ NTS with ANTS

With regard to assessment, ANTS has been used in practice in hospital anaesthetic departments, as well as in simulation centres, which is typically for formative purposes [51]. Rall and Gaba [54, p3088] considered the ANTS system and concluded, “On the whole, the ANTS system appears to be a useful tool to further enhance assessment of nontechnical skills in anaesthesia, and its careful derivation from a current system of nontechnical assessment in aviation (NOTECHS) may allow for some interdomain comparisons.” They also outlined some of the general issues inherent in both technical and non-technical performance assessment, including criterion thresholds, rating fluctuating performance and inter-rater reliability.
Both ANTS and NOTSS taxonomies were designed to make observations as objective and the rating methods as straightforward as possible to use. However, this apparent simplicity belies the challenge of observing multiple different behaviours, which will commonly vary in effectiveness over time. In contrast to making observations of technical skills (DOPS — direct observation of practical skills) or discussions to probe understanding of a case (case-based discussion), where ‘acceptable’ standards are agreed, the observation of behavioural skills may feel less definitive.

Graham et al. [55] carried out an evaluation study where a cohort of anaesthetists in Australia were given a short training session on using ANTS in the morning following which they rated five videotapes each of anaesthetists in the operating theatre. The participants were positive about the content validity, and the internal reliability (Cronbach’s alpha) scores at the category level were acceptable; however, they found low inter-rater reliability at the element level. This was unsurprising given the short period of familiarisation with the system. In aviation, both trainers and examiners of pilots’ NTS require to be specially trained and formally qualified for these tasks, as recent guidelines from the UK Civil Aviation Authority show [56]. For those beginning to use behavioural markers systems for the first time, an expert group (led by the late Professor Helmreich) recommended a minimum of two full days of training — that is, four times as long as in the above evaluation study (see Ref. [4] for details).

ANTS has now been incorporated into training curricula for anaesthesia in the UK [57] and across Europe [58]. Elements of the taxonomy have been incorporated into workplace-based assessment instruments in the UK. Gale and colleagues have used elements of the ANTS taxonomy to rate NTS in trainees for selection into anaesthesia and demonstrated good predictive validity [59].

As the focus on revalidation and relicensing in the UK grows, it seems likely that assessment of NTS will feature, particularly in doctors identified as having difficulties in clinical practice through other means.

**Practical application of ANTS**

Training in identification and use of NTS behavioural marker systems is key to effective utilisation. Regular use, training and calibration are necessary to ensure high inter-rater reliability where the tool might be used for summative assessment. However, the introduction of NTS rating systems in clinical practice may be assisted by concentrating on an individual category (such as situation awareness or task management) for the duration of a case. Alternatively, breaking the task down into phases (such as induction of anaesthesia) allows the trainer to focus attention on the importance of NTS during one discrete part of the anaesthetic (see Fig. 2).

Asking new learners to list the behaviours used at different phases of the anaesthetic (for example, prior to extubation) under each of the elements can be a useful way of introducing the framework and encouraging observation of skills and effective behaviours. This technique is used with all novice anaesthetic trainees in one Scottish hospital. Trainees should then be encouraged to use these same
skills during low-fidelity simulation training (skills for drills). Asking trainees to observe the effective (and indeed ineffective) behaviours of supervisors using the framework may also be a non-threatening way in which to allow trainees to become familiar with the taxonomy but also to recognise and describe effective skills which they may want to emulate.

Summary/future developments

NTS are the cognitive and social skills set that support the application of knowledge and practical skills to safe anaesthetic practice. These skills are not new and are observable in expert practitioners; however, until recently, such skills were not explicitly described or discussed. Investigation of adverse events often highlights the important part played by failures in NTS of individuals and within teams.

Over the last decade, the explicit description of NTS through taxonomies such as ANTS, NOTSS, SPLINTS and ANTS-AP have allowed identification of skills at the individual level within the operating theatre. Increasingly, these skills are being incorporated into curricula for postgraduate training in anaesthesia and surgery. Feedback in the simulator environment allows learners to reflect on their own practice and understand their strengths and weaknesses. Continued, regular feedback and reinforcement in clinical practice should allow learners to further develop effective skills. Although such systems appear easy to use, achievement of good inter-rater reliability requires considerable rater training and calibration [60] and important lessons in this regard can still be learnt from the airline industry.

Incorporation of human factors and NTS teaching from the earliest phases of undergraduate training makes it likely that, over the next decade, we will see a generation for whom the theoretical concepts and behaviours are a fundamental part of the skills set of a new doctor and therefore that NTS will be an integral part of postgraduate speciality selection, training and assessment.

Practice points

- Behavioural marker systems such as ANTS allow objective observation of nontechnical skills to be used for feedback in simulated or clinical environments.
- Where simulation is used for non-technical skills training, scenario learning objectives should be designed to address specific non-technical skills.
- Applying the ANTS taxonomy to discrete phases of the anaesthetic, such as induction, improves usability in the early stages of implementation.
- Although deceptively simple in appearance, rating non-technical skills is prone to greater variation than assessment of knowledge or practical skills.
- Rating of non-technical skills for the purposes of assessment requires rater training in order to improve inter-rater reliability.
- The importance of non-technical skills is acknowledged by recent incorporation into undergraduate medical and postgraduate speciality curricula.

Research

- Time-effective techniques for rater training and calibration.
- Analysis of anaesthetic team performance using both ANTS and ANTS-AP.
- Low-fidelity simulation methods for enhancing non-technical skills.
- Optimum methods to integrate non-technical skills training into undergraduate curricula.
Conflict of interest

The authors have no conflicts of interest to declare.

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Simulation in the operating room

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in-team debriefing
developing world

Simulation has become a significant training tool in the operating room (OR). It can be used in both simple task training and complex scenarios. The challenge for simulation in the OR is how to translate that which is learned, and perceived to beneficial, into behavioral change and improved patient outcomes. Simulation in the developing world is progressing, but is still hampered by a shortage of material, personnel funding.

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Introduction

The operating room (OR) is one of the most complex and challenging environments that health-care workers must perform in. Crises in the OR are believed to be rare but according to a World Health Organization news release from 2007, at least 50% of all adverse events in developed countries occurred in the OR. In addition to this alarming fact, their outcomes can be potentially devastating. Surgical care in developing countries is also hampered by a low number of adequately trained staff and poor facilities [1]. Simulation has been advocated as a way to prepare health-care professionals better to effectively manage these crises.

Simulation in health care, and specifically in anesthesiology, takes on many forms. An Institute of Medicine report in 2010 sought to address the problem of inconsistent professional health-care workforce training and suggested a redesign of continuing education. The report defined simulation as “The act of imitating a situation or process through something analogous. Examples include using an actor to play a patient, a computerized mannequin to imitate the behavior of a patient, a computer program to imitate a case scenario, and an animation to mimic the spread of infectious disease in a population.” [2] This broad definition does not only refer to high-fidelity simulation.

Within anesthesiology, simulation experiences can range from purely computer-based simulations, to simple partial-task trainers for airway management training, to elaborate courses employing full-scale high-fidelity simulation. These courses have been traditionally offered to trainees, but there are also cases where board-certified practitioners have been tested. The authors’ own department requires physicians applying for credentials to practice anesthesiology to first satisfactorily complete its own continuing medical education course on the management of the difficult airway.

Simulation is a very useful tool and has been found to be highly effective in health-care training [3]. It is regarded as being superior to traditional training methodologies in both technical and non-technical skills such as teamwork [4]. More recently, the American Board of Anesthesiology has adopted simulation as a key component of its maintenance of certification program (MOCA) that is an effort to ensure continuing competency in the specialty.

However, questions still remain about the validity of the data that are generated by simulation courses and studies involving simulation. One of the primary challenges is determining how to translate the performance that occurs in the simulated environment to the clinical realm in a meaningful way. Another challenge is implementing simulation in the developing world in such a way that maximizes the constructive effect while keeping a rein on cost in locations that often do not have an abundance of fiscal or personnel resources to be adequately trained to conduct contextually appropriate high-quality simulations.

The promise of full-scale high-fidelity simulation rose to prominence in 1988 with the first Anesthesia Patient Safety Foundation (APSF) simulation meeting. This was followed the next year by the Anesthesia Simulation Curriculum Conference, which was also sponsored by the APSF [5]. In this chapter, we attempt to focus on a number of ways in which simulation is being used in the OR today and on some of the barriers to wider implementation that exist. We will also explore some of the long-term challenges which simulation will need to overcome in proving itself useful in the coming decades. This will include a perspective from the developing world where often monetary and material resources are more limited.

Simulation-based education in medical education

The benefits of simulation-based education in several competencies relevant to the OR and beyond have been described at many levels of clinical education. Paige et al. demonstrated that even the most junior medical trainees benefit from simulation-based education in OR team training. Undergraduate nursing students, nurse anesthesia students, and medical students were arranged into multidisciplinary teams and exposed to two standardized intraoperative emergencies in a high-fidelity simulated OR environment which was followed by a structured debriefing. These authors clearly demonstrated statistically significant increases in participants’ self-reported efficacy for team-based competencies. In addition, there was a statistically significant increase in mean observer performance scores for
teamwork metrics. This suggests that early utilization of simulation improves teamwork even in the absence of mature clinical knowledge or experience [6].

Though challenging to achieve, data do exist which demonstrate that crisis management skills learned in a simulated environment transfer to the clinical setting and may improve clinical outcomes which may even include a reduction in patient mortality [7]. Specifically, Bruppacher et al. demonstrated that simulation-based training for anesthesiologists improved performance in patient care during cardiac surgery, and that this improved performance was retained for at least 5 weeks [8]. The retention of the improved performance is extremely important as it shows the effectiveness of simulation-based training but may also provide guidance about how often these training sessions may need to be repeated. Multiple studies have demonstrated improved patient outcomes after simulation-based training programs were instituted to improve crisis management. Improvements in efficiency [9,10], outcome [1,11], and rates of complications [12] have also been demonstrated. The most powerful validation of a simulation-based crisis management educational program showed increased survival rates for in-hospital pediatric cardiac arrest from 33% to 50% within 1 year from initial training [13].

A wealth of research also demonstrates the value of simulation-based education of procedures which are often performed in the OR. One of the most-studied tasks taught with the aid of simulation is central venous catheterization. Relative to training without the utilization of at least a partial-task simulator, simulation-based education has been shown to provide improvements in both learner outcomes and patient outcomes [14]. Learners taught with simulation-based education were shown to have statistically significant greater increases in knowledge and confidence regarding insertion of central lines than those learners who were trained without the benefit of simulation [14]. Perhaps the most powerful demonstration in the value of simulation-based education lies in the demonstration of improved patient outcomes, which included fewer needle passes to insert the line as well as fewer pneumothoraces [14].

Simulation has also been shown to be effective in the assessment of physicians’ skills in simulated perioperative environments. Blum et al. demonstrated that a simulation-based performance assessment identified critical gaps in safe anesthesia performance by anesthesiology residents in a reliable, generalizable, and valid fashion. The trainees and faculty involved in the study judged the performance assessment to be useful, realistic, and representative of the critical skills required for the safe practice of anesthesia [15].

Simulation-based education is also rapidly being incorporated into education beyond the traditional duration of postgraduate medical training. The American Board of Anesthesiology Maintenance of Certification program, for American-trained anesthesiologists who have achieved their initial certification since 2000, incorporates a simulation-based component. This complements a professional practice assessment and improvement requirement.

A simulation-based clinical training and evaluation experience is being utilized to ease the return to clinical practice of anesthesiologists who have had extended absences from clinical care. The reasons for these absences range from wanting to expand practice scope and breadth to physicians who are trying to regain licensure after it was lost or restricted [16]. The educational and evaluative experience resulted in a successful return to unsupervised practice for 70% of the participants over a 10-year period [16].

Overall, data support that simulation-based medical education yields better results than traditional clinical education across a variety of educational settings and skills, including advanced cardiac life support, laparoscopic surgical techniques, central venous catheter insertion, cardiac auscultation, and thoracentesis [3]. This effect was present in a meta-analytic comparative review of the evidence when the simulation-based education involved deliberate practice [3]. Deliberate practice of simulation-based education describes the educational quality of the experience and involves nine key elements as seen in Table 1 as originally described by Ericsson.

### Evolving methods in crew resource management training

Simulation has been utilized in the aviation field for many years to enhance the performance of pilots and crew during in-flight emergencies. Better known as crew resource management (CRM), a similar concept has been applied to the OR, specifically in the anesthesiology realm to improve anesthesia nontechnical skills (ANTS). ANTS include leadership, communication, teamwork, task
management, decision making, and situational awareness [18]. Following technical errors, communication and teamwork breakdowns have been shown to be the second most common cause of intraoperative errors.

Anesthesiology has been a pioneer in the field of team training. However, one of the problems that has arisen is that such training has inherently reinforced a silo (compartmentalized) approach to training. As described in a paper by Paige et al. [6], some of the most significant barriers to effective teamwork are the existence of silos (compartments), tribalism, and interprofessional friction. Tribalism is the concept that each specialty sticks with its own kind and tends to reflexively support each other when a collaborative approach may benefit the interaction and ultimately the patient. The idea of silos is that each specialty trains in their own realm. The closest that they come to working together is when they are thrust into the patient-care setting and are expected to then work as a team to provide that patient with the most effective and coordinated care. As a result, anesthesiology simulation training, specifically in the CRM realm, risks becoming one dimensional because it is often being carried out solely by anesthesia personnel. These personnel are also often inexperienced trainees with the roles of surgeon and OR nursing often being portrayed by anesthesia personnel or other nonmedical actors. The benefit is that this serves the purpose of having the anesthesia personnel practice their ANTS in a nonthreatening environment; however, it also creates silos of training that potentially limit the full benefit in the clinical realm. A study by Acero recruited anesthesiology residents, surgical residents, and perioperative nurses and demonstrated that multidisciplinary team training in a high-fidelity simulator was effective and specifically noted that participants reported that they understood their roles better in the emergency situation and significantly improved their performance time for eight predefined critical tasks [19].

Newer technology has allowed investigators to attempt to bridge this gap as described by Kjellin et al. who used hybrid simulation composed of a Laerdal SimMan 3G in conjunction with a laparoscopic simulator in a scenario that engaged OR nurses, anesthesia residents, anesthesia nurses, and surgical residents [20]. The benefit of getting all the interested specialties in the same location at the same time is that specialties most likely to be working together in the future have an opportunity to practice as a team delivering coordinated care.

Literature that has its roots in the trauma team and was tested in the emergency department (ED) has also shown an attempt to engender a team-based approach to dealing with emergent trauma admissions to the ED [21]. The authors witnessed an improvement in patient information handover, team leader identification, as well as designation of roles. These authors also acknowledge that there is a lack of evidence of the translation of simulation-based training into the clinical realm. This group also has created a CRM module that is available online for participants to review on an ongoing basis to attempt to have greater retention.

A significant challenge that exists in the simulation literature is the ability to show correlation between results from simulation training or simulation studies and the performance of the participants in the clinical setting. In an attempt to better translate the validity of simulation training into clinical practice, one tool that is being used is the Kirkpatrick Level of Learning [7]. Donald Kirkpatrick originally described four levels of learning in ascending order: Reaction, Learning, Behavioral change, and Results, which would be analogous to improved patient outcomes. A majority of the published articles

<table>
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<th>Table 1</th>
<th>Nine elements of deliberate practice [17].</th>
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<tr>
<td>1.</td>
<td>Highly motivated learners with good concentration who address</td>
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<td>2.</td>
<td>Well-defined learning objectives or tasks at an</td>
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<td>3.</td>
<td>Appropriate level of difficulty with</td>
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<td>4.</td>
<td>Focused, repetitive practice that yields</td>
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<td>5.</td>
<td>Rigorous, reliable measurements that provide</td>
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<td>6.</td>
<td>Informative feedback from educational sources that promote</td>
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<td>7.</td>
<td>Monitoring, error correction, and more deliberate practice that enable</td>
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<td>8.</td>
<td>Evaluation and performance that may reach a mastery standard where learning time may vary but expected minimal outcomes are identical and</td>
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<td>9.</td>
<td>Allows advancement to the next task or unit.</td>
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in the simulation literature fail to extend beyond the second level; that is, they fail to demonstrate that participants have achieved anything more than simply acquiring more knowledge. Despite the seemingly universal adoption of simulation in anesthesiology and other medical specialty training, it has proved difficult for researchers to consistently demonstrate meaningful evidence of simulation having an impact of behavioral changes or patient outcomes.

