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Recommendations to Develop a Laparoscopic Surgical Simulation Training Program. Insights Gained After 12 Years of Training Surgeons

Recomendaciones para desarrollar un programa de formación en simulación quirúrgica laparoscópica. Perspectivas obtenidas tras 12 años de formación de cirujanos

Recomendações para o desenvolvimento de um programa de formação em simulação cirúrgica laparoscópica. Perspectivas obtidas após 12 anos de formação de cirurgiões

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ABSTRACT

Introduction. The use of simulation in surgery has made it possible to shorten learning curves through deliberate practice. Although it has been incorporated long ago, there are still no clear recommendations to standardize its development and implementation. This manuscript aims to share recommendations based on our experience of more than twelve years of employing and improving a methodology in laparoscopic surgical simulation. **Topics for Reflection.** To transfer surgical skills to a trainee, we base our methodology on a three-pillar framework: The hardware and infrastructure (tools to train with), the training program itself (what to do), and the feedback (how to improve). Implementing a cost-effective program is feasible: the hardware does not need to be high fidelity to transfer skills, but the program needs to be validated. These pillars have evolved over time by incorporating technology: the on-site guidance from experts has changed to a remote and asynchronous modality by video recording the trainee's execution, and by enabling remote and asynchronous feedback. The feedback provider does not necessarily have to be an expert clinician in the subject, but a person previously trained to be a trainer. This allows for deliberate practice until mastery has been reached and learning curves are consolidated. **Conclusions.** Recommendations based on the experience of our center have been presented, explaining the framework of our strategy. Considering these suggestions, it is hoped that our simulation methodology can aid the development and implementation of effective simulation-based programs for other groups and institutions.

Keywords:
Simulation Exercise; Laparoscopy; Education, Medical; Feedback; Simulation Training; General Surgery.

RESUMEN

Introducción. El uso de la simulación en cirugía ha permitido acortar las curvas de aprendizaje mediante la práctica deliberada. A pesar de que se ha incorporado previamente, aún no existen recomendaciones claras para estandarizar su desarrollo e implementación. Este manuscrito pretende compartir recomendaciones basadas en nuestra experiencia, con más de doce años empleando y mejorando una metodología en la simulación quirúrgica laparoscópica. **Temas de reflexión.** Para transferir las habilidades quirúrgicas a un aprendiz, basamos nuestra metodología en un marco de tres pilares: El hardware y la infraestructura (herramientas con las que entrenar), el programa de entrenamiento (qué hacer), y la retroalimentación (cómo mejorar). La implementación de un programa rentable es factible: el hardware no necesita ser de alta fidelidad para transferir las habilidades, pero el programa necesita ser validado. Estos pilares han evolucionado a lo largo del tiempo incorporando tecnología: la presencia de expertos ha evolucionado a una modalidad remota y asincrónica mediante la grabación en vídeo de la ejecución del alumno, y permitiendo su retroalimentación. Aquel que entrega retroalimentación no tiene que ser necesariamente un clínico experto en la materia, sino una persona previamente formada como instructor. Esto permite una práctica deliberada hasta dominar la habilidad y establecer curvas de aprendizaje. **Conclusiones.** Se han presentado recomendaciones basadas en la experiencia de nuestro centro, explicando el marco de nuestra estrategia. Teniendo en cuenta estas sugerencias, se espera que nuestra metodología de simulación pueda ayudar al desarrollo e implementación de programas efectivos basados en la simulación a otros grupos e instituciones.

