



Review article

Simulation as a Surgical Teaching Model[☆]

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A B S T R A C T

Teaching of surgery has been affected by many factors over the last years, such as the reduction of working hours, the optimization of the use of the operating room or patient safety.

Traditional teaching methodology fails to reduce the impact of these factors on surgeon's training. Simulation as a teaching model minimizes such impact, and is more effective than traditional teaching methods for integrating knowledge and clinical-surgical skills.

Simulation complements clinical assistance with training, creating a safe learning environment where patient safety is not affected, and ethical or legal conflicts are avoided.

Simulation uses learning methodologies that allow teaching individualization, adapting it to the learning needs of each student. It also allows training of all kinds of technical, cognitive or behavioral skills.

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La simulación como modelo de enseñanza en cirugía

R E S U M E N

La enseñanza de la cirugía se ha visto afectada por múltiples factores a lo largo de estos últimos años, como son la reducción de la jornada laboral, la optimización del uso del quirófano o la seguridad del paciente.

La metodología de enseñanza tradicional no logra minimizar el impacto de estos factores en la formación de los cirujanos. La simulación como modelo de enseñanza minimiza dicho impacto y es más eficaz que los métodos docentes tradicionales para integrar los conocimientos y las habilidades clínico-quirúrgicas complejas.

Palabras clave:

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La simulación complementa la asistencia clínica al paciente con la formación, creando un entorno de aprendizaje seguro en el que no se ve afectada la seguridad del paciente ni se generan conflictos éticos ni legales.

Las metodologías de aprendizaje que utilizan la simulación permiten individualizar la enseñanza adaptándola a las necesidades de aprendizaje de cada alumno. Además, permiten entrenar todo tipo de habilidades técnicas, cognitivas o de comportamiento.

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Introduction

Traditionally, surgeons learn surgical techniques by following the classic methodology designed in the 19th century by William Steward Halsted. This methodology is based on the progressive assumption of responsibilities by the surgeon-in-training, tutored by a surgeon with greater experience, with training techniques used directly on the patient.

Currently, surgeon training with the traditional methodology is under pressure from various fronts, including the limited training time, the large amount of skills to be acquired, and the concern for guaranteed patient safety, while health-care administrators look to control costs.¹

In this study, we analyze in detail the characteristics of simulation as a teaching tool, advantages that it can provide compared with the traditional method, as well as solutions that it may contribute to the different factors currently affecting the education and training of surgeons.

What Are the Characteristics of Simulation?

Complement to the Clinical Setting

Today's hospitals are excellent tools for patient diagnosis and treatment, but it is becoming increasingly complicated for them to continue functioning as teaching instruments, as patients are more complex and medical professionals have a more limited schedule.² Simulation arises as a complement to the time that surgeons educate to patient care. Training by means of simulation does not substitute the immeasurable value of the clinical experience; instead, it complements it.

Creation of a Safe Training Setting

Simulation is able to realistically reproduce many work situations of healthcare professionals, from the Emergency Room to the operating room. The objective is to provide training for professionals, without endangering patient safety. Surgeons should not complete their learning curve in the operating room, for the sake of patient safety, quality care, cost savings of an operation and patient complications.

Currently, what is becoming more relevant in surgical training is not just knowing, but knowing how to do and doing. Hence, in order to pass from training to clinical practice, the surgeon should objectively demonstrate that he/she has acquired competence. To this end, simulation can play a key role in the evaluation of competence.

Training in All Types of Skills

Simulation enables training of different skills that comprise the spectrum of professional competence. Technical, cognitive and behavioral abilities are objectives that can be achieved with simulation-based training.

The effectiveness of training based on simulation has been demonstrated for the acquisition of technical skills, especially in minimally-invasive surgery, where we have gone from wondering if simulation is effective for training to wondering how to make it more effective.^{3,4}

Development of Flexible and Individualized Training Programs

Simulation is able to carry out competence-based training and to center learning on the student more than on the content or the instructor. In this manner, *à la carte* training programs can be designed according to the needs of the hospital, patients or the surgeons themselves. If the needs are identified, specific programs can be developed aimed at resolving these gaps in training.⁵

Acceleration of the Learning Process

Training through simulation shortens the learning curve of minimally-invasive surgical procedures compared to the traditional methodology.^{6,7} The training objective is to achieve what is known as a *pretrained novice*.⁸ A pretrained novice can be a resident that has been trained with simulation techniques until achieving automatization of surgical motor skills, in such a way that, when the resident is in the operating room, he/she can concentrate on superior skills, such as identifying and predicting the steps of the procedure or the management of unforeseen intraoperative complications.