Debriefing has always been regarded as a key component of any effective simulation. It provides the participants the opportunity to openly discuss their personal performance and the team’s performance during the scenario. Ideally, this is conducted in a nonjudgmental way in a neutral setting where all participants have an equal voice. This has unfortunately also proven to be a stumbling block for CRM training, as it requires a significant investment of time for training of debriefers in addition to making them available to facilitate the simulation sessions amid busy clinical schedules. One concept that is starting to be seen and has been tested is that of self-assessment debriefings that occur within the team but without the need for the instructor in the scenario. Boet et al. showed in a randomized controlled trial that a debriefing that was carried out utilizing the within-team structure showed an improvement in survey data that was no different from debrie of trained raters who had experience in simulation and CRM reviewed all debrie with a clear framework for the debrie themselves after being given clear instructions by a facilitator. The within-team groups were provided medical simulation. With-in team structure refers to the concept where the participant team debriefs themselves after being given clear instructions by a facilitator. The within-team groups were provided with a clear framework for the debriefing. The study was well designed and an interprofessional team of trained raters who had experience in simulation and CRM reviewed all debriefings. The study showed good inter-rater reliability [18].

The same group published a similar study that focused on the difference in the traditional types of assessments used in simulation-based training and offered the alternative of a formative assessment. Traditionally, evaluations are summative and seek to assign a grade for the participants’ performance. This leads to a rank list of the various participants in the training session. The concept of a formative assessment is different in that it seeks to determine the difference between the participant’s performance and what would be regarded as standard of care for a given scenario. After this gap is assessed, then it seeks to determine how to make the perceived gap smaller, thereby empowering the participants to improve their performance. Ideally, self-assessment should contain both of these descriptors with the summative assessment allowing for the creation of a baseline evaluation of performance, and then the formative assessment serves to describe or document improvement of the participant in the goal of achieving standard of care management for the given tested situation.

The authors suggest that the benefit of having a self-assessment that performs well on both of these areas is that it allows the participant to have multiple opportunities to assess their performance and it does not have to occur in the rigid confines of a dedicated simulation center [22]. This could serve to allow simulation training to be provided to participants without the need for personnel and all the costs that are typically associated with a formal simulation center.

The final interesting concept that we want to raise is that of motivation. Self-determination theory states that the quality of motivation is more important than the quantity of the motivation. Kjellin et al. make the point that how a person is motivated will determine how they perform in a given setting. There are four levels of motivation. The first is intrinsic motivation (IM) where the learner is naturally motivated from within. The next level is identified regulation (IR), which refers to recognizing a valued behavior, but the motivation is originating from outside the individual because it is an integral part of a training/educational program. External regulation (ER) is motivation that is derived by the fact that a goal needs to be achieved, not necessarily because the individual wants to do it. An example of this would be having to complete a particular assignment so that they can graduate. The final and least effective form is amotivation (AM) where the individual does not see the need nor the purpose of meeting a certain requirement, but just completes it because it is part of the expectation. Although there might not be a specific way that this can be addressed in simulation, it does provide insight into the variance in performance by certain individuals. Understanding their type of motivation may make it possible to tailor a training program to make it the most beneficial irrespective of the motivation of the participant [20].

Bandura’s social cognitive theory states that individuals learn by observing and replicating the successful actions that they observe. Literature suggests that this is also true in the medical field, and that practitioner’s self-efficacy increases the more times that they successfully perform a task [18]. The
converse is also true; a repeated failure decreases self-efficacy. It is clear that simulation provides the opportunity for practitioners to repeatedly practice a particular task or set of tasks successfully. Bandura has made the argument that high levels of self-efficacy positively influence motivation in such a way that the person is more likely to choose a difficult task, persevere in completing that task, then move on to increasing the difficulty of the subsequent difficult task. The benefit that exists in simulation is that participants will have the opportunity to be able to repeat the way they perform a particular procedure or respond to a defined crisis so that the positive reinforcement can develop and increase their self-efficacy [20].

In-situ simulation has developed a presence in health-care partly as centers attempt to rein in the cost of simulation, but it also brings other benefits to the table. It allows for the conduct of simulation-based training to occur in the clinical setting with a high-fidelity simulator in a realistic environment without the need for a remote simulation center. Technological development has allowed the portability of simulation equipment that makes this possible. By utilizing an actual clinical location, it minimizes the disruption of clinical activity and perhaps shortens the time participants are away from their clinical work. Such an approach, however, can be limited by the availability of the location.

One significant advantage is that in-situ training does allow for testing of multiple functional aspects of an operating suite in addition to enhancing learning for the individual or teams. It allows a team to develop cohesion in their interaction with each other as well as, analogous to finding the weakest link, being able to determine what situations may cause a breakdown in the care that is being delivered. It has also been used to test the readiness of a clinical care delivery unit after relocation before being placed back into service [23,24].

Challenges in the simulation literature

One of the major goals for medical training is being able to predict how students will perform in real-world situations when having to recall diagnostic and treatment options for a given clinical situation. Traditionally, this has been done with standardized patients and patient/doctor interviews followed by case presentation to a supervisor and examination of the treatment plan. However, this is not a very helpful mechanism when it comes to dealing with acute care settings like the OR or the ED.

The advent of high-fidelity simulation has allowed for instructors and evaluators to design highly realistic scenarios that are reproducible for subsequent participants. The added benefit is that it is achieved without the need for a real patient to be at risk during these situations. In addition to the opportunity to evaluate students, it also affords the chance to evaluate the care of practitioners who are already out in practice.

One of the challenges to make simulation-based education a feasible training and evaluation tool is how to reliably evaluate the participants. Inter-rater reliability becomes an important concern when more than one evaluator is being utilized. The principles that guide good inter-rater reliability are:

1. Raters agree on the official performance.
2. Agreement on what ratings are to be awarded.
3. There is understanding of what comprises a better versus a worse performance.

Two principles that are key are that of reliability and validity. Reliability relates to the ability for consistent evaluation of participants’ performances to occur as scored by different raters. This is referred to as inter-rater reliability. One group who looked at medical student performance with high-fidelity simulation believes that one of the reasons that they had very good inter-rater reliability was that the agreement was made during the scenario development as to what the key performance measures had to be met during the scenarios [25]. The same group also ensured that the individuals doing the rating of performances were not involved in the scenario development so that they would not be biased by the development experience.

Another key principle is that of validity and this refers to whether the ratings accurately could differentiate between low-performing and high-performing individuals based on their performance in the simulated scenario [25].
Interestingly, Gaba et al. stated that due to the complexity of the simulations, and the number of actions being rated, there needed to be multiple raters to ensure greater validity [26]. However, Boulet et al. asserted from their data that it was not necessary to have multiple raters, but that the same degree of validity could be achieved as long as agreement on what constituted key actions was made during development of the scenarios [25].

**Challenges in the implementation of simulation into anesthesia in sub-Saharan Africa from a South African perspective**

**Background**

About 70% of the world’s poorest countries are in sub-Saharan Africa, which carries a high burden of disease including HIV/AIDS, malaria, and tuberculosis [27]. The health services and resources in these regions are limited, especially in rural areas due to a critical shortage of manpower compounded by poor infrastructure, erratic electricity supplies, paucity of equipment and drugs, inconsistent oxygen supply, and even the absence of running water [28].

Anesthetic care is often provided by non-physician anesthetists who have little or no medical background apart from 1 to 3 years of anesthetic training. These health-care workers face conditions in which the service load is disproportionate to the number of anesthetic providers and the development of anesthesia as a discipline is too often not given the attention it deserves among other existing major health-care issues [29].

The exodus through medical migration of the few trained physician anesthetists further compounds these issues.

The biggest problems exist in the fields of obstetric and pediatric anesthesia, mirrored by an unacceptably high perinatal morbidity and mortality, and a common inability to provide safe anesthesia for pediatric patients [30,31].

Given the challenges providers face just in providing clinical care, it should come as no surprise that simulation remains uncommon in these regions [32].

Despite this, there are some examples of emerging simulation centers being established in some sub-Saharan countries such as Ghana [33] and Rwanda [34]. Most of these centers and initiatives focus on nursing, surgical, emergency, and family medicine skills, with anesthesia only playing a minor role.

**A South African perspective**

South Africa plays a unique role among all other sub-Saharan African countries:

Out of the existing 19 postgraduate anesthetic programs at 23 medical schools in the 16 Southern African Development Community (SADC) countries, eight are in South Africa [35].

Despite also suffering from specialist shortages, particularly in rural areas due to “brain-drain” to more affluent countries and the local private sector, South Africa is also on the receiving end of medical migration from other African countries and simultaneously plays a role in training of physicians from these countries to some degree.

In South Africa, simulation has been employed as a teaching tool in medical training across the board and is steadily increasing, even though at a slow pace. Six of the country’s universities have a simulation unit or center incorporated into their Faculties of Health Sciences, the latest, a state-of-the-art center at the University of Johannesburg was unveiled in September 2014. With the exception of the SMART (Simulated Modules in Anaesthesia & Resuscitation Training) center at the University of KwaZulu Natal in Durban that makes use of high-fidelity simulators, none of the others have a strong focus on simulation in anesthesia.

**Simulation specific challenges**

Funding for high-fidelity equipment and maintenance costs, space, and staffing and their training creates major problems for the implementation of simulation in anesthesia in Africa. Factory servicing,
Maintenance, and repair of high-fidelity simulators are particularly difficult due to the poor after-sales support by the local manufacturers.

The adequate training of a skilled simulation faculty poses another serious obstacle because of the unavailability of regular simulation instructor courses in sub-Saharan Africa. Instructor training and refresher courses invariably require expensive and time-consuming travel abroad.

There is a widespread unawareness of simulation and its capabilities due to the paucity of simulation centers in Africa, which results in a lack of interest into utilizing simulation.

To provide good results, the format of simulation training needs to be adapted to the training needs that vary widely from region to region with regard to available equipment and drugs as well as training level of anesthesia providers that makes the development of suitable curricula difficult.

**Future perspectives**

Close collaboration networks are required between resource-rich established simulation centers in developed countries and emerging centers in the developing world.

The goal should be the spread of sustainable quality simulation that can reach out to rural areas and help improve patient management and outcome where it is most desperately needed.

This can be achieved by a combination of efficient center-based, large simulation facilities that can provide a focused in-reach component coupled with outreach programs that include mobile and “in situ” simulation tailored to specific regional training needs by adapting for rural resources and equipment.

**Conclusions**

Simulation is a very useful and effective tool for educating medical professionals. It has expanded in use significantly, and in addition to remaining a mainstay in education, we believe that it will expand its role further into medical training. The challenge still remains to produce more data showing its effectiveness, not only in the classroom or cognitive realm but also how it positively impacts patient outcomes. We hope to see more early intervention in team training of medical professionals to allow more collaborative care to take place in the high-paced stressful environment of the OR.

**Practice points**

- Simulation is an effective tool for training technical and nontechnical skills.
- Simulation-based training with deliberate practice yields better results than traditional medical training to achieve specific skills goals.
- In-situ simulation can lessen the need to remove practitioners from the clinical situation to be able to participate in simulation training.
- Multidisciplinary CRM training should be introduced early to lessen the effect of training silos on clinical care.

**Research agenda**

- Particular attention needs to be paid to designing studies that have a high degree of validity and reliability.
- Further research is needed to examine the effect of simulation on actual practitioner behavior changes.
- The impact of simulation training on individual patient outcomes needs to be investigated.
- Validation is needed of the effect of simulation on maintenance of clinical skills.
Statement of Coi

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References

Simulation in the intensive care setting

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Keywords: patient simulation critical care education medical

About 10 years ago, the first human patient simulators were introduced to intensive care units (ICUs). Since then, there has been a rapid development of both technical and non-technical aspects in medical education. The aim of this review is to elaborate how simulation training is already used in the intensive care setting, the role of different types of commercially available mannequins and which benefits can be achieved for participants by using this teaching method. Furthermore, a practical example describes how a simulation curriculum can be designed, which challenges might need to be faced and which steps need to be taken to make the most out of the training. Human patient simulation is an effective tool in the education of health-care professionals and will surely become an important part in the training of ICU physicians as well.

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A short outline of the history

The history of simulators in medical education began almost five decades ago when the Norwegian Asmund Laerdal was the first to design a mannequin for practising mouth-to-mouth ventilation in the early 1960s. His pioneering feat 'Resusci ®—Anne' was a key to developing numerous part-task trainers [1]. Only a few years later but some thousands of miles away, Abrahamson and Denson created the first computer-controlled patient simulator in 1969 [2]. In the beginning, the low-fidelity mannequins were used for training in basic skills such as cardiopulmonary resuscitation, oral intubation or venipunctures.

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Numerous extra features quickly developed to provide the most possible realistic setting; the focus was reset on non-technical skills in the early 1990s as mistakes such as ‘fixation errors’ had been shown to cause a majority of medical failures [3]. About 10 years later, the first human patient simulators were introduced to intensive care units (ICUs) in order to develop crisis management and communication skills as well as to practice how to use the human and technical resources of an ICU effectively [4]. Nowadays, a broad variety of simulators are available with different features and offering different levels of fidelity. Furthermore, many different teaching curriculums have been published and many of them have been scientifically evaluated regarding the training effects. This article aims to give an overview of simulation in the intensive care setting. A special focus will be set on curriculum design.

Current state of the art

Over the last five decades, there has been a continuous development in human patient simulators and several features have increased their importance for the use in the intensive care setting.

Skills and procedures

For the intensivist, some skills and procedures are not only important; the patient’s life may depend on the physician’s performance. Typical examples include airway management skills: Endotracheal intubation requires 30–74 cases to reach a 90% success rate [5,6]. Although experience with intubation in real patients is most helpful, not all physicians may have the opportunity to gain enough experience in the operating room. Furthermore, performing the first few endotracheal intubations in real patients may be harmful for the patient even when an experienced anaesthesiologist supervises the learner. Thus, patient simulators may offer the opportunity to exercise without any risk for patients. However, let us first define what simulation is: It is defined as the imitation of the operation of a real-world process or system over time [7]. There are different types of simulators offering different degrees of fidelity and being available at different prices. Some simulators allow exercising just one single measure such as, for example, a venipuncture trainer. Other simulators can be used to perform different tasks and complex procedures such as resuscitation mannequins (chest compressions, ventilations, airway management, electrocardiography (ECG) and defibrillation). If a specific task is to be exercised, the fidelity of the simulator may be an important prerequisite to reach the specific learning objective. Regarding endotracheal intubation, the learner would expect a realistic airway anatomy to exercise how to identify the glottis and other structures. Furthermore, the haptic during the procedure should resemble that in a real patient. At last, the fidelity of the environment is of utmost importance. Our performance is influenced by stress, time pressure and dynamic changes of the patient’s condition. Performing a cricothyroidotomy using a static plastic airway model is relatively easy; performing the same procedure in a patient mannequin with a patient monitor and listening to the saturation tone while the patient deteriorates is much more difficult. As we want the learner to succeed in real situations, the learning environment should be as realistic as possible. When selecting teaching aids and buying simulators, we should always carefully evaluate the realism provided by the specific model. For some skills and simulators, this has been investigated and published [8]. When specific learning goals should be achieved, we might select a low-fidelity simulator, which is sufficient to reach the learning objective. Regarding cricothyroidotomy training, we often use very simple anatomic models to just exercise the handling of the equipment. During critical airway management, it can be detrimental when the responsible anaesthesiologist has never used a needle cricothyroidotomy set and when he or she is not able to perform the required steps in the correct order and in an adequate time period.