Palabras clave:
Ejercicio de Simulación; Laparoscopía; Educación Médica; Retroalimentación; Entrenamiento Simulado; Cirugía General

RESUMO

Introdução. O uso de simulação em cirurgia tornou possível encurtar as curvas de aprendizagem por meio da prática deliberada. Embora tenha sido incorporado anteriormente, ainda não há recomendações claras para padronizar seu desenvolvimento e implementação. Este manuscrito pretende compartilhar recomendações com base em nossa experiência, com mais de doze anos usando e aprimorando uma metodologia em simulação cirúrgica laparoscópica. **Temas de reflexão.** Para transferir habilidades cirúrgicas para um aprendiz, baseamos nossa metodologia em uma estrutura de três pilares: o hardware e a infraestrutura (ferramentas para treinar), o programa de treinamento (o que fazer) e feedback (como melhorar). A implementação de um programa rentável é viável: o hardware não precisa ser de alta fidelidade para transferir as habilidades, mas o programa precisa ser validado. Esses pilares evoluíram ao longo do tempo incorporando a tecnologia: a presença de especialistas evoluiu para uma modalidade remota e assíncrona por meio da gravação em vídeo do desempenho do aluno e permitindo seu feedback. Quem dá feedback não precisa ser necessariamente um clínico especialista na área, mas sim uma pessoa previamente treinada como instrutor. Isso permite a prática deliberada até que a habilidade seja dominada e estabeleça curvas de aprendizado. **Conclusões.** Foram apresentadas recomendações baseadas na experiência do nosso centro, explicando o enquadramento da nossa estratégia. Levando em consideração essas sugestões, espera-se que nossa metodologia de simulação possa ajudar outros grupos e instituições a desenvolver e implementar programas eficazes baseados em simulação.

Palavras-chave:
Exercício de Simulação; Laparoscopia; Educação Médica; Retroalimentação; Treinamento por Simulação; Cirurgia Geral

Introduction

What is simulation?

Simulation is the technique that recreates a real scenario and allows it to be replaced by an interactively guided scenario (1). The increasing demands of society have required simulation to be installed as part of the gold standard in training, especially in the area of health education, where patient safety has become a priority (2).

The history of simulation dates back to the time of Susruta, a physician by profession in 800 BC, in India. He recommended the use of melons, pieces of leather, or cloth to learn how to make incisions, ligatures, and sutures (3). The introduction of mannequins in medical training began in France in the 18th century with Angélique Du Coudray, who as a midwife recreated a female pelvis covered in rag and leather, together with a life-size rag doll of a newborn. It was she who gave origin to the expression "to make learning palpable" (4).

In 1960, Asmund Laerdal's model recreated the first life-size simulator for cardiopulmonary resuscitation training, called Resusci-Anne, giving birth to the high-fidelity simulators we know today (5).

Modalities of simulation

According to the Healthcare Simulation Dictionary, modality is the term used to refer to the type of simulation equipment or methodology used in a simulated scenario (6,7), in which we can find:

- Partial task simulators: equipment that recreates only a part of the body. They are used for basic psychomotor tasks such as orotracheal intubation, venous puncture, or central venous catheter installation.
- Simulated or standardized patients: actors trained in interaction as if they were patients. They are used to train interpersonal skills such as delivering bad news or obtaining a medical history.
- On-screen virtual simulators: a situation is recreated in computer programs. They are used to evaluate decision-making or knowledge. Our group also considers the inclusion of augmented, mixed and virtual reality.
- Complex task simulators: a combination of part-task trainers and the use of software and devices. They are used to train for tasks that require three-dimensional orientation skills, for example, laparoscopic or endoscopic training.
- Full patient simulator: life-size mannequins that nowadays incorporate the possibility of computational management of various aspects. They are used to develop competencies in crisis scenarios and to improve teamwork.

There are also new modalities that have arisen from combinations of the previous ones:

- Hybrid patient simulation: simulated patients are combined with part task trainers, e.g., a trained actor with a silicone pad attached to the arm for suturing skills. They are used to develop technical and non-technical skills (8).

Levels of fidelity in simulation

Fidelity is defined as a multi-dimensional concept corresponding to the degree of realism created through the selection of simulation equipment, setting, and scenario, according to the Healthcare Simulation Dictionary (7). There are several levels defined:

- High fidelity: integration of multiple variables that consider the creation of realistic scenarios and

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combine technical and non-technical skills training. For example, crisis scenario training.

- Intermediate fidelity: a combination of an anatomical part with less complex computer programs aiming to develop specific competencies. For example, training in cardiopulmonary resuscitation using a manikin.