Feedback and Debriefing

Experience is not a synonym of expertise; better yet, expertise is not experience alone. There are many factors of learning that modulate results, and one of the most important is the possibility to be supervised by an expert during the learning process.⁹ Repetition of psychomotor skills is a condition necessary for learning, but it is not enough. The help of an expert instructor plays a crucial role in the learning process, but that role should be carried out carefully to be effective.

The instructor has available 2 powerful weapons for learning to be successful: *feedback* and *debriefing*. The instructor should be a clinical expert in order to teach what

should be done, but, in addition, the instructor should be an expert in education. Using feedback, the instructor provides the student with the information generated during training.

Experts in education recognize feedback as a fundamental element in learning.¹⁰ They do not consider it a criticism, but instead a correction in behavior necessary to learn new skills.

Hewson and Little¹¹ described the ideal characteristics of feedback: it should be respectful of participants, be centered around behaviors and not persons, and provide suggestions for improvement in the development of the task.

The power of feedback lies in its capability to integrate the information generated and motivate patients to reach the goals sought after, while providing the capability for self-evaluation.¹²

Feedback can be classified as formative or summative. Formative feedback provides detailed information about the behavior or skill while it is being carried out, evaluating it as either correctly or incorrectly performed, which is able to improve what is being learned as it is happening. Summative feedback takes place after the training process has been completed, and its objective is to establish assessment of the training performance.

Overall, formative feedback is superior to summative feedback, except in 2 situations: those cases in which the task is very simple, or when the participant is an expert.¹³

The most extensive manner to provide *feedback* is through instructors. These instructors are usually physicians who are experts in what is being taught, although lately there is much talk about the role that could be played by other non-medical staff, such as educators.¹⁴

Feedback can also be classified as immediate or delayed. Immediate feedback is provided immediately after the performance, with the advantage of correcting actions before becoming fixed in the participant's memory. This, however, requires a dynamic educational setting. Delayed feedback is given to the participant once the practical session has ended. The advantage of the delay is that it allows the participant to devote all their attention to the content of the feedback itself. Feedback provided immediately to a participant with a heavy workload can be detrimental. Immediate feedback is associated with better and faster learning, while delayed feedback is associated with better retention over time. In short, feedback is a very important part of the learning process, but it must be timely, specific and provide advice for improvement.¹⁵

Debriefing is a term that refers to a kind of feedback given to participants after a simulation experience. In the context of the education of medical professionals, debriefing is a standardized process that takes place between the instructor and the participants when the simulation has ended. By evaluating the session, the objective is to have participants reflect on their actions, which is a starting point for improvement in the near future. For a participant to improve, it is not enough for the instructor to describe what he/she has done wrong and what should be done to improve the final result. This approach is only valid for simulations of very simple procedures; in complex scenarios, a more in-depth approach is required.

In order for participants to retain what they have learned during simulation and for an effective change to take place in their actions, they must be able to develop ideas about what

guided their actions and have an opportunity to talk about them. Discovering and examining the impact of the cognitive and emotional process that is behind the performance of an individual and a whole team can dramatically improve learning and subsequent clinical performance. At that time, instructors and participants decide what actions should be changed in the future.

Debriefing is a key tool to improve learning and the transference of knowledge to the clinical environment by understanding the thoughts, assumptions and feelings that motivate the actions of participants. Providing ideas offers them a unique opportunity to improve their clinical activity by changing the way they perform their clinical tasks.¹⁶

Interprofessional Training

In the last 10 years, there has been a worldwide change from healthcare based on expert professionals to a medical practice based on expert interprofessional teams. There is growing literature that describes this type of approach, its development, implementation, evaluation and, most importantly, its educational and clinical value.¹⁷

Given its intrinsic characteristics, simulation is an ideal method for team training. It allows for practicing communication, decision-making and resource management during crises,¹⁸ aspects that are fundamental in the training of multidisciplinary and interprofessional teams.