When an intensivist should be trained with the objective to be competent in cricothyroidotomy, he or she needs to learn the following:

The skill

Simulators can be helpful, especially when the respective measure is rarely performed in real patients or when the measure is associated with any risk or discomfort for the patient and we do not want our trainees to perform it in real patients.
The skill in the context

It is not sufficient to exercise the skill only. At the ICU, each single task is part of a complex treatment. Some tasks have to be performed in highly dynamic situations and under time pressure. Training of these tasks requires not only simulation of the patient but also a real or simulated environment such as monitoring, ventilator and the ICU team.

Decisions

Regarding the management of the difficult airway, there are different options. We usually have an algorithm for critical airway management; following the algorithm has to be exercised as the respective single tasks. Simulation of the patient and the environment can facilitate highly realistic training: In a simulator scenario with a deteriorating patient, we can simulate failure of different airway management strategies such as bag mask ventilation and supraglottic airway management strategies. The trainee exercises the algorithm: choosing a surgical airway in a cannot-ventilate—cannot-intubate situation and performing cricothyroidotomy.

ICU teams must be competent in many different procedures and algorithms; some of them have a major impact on the patient’s outcome. Let us have a closer look at cardiac resuscitation. What do we expect from an ICU team treating a patient in a cardiac arrest? They should provide high-quality chest compressions without unnecessary interruptions, early defibrillation (if necessary) and advanced life support (ALS) according to the current guidelines for cardiopulmonary resuscitation. These guidelines demand team members to minimise interruptions of chest compressions. For example, the interruptions during endotracheal intubation should not exceed 10 s. This does not mean that the intubation must be performed in 10 s; although we might need a longer duration for the procedure, the interruption can be below 10 s. Training of the skill alone is not sufficient and may not lead to optimal performance. Furthermore, the complete sequence of actions during ALS should be exercised. In our example, this includes applying chest compressions and ventilations (30:2), preparing the equipment for endotracheal intubation, performing laryngoscopy during ongoing chest compressions, passing the glottis during a short phase without chest compressions and performing uninterrupted chest compressions when the airway is secured. Thus, the training should be done in teams as in daily practice, and the simulation equipment should allow performing all single measures required in the ALS treatment algorithm.

We have now discussed where simulation can be used in the field of intensive care medicine. When we plan a specific training course, we are often able to choose between different simulators available on the market. They widely differ regarding realism, degree of fidelity and price. The decision to find the optimal simulator to be used in the training course is often difficult. Even worse, we mostly have to accept the fact that, in the field of medicine, no full-scale simulators are available today. However, different high-fidelity simulators are used in training courses for intensivists.

High-fidelity simulation

How simulation is already used in the ICU setting

Geoffrey Light hall and colleagues were the first to describe a simulator-based training curriculum for residents in intensive care medicine [4]. The course’s participants exercise the management of critical incidents and medical emergencies in scenarios using a high-fidelity patient simulator in an ICU environment. The authors describe the following essential elements [4].

- Simulation of the environment
- Case scenarios
- Managing the cases without direction by the instructors
- Debriefing including reflection by the trainees, and feedback by the peer group and experts
High-fidelity simulator training can be used in intensive care medicine to facilitate the following learning objectives:

To learn and exercise specific procedures, algorithms and standard operating procedures

This is undoubtedly very important for intensivists and simulator training may be helpful. However, many of the procedures and algorithms can be trained using part-task trainers and low-fidelity simulators as described above. Selecting the optimal training tool/simulator is important, and we discuss this issue later in this paper.

To learn to recognise specific diseases and emergency situations

One example is the recognition of a tension pneumothorax. This emergency is extremely time critical, and we want our intensivists to make the correct diagnosis as early as possible as any delay may increase the mortality. After having experienced a specific situation during a simulator scenario, it is easier to recognise a similar situation in real life [9]. Especially young physicians might benefit from such training. Henk Schmidt studied knowledge and expertise in physicians and described a psychological effect called ‘knowledge encapsulation’. He found that medical students recalled more information from cases after a case presentation as compared to experts. However, the experts arrive at the correct diagnosis more often and faster than novices [10]. Following these findings, young physicians would easily recognise abnormal findings such as hypoxia, hypotension, tachycardia and high peak airway pressure in a case in the ICU or in a simulator scenario. However, due to the lack of experience, they are not able to merge the puzzle pieces and recognise the tension pneumothorax, as the expert would easily find. Learning to recognise life-threatening emergencies can be facilitated using a high-fidelity simulator. However, these simulators are expensive and we can question which emergencies should be taught using this expensive educational method. It is not possible to ensure that every resident in intensive care medicine experiences every possible emergency at least once in a simulator scenario prior to experiencing the respective case in real life. Thus, we should teach not only how to recognise specific diseases but also how to develop problem-solving strategies, which are helpful in situations that the trainee has never experienced before.

To develop problem-solving strategies

What should an intensivist do in a critical situation, which he or she had never experienced before? Human beings tend to use so-called heuristics to speed up decision-making in uncertain situations and under time pressure. One well-known example is the availability heuristic. When a doctor is called to a patient in the ICU and finds hypotension and tachycardia, he or she might think of hypovolaemia as the cause of the emergency situation as this is a situation that he or she has experienced frequently prior to the actual case. However, a cardiac tamponade may have caused hypotension and tachycardia. A typical mistake in such a situation is due to the confirmation bias: We tend to rather confirm a diagnosis (hypovolaemia) than trying to look for other differential diagnoses (cardiac tamponade). In our case of a cardiac tamponade, a typical human behaviour would be to look at further values and parameters and rather looking at the low cardiac output (which can be found in hypovolaemia) than at the distended neck veins (which exclude hypovolaemia as a possible cause and are a clear hint towards cardiac tamponade).

High-fidelity simulation courses enable us to teach (behavioural) strategies to manage typical sources of human error and to increase the performance of ICU teams in emergency situations [11,12].

As it is known that approximately three-quarters of adverse events in medicine are due to a lack of non-technical skills [13], knowledge about and competency in the management of typical human errors should play an important role in every teaching curriculum in intensive care medicine. Can this issue be addressed in simulation training?

Non-technical skills

Steven Howard established the Anaesthesia Crisis Resource Management Course, which was the first curriculum using high-fidelity simulation to improve non-technical skills [12]. The courses included a lecture about human error, a video demonstration of a real airline accident, and discussion of crisis resource management (CRM) principles. The course was derived from crew resource
management training in commercial aviation. The same group established a similar training course for intensivists. During the structured debriefing after each simulator scenario, typical questions addressing non-technical skills are discussed with the participants: ‘Who is in charge?’, ‘Does the whole team, including ancillary personnel, understand the working diagnoses and priorities?’ and ‘Was the leadership style effective?’ [4].

St. Pierre and colleagues were the first to establish a simulator-based human factor training with physicians and psychologists as instructors [14]. The psychologist leads an intensive briefing session with focus on communication and cooperation. Furthermore, the psychologist facilitates the debriefing together with a physician.

Another simulator-based curriculum uses a six-step approach to teach non-technical skills [15]. The main intention of this educational approach was to enable participants to transfer psychological knowledge into daily practice. The course consists of four modules representing the main categories of non-technical skills described by Fletcher and colleagues [16]: task management, team working, situation awareness and decision-making. The instructors manage a demo crisis scenario in the beginning of the course, during which they demonstrate some key elements of CRM, which have been previously defined by David Gaba [17].

- Know the environment
- Anticipate and plan
- Use all available information and cross-check
- Prevent or manage fixation errors
- Use cognitive aids
- Exercise leadership and followership
- Call for help early
- Communicate effectively
- Distribute the workload
- Mobilise all available resources for optimum management

In the demo scenario, a model for CRM behaviour is built, which is thought to improve the performance of teams in crisis scenarios. The objective of this intervention is the participants’ model learning by observing CRM behaviour [18]. In the second step, psychological knowledge about the non-technical skills is taught in a seminar style. This is followed by psychological exercises, during which the participants experience typical sources of human error and exercise strategies to improve error management. To facilitate the transfer of psychological knowledge into daily practice, the psychologist and the medical instructor run a psychological exercise, which is embedded in the context of a simulator scenario [15]. Steps five and six consist of simulator scenarios and debriefing sessions as in other CRM courses. However, as a special focus is set on human factors, a psychologist and a physician moderate every debriefing session.

**How to implement an ICU simulation setting**

High-fidelity simulation training is very cost intensive. Not only are the mannequins or simulators expensive, but we also need experienced faculty and the courses are usually held in small groups. Thus, when setting up a curriculum in intensive care medicine, we should carefully think about objectives, teaching methods and resources. In medical education, a six-step approach to develop and implement new curricula has been proven to be suitable and successful [19]. Based on this widely accepted educational strategy, implementing an ICU simulation course can be realised as follows.

Let us apply the six-step approach.

**Step 1: Problem identification**

Systemic inflammatory response syndrome (SIRS), sepsis and septic shock are a leading cause of morbidity and mortality in patients in ICUs worldwide with an estimated incidence between 50 and 100 cases per 100,000 people in the population and may occur in up to 30% of all ICU patients [20].
Hence, the importance of teaching physicians and nurses in coping with this complex disease is clear. The current therapeutic strategy of sepsis is based on the International Guidelines for Management of Severe Sepsis and Septic Shock [21]. Recent findings in the Australasian Resuscitation In Sepsis Evaluation (ARISE) [22] and Protocolized Care for Early Septic Shock (ProCESS) [23] trials showed that a therapy of the septic shock in which vasopressors, blood transfusions and intravenous fluids are adjusted to the central venous pressure and the central venous oxygen saturation \( \text{ScvO}_2 \) does not improve the outcome of patients compared to those undergoing usual care. However, higher compliance with the Surviving Sepsis Campaign (SSC) is associated with greater survival rates [24]. Regarding the curriculum on the therapy of severe sepsis and septic shock, we would like to define the SSC care bundles as the ideal approach.

Step 2: Needs assessment of targeted learners

In our example, residents in their first weeks in an ICU may be the learners we want to teach in the new curriculum. The evaluation of the residents’ performance may have uncovered deficits in their ability to recognise early symptoms of severe sepsis and septic shock with the result of a delayed therapy. Moreover, we might have found a lack of adherence to the SSC care bundles. However, they are thought to be competent in most skills needed when taking care of septic patients as they have already completed 3 years of training in anaesthesiology. Thus, this course will focus on diagnostic competency and treatment algorithms.

Step 3: Goals and objectives

The most important goal of the training is to teach young doctors to recognise severe sepsis and septic shock in order to make them feel more secure in diagnosing this disease. Moreover, they should have in-depth knowledge about the current SSC guidelines. To follow the SSC performance bundles within 3/6 h is another goal of the new curriculum. We may now define the objectives of the course as follows: The resident in the ICU is able to diagnose severe sepsis and septic shock, and to follow the SSC care bundles during initial resuscitation after having completed the course.

Step 4: Educational strategies

Now, we have to carefully select the teaching methods. Teaching knowledge about sepsis, the symptoms, the SSC guidelines and our treatment algorithms can be done in lectures or in seminars. However, we want our residents to show correct treatment in real sepsis scenarios. Thus, they should gain practical experience and we might want to let the participants exercise in some simulated cases. The simulation should take place in familiar surroundings, for example, monitors, infusion pumps and respirators should be the same as in the physicians’ daily work to avoid distracting stressors. Which simulator should we use? A broad variety of patient simulators is available ranging from resuscitation mannequins to high-fidelity simulators. Let us have a closer look into the SSC care bundles: We should be able to simulate haemodynamic values including mean arterial pressure, central venous pressure, central venous oxygen saturation (\( \text{ScvO}_2 \)) and lactate levels. The treatment during the scenarios will comprise fluid therapy, drawing blood for blood cultures, lactate levels, \( \text{ScvO}_2 \), blood gases and some biochemistry values. Drawing blood can be done with very simple mannequins: Just connect an infusion system with a (fake) arterial catheter and supply artificial blood. Most simulation centres have set up such systems; after drawing blood and giving the syringe to a ‘nurse’ (actor of the simulation centre team), the syringe is brought to the laboratory and sometime later, a ‘lab assistant’ will call and report the results. However, haemodynamic values must be displayed in an ICU monitor. A high-fidelity patient simulator can be used, which is connected to a standard ICU monitor. Although this may be recognised as the gold standard, a very simple mannequin might be used instead of the expensive high-fidelity simulator. Using a tablet and a low-cost application, an ICU monitor can be simulated, which enables us to demonstrate all haemodynamic values during the scenarios. In our setting, we would choose a high-fidelity simulator if available, but we would also be able to set up our curriculum with low-fidelity technology, if we only have limited resources.
Step 5: Implementation

Political support and financial resources are two very important and not uncommonly limiting factors in medical education. Hence, we have to confront the hospital management with the need for training in this field and we have to persuade them of the curriculum’s importance. Further barriers may hinder the introduction of the curriculum to the targeted learners: Are the residents motivated to participate? Are they required to participate? Will the course be held at the weekends or during over-hours? Careful preparation is needed to get the most out of the training; perhaps, it may be helpful to pilot the course with only few participants who are highly motivated and who forgive the instructors if something goes wrong during the first courses. As technology is involved, we always need to have a plan if a mannequin or simulator is broken. Careful planning of the scenarios is even more important: If we use the simulator software to prescribe a scenario, the participants not recognising the specific problem or initiating treatment different from what we expect might surprise us. The instructors should always be able to react and change the most important settings by hand rather than letting the simulator drive in the automatic mode.

One of the most important prerequisites to successful simulator training is the learning atmosphere: At the beginning of the course, the instructors and the participants sign a confidentiality form. Both parties grant not to talk about any issues arising in the debriefing and not to talk about the participants’ performance or behaviour. Furthermore, we ask our participants to grant confidentiality regarding the scenario, as we do not want to have residents in the second or third course knowing that the problem in the first scenario is a pulmonary embolism.

Step 6: Evaluation and feedback

This last step closes the cycle. Our intention is to receive feedback from the learners, which may help us to further improve the curriculum. Questions to be addressed include whether the participants find that the course meets their expectations and whether the selected teaching methods were adequate. We are furthermore interested in the effects of the course on knowledge, skills and performance in sepsis scenarios. The repetitive debriefing sessions represent formative assessment and enable students to reflect their learning progress. Formative assessment of the students’ learning is also helpful for the instructors as it helps us to further improve our curriculum.

We may also use summative assessment: We may define successful participation in the course as a minimum prerequisite to take part in the ICU shifts. A simulator scenario can be used to carry out the summative assessment, and the performance of the participants is usually evaluated using a checklist or a global rating scale.

When looking at behavioural changes, we have to observe our residents in testing scenarios at the patient simulator or – even better – in daily life/real scenarios. Educational research is important to find out whether the simulator helps to meet the objectives and whether the (practical) training is superior to theoretical teaching methods.

The evaluation results may be important to gain continued support and resources for the curriculum. We should discuss the results with the hospital management: if we can demonstrate positive training effects resulting in better patient care, they might support the course as standard preparation for residents prior to an ICU rotation. However, we always have to be critical. The evaluation should also help us to find answers to critical questions: Can we use a low-fidelity mannequin instead of an expensive high-fidelity simulator? How long should the training last? How many participants can we teach in a course, and what is the optimum ratio of instructors versus participants?

Effectiveness of simulation training

Numerous studies have been published presenting evaluation data from simulator training. Courses including a simulator are rated as better suited to link practice and theory in several fields of medical education, and participants appreciate the teachings as intense, but enjoyable and helpful to their practice [11,12,25]. Mannequin-based simulation is widely considered to be a useful tool for addressing important issues, allows to make teachings more effective by achieving proficiency levels in a smaller number of trials and helps to detect critical events more rapidly. Many studies are published showing
improved performance after simulator training in intensive care medicine. Chopra showed as early as 1994 that physicians performed better in a simulated malignant hyperthermia case 4 months after a training session on malignant hyperthermia as compared to a group of physicians who had exercised the management of anaphylactic shock [26]. Steadman compared simulator training and problem-based learning and found that students who have been taught using high-fidelity simulation performed better in a crisis scenario than students who had received problem-based learning [27]. Repetitive simulator training has also been shown to reduce stress response during crisis scenarios, which may contribute to improved performance when managing emergency situations [28].