- Low fidelity: low complexity simulation that seeks to train psychomotor skills. For example, venous puncture.

There might be a tendency to think that using high-fidelity simulation will always have faster and better results (higher-faster-further attitude), but this is not the case. Using high-fidelity scenarios may cause overconfidence (9) or increase the cognitive load on the learner and block their learning, which could eventually be detrimental. This could also result in an inappropriate use of expensive resources, which is usually the case in high fidelity models (10).

Simulation in surgery

Traditionally, surgery has been taught by a mentor or an expert. It was in the late 19th century that Dr. William Halsted created the first official surgical training programs in the United States at the John Hopkins Hospital (11). The methodology used in this first surgical residency program was based on the mentorship model. It consisted of giving a demonstration of an ability to the apprentice so that he or she could then execute it and finally transmit this knowledge to other apprentices. These principles were coined by Halsted, known as "see one, do one, teach one" (11).

Simulation in surgery allows one to practice a new skill for the first time and be able to make mistakes in a safe and controlled environment (12,13). Carefully dissecting a procedure into fragments or steps and being able to dedicate oneself to mastering one step at a time before moving on to the next, thus adding complexity until the procedure is performed to perfection, are the paradigms of Mastery learning (14). Added to Deliberate practice, according to Ericsson et al. understood as "a quality practice that includes individualized training of a trainee by a well-qualified teacher, who must be able to communicate the goal to be achieved by the trainee, and describe a practice activity to attain the identified goal", (15), are the secrets to getting the most out of simulated training (16).

Laparoscopic simulation is a feasible training strategy that has demonstrated not only the acquisition of competencies in the lab but also its transference to the operating room (12,17). To achieve the transfer of skills, it is necessary to generate an environment conducive to deliberate practice (18). The difficulty in achieving this lies in the fact that nowadays there are restrictions on practice schedules during residency, simulation facilities are limited, and the availability of experts to provide feedback is scarce (19,20).

What the pandemic taught us is that simulated training is a feasible and effective option (21). Faced with the problems that come with simulation training, namely the scarcity of an in situ expert providing instructions and feedback, we experimented with the solution of supporting training with videos. However, these did not replace the need for some kind of expert feedback (22). Problems related to low availability of experts, space availability and lockdown schedules were surpassed with the help of technology by enabling remote and asynchronous feedback via web-based platforms (23). The great utility of these methods allowed them to remain in force as a feasible and effective alternative in skills acquisition, even after the worst of the pandemic passed and most restrictions were lifted.

Although different modalities have been used for laparoscopic simulated training over time (24), there are differences worth mentioning. While short and intensive formats (or "bootcamps") could be completed more quickly, they generally bring limited outcomes regarding scores, timing, and long-term retention of skills, and they take the trainee away from deliberate practice and the time required to consolidate new knowledge (25,26). This is why the latter plays a fundamental role in our methodology. Feedback, rather than meaningless repetition, is essential to improve performance through deliberate and good quality practice (15,16). Athletes, musicians, and plane pilots all perform feedback-guided training until they achieve proficiency. This is why we decided to implement a methodology similar to a gymnasium, where people train at their own pace with personal trainers and work out consistently throughout the year, developing and consolidating knowledge and learning curves through deliberate practice (27,28).

Although simulation training (ST) has been added to most surgery residency programs, there is still heterogeneity in its implementation (29). The objective of this manuscript is to provide recommendations based on the experience of the Center for Experimental Surgery and Simulation of the Pontificia Universidad Católica de Chile, with more than 12 years of experience implementing this methodology and developing several validated programs for various medical specialties.