Simulation offers participants the possibility to face real-life situations and, therefore, to reflect on how organizations work and why individuals behave as they do during simulation. This helps trainees learn how to be more effective when working as part of a team. Let us be reminded that the report of the American Institute of Medicine (*To err is human*) identified human factors as a key component of errors, and that insufficient or ineffective communication among professionals is a contributing factor in 60%–80% of adverse events around the world.¹⁹

Technique Standardization

The lack of consensus on the ideal steps to follow in a given situation is what leads to variability in medical practice. Training with specific objectives, followed by structured evaluation, is a powerful tool to improve variability in patient care and efficiency in the use of resources.

In the traditional training model, the training of medical professionals, particularly residents, depends on chance. In order to learn how to perform a procedure, the patient must be available at the time the resident is prepared to operate, which depends on many factors, such as luck, having the necessary skills at that moment, being present in the hospital, or that the head surgeon agrees to assist during the procedure.²

R+D+i+d Opportunities

Simulation as a training methodology allows for new knowledge to be discovered and existing knowledge to be improved (Research). It also allows research results to be applied for the development of new materials and the testing of new technologies (Development).

In addition, it stimulates creativity, generating activities that culminate in higher quality care and professional activities (innovation). It also provides for the communication of advances that are made (disclosure).²⁰

Stimulation of Learning

Simulation creates an exciting environment that stimulates learning and recall of the experience. It seems paradoxical that an artificially created medical experience can provoke such an intense emotional response in students. The explanation of this event is inferred from the circumplex model of affect.^{21,22} This model has been interpreted and applied by researchers at the Institute for Medical Simulation of the Center for Medical Simulation in Boston (Massachusetts, USA) and offers a theoretical basis from which to understand why simulation offers a learning experience that is so intense yet safe for patients.²³

This model derives from research about the understanding of how human beings respond emotionally. The model maintains that people move between 4 rather broad, preconceived emotional states: (1) comfort, well-being and activation (happy, excited); (2) comfort, well-being and low activation (calm and relaxed); (3) uncomfortable and low activation (sad and bored); or (4) uncomfortable and activation (nervous and stressed). During a learning experience, emotion generates a lasting fixation. It is very important to know how to correctly use the participant's emotional state to generate effective, long-lasting knowledge.

Kolb's experiential learning theory explains how a learning experience generates new knowledge. The participant reflects on what happened to later conceptualize it and relate it to his/her usual professional practice (what I have learned has to do with . . .; this could be applied to . . .). After finding the "niche" where that experience can be applied, it is time for experimentation by applying the learned knowledge in either real life or laboratory work to perfect the technique before carrying it out with patients.

Another theory that helps comprehend why simulation is so effective in learning is the "theory of change"²⁴ developed in 1947 by the German-American psychologist Kurt Lewin (1890-1947). This theory helps understand why a person (in this case a medical professional) decides to seek an educational experience with the intention of improving. This happens in 3 stages: (1) defrost, (2) change, and (3) freeze. Defrosting begins when a person realizes that their current behavior is not appropriate and this triggers a feeling of discomfort that induces a desire for change. This change will allow the participant to adopt new knowledge, skills or attitudes in their professional life. This new knowledge replaces previous knowledge, the level of restlessness diminishes and disappears completely once the new knowledge has crystallized in our mind. Simulation as a teaching tool is in tune with pedagogical principles for adults.²⁵

Deliberate Practice

Deliberate practice refers to a training mode that does not consist in the mere repetition of training as a learning method, but instead training specially designed to improve perfor-

mance. The main force behind deliberate practice is the student's motivation to improve their skills, which feeds the effort involved in embarking on deliberate practice. According to Ericsson, deliberate practice must be structured around perfectly defined tasks, with a set duration for training sessions, as well as immediate feedback for the correction of errors.²⁶ The ultimate goal of deliberate practice goes beyond the concept of becoming an expert; its goal is for people to reach the level of master, although not all do.