When assessing the effects of our teaching courses, we desire to find changes in daily patient care [29]. This is not easy to prove, and most studies focus on the assessment of the third level of the Miller’s pyramid: the participant is able to demonstrate skills or competency in a simulator setting. Experts in the field of medical education and simulation are mostly enthusiastic teachers and have spent considerable time and effort in the development of simulation centres and curricula. However, we should always critically question what we do. Looking at the international literature, we find some really interesting studies uncovering results that should influence our future curricula. Let us give some examples:

- We love to work with high-fidelity patient simulators, and so do our students. However, when teaching fibre-optic oral intubation, the high-fidelity simulator adds costs but is not associated with improved learning [30].
- Even high-fidelity patient simulators have different airway anatomy compared to real patients [8]. Do we expect our residents to be competent in airway management after simulation training? How can we close the gap between simulation and real patients?
- Staff anaesthesiologists having completed a cannot-intubate—cannot-ventilate scenario at a high-fidelity patient simulator followed by an intensive debriefing and practical training in airway management did not improve in a second similar scenario [31]. Simulation training is a powerful educational tool, but we should not expect to change the behaviour of experienced physicians after 2 h of simulator training.

Conclusion

Simulation scenarios in the intensive care setting can be useful in the education of health-care professionals, and they can help to manage complex situations while enhancing patient safety. A thorough preparation is mandatory and should include a curriculum based on the six-step approach. To achieve the best possible results, the setting should take place in familiar surroundings with medical devices and monitors used in the daily work. High-fidelity mannequins offer good possibilities to simulate, for example, certain respiratory complications, but depending on the objectives, low-fidelity simulators can be more appropriate to ensure a good cost–benefit ratio.

<table>
<thead>
<tr>
<th>Practice points</th>
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<tr>
<td>• ICU physicians must be competent in many different procedures and algorithms to ensure the patient’s safety. Thus, an excellent practical training in technical and non-technical skills is mandatory.</td>
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<tr>
<td>• Simulation-based training can be an important component in the education of ICU teams. However, high-fidelity simulation is expensive. When using simulation, we should carefully select the most appropriate teaching method. Sometimes, low-fidelity simulation may be more effective than high-fidelity simulation.</td>
</tr>
<tr>
<td>• The six-step approach to curriculum design described by Kern can be a useful tool for teachers establishing (simulation-based) courses for intensivists.</td>
</tr>
<tr>
<td>• The simulation should take place in familiar surroundings with monitors, infusion pumps and respirators used in the physicians’ daily work to avoid distracting stressors. When we talk about simulation fidelity, we do mean the simulator alone.</td>
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Research agenda

- Simulation training is very costly in terms of time, personnel and money. Therefore, more research is mandatory to investigate whether the simulation training helps to meet the objectives.
- We need more studies comparing high-fidelity simulator training with low-fidelity simulator training.
- Research on the effects of simulation training on daily life (fourth level of Miller’s pyramid) is of the utmost importance.

Conflict of interest

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References

7 Simulation in preclinical emergency medicine

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Keywords: emergency medicine simulation preclinical training evaluation education

Introduction

Medical education has strived to employ educational formats relevant to current medical practice and reality forever. This fact is even more important for medical specialties necessitating immediate attention and sufficient team action for life-threatening situations – such as emergency medicine. However, it is impossible to train medical personnel exclusively on real-life cases, which may not happen in due time and may not include all aspects necessary for efficient training. In a time of “high-quality care” and an increasing discussion about patient safety, it is difficult to justify pre-emptive training for critical situations in real emergencies [1,2]. This environment sets the stage for simulator-based educational strategies in emergency medicine, which has been at the forefront of this particular format for as long as it exists. Simulator-based training enables not only conventional skill-based training, which aims at theoretical and practical knowledge transfer and consolidation, but also real or simulated team training of group-specific “soft skills” and both active and passive
communication aspects [3]. Simulator-based training also allows for a graded increase in the complexity level of the employed scenarios, thereby individually steering the participant’s stress levels [3] into an area rather close to reality [4]. It has been proven that simulator training raises motivation and satisfaction of participants, and that target groups largely appreciate the format [5,6]. In particular for all acute specialties of clinical teaching, simulator-based training helps to increase specific knowledge while reducing the amount of errors [7–10]. Nevertheless, there is a debate on the matter of its costs, which by far exceed those of conventional formats. Cost issues are subject to questions wherever there are financial constraints in present-day health-care economy, especially since it is difficult to prove the effectiveness of highly resource-intensive simulator training with the terms of evidence-based medicine [11]. Defending the approach, David Gaba, one of the early fathers of simulator training, argued that no high-ranking safety organization in charge of human lives has been asked to deliver proof of the methods employed being superior to some alternative approach [11,12].

Therefore, it is the goal of this work to evaluate the currently available data on medical simulation in emergency medicine, with an emphasis on preclinical situations. Our emphasis was, in particular, on work in subsets of trainings, along with their content weighing towards either skill-based or interdisciplinary team training. Given the above-mentioned criticism, we tried to concentrate on efforts measuring the teaching success of individual participants and/or groups.

This systematic review was designed under the rules of the Prisma-Statements (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [13]. Three major questions are at the core of the review:

1. In which areas of emergency and acute medicine is there relevant evidence for simulator-based training?
2. Are these trainings aimed towards (knowledge and personal) skills training, team (soft skills) training, or both?
3. How are training results evaluated by the teachers?

The work is based on both English and German literature published on simulation-based (1) skills and (2) team training efforts in areas relevant for emergency medicine with an emphasis on the preclinical setting published until 2014. “Simulation-based” was defined as any setting that included realistically displayed surroundings for the clinical situation. The use of video debriefing and “high-fidelity-simulation” was not deemed essential. Any training using video-based displays of cases merely as a sort of illustration of case discussions, but not necessitating active intervention of participants in the scenario or mannequin, was excluded from analysis. Naturally, no simulator studies looking at particular aspects of medical equipment use could be analyzed for the purposes of practical training of participants in emergency medicine. The focus was on original publications regardless of the particular target audience within emergency medicine training. Evaluation as a means of training success was quantified using the Kirkpatrick’s four-level model [14].

MEDLINE and Cochrane Database of Systematic Reviews as well as the Cochrane Central Database of Controlled Trials were searched for the terms “emergency,” “pre-clinical,” “training,” “education,” and “simulation”, or a combination thereof until November 2014, and abstracts and subsequently full-text versions analyzed.

Results

A total of 1068 possible hits were identified, out of which a total of 28 qualified for the scope of the work due to the criteria described above. All the selected studies described training of personnel employed in preclinical emergency medicine settings. Out of the 28 selected studies, 16 (57.1%) primarily dealt with skill-based training, aiming at teaching a defined medical procedure to individual training participants. Six of those studies (21.4%) primarily dealt with the emergency airway, focusing on the skill of securing the airway by means of a supra-glottic device [15,16], a rapid-sequence induction [18], specific aspects of emergency patients [17,19], and the emergency coniotomy [20,25]. In two studies (7.1%), the goal was to train surgical treatment of a tension pneumothorax under realistic


The reported degree of both, complexity and resolution, varies widely within the published literature. While seven studies (25%) stuck to low-fidelity simulations [21,23–25,27,32,35], another four (14.3%) performed so-called hybrid simulations, consisting of a merged setup including both, mannequins, actors, and videos, with differing quantitative emphases [29,33,36,41]. However, the majority of the published studies (17 studies, or 60.7%) employed high-fidelity simulation techniques, enabling the participants to use video analysis and debriefing techniques [15–20,22,26,28,30,31,34,37–40,42].

The number of participants in the published preclinical emergency medicine simulation literature varies between 10 and 504, with one publication not giving any number due to the focus of the work being on the educational concept per se. All selected publications (n = 28) were done prospectively; however, only two studies employed a randomized approach to compare different setting towards efficiency and educational success [18,24].

Kirkpatrick’s four-level model warrants a distinction with respect to educational levels in order to classify a method. In general, the quoted literature aims towards the two lower levels of the model. While one of the studies [37] yielded to change level 4b, “benefits to patients,” the concept was not followed up towards the real (patient-related) results. The majority of studies displayed the effectiveness of the introduction of a procedure itself by means of its functioning and/or its time-saving potential or a pre-versus posttest comparison of certain knowledge. The training focused on the acquisition or improved performance of a particular skill (n = 21), with more than half of the studies (61.9%) comparing the preexisting with the resulting situation after the measure [22,25–29,31–36,39]. In order to investigate its sustainability, three of those trainings (10.7%) repeatedly performed the posttest survey [15,17,30]. Two other studies (7.4%) compared different performance techniques for a particular skill using randomization of participants into different groups, with the correctness [24] and time needed to perform [20] as objective markers for success. Lammers [21] tested guideline adherence in pediatric resuscitation by means of different procedures in a variety of scenarios. According to Kirkpatrick’s Adapted Hierarchy of Evaluating Educational Outcomes [14], the results for the individual studies can be summarized as follows:

Level 1: Reaction. Participation in educational programs, gathering data about satisfaction and reaction with questionnaires or surveys:

If defined as participant feedback, only one study [22] qualified for this level, which asks for satisfaction of participants after mega-code training in the field. Smith and colleagues [38] observed and documented the lessons learned, but failed to report on a systematic analysis of a post-procedural survey or test among participants, such as a crew resource management (CRM) debriefing to optimize soft skills.

Level 2a: Learning: changes in attitudes/perception: In this level, the participants show a change in reciprocal attitudes or perceptions between team members showing CRM skills or towards an intervention or solution. The data are also collected via surveys or questionnaires. No study screened for the present review fell under this category.

Level 2b: Learning modification of knowledge or skills: Here we find a modification of knowledge or skills related to the acquisition of procedures or principles including psycho-motor and social skills. For
this, one needs a pre- and posttest setting or maybe a repetition after a defined time, but these changes were not maintained beyond 6 months. The majority (78.6%) of the studies reported on here qualifies for this level [16,18–21,23–29,31–36,39–42]. These studies report written surveys comparing pre- and post-simulator training, demonstrating at times remarkable increases.

Level 3: Behavior: Documents the transfer of learning to the workplace. Only two of the screened studies (7.4%) suggest the possibility of a sustained behavior change of participants at their respective workplace, namely securing the airway and triage technique for mass casualties [17,30]. Thomas et al. could demonstrate an elevated success level for securing a difficult airway even 1 year after the training [17]. Cone et al. compared two different triage algorithms for mass casualty scenarios and compared the results after 3 months had lapsed [30].

The highest of the four levels could not be attributed to any of the screened work. The definition is given for completeness:

Level 4a: Results: change in the professional practice: Changes in organizational practice attributable to an educational program.

Level 4b: Benefits to patients: Improvement of health as a direct result of an educational program.

Discussion

Simulation-based training in emergency medicine is usually highly appreciated by participants. Predominant positive factors being mentioned across the board include the safe and enclosed environment, in which relevant skills, algorithms, and soft skills can be learned in a team approach. Moreover, training within a high-fidelity environment with video debriefing empowers participants of team trainings to self-reflect within the “safe zone” of simulation reality, which may even be their own real-world workplace in case of in-situ trainings, which then also allow to draw conclusions for existing systems, processes, and resources.

For the purpose of this review, a total of 1065 simulation-related emergency medicine studies were screened, and 28 with relevance for preclinical simulation training chosen for further review. Based on the criteria described above, the following questions can be discussed:

1. Content: Which topics of preclinical emergency and acute medicine are currently covered by simulation-based training, and with which emphases, respectively?

There are two “heavy weights,” the (team) training of mass casualties and the (skill) training of securing the airway, with different degrees of algorithm training present in both areas. Of note, there is evidence for the simulation of particularly rare events of high complexity, as well as for particularly critical events.

As for the body of work dealing with mass casualties (seven of the selected articles), the necessary skills are rightfully addressed prior to a rather rare event. The content of simulation scenarios includes triage in general as well as in specific situations, such as anticipated terrorist attacks using chemical or biological weapons. Subarao et al. [34] trained a total of 54 and Scott et al. [35] 220 participants in the area of triage following an ABC attack under simulated conditions. Situations involving mass casualties following such an event are extremely rare, but require the seamless and ad-hoc integration of large interdisciplinary and interprofessional teams of different origins. Therefore, the simulation-based approach is the most appropriate way for potential error analysis and “lessons-learned” scenarios. King et al. [41] report on the training of complete Forward Surgical Teams of the US armed forces dealing with scenarios of simulated mass casualties. Their work describes the training of a total of 16 individual teams being trained over the course of 2 years. Their results highlight the necessity of such extensive trainings, which uncovered weak points in aspects of algorithm-based knowledge, primary survey, and triage details, which would have otherwise gone unnoticed. In fact, they conclude that the training of algorithms in conjunction with individual checklists remarkably helps to structure unclear and complex situations. The time factor gains more and more attention in scenario training of mass casualties, as it is critical for the critically injured individual to be identified rather quickly by means of the algorithm-based triage systems mentioned above. Cone et al. [30] compared two individual triage...
systems employed in a scenario of a highway bus motor vehicle accident, and repeated the test after 3 months with the same participants in order to study the sustainability for the two protocols.

The second major focus of the published literature in preclinical simulation deals with the correct techniques to handle a critical patient’s airway, which has been addressed by a total of six studies. Byars et al. [15] prospectively investigated two cohorts of paramedics, who were simulator-trained to use a mask airway in a simulated scenario of a difficult airway. Out of 40 trained participants, 39 were able to correctly place both, an intubation laryngeal mask and the endotracheal tube itself, with all participants being able to properly mask-ventilate. Two separate studies [20,24] dealt with the technique of emergency tracheostomy, which is an essential option of any emergency airway scenario, but also conventional coniotomy regains attention by means of simulator training, particularly in military environments [43]. Of note, the training is not limited to physicians, as there are tactical settings, in which non-physicians can employ this technique after thorough (and simulation-based) training in the field. Both emergency tracheostomy studies demonstrate that these procedures can be taught to and performed correctly by non-physician personnel. Quick et al. [20] conclude that there are no differences between the performance of different conventional techniques, which can all be successfully conducted after simulation-based training. Accordingly, Saxon et al. [24] demonstrate successful performance of emergency thoracocentesis in a simulated preclinical setting.

The repeated element of teaching algorithms is a cornerstone for many different bodies of published work in the area, potentially due to the fact that one can easily test performance in the complex scenario settings. Algorithm-as well as checklist-based training, which was part of five published manuscripts (17.9%), may help to prioritize participant’s thinking in simulated scenarios, which necessitate handling of various different tasks seemingly at the same time [3,44].

2. Format: What are the predominant simulation environments, which are chosen to transport content, and how does the training of an individual (knowledge-based or technical) skill interrelate with (team-associated) soft skills necessary for an improved team performance?

If asked without the conjunction of the learning context, this question is difficult to answer for most of the published manuscripts, as there are few skills, which do not relate to teamwork at all. It therefore seems reasonable to distinguish technical and soft skills training and any formal elements of CRM training [12]. From the analyzed manuscripts, 57.1% deal with technical skills, while 52.9% contain elements of soft skill training, with some overlap as described above. In terms of educational theory, it remains to be determined whether true CRM training is appropriate for “starters,” or requires some extent of emergency medicine knowledge to build on, depending on the level of complexity and difficulty of the scenario. Undoubtedly, the proper application of basic technical skills, which then can themselves be enhanced during team trainings, allows for an improved experience for both the individual and the team to be trained in a team scenario. Thus, a decisive approach to test incoming training participants for basic skills may lead to improved performance not only of specific motor but also of critical decision, variation, and “soft” skills too in the rather tense team scenario.

The hardware for high-fidelity simulator training furthermore opens the chance to mix common and rare scenarios in a safe environment, thereby practicing the general means of the format, including video debriefings, self-reflection, and a sustainable learning success in line with current lifelong learning theories [5]. Naturally, high-fidelity simulator training allows for training high-level skills if applied properly [5]. The need for repetitive training for a sustained success has been pointed out, also for action-related learning, but without evidence for any clear-cut intervals for specific skills [5].

3. Evaluation: Are trainers able to reliably measure the success of their teaching?

The majority of the available literature reporting preclinical emergency simulation solely discusses reaching a predefined end point, such as the quality of an acquired skill or the presence of a piece of knowledge in the group of participants, compared to the situation before the training. Only two studies intentionally looked at the success of repeated training [17,30], a measure aimed towards evidence for the quality of simulator-based training, which maybe crucial for the proof of simulation-based
sustainability of knowledge acquisition. Thomas et al. [17], looking at airway skills, demonstrated that the skill level of participants increased after simulation-based training from 19% to 36%, dropping to only 34% over a year’s time. Even though these results are promising and they encourage supporters of simulation-based training, it seems appropriate to ask for true randomized comparison studies between simulation and “conventional” training groups, where that is (technically) possible. This also applies to the reported surveys, which are common after the simulation trainings, and which lack comparable “conventional” counterparts. Therefore, it seems advisable to design simulation trainings in a way addressing exactly definable and thus measurable goals, and to also test for sustainability of the acquired knowledge and/or skill.

Taken together, simulator-based training methods are successfully applied to preclinical emergency medicine training, in particular in order to train rare, complex, and dramatic events in a protected environment and in an action-related context. The technology also allows for the training of high-performance skills, which necessitates diligent planning and participant selection to reach the appropriate educational goals. Both trainers and participants appreciate the effectiveness of the training method for the specific needs of preclinical setting, even though thorough prospective randomized comparison studies are still lacking. Therefore, it cannot be said which area of preclinical simulation of medical content would be more or less suitable for which teaching technique, skill, or team training. Likewise, there are no solid data referring to the sustainability of the method in the particular medical field, compared to conventional teaching techniques or standards. Finally, it seems reasonable to measure teaching methods against its ultimate target — increased patient safety and the well-being of emergency patients in the field. The ideal study would therefore try to address behavioral changes of simulator-trained participants in their daily practice, along with their rate of critical events, which admittedly would be a difficult thing to do. Nevertheless, this approach would help to justify this immensely resource-intensive area of modern medical education, which rightfully attracts crowds of educators, medical students, and health-care professionals alike.

**Practice points**

Simulation training in preclinical emergency medicine:

- seems predestined for technical skills as well as team training;
- is ideal for the training of rare events, where certain emergencies are available for training regardless of real event frequencies;
- improves algorithm adherence through specific training approaches;
- enhances the performance of teams training together.

**Research agenda**

- Skill trainings and performance evaluation need proper validation;
- Open questions include sustainability aspects (i.e., frequency of re-training);
- Lack of data regarding prospectively randomized comparisons requires thorough research;
- The intention of improved patient safety through simulation training is difficult to prove scientifically.

**Conflict of interest statement**

None.
References


First of all: Do not harm! Use of simulation for the training of regional anaesthesia techniques: Which skills can be trained without the patient as substitute for a mannequin

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Character of clinical skills training is always influenced by technical improvement and cultural changes. Over the last years, two trends have changed the way of traditional apprenticeship-style training in regional anaesthesia: firstly, the development in ultrasound-guided regional anaesthesia, and secondly, the reduced acceptance of using patients as mannequins for invasive techniques. Against this background, simulation techniques are explored, ranging from simple low-fidelity part-task training models to train skills in needle application, to highly sophisticated virtual reality models — the full range is covered. This review tries to discuss all available options with benefits and neglects. The task in clinical practice will be in choosing the right level of sophistication for the desired approach and trainee level. However, the transfer of simulated skills to clinical practice has not been evaluated. It has to be proven whether simulation-trained skills could, as a last consequence, reduce the risk to patients.

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Introduction

Cultural changes in medicine have reduced the acceptance of the traditional apprenticeship-style training in patients and trainees. This influences the character of clinical skills training. Simulation is
an educational technique that allows interactive, and at times immersive, activity by recreating all or part of a clinical experience without exposing patients to the associated risks. For this reason, the number and range of technologies used in simulation for education of health-care professionals are growing exponentially. These range from simple low-fidelity part-task training models to highly sophisticated computer-driven models [1].

This paper reviews the range of currently available simulators and the educational processes that underpin simulation training in regional anaesthesia. The safe performance of regional anaesthesia requires knowledge of theoretical facts, such as anatomy and physics, and good manual skills. Ethically, skills in needle placement should be gained in a phantom before performance of nerve blocks on patients in clinical practice. Trainees should be able to learn and practise different techniques in a safe environment. Simulation in this complex setting should create a realistic environment with standardized and reproducible scenarios without endangering patients [2].

This review focusses on peripheral nerve blocks. In this field, most simulation techniques can be elucidated. These are easy to transfer to neuraxial blockades such as epidural and spinal anaesthesia. However, different techniques such as regional anaesthesia performed with nerve stimulation of peripheral nerves or ultrasound-guided regional anaesthesia require different simulation scenarios.

**Nerve stimulation guided peripheral nerve blockade**

Regional anaesthesia with nerve stimulation technique encompasses several skills, such as positioning the patient, determination of the needle insertion site with the help of surface and anatomic landmarks and the use of electric nerve stimulator in order to locate nerve cords with muscular response (e.g., twitches in the hand or knee). After successful localization, local anaesthetics are injected to block the desired nerve.

One essential requirement for simulation is a precise, anatomic plausible model of the nerve cords. In addition, representations of bones, blood vessels, muscles and skin tissue are needed to frame the peripheral nerve system.

The simulation itself should allow training of all steps of a typical procedure as described above. Especially, anatomical correct models with options for positioning extremities and reality-based haptic impressions are required. Perception and manipulation of these objects using sense of touch and proprioception should create the illusion of body substance and needle force within the virtual world. Even though specialized haptic solutions are used by applications for simulation of insertion of IV lines and central venous catheters, there is currently no phantom for nerve stimulation-guided regional anaesthesia of peripheral nerves available.

On the other hand, high-end solutions such as virtual-reality (VR)-based simulators are developed in feasibility studies [4].

**Virtual reality**

VR is a computer-based technology that presents virtual objects or environments to all human senses in a way that is identical to their natural counterpart. Improvements in computing technology and in the development of techniques for acquiring data (e.g., medical imaging) are able to generate models. These are often combined with part-task trainers to allow a physical interaction to take place within the virtual environment where haptic feedback is used to produce a feeling of resistance when using instruments within the simulated environment [5].

To give an impression, Fig. 1 shows a VR-based simulator for regional anaesthesia with two haptic interaction devices for palpation and needle insertion. Magnetic resonance imaging (MRI) morphology and magnetic resonance angiography (MRA) were acquired from five subjects for the inguinal region. From these sources, three-dimensional anatomical data sets were created and nerves modelled. This model of flexible anatomical structures was implemented in the VR toolkit VISTA using modules for collision detection, virtual humanoids, interaction and visualization [6].

Clinical acceptance of this specialized haptic solutions is very low. The reasons are firstly due to the complexity of this elaborate setting. Data calculation from medical imaging and preparation of the high-fidelity setting need time, education and manpower. This may be available in feasibility studies...
but not in a clinical trainee setting. Secondly, the reasons are in the VR setting itself, for example, restrictions to datasets of single peripheral nerve cords, rigid virtual patients that cannot be repositioned and no proper training of needle insertion site localization [3].

For that reason, currently, there is no extendable, software-based simulator for regional anaesthesia available.

In vivo models

Another approach to high-fidelity simulation is in in vivo workshops in living animals. There are few courses that provide hands-on practice for a small number of participants in regional anaesthesia placement with electrostimulation in living pigs.

The pig weighs usually around 40 kg and, although much of the anatomy differs from that of a human, for example, the absence of a clavicle, most of the blocks important to anaesthesia can be demonstrated and practised. The most important aspect of this kind of workshop for the trainees is to practise navigating a needle in live tissue. Once the predetermined structure is reached, a nerve stimulator will confirm the structure to be a nerve with twitches in belonging muscular groups [7,8].

Beyond ethical reasons, there are many practical obstacles with using a pig as a ‘living simulator’. Medical treatment of pigs is applied in large animal operating rooms taking into account aspects of animal needs. For this reason, there are only a few suppliers of this training, mostly departments of experimental anaesthesiology. The range of skill training in regional anaesthesia with nerve stimulation cannot be covered in this way.

On this account, training is still done on living patients. A practical approach for daily training could be to simulate single steps of the whole procedure. For example, healthy ‘mannequins’ could be used for positioning, visual scanning and manual examination of the surface for the right needle insertion site and transcutaneous stimulation of peripheral nerves. This would be a sufficient training for all non-invasive parts of the task inclusive of training the optimization of muscle stimulation through modification of electric impulses.

Ultrasound-guided peripheral nerve blockade

The popularity of real-time ultrasound guidance for nerve blockade has increased dramatically over the past 10 years. The application of ultrasound for the performance of peripheral nerve blocks is evolving to become a common practice in regional anaesthesia [9,10].

New skills have to be acquired when compared to the traditional nerve stimulation technique. Ultrasound-guided peripheral nerve blocks facilitate direct visualization of nerves, needle placement
and distribution of local anaesthetic. Its use has become popular in regional anaesthesia because it frees the operator from using the classically described landmarks and nerve stimulation [11].

However, for residents or novice anaesthesiologists, learning this new technology poses a challenge. There are some aspects to learning how to perform an ultrasound-guided peripheral nerve block:

1. Knowledge of physics and the use of the ultrasound machine;
2. Extensive knowledge and interpretation of sonographic anatomy, which involves identification of anatomic structures as seen on the ultrasound images; and
3. Needleling technique, which involves learning to manipulate the ultrasound transducer and needle to direct the needle to the target under direct vision.

The last aspect requires knowledge of sonoanatomy as well as hand—eye coordination [12,13].

Basic physical principles such as characteristics of ultrasound waves, tissue echogenicity and generation of an ultrasound image can be easily achieved through textbooks or web-based courses. If simulation is needed to visualize these facts, then every trainee can use his own skin and tissue for example. In addition, the use of the ultrasound machine could be learnt in a theoretical approach.

**Sonographic anatomy**

With regard to sonographic anatomy, there is a difference. The key to understanding is of course general anatomy of tissues and organs, knowledge based in primary student training. However, topography in general and topography of nerves in particular must be combined with somomorphology and artefacts to route to individual anatomy. The importance of sonoanatomy as knowledge of individual anatomy is obvious. With ultrasound-guided regional anaesthesia, we see what we are doing, but we only see what we know.

Real-time hands-on scanning of models provide experience at locating the anatomical structures. Sonography of nerve structures is easily demonstrated. Teaching the practical skills is more difficult. The ability to find peripheral nerves and demonstrate tracking of peripheral nerves is the first step of hand—eye coordination. A reproducible two-dimensional screenshot has to be generated in a three-dimensional motion with motion of the probe. The ‘Image seeking’ should route to the determination of the optimized needle insertion site.

Simulation in this field of interest is normally bound to liveliness. Real ‘mannequins’ model in realistic situations for ultrasound scanning under supervision of experts. This training is usually performed in specialized courses. Participants regularly return to their institutions after attending educational courses as proficient ‘image seekers’, yet still feel untrained and unsure about performing in daily practice. They are able to find and demonstrate the nerves in regular anatomical surroundings, but struggle to translate this theory into actual nerve blocks on patients.

Another approach is to train with fresh-frozen or embalmed cadavers. These methods are designed to conserve texture, volume, colour and shape of the body as perfectly as possible. There is strong acceptance for the use of cadavers as a training model and a preference for the tissue properties of Thiel-embalmed cadavers. Although muscle rigidity and lack of flexibility are still a problem, ultrasound picture performance is satisfactory. A preferable advantage lies in existing pathologies, for example, high body mass index, which reflect real conditions [14].

**Needle advancement**

Success in performing any procedure using real-time ultrasound demands proper hand—eye coordination. The needle-to-image coordination is one of the most vital and difficult skills to master. During these procedures, one has to look at a two-dimensional image while working with the hands and probe in three dimensions. Due to the complexity of the process, this task can be challenging even in experienced hands. For this reason, the two most frequent errors are the failure to visualize the needle before advancement and unintentional probe movement as described by Sites et al. [15].
Uncontrolled needle advancement and lost visibility of the needle tip can potentially injure the target nerves or adjacent tissue, including vessels [16,17]. For this reason, there is an ethical consensus, that skills in ultrasound-guided needle placement should be gained no longer through use of patients to learn performance of nerve blocks in clinical practice. The use of phantoms is required to facilitate the approach to ultrasound-guided regional anaesthesia [18].

Significant improvements in practitioner confidence, in-plane needle visualization, success rate and safety of needle approach through training with target phantoms could be demonstrated by interventional radiologists [19].

A phantom from this point of view is any media used for research or training other than living human tissue. Under this definition, phantom technology is varied, and critical evaluation of the images generated is needed to understand their application to clinical use. There are benefits and pitfalls in each type, because needle visibility depends on the echogenicity of the needle relative to the echogenicity of the tissue adjacent to the needle. The echogenicity of phantoms varies enormously, and this impacts on how needles are visualized [20,21].

Although numerous interventional phantoms have been described in the literature, there are four main types with similar characteristics in each group. Needle brightness is not simply a function of the needle and insertion angle, but it depends on the difference between the needle and phantom echogenicity and the effect of image processing, in particular, the gain setting [22].

**Water**

Water is anechoic, making all needles highly visible, but does not fix the needle to allow practice placement. It is the lowest-fidelity phantom, readily available everywhere, inexpensive and targets are easily added. It is useful for first step imagination of complex structures, such as spinal phantoms, because the trainee can compare both images, one from three-dimensional reality in the water bath and one two-dimensional plain on screen [23].

The practical use for needle guidance is very limited, as there is no tactile feedback in this media, because of which it is even difficult to hold the probe in the ideal position. Therefore, water bath imaging does not translate well into reality of clinical practice.

**Gelatine and blue phantoms**

One step further leads to gelatine phantoms. In the literature, one can find numerous recommendations and recipes for the construction of low-fidelity phantoms. Some use gelatine alone [24], whereas others create a visually opaque and echogenic background by the addition of materials such as flour, corn starch, graphite powder or Metamucil [25]. These phantoms have been adapted to the use for biopsy or ultrasound vascular access training [26,27].

To design a usable phantom for ultrasound-guided peripheral nerve blocks, gelatine phantoms were constructed in layers with the addition of simple to elaborate targets. The background could change from relatively anechoic and transparent to visually opaque and echogenic. Such phantoms are relatively simple and cheap to produce [22].

In this setting, needles look often artificially bright, especially if the background is relatively anechoic and an auto-gain function is used by the trainee. This may lead to false confidence with regard to clinical ability, because needle imaging in a live patient would be far more challenging [28].

For this reason, it is important to change the design of home-made phantoms as a trainee progresses. Simple needle-visualization models can subsequently be replaced or modified to incorporate target structures. These targets can then be progressively decreased in diameter, and as a final step in complexity, their orientation can be changed relative to the phantom's scanning surface. This increases the level of accuracy and efficiency needed to master the task and could be challenging even for experts [29].

In our courses we use phantoms that modify background echogenicity and target depth because both play a key role in the ease of identifying both needle and target structure.

Most currently presented phantoms lack the facility to detect needle-to-nerve contact and to inject local anaesthetics. This remains a key safety issue with regard to subsequent progression to clinical practice.
Recently, a new elaborated home-made phantom was presented, made from a piece of spaghetti to simulate a nerve, within a starch core and embedded in gelatine usable for ultrasound-guided simulation of a peripheral nerve block. Fig. 2 shows how the choice of materials sufficiently mirrors tissue echogenicity in ultrasound. The needle is visible as a hyperechoic object at 11; hypoechoic fluid surrounds the simulated nerve as fluid is injected. A doughnut sign is clearly visible. This setting not only allows to assess hand–eye coordination in needle placement, but to rank the application and distribution of local anaesthetics around the virtual nerve. This covers all quality parameters and skills needed for a successful peripheral nerve block [30].