Another important concept in the training structure is the sequential steps of learning. Complex procedures are broken down into their basic components for training. This is called partial task training. The participant gains skills in the individual parts before moving on to the complex task.²⁷ The objective of this type of training is the reduction of the high demand of mental resources that are entailed in a complex task.

The chronological pattern of the practices, meaning how they are distributed over time, is another crucial aspect in the design of a learning method. From this point of view, practical sessions can be programmed in 2 different ways: concentrated or spaced out over time (distributed). There are several reasons why distributed practice is considered preferable for learning psychomotor skills:

- (a) From a mental standpoint, fatigue interferes with skill training. During the initial stages of acquiring a new skill, the mental demands are very high and fatigue can interfere with learning. Therefore, it has been stated that surgical skills should be practiced for a maximum of 1.5 h, with interspersed breaks between sessions and a maximum of 2 sessions per day.^{28,29} The same happens with physical fatigue that hinders learning: spaced practice periods allow for recovery between sessions and improve training effectiveness.³⁰
- (b) Most learning takes place more during rest periods than during the training itself. Spaced-out practice sessions allow for what is learned to be consolidated, typically during sleep.^{30,31} Mental consolidation is the process by which new memories, which are fragile by nature, take hold in our brain. This process is similar for mental and psychomotor skills.
- (c) Massive amounts of practice lead to the overestimation of the skills acquired by the participant, which affects long-term retention.³⁰
- (d) Each time a new training episode is initiated, there is a distance between the current level of the participant and the level of skill to be achieved. This distance is typically smaller in cases of massive practice, because it is occupied by knowledge and memory of the skills practiced recently, so the participant needs to make little effort. In cases of staggered practice, the memory must be activated before each training session, which forces the participant to invest a greater doses of effort to reach the required skill level, which facilitates and reinforces the acquisition of the skill.³⁰ For all these reasons and according to the psychological literature, distributed practice provides for better long-term retention of what is learned than massive practice.^{30,32}

The duration of rest periods continues to be a matter of debate. The nature of the task and the level of the participants are 2 important parameters to define the duration. In the case of simple tasks, learning is best with short intervals between training sessions, while for complex tasks or procedures the intervals should be longer.¹³

Discussion

Throughout history, surgeons have learned new surgical techniques by following a traditional methodology by practicing directly on patients, viewing videos on different internet platforms, attending courses and conferences of different duration, or participating in fellowship programs with progressively increasing surgical responsibility.

Training or learning through simulation is done outside the clinical treatment of patients, using realistic simulated environments, which guarantees patient safety as they are not affected by learning errors. Furthermore, surgeons-in-training have the time necessary to acquire a sufficient level of competence for maximum performance in the operating room.

It is known that the learning curve for technical skills acquired through simulation, especially those related to minimally invasive surgery, is shorter than when using the traditional methodology.⁸ In addition, the stimulus and the involvement of the trainee in the learning process is also greater.^{21,22}

It has been shown that simulation is more effective than traditional teaching methods to promote the integration of knowledge and complex clinical-surgical skills, increasing the retention of what has been learned.³³⁻³⁷ This applies to technical skills as well as behavior and decision-making.³⁸ Authors like Varas have shown that these skills acquired through simulation are transferred to the work environment (operating room) with better results than those acquired by traditional methods, which would lead to improved quality of care.³⁹

The methodology used in simulation should include feedback between instructors and trainees, as this increases the performance of learning and long-term retention. It also increases the involvement of the trainee in the learning process, which is motivation to improve the use of the practice.⁴⁰

The training methodology should be designed with perfectly defined tasks aimed at improving skills and correcting errors.²⁶ In addition, unlike the traditional methodology, simulation allows for tasks to be trained in parts, so simple skills are learned first and, once these are mastered, more complex tasks are learned thereafter.²⁷

After designing a new training methodology, it is important to evaluate it and demonstrate its effectiveness in learning the technical skill for which it was designed.⁴¹ The evaluation should be done with validated measurement tools that also serve to evaluate the competences acquired by the participants after training and their transference to the real work environment (operating room).

Conflict of Interest

The authors have no conflict of interests to declare.

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