So far this phantom is rather unspecific in terms of safety. One can guess that more puncture trials, longer time to application of fluid and lower quality of block may indicate less precision. Future ultrasound phantoms could also incorporate vulnerable structures such as vessels near vulnerable nerve structures to cover terms of patient safety.

Further development includes the completion of an electrical circuit between needle and target or the detection of pressure changes in the target via a transducer set, although this additional level of sophistication may be hard to achieve on a home-made phantom [22].

To present the most common commercially available phantom, ‘Blue Phantom’ should be mentioned. Very similar characteristics as in gelatine phantoms are found in the patented Blue Phantom (Blue Phantom, Seattle, WA, USA). Speed of sound and attenuation are designed from an elastomeric rubber to mimic human tissue. The material is tailored to ‘self-heal’ needle tracking artefacts if treated with unbent and sharp needles. Dull, bent or echogenic needle use is followed by visible and permanent needle tracks caused through air trapping. There are multiple models available with different targets always in front of a homogeneous echogenic background. Although the Blue Phantom is expensive compared with home-made phantoms, it has been the training ground for many practitioners in ultrasound-guided regional anaesthesia courses for practical reasons such as easy care and preservation. In addition, there are many studies performed with this clearly defined phantom for the sake of reproducible and comparable results [31].

In the context of skills training in a clinical education system, it may be too expensive, especially if a predicted life span of only 200 needle placements is included in calculation.

Gelatine phantoms and Blue Phantoms provide a firm texture for needle insertion and a good tactile feedback. Both phantoms fix the needle in path and generate a haptic element as the needle is inserted. Skills acquisition is easy through good visibility of any needle type but this can lead to false confidence in regard to clinical ability. The design of home-made phantoms is flexible and should be altered as a trainee progresses [22].

Similar to those already mentioned features, there are other low-fidelity phantoms described as listed in Table 1 [22].

Meat phantoms

Many studies on the object of how to teach ultrasound-guided regional anaesthesia deal with using meat phantoms as practice medium. This material is widely available, moderately cheap and surprisingly long lasting for practising needle visualization, if correctly treated. To deodorize and preserve the meat phantoms, they have to be soaked for about 8–10 h in 66–70% alcohol [36]. In general, meat phantoms generate a more ‘real’ impression as low-fidelity phantoms. This is based on clear visualization of anatomic structures such as tissue layers and background echogenicity. Needle imagination and tactile feedback are comparable to those in human tissue. Even needle tracking artefacts are filled with tissue fluid and are less detectable compared to gelatine or blue phantoms. Hydro-dissection and simulated local anaesthetic injection can also be performed [37].

There are multiple descriptions of meat phantoms in the literature, such as pork phantoms for ultrasound-guided neuroaxial or peripheral nerve blocks [38] and beef and turkey breast with olives for examination of needle approach [39]. We have found beef to be less effective because of thick adipose layers excessively degrading the ultrasound images. Experience with turkey has also been disappointing, as it is slippery, hard to hold in position and difficult to stop the tissue deforming from transducer pressure. Tissue layers are also unlike those in humans and the smaller size of the animal means that deeper needle insertion techniques are less easily practised [22].

Cadavers

Cadaveric workshops are a long-known component of regional anaesthesia training. Sometimes even required in evaluation for a specific degree, for example, cadaveric experience is a prerequisite for the ESRA diploma [41,42]. Ethical reservations are widespread although every trainee in regional anaesthesia goes through anatomical theatres and examinations in his or her basic medical training. Rational and ethical use of high-fidelity human cadavers dictates that participants should already have an understanding of the theoretical impact of ultrasound-guided regional anaesthesia, sonographic anatomy and have obtained the basic hand–eye coordination for manipulation of a transducer and needle. These skills can be inexpensively and efficiently gained on low-fidelity phantoms [22]. Live human tissue still presents the greatest challenge to needle visibility because of its high background echogenicity. Cadavers are nearly as echogenic as live human tissue and represent much of the textural feel. Needle inserted at steep angles are nearly invisible or highly echogenic. Even fascial ‘pop’ sensations are reproducible. They are the closest phantom media to live human tissue [42].

Another key point to successful peripheral nerve blockade as visualization of injection and spread of local anaesthetics is also feasible in cadavers. This setting provides true anatomy with all its pitfalls in a time-rich environment without the risk of clinical consequence. Some preparations provide even reasonable flexibility [39]. Usually the absence of normal vascular anatomy is the drawback with cadavers. Vessels are normally collapsed and cannot be used as reliable landmarks in orientation. This fact depresses the realism of this model [43].

Although available human cadavers provide an invaluable training resource, they are an expensive and difficult resource to access, whether “fresh” or embalmed, and there are grave ethical issues to consider. However, given the problems with the availability, it seems likely these will be replaced with other simulators or VR devices [44].

The same statement is valid for in vivo workshops with living animals. These are provided in the same way for ultrasound-guided regional anaesthesia as for nerve stimulated peripheral nerve blocks.
High-fidelity models cannot cover the range of skill training in ultrasound-guided regional anaesthesia. However, it has been shown that there is no difference in learning when a high-fidelity model is compared with a low-fidelity model [45]. If low-fidelity models can satisfy this educational goal as well as high-fidelity models, then it remains to be elucidated whether more sophisticated low-fidelity models can improve the sonographers’ ability to identify the target structure and the injection needle or a modification of educational aspects is requested.

Educational aspects

The concept of “see one, do one” has proven to be an expensive, time-consuming and inconsistent model for teaching health professionals to perform complex procedures [46]. It has been recommended that four major components of technical skills be taught before application of the new skill within a clinical setting [47].

These include the following:

- Acquiring cognitive knowledge about the specific procedure, including the steps of the procedure, the function and operation of the equipment;
- Receiving instruction on basic enabling skills required for the procedure;
- Simulation-based education with deliberate practice in achieving specific clinical skills with feedback during training; and
- Continued access to this practice for continued improvement

Based on these theoretical considerations and long-term experiences with clinical courses, recommendations from various medical societies are expressed. In Germany, DEGUM and DGAI, for Europe ESRA, and in United States ASRA have presented guidelines with small differences. These guidelines represent current ‘Eminence’-based opinions, but have little evidence-based background, most level III to IV. None of them is evaluated on impact on clinical performance of trainees incorporated [40,48].

Traditionally certified courses start with didactic lectures to transfer a knowledge base about the specific procedure. This takes up to 50% of time to disposition. Unpublished data from our own courses suggest that there is no difference in outcome between a web-based pre-course instruction, requiring approximately 4 h of study time, combined with 1 h FAQ time with experts before practical teaching and a traditional course structure with didactic lectures followed by the same practical teaching. The outcome performance of the trainees was tested here in an Objective Structured Clinical Examination.

Web-based instruction cannot only permit learning at one’s own pace with information in standardized quality and content, but it has the option to integrate basic simulation such as handling a probe in three dimensions or improving hand to eye coordination as shown in video games.

Giving and receiving instructions on basic skills is the second recommended component before clinical application of a new skill. We found a significant difficulty in transferring these skills in regional anaesthesia from one individual to another. This difficulty was found independent from the actual combination of teacher and trainee and independent from teaching in courses or everyday practice. Specific instructions are required to describe hand and needle or probe movement and to control the approach. Trainees frequently misunderstand the directions. The trainer has often to demonstrate a particular movement that is not easily replicated by the trainee. Here, different equipment and instruction techniques are required, which could help demonstrate the trainee’s own movements providing direct feedback rather than a trainee attempting to learn from another’s indirect instruction.

The last component mentioned opportunities to perform the procedure in education and continuous training thereafter in a variety of platforms, such as VR, bench model simulators, cadavers and live animal models.

Little is known about the learning skills needed to perform ultrasound- or nerve stimulator-guided peripheral nerve blocks. Training for ultrasound-guided peripheral nerve blocks has not reached a curricular level yet; guidelines recommend that this skill should not be learnt in patients, but rather be
taught in a safe environment with the use of a phantom [49]. However, calculations from learning curves are useful for predicting numbers of trials before an ultrasound-inexperienced physician can safely perform [39,50].

A review of current literature shows little data about simulation and learning curves of peripheral nerve blocks with nerve stimulation. Konrad et al. evaluated learning curves of first-year residents for peripheral nerve stimulated axillary blocks. The trainees required 60 blocks for an 80% success rate. This seems reliable, in comparison with other tested manual tasks in this study group [51].

On the other hand, learning curves in ultrasound-guided regional anaesthesia follow different rules. There are many studies about effects of simulation scenarios on the performance of simulated task. Sites et al., for example, demonstrated rapid improvements in both operator accuracy and efficiency, regardless of prior operator experience, for needling an olive in a turkey breast. The time required was reduced about 48% at the third trial [39]. Kim et al. presented a simple model for ultrasound-guided peripheral nerve block, which can be used for education and practice with ultrasound novices in combination with a mathematical model; this predicts the number of trials that are necessary for a satisfactory ultrasound-guided injection in the presented phantom. After five attempts, novices were able to fulfil 95% of the task. The learning curve was flattening after eight attempts. The study group presents, in the discussion, the question of whether future studies can evaluate if the use of simulation techniques likewise improves the learning curve in patients [30].

In another approach, Hocking’s use of a porcine phantom for practising ultrasound-guided central neuraxial blockade has resulted in increased confidence among the trainees [38]. On the other hand, this may lead to false confidence in their clinical abilities in a real patient-related context.

However, the transfer of this skill to clinical practice has not been evaluated as to whether it aids achievement of proficiency in clinical performance of ultrasound-guided peripheral nerve blocks. Future randomized controlled trials have to evaluate whether the use of simulation likewise improves the learning curve in patients.

Phantoms have also been proposed as a platform for the assessment of trainee competence. Minimum standards could be set, and these would need to be achieved before a trainee is allowed to progress to performing ultrasound-guided nerve blocks on patients. In the evolving field of simulated training, some form of in vitro competency testing seems inevitable on grounds of both patient safety and quality of care [14].

Multiple training courses are available, but these may not cover the practical issues of performing nerve blocks once participants return to their own institutions. Without the support of a colleague experienced in the techniques, clinicians may be reluctant to start using their newly acquired knowledge and these skills may rapidly fade [14].

Our course trainees are likely to report increased confidence immediately following a course-weekend, but this seems to rapidly disappear once the participant returns to his own institution without the support and guidance of experts surrounding them. This could not be covered by the option of an individual web-based after-course teaching by our experts. We felt that by 3 months, participants either would have made a change and progressed or would have lost the confidence to start. Unpublished data of after-course follow-ups and evaluations underline this impression.

Simulation can help bridging the gap between learning how to obtain an appropriate sonographic image and actually perform a nerve block. The ability to practise in a stress-free, non-clinical environment without time pressure or fear of patient discomfort enhances confidence and can lead to a sustained change in clinical practice as part of a comprehensive resident teaching course, which should lay the ground for residents and medical students to learn and improve their technical skills in a safe environment [51].

**Conclusion**

Cultural changes in medicine have reduced the acceptance of the traditional apprenticeship-style training in patients and trainees, especially in regional anesthesia. This influences the character of clinical skills training. Simulation offers a safe environment in which trainees may develop and improve skills through sustained deliberate practice by recreating all or part of a clinical experience without exposing patients to the associated risks. For this reason, the number and range of
technologies used in simulation for education in anaesthesia are growing exponentially. These range from simple low-fidelity part-task training models to train skills in needle application to highly sophisticated VR models. For this reason, clinicians need a clear idea of what they require from a phantom before choosing which type to use and to understand that no current phantoms currently replicate clinical practice.

The ability to practise in a stress-free, non-clinical environment without time pressure or fear of patient discomfort enhances confidence and can lead to a sustained change in clinical practice, which should lay the ground for residents and trainees to learn and improve their technical skills in a safe environment. The key to successful training is to underpin educational programmes with sound educational principles.

**Practice points**

- When beginning with simulation in a clinical or educational context keep it inexpensive and simple. Start with low-fidelity home-made models and develop a feeling for this teaching method.
- Simulation is fun. Keep it playful, not doggedly. Take your time out in this stress-free practice.
- After starting you will be soon addicted to this method. This may be the time for a contest: Who could build the most sophisticated model for the next term?
- Take your confidence in your daily clinical praxis and practise your improved skills.
- Share your experience. You learn most in teaching your colleagues.

**Research agenda**

- Further research is warranted to evaluate how much fidelity is needed in a phantom to guarantee an effective simulation impact on regional anaesthesia.
- Also to be assessed is whether the simulated tasks are leading to a clinical improvement in trainees.
- The assumption of improving patient safety by simulation of invasive tasks is to be tested.
- Existing curricula are to be evaluated on their impact on improvement of clinical abilities in trainees.

**Conflict of interest statement**

None.

**References**


Simulation for anesthesia in obstetrics

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Simulation has become a major player in the medical world. Still way behind other high-risk industries, simulation is being increasingly accepted and finds its ways into many clinical areas. Simulation offers the possibility to train individual skills as well as to evaluate performance, provide group crisis management training or even investigate the safety of installed systems and algorithms without risking patient’s life. Obstetric units and labor suites have been identified as high-risk areas in the hospital setting and can be challenging environments for the anesthesiologist. Simulators can be used to improve communication skills and workload distribution, and specifically drill for obstetric-relevant crisis scenarios. However, it remains unclear how well these trainings do transfer into clinical performance and improved patient outcome. Being a relevant cost factor, simulation will have to provide answers to these questions; hence, more research is needed in the future.

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Introduction

In times where patients are more self-confident and better informed about health care than ever before, they have developed an increasing awareness regarding their doctors’ performances. In
combination with the self-dictated standard in the medical community to provide excellent and safe
care using evidence-based medicine in potentially high-risk environments, the training of junior
doctors becomes an increasing dilemma. Medicine is — and has always been — an art where knowledge
and skills are passed down from the paternal (or maternal) experienced doctor to the learning disciple.
However, this involves a “hands-on-patient trial-and-error” approach to a certain extent in the
learning curve of the disciple that may potentially translate into medical error with a measurably
increased morbidity and mortality rate [1]. To provide the practice of medicine to patients with the
rightfully deserved safety by an experienced doctor, simulation has been tagged as the solution to
overcome this conundrum.

Labor and delivery departments have been identified as high-risk areas [1]. More than that, labor
and delivery has further implications for the hospital. First, there are some economic and corporate
design considerations: Parents who had a good experience in the delivery unit are more likely to return
or to recommend the hospital and translate their experience in the delivery ward onto other disciplines
they had not had any contact with assuming to receive similar care. Second, parents currently have an
extensive network via the Internet or in forums and playgroups where they pass on the experience
they had with a certain department or hospital in general [2,3]. Hence, any problems and discomforts
occurring during their stay in the labor and delivery unit may find themselves being reported unfiltered
and biased in the public, directly influencing patient pathways and creating “popular” and
“unpopular” hospitals [4].

The labor ward is — at first glance — an uncomfortable place for the anesthesiologist: He has to get
used to working in a completely different setting and environment than usual with possibly two pa-
tients (mother and child) simultaneously who are themselves in a very special and stressful situation.
Often, there are relatives in the room observing and judging everything that is being said and done and
there are midwives who may at times express a critical view towards any other person disturbing the
intimate relationship between midwife and parturient by laying hands on “their” patient [5].

And last but not least, the labor ward can be a place of major catastrophic events such as severe
bleeding or emergency cesarean section, requiring a high level of skill and experience from the
attending anesthesiologist [1].

Consequently, the perfect anesthetist working in the labor ward is highly experienced, able to work
under stress and time pressure, and able to communicate well with the parturient and the observing
relatives. He must be highly knowledgeable with respect to the peripartal processes in order to be able
to communicate adequately with obstetricians and midwives and to understand the dynamics. Ob-
stetric emergencies are understood and the anesthesiologist is able to cover those. This demanding
profile of requirements may be met by a great number of the experienced anesthesiologists but is
certainly not by the doctors in training who actually may suddenly find themselves alone in the ob-
stetrics department at certain times.

How do we educate and train these junior doctors in order to have them ready and be able to
perform adequately on all required levels in a labor ward?

Apart from gaining purely theoretical knowledge through individual studying, professional
development, or visiting courses, simulation has become a main stake in the development of profes-
sional communication and competency-based technical skills that can be progressively developed and
demonstrated by doctors in training hopefully leading them into unsupervised practice in the specialty.

**Obtaining individual skills**

Individual skills required on the labor ward are ubiquitous and can therefore easily be trained in
lower-risk areas that do not expose the junior doctor to time pressure, observation by relatives, or the
difficulties of an unfamiliar environment.

A multitude of single tasks can also be trained in simulated scenarios. There are commercially
available simulators mimicking the spinal column and hence providing a training ground for epidural
and intrathecal access [6,7]. Interestingly, some studies have shown that a similar learning experience
in terms of developing a “feeling” for the procedure and handling of the equipment can be obtained by
using ultra-cheap self-made simulators consisting of styropor, rubber gloves, or various fruits [8,9].
These “simulators” were shown to be as effective as far more expensive industry-made machines.
A study last year blinded participants and compared four different fruits (bananas, oranges, kiwis, and melons) investigating which fruit provided the user with the best simulation of the “loss-of-resistance” technique [9]. In the end, it was the banana which turned out to be the best representation of the “feeling of loss-of-resistance.”

Airway problems are far more often encountered in obstetric anesthesia as compared to other specialties. This is based on an altered anatomy of the mother’s neck mainly due to a fluid shift causing interstitial edema. Hence, simulating airway problems and developing adequate drills and algorithms appear to be a logical intervention. In fact, several studies have shown, in both simulated parturients and nonpregnant patients, that airway training does in fact significantly increase performance to an acceptable level and beyond [10–13].

Furthermore, individual performance can be assessed in simulated environments by utilizing standardized and validated scoring systems. Several studies have investigated junior doctors’ technical response and performance to medical emergencies and for several scenarios such as cesarean section an improvement in efficacy and overall management has been described [14,15]. Hence, individual assessment can be used as a measure of whether a resident is ready to be exposed to the “real-life” situations encountered in the labor suite.

Based on these experiences, several boards in various countries require — or at least recommend — participation in simulated clinical scenarios with feedback mechanisms. However, up until today there is a lack of data showing that all these measurable outcomes in the simulated environment actually do translate into a better clinical performance and thus saving lives. Even expert anesthesia providers tend to perform differently in the simulated environment and performance during simulated crisis resource management does not necessarily reflect clinical performance [16].

**Obtaining group performance skills**

Besides the development of individual task-based training, simulation furthermore offers the opportunity to simulate and evaluate group dynamics and their respective communication, behavior, or problem—solution strategies. As described earlier, the practice of anesthesia changes dramatically in the labor suite, exposing the anesthesiologist to a different environment with many different people of varying expertise, such as obstetricians, midwives, or pediatricians, and last but not least the (awake) parturient and her family. More than anywhere else, extended qualities in communication skills, distribution of workload during crisis, and debriefing are required and rightfully demanded by the patient.

A multitude of simulated labor suite scenarios are available that help to build a team approach by developing improved communication skills and helping the team to better understand the demands of the other providers involved, thus leading to an improved distribution of workload in simulated crisis management [17,18].

Furthermore, the group training is usually embedded in a clinical scenario, requiring participants to perform clinical skills. Hence, the group training does actually always also provide an individual (skill) training for the participant even though that may not necessarily be the main goal of the session.

Available data show that a team training is usually well accepted and liked by the participants [19,20]. Furthermore, improvements in team behavior that translate into better clinical performance can be shown, however, only in the simulator [19]. Again, it is not clear whether this also translates into better patient outcomes in the clinical setting. From what we have learned about simulation, it actually does seem unlikely that a single team training in the simulator does alter clinical behavior in the real-life setting. To really change a system, continuous and repetitive training in the simulator would be required to make the multiple repeated simulated situation the standard for clinical behavior that is then applied to the more rarely appearing real-life situation.

One study from 2008 found improved communication, debriefing, and overall team response to any given crisis in the clinical setting 1 year after a simulated team training [21]. However, the results were based on participants’ self-assessment and it is well known that people tend to overrate their experience and performance and its effects on real life, especially if it was enjoyable [22]. So these results should be interpreted with reasonable caution.
To date, only one study has appeared that demonstrates an improved outcome for neonates risk to develop hypoxic ischemic encephalopathy (HIE) after the initiation of a simulated team training in obstetric crisis [23]. The authors compared the years before the training was established and then after initiation of the training. They found a significant improvement in the number of neonates developing HIE; in fact, the number almost halved. Whether this can be attributed to the introduction of simulated crisis management alone is highly questionable. And if so, which part of the team training was the relevant bit: technical skills, team skills, or something else? Other effects may have played a major role here since it was a historical comparison not a randomized-controlled study. So even this study — in fact the only study showing any clinical benefit of simulation — has major limitations and must be interpreted with great caution.

Assessing the work environment

A further application of simulation that is often forgotten or considered as not so important is the assessment of the work environment. However, the authors of this review consider this as the most effective and worthwhile aspect of simulation for anesthesia in obstetrics. Performed similar to the team training, the work environment assessment does not concentrate on single person’s performances or team communication but instead investigates the work system as a whole as it tries to identify weaknesses in the (hospital) system, for example, how well can the team respond to a given crisis based on the infrastructure that is available. By simulating these scenarios, unsafe conditions can be identified in a safe learning environment and then (usually) be solved. However, establishing these scenarios is highly difficult for the providers as they require a perfect simulation of the real-world clinical environment which may include — but not limited to — laboratories, transfusion medicine, equipment (such as access to real instruments and machines), and real personnel [24–26]. This is obviously associated with high costs and may seem like an overwhelming organizational task [27]. However, it is well known from other high-risk industries such as aviation, space flight, or nuclear power stations that these work environment simulations are the most effective ones, as problems in the system are highly significant and usually better solvable than the difficulties of a single performer operating in a faulty system [28,29].

For the obstetric environment, several simulation scenarios have been developed and include situations such as the response to cardiac arrest, major hemorrhage, eclampsia, fire in the operating room, or failed intubation [30–32]. Many of these scenarios and drills have been developed by the relevant associations and can be obtained online.

There are only little data available about the prevalence of these in situ drill simulations in various countries. Data from England show that almost half of the obstetric units there actually do perform drills on a monthly basis [33]. The lack of data from other countries may suggest that these (costly) drills are scarcely performed.

Several studies have performed simulated drills for typical scenarios such as hemorrhage or eclampsia and all studies have described (latent) errors or problems in the system that were later solved based on the findings of these studies, without placing any patient at risk and may lead to an improved care of patients in the future [25,26]. These failures included problems such as difficulty to summon senior staff, which was resolved by installing a raid activation from switchboard with just one call or waste of time looking for individual items to treat seizures which was then solved by creating a designated “eclampsia box” with all equipment and drugs necessary to handle the situation. Other problems involved confusion about roles of staff or multiple different protocols in different units, which were solved by clearly dividing roles of staff and developing and disseminating evidence-based protocols for given situations.

Interestingly, failures in the system become more apparent when the acuity of the situation was increased. Riley et al. [26] calculated that with 208 clinicians potentially involved in handling an acute crisis in the obstetric unit, there were 381 million combinations of staff that could make up the team caring for the patient on any given shift. This alone appears to make it impossible that staff — even though they individually belief that they communicate well — actually do so in all possible combinations leading to miscommunications and — consequently — medical error.
Conclusion

Simulation may lead to improved individual technical abilities and better overall team performance resulting in improved patient care – at least in the simulated environment. With the currently available data, it remains a difficult task to show that these simulations do translate into better patient outcomes in the real-world clinical environment. With the immense costs and personnel involved in developing a proper simulation center and the apparent lack of data showing its clinical significance, it remains a difficult job to convince those distributing the money that simulation holds a potential key to better clinical outcomes and may in the long-term reduce costs. We have to rely on the experience of other high-risk industries that have already established a self-evident culture of simulation. The improvements that can be obtained by simulated work environment assessment are the most obvious and potentially most worthwhile.

For the individual anesthesia trainee, the simulator may help to improve technical and communication skills that provide him or her with the self-confidence to act professionally in the clinical environment that may otherwise seem like an uncomfortable place to be.

Practice points

- Obstetric units expose the anesthesiologist to uncomfortable territory involving work outside the operating theatre and involving many different clinicians in addition to an aware patient with relatives closely observing.
- Simulation for anesthesia in obstetrics can significantly improve both individual technical performance and team performance.
- It is unclear whether this translates into improved patient outcomes.
- Simulation is usually well liked by participants and hence easily accepted as a method of training.
- In-situ work environment simulation is currently the most useful but also the most expensive way to detect problems and latent errors in the system of the real-life work environment.
- There is a risk that participants of simulation training subsequently overestimate their performance ("Lake Wobegon effect").

Research agenda

- Further research is warranted to investigate the actual impact of simulator training on real-life patient outcome.
- It is unclear which part of simulation training may lead to improved outcome: individual technical skill training or group simulation?
- How do resources (physical/financial/models) influence optimal simulation learning?

References


Briefing and debriefing during simulation-based training and beyond: Content, structure, attitude and setting

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Keywords: communication debriefing learning patient simulation safety

In this article, we review the debriefing literature and point to the dilemma that although debriefings especially intend to enhance team (rather than individual) learning, it is particularly this team setting that poses risks for debriefing effectiveness (e.g., preference-consistent information sharing, lack of psychological safety inhibiting structured information sharing, ineffective debriefing models). These risks can be managed with a mindful approach with respect to content (e.g., specific learning objectives), structure (e.g., reactions phase, analysis phase, summary phase), attitude (e.g., honesty, curiosity, holding the trainee in positive regard) and setting (e.g., briefings to provide orientation and establish psychological safety). We point to the potential of integrating systemic methods such as circular questions into debriefings, discuss the empirical evidence for debriefing effectiveness and highlight the importance of faculty development.

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Debriefing is a core element of team learning and simulation-based training [1–5]. It is an instructor-guided conversation among trainees that aims to explore and understand the relationships among events, actions, thought and feeling processes, as well as performance outcomes of the simulation [1,3,6,7]. Those of us who have debriefed a team or have been debriefed after a simulation or an event have most likely gotten a feel for how challenging this conversation can be.

If a debriefing is such a challenging conversation, why could we as instructors not simply give feedback to the learners and hope they perform better next time? The answer is manifold: unidirectional feedback does neither help understanding the learners’ point of view, nor identifying the actual performance gap nor exploring the meaning of patterns among team members. Behaviour change is more likely to occur sustainably via double-loop (i.e., correcting errors by altering the underlying values and then the actions) than single-loop learning (i.e., correcting errors without changing underlying values) [1,8,9]. Adult learners benefit from experiential learning in which concrete experiences (e.g., participating in a simulated case) are the basis for observations and reflections that are consolidated into abstract concepts (e.g., during debriefings) that can be actively tested in a subsequent experience (e.g., participating in another simulated case) [10]. Ideally, debriefings allow for developing strategies that can be applied in future performance episodes [2,11–13]. This makes them a core element of team learning and simulation-based training.

In this article, we review the debriefing literature and describe debriefing pitfalls as well as ingredients for debriefing success with respect to content, structure, attitude and setting. These pitfalls and success criteria are not limited to the context of simulation-based training but can be applied to clinical debriefing contexts as well. In both contexts, debriefings are particularly used to facilitate team rather than individual learning [14,15]. Though essential, it is particularly this team-setting that poses risks for debriefing effectiveness [16]. We therefore start by highlighting this debriefing dilemma of having to reflect on teamwork (e.g., updating team mental models in a dynamic situation) within the team setting while dealing with common team phenomena (e.g., preference for talking about task work rather than teamwork).

Talking about teamwork

Why teams need to reflect on teamwork

The empirical evidence demonstrating that poor teamwork represents one of the major factors contributing to medical error and can result in the loss of life has been growing [17,18]. Still, medical and nursing schools do not yet sufficiently teach teamwork skills, resulting in clinicians’ underestimation of the contribution of teamwork to high-quality patient care [17]. The importance of good teamwork and the unawareness of this importance are all the more reason to help health care teams embrace teamwork and learn how to improve it.

Why teams need debriefings to reflect on teamwork

High team performance requires regular reflections on teamwork; teams that reflect outperform teams that do not reflect [19,20]. Unfortunately, teamwork is not yet a given, regular subject in clinical education. Students do not sufficiently learn how to work in inter-professional teams, let alone how to reflect on it. In addition, teams are generally reluctant to systematically talk about teamwork [21], explaining why discussions about teamwork rarely just happen [16,22–24]. Without debriefings that are explicitly initiated, embedded in simulation-based training or even in the clinical context, well-structured and supported by leadership, learning to improve teamwork will remain sparse.

Why debriefings need debriefing expertise

The limited use of debriefings in clinical practice may also be due to barriers that make team debriefing a daunting task (Table 1). As Eddy and colleagues put it, ‘if left on their own, teams often fail to debrief, and, even if they do, their natural information processing tendencies can inhibit the quality of the debrief’ (p. 4) [16]. Ill-structured debriefings risk failure due to individual and social phenomena
such as preference-consistent information sharing, lack of psychological safety inhibiting structured information sharing and ineffective debriefing models [16,22,25,26]. Without establishing debriefing routines, the undiscussable will hardly become discussable [27].

**Table 1**

<table>
<thead>
<tr>
<th>Level</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual</td>
<td>Cognitive biases, heuristics and errors such as the fundamental attribution error [28]</td>
</tr>
<tr>
<td></td>
<td>Lack of trained debriefing competence [29,30]</td>
</tr>
<tr>
<td></td>
<td>Lack of knowledge about human factors and teamwork patterns</td>
</tr>
<tr>
<td></td>
<td>Unilateral focus on either human or physical/environmental factors [31]</td>
</tr>
<tr>
<td></td>
<td>Talking primarily about actions instead of meanings, thoughts and feelings and interactions [26]</td>
</tr>
<tr>
<td></td>
<td>Premature feeling of certainty rather than being truly open for new perspectives which puts debriefers at risk to provide unidirectional feedback: they would tell their colleagues what they did wrong rather inquire their point of view and elicit mental models which would allow for detecting and correcting performance gaps in a sustainable way and permit double-loop learning from experience [1,8,22,28,32,33]</td>
</tr>
<tr>
<td></td>
<td>Stuck in dilemma of judgemental vs. non-judgemental debriefing [26,34]</td>
</tr>
<tr>
<td>Team</td>
<td>Reluctance against explicit communication among trainees [21]</td>
</tr>
<tr>
<td></td>
<td>More comfort with talking about technical aspects than with talking about teamwork [22]</td>
</tr>
<tr>
<td></td>
<td>Tendency to rather talk about issues that are already known to all team members instead of sharing new and unique perspectives [35,36]; especially during constrained time periods as is the case with debriefings [37]</td>
</tr>
<tr>
<td></td>
<td>Risk to share only information that is consistent with existing views [38]</td>
</tr>
<tr>
<td></td>
<td>Waiting until late in the debriefing before bringing up new information [16]</td>
</tr>
<tr>
<td></td>
<td>Not feeling psychologically safe to speak up [39]; especially young or subordinated team members would be less likely to speak up with ideas and concerns [40,41], and their ideas would probably not influence the debriefing outcome [35,42]</td>
</tr>
<tr>
<td></td>
<td>‘Undiscussable’ topics [27]</td>
</tr>
<tr>
<td>Organization</td>
<td>No organizational support and no clarification of roles</td>
</tr>
<tr>
<td></td>
<td>No embeddedness in organizational learning structure (e.g., no follow-up on issues raised in debriefings)</td>
</tr>
<tr>
<td></td>
<td>No ‘safe container’ for learning during simulation-based training [42]</td>
</tr>
<tr>
<td></td>
<td>‘Undiscussable’ topics [27]</td>
</tr>
</tbody>
</table>

Talking about the ‘right’ things in the ‘right’ way

**Ingredients for debriefing success**

To overcome the barriers for debriefing effectiveness, instructors can use a mindful interplay of content, structure, attitude and setting factors.

The content of the debriefing is to a large extent predefined by the learning objectives of the simulated case or the clinical encounter [43,44]. They provide the basis for defining the desired behaviour. After having observed a gap between (or match of) desired and actual performance, the instructor provides feedback on this gap (or match) and, with the team, investigates the basis for the gap (or match) by exploring the trainees’ underlying frames as invisible drivers of their actions [1,8,43]. Once frames are identified, the instructor helps the trainees to explore and reinforce frames that contributed to high performance and/or to close performance gaps by reframing and didactics [43]. Given that teams tend to talk about task work rather than teamwork, it seems useful to introduce those learning objectives involving teamwork, communication and crisis resource management early in the debriefing and to help the team surfacing dynamic interaction patterns [15,22,45]. Ideally, trainees leave a debriefing with a deeper understanding of how teamwork and human factors contributed to clinical outcomes [6,15,46].

Although the debriefing structure suggested in the literature varies to some extents, it usually follows three main phases: reactions, analysis and summary [23,43]. In the reactions phase, trainees can express their emotional reactions to the simulated case which also serve as critical information for the instructor and can help refine the learning objectives [15,43,47]. For example, if a trainee said that she found the simulation very chaotic, the instructor can help explore — during the later analysis phase — what might have contributed to the chaos and which interactions among team members may
facilitate order. The instructor also previews the purpose and form of the debriefing as well as provides facts about the simulated case and clarifies clinical questions, and may address issues of realism [15,42,43,48,49]. In the analysis phase, the instructor addresses each of the learning objectives, helps identifying performance gaps and provokes in-depth discussion allowing the trainees to reflect on their thinking behind their actions within the team and to close performance gaps [43,47,48]. In the summary phase, the instructor asks the trainees to distil their reflections into take-aways with respect to future performance [43,49]. If required and possible, deliberate practice of specific actions may follow the debriefing [15,50]. Recent research has also pointed to the crucial role of the pre-simulation briefing — as a precursory phase — for setting the stage for an engaging learning environment at all [42].

With respect to attitude we will highlight three mindsets which we consider vital for debriefing effectiveness: honesty, curiosity and holding the trainee in positive regard [1]. Over the last 15 years, debriefing concepts have moved away from the non-judgemental approach, which suggested that instructors should withhold their point of view and that trainees should find out on their own what they did wrong and how to improve it. For example, the training manual for facilitating line-oriented simulation (LOS) debriefings in aviation suggested that ‘rather than telling the crew what they did wrong during the LOS and how they can improve, try to get the crew to figure it out for themselves. If they discover what they need to work on by themselves, then they are much more likely to learn from their own mistakes and carry that learning over to the line' [...] If you give your analysis before the crew does, the crew will feel less responsible for making their own analysis’ (p. 4) [51].

By contrast, the more recent Debriefing with Good Judgment approach draws on research on behavioural and cognitive science and emphasizes the disclosure of the instructors’ point of view [26]. This approach proposes that ‘in spite of a desire to appear nonjudgmental, hints of one’s views often “leak” via subtle cues such as facial expression, [...] and body language’ and that withholding judgment ‘conveys that mistakes are not discussable, or possibly shameful, undermining the very values — mistakes are puzzles to be learned from rather than crimes to be covered up — instructors aim to endorse with the nonjudgmental approach’ (p. 52) [26].

Thus, to stop treating mistakes as an undiscussable topic, instructors must reveal their point of view [27]. The instructors’ honesty about their frames combined with genuine curiosity about the learners’ frames and holding the learner in positive regard is what Rudolph and colleagues have described ‘an underlying debriefing “stance”’ that facilitates double-loop learning [25,26].

Consequently, recent debriefing concepts are outlining how to create a setting in which trainees feel simultaneously challenged and psychologically safe to engage in rigorous reflection [42]. Particular times for creating such a setting are the pre-simulation briefing and the beginning of the debriefing in which the instructors provide transparency about objectives, expectations, rules of conduct and logistics [42,48,49]. The instructors can reinforce this setting by holding the underlying debriefing stance (i.e., honesty, curiosity, positive regard of trainee) and by talking via combining advocacy with inquiry [1,25,26,43]. An ideal setting does not leave the trainees guessing about expectations or the instructor’s point of view but provides orientation, engagement and curiosity. More literature findings on characteristics of effective debriefings are listed in Table 2.

**Briefing and debriefing tools**

In line with the growing realization of the importance of reflections during and beyond simulation-based trainings, more and more briefing and debriefing tools are developed:

For **briefings**, Rudolph and colleagues have suggested a way for establishing a ‘safe container’ allowing trainees to engage actively in simulation and debriefing. It includes clarifying expectations, establishing a fiction contract with trainees (i.e., collaborative and explicit agreement among instructors and trainees to commit to playing fair with respect to fidelity and realism), explaining logistic details and declaring and enacting commitment to respecting trainees and concern for their psychological safety [42,67].

For **debriefings**, the Debriefing with Good Judgment [1] is the fundamental approach stimulating the development of discipline-specific (e.g., the EXPRESS - Examining Pediatric Resuscitation Education
using Simulation and Scripting - debriefing tool for paediatric advanced life support training) [44] and supplementary approaches (e.g., TeamGAINS which includes systemic-constructivist techniques) [15] for simulation-based trainings. For debriefings outside of simulation, SHARP (Set learning objectives, How did it go?, Address concerns, Review learning points, Plan ahead) has been developed for debriefings in surgery [24] and DebriefNow has been developed as a web-based tool particularly focusing on teamwork and shared cognition [16,22].

### Table 2

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sample references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How?</strong></td>
<td></td>
</tr>
<tr>
<td>Explicitly initiated</td>
<td>[14,16,22]</td>
</tr>
<tr>
<td>Active (vs. passive)</td>
<td>[1,10,22,47,48,51,52]</td>
</tr>
<tr>
<td>Structured, following a specific order of questions (vs. unstructured), e.g., 1. Reactions, 2. Analysis, 3. Summarize</td>
<td>[1,15,16,22,49]</td>
</tr>
<tr>
<td>Developmental (vs. administrative) intend</td>
<td>[1,22,47,52]</td>
</tr>
<tr>
<td>Instructors/leaders should engage in leader inclusiveness (i.e., by explicitly inviting and appreciating team members’ input) to establish psychological safety in the team</td>
<td>[1,6,39,41,47,48,53,54]</td>
</tr>
<tr>
<td>With ‘good judgement’ (i.e., honest, curious, holding learner in positive regard, combining advocacy with inquiry) instead of judgemental or non-judgemental</td>
<td>[1,15,22,25,26,32,43,47,48,52,55]</td>
</tr>
<tr>
<td>Specific (vs. general)</td>
<td>[1,22,47,48,52]</td>
</tr>
<tr>
<td>Include multiple (vs. single) information sources; video-assistance is helpful but not necessary</td>
<td>[9,22,56]</td>
</tr>
<tr>
<td>Double-loop instead of single-loop learning, i.e., inquiry instead of only telling</td>
<td>[1,8,32]</td>
</tr>
<tr>
<td>Exploring team behaviour patterns via systemic-constructivist methods</td>
<td>[15,57]</td>
</tr>
<tr>
<td>Adaptive to team’s responsiveness</td>
<td>[51]</td>
</tr>
<tr>
<td>During simulation-based training: embedded in a psychologically safe training context with steps taken to allow for a fiction contract (both established in introduction/briefing and maintained during each debriefing)</td>
<td>[7,42,58,59]</td>
</tr>
<tr>
<td><strong>When (in clinical practice)?</strong></td>
<td></td>
</tr>
<tr>
<td>Regularly, consistently</td>
<td>[14,22]</td>
</tr>
<tr>
<td>After any team experience</td>
<td>[22]</td>
</tr>
<tr>
<td>Depending on learning objective either terminal or concurrent</td>
<td>[9]</td>
</tr>
<tr>
<td>After real patient cases or work shifts</td>
<td>[22]</td>
</tr>
<tr>
<td>Close in time to the performance of interest to avoid loss of information</td>
<td>[22]</td>
</tr>
<tr>
<td>During team transition phases</td>
<td>[20,60–62]</td>
</tr>
<tr>
<td><strong>How long?</strong></td>
<td></td>
</tr>
<tr>
<td>Usually 30 min, but can be as short as 5 min</td>
<td>[22,52]</td>
</tr>
<tr>
<td>During simulation-based training: 30–60 min</td>
<td>[15,52]</td>
</tr>
<tr>
<td><strong>By whom?</strong></td>
<td></td>
</tr>
<tr>
<td>Trained instructors who regard learners as intelligent, competent, willing to do their best and wanting to improve and who are open for learners</td>
<td>[1,13,26,43]</td>
</tr>
<tr>
<td>Personal instructor (vs. multimedia with no instructor)</td>
<td>[9]</td>
</tr>
<tr>
<td>Trained team leaders and facilitators</td>
<td>[1,6,15,22,47,59,63,64]</td>
</tr>
<tr>
<td>Physicians and nurses trained in conducting debriefings</td>
<td>[14,24]</td>
</tr>
<tr>
<td><strong>What about?</strong></td>
<td></td>
</tr>
<tr>
<td>Predefined learning objectives of the simulated case or the clinical encounter</td>
<td>[43,44]</td>
</tr>
<tr>
<td>Interplay of cognition, clinical and teamwork behaviours, and clinical and behavioural outcome, crisis resource management</td>
<td>[6,15,43,51]</td>
</tr>
<tr>
<td>Teamwork (as early as possible); interaction patterns among team members and their meaning</td>
<td>[6,15,22,45]</td>
</tr>
<tr>
<td>Role-behaviour</td>
<td>[14]</td>
</tr>
<tr>
<td>Frames that led to observed actions</td>
<td>[1,8,43]</td>
</tr>
<tr>
<td>Exploring both positive (i.e., reinforcing ideal actions) and negative (i.e., closing performance gaps) performance outcomes</td>
<td>[15,43,63,65]</td>
</tr>
<tr>
<td>The ‘elephant in the room’</td>
<td>[27,66]</td>
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Applying systemic-constructivist methods to reflect on team interaction

Systemic-constructivist techniques have recently been introduced as a promising complement to established debriefing approaches [15,57]. They are based on family systems theory and constructivism as they are used in systemic therapy. Systemic therapy focuses on individuals within their systems, looking at patterns and dynamics of interactions rather than at isolated individual behaviour [68]. This makes them suitable for reflection on team interactions.

A particularly useful systemic technique is the circular question. Circular questions explore a dyadic relationship as it is seen by a third person by inviting the third person to describe the relationship between two others in their presence, for example, by asking a daughter how she sees the relationship between her sister and her mother [69]. They were initially developed as an interviewing tool but were soon considered an intervention tool in itself, triggering change [69—71]. By asking circular questions, an instructor can explore interactions, challenge linear perceptions of causality and introduce a circular perspective [70]. This not only helps the team learn about the recursiveness of behaviour patterns and view itself systemically, [72,73] but also helps revealing that views about problems and solutions may not be identical and that team members may have contrasting frames, thus enabling reflection on social phenomena such as the false consensus effect (i.e., tendency to overestimate the commonness of one’s beliefs) [70,74]. As a side effect, the — often surprising — information gain might help the instructor maintain their curiosity [75]. Circular questions can complement common debriefing approaches. For example, if a nurse responded to the instructor’s open-ended inquiry of the Debriefing with Good Judgment approach [1] (e.g., ‘What was on your mind at that time?’) with ‘I thought that I would prepare the intubation while the registrar would start chest compressions’, the instructor could explore this delayed start of the CPR with a circular question (e.g., ‘Whose is usually the first to voice his or her concerns about delaying the start of CPR?’). More examples of circular questions are listed in Table 3.

Does it matter? Evidence for debriefing effectiveness

Research on debriefings is growing. A recent meta-analysis found that debriefings improved performance by 20–25% on average [76]. In surgery, for example, regular, role-based and guided debriefings were found to be associated with higher team performance [14]. However, empirical research investigating how differences in instructor communication are related to differences in debriefing outcome is just beginning to emerge. Although there is evidence demonstrating that facilitated debriefings are much more effective than non-facilitated debriefings, few studies have compared different debriefing facilitation methods or examined how differences in debriefer communication impact trainees’ learning [16,24,55,76,77]. In addition, most studies examined debriefing effectiveness on the individual rather than team level and studied business students in experimental contexts rather than teams in the training or clinical setting, leaving open whether or how their findings are generalizable to non-experimental and team contexts [16,78—80]. Thus, in spite of the general evidence that debriefings work, more detailed, empirical research is necessary [4,76,81].

Table 3
Examples of circular questions.

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<th>Focus [69]</th>
<th>Sample question</th>
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<td>Specific interactions patterns</td>
<td>‘When a consultant joins the management of an unexpected difficult situation, what does the registrar usually do?’</td>
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<td>Differences in behaviour rather than personality traits</td>
<td>‘What does your consultant do when she seems not interested in hearing your point of view?’</td>
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<td>Ranking and classification</td>
<td>‘Who can speak up the most to the registrar when he seems stuck in an unsuccessful intubation?’</td>
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<td>Change in the relationship before and after an event</td>
<td>‘Do you feel that your colleagues shared their points of view more frequently before or after the consultant entered the OR?’</td>
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<tr>
<td>Hypothetical conditions</td>
<td>‘If an intern had just observed you managing that case, what do you think he might have learned?’</td>
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Raemer and colleagues have suggested a guiding framework for debriefing research combining the ‘5 Ws’ of debriefing research (Who?, What?, When?, Where?, Why?) with the PICO concept (population, intervention, comparator, outcome) [4].

**Conclusion**

As conducting debriefings is a challenging task — especially in light of the instructor’s feedback dilemma of offering honest feedback without damaging the relationship with the trainees [25] — instructors benefit from deliberate practice as well as from training helping them to reflect on their debriefing practice [6]. Faculty development programmes can help instructors on basic, intermediate and advanced level to develop and enhance their debriefing competence. Especially for instructors on intermediate and advanced levels, regular, formative evaluation of their debriefings can provide feedback on strengths and fields of improvement. Validated tools for debriefing assessment are available, such as the Debriefing Assessment for Simulation in Healthcare (DASH) [7] and the Objective Structured Assessment of Debriefing (OSAD) [47]. In addition, as frequently done by psychotherapists, watching one’s own videotaped debriefings can provide useful information for reflecting on one’s debriefing practice [82].

**Practice points**

- Debriefing is different from unidirectional feedback. It aims for understanding the trainees’ point of view, exploring interaction patterns among trainees, and identifying and closing actual performance gaps in a sustainable way.
- Debriefings rarely just happen because teams are generally reluctant to talk about teamwork. Teamwork is not yet a regular subject in clinical education and students do not yet learn how to reflect on it.
- Ill-structured debriefings risk failure due to pitfalls (e.g., preference-consistent information sharing, lack of psychological safety inhibiting structured information sharing and ineffective debriefing models).
- To overcome barriers for debriefing effectiveness, instructors can mindfully use an interplay of content, structure, attitude and setting factors.
- The content of the debriefing is predefined by the learning objectives of the simulated case or the clinical encounter, should focus on invisible drivers of actions rather than on actions only. Teamwork, communication and crisis resource management should be introduced early in the debriefing.
- The debriefing should follow a structure in which an initial reactions phase is followed by an in-depth analysis phase (including a preview of aim and content) and a concluding summary phase.
- Honesty, curiosity and holding the trainee in positive regard are necessary as well as helpful attitudes of instructors.
- Instructors need to create a setting in which trainees are not left guessing about expectations or the instructor’s point of view but are provided with orientation, engagement and curiosity.
- Systemic-constructivist techniques such as circular questions are specifically suitable for reflecting on team interactions and can complement other debriefing approaches.
- Regular, formative evaluation of debriefings using validated assessment tools and targeted faculty development programmes can help instructors develop and enhance their debriefing competence.
Conflicts of interest statement

MK and BG received a grant from the Swiss National Science Foundation for the project ‘Debriefings as Enabler for Learning in Ad-hoc Action Teams in Healthcare’. MK and BG received their simulation instructor training from the Institute of Medical Simulation at the Center for Medical Simulation in Boston, MA.

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