Validity in surgical training

Validity refers to the evidence presented to support or refute the meaning or interpretation assigned to an assessment result, or it may be understood as the degree to which conclusions or interpretations derived from the results of an assessment are plausible or justifiable (30-32). According to Cook et al. there are different types of validity. There is content, construct, and criterion validity. Content validity refers to the representation of the knowledge that the learner is expected to acquire during the training program. Construct validity is understood as the degree to which the evaluative processes are capable of identifying the skills for which they were designed, discriminating between different levels of performance. Criterion validity evaluates the precision with which an evaluative instrument measures the outcome for which it was designed. In turn, criterion validity includes correlational, concurrent and predictive validity. The most commonly used are concurrent and predictive validity. Concurrent validity considers the consistency of results in different environments with the same construct, for example, demonstrating that the results of an evaluative scale obtained in a simulator are similar both in the simulator and in the ward. In turn, predictive validity refers to the ability of a measurement to predict a future outcome, e.g., demonstrating that if a student does well in a simulated program, he/she will do well in the surgical ward. Understanding predictive validity is critical, as it will determine the actual usefulness of the training program (27).

A training program should start by having clear learning objectives and then a construction and instructional design to achieve those objectives. The simulated training program must demand a minimum level of competence, which the students must reach to achieve the transfer of skills. This required performance level is the point of discrimination between experts and novices, which will relate to the previously designed program construct. From this point of developed competencies, the student will be able to practice in a real scenario, albeit under supervision.

What is known about the topic?

- Simulation allows you to train almost any skill. The best results have been achieved through deliberate practice and the Mastery learning paradigm.

- It is necessary to develop evidence-based simulation programs searching for predictive validity, which means the transfer of skills to the real scenario.

- There are different types of classification according to the simulation modality (Partial task simulators, Simulated or standardized patients, On-screen virtual simulators, Complex task simulators, Full patient simulators, Hybrid patient simulation) and fidelity (high, intermediate, low). The transfer of skills is not directly linked to any of them, but to the overall design of the scenario, in the context of a program aligned with the learning objectives to be achieved.

Topics for Reflection

Identifying the skill

It is critical to identify the skill that needs to be trained. This implies being attentive to procedures that may be underperformed when in professional practice, clinical situations, or self-reported difficulties when performing them. For instance, residents were identified to have difficulties performing laparoscopic handsewn intestinal anastomosis: they took a longer time, their hand-movements were not precise, and they reported they did not feel comfortable performing this procedure.

We will use an advanced laparoscopic training program as an example to illustrate a laparoscopic simulated training program and will guide the implementation of a simulated training program using a framework based on three pillars.

The three-pillar framework

1. **Hardware or equipment:** when developing a simulation program, it is important to consider all of the physical equipment that will be required. For the example of laparoscopic training, the following is needed:

   a. Training box or bench model: a laparoscopic simulator or trainer (Figure 1) that allows the entrance of real laparoscopic instruments. It is important to mention that, regarding the transference of skills, high fidelity simulators have not been found to allow better transference of skills than those of low fidelity (33).

   b. Camera: A high definition camera (HD, Full HD or UHD/4K) inside the laparoscopic training simulator to project the image from the simulator to the outside screen will help facilitate executing more advanced procedures. It is important to avoid delays between what is happening inside the simulator and the live image streamed to the screen. Most cameras that can live-stream at over 60 fps will do the job.

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c. Video recording device: We have found that it is critical to record the execution of each exercise in order to allow both the trainee and trainer to analyze it, to record the time, and provide effective feedback on-site or remotely and asynchronously to the trainee. This also allows collecting data and generating databases that may subsequently be used to improve each training program.

Figure 1. Laparoscopic training simulator.
Source: elaborated by the authors.

In our experience, we use video game personal-video-recorders such as the AverMedia (Figure 2) to record the sessions. We suggest avoiding the use of other interphases such as computers to record the simulation.

Figure 2. Video recording device. AVerMedia Live Gamer (AVerMedia, New Taipei City, Taiwan).
Source: retrieved from the official website of AverMedia https://www.avermedia.com/

d. Ex-vivo material: we use ex-vivo material from any butcher store's waste to train gastrojejunal anastomosis and jejunojejunal anastomosis. It improves the program's fidelity without using living animals. We sometimes combine the ex-vivo tissues with synthetics (plastic, latex or silicone anatomical models).

In this laparoscopic simulated training example, we use a pig or bovine stomach and intestine (Figure 3).

e. Time and workstation optimization: the designated workstation (simulator, table and screen) can be used efficiently by giving trainees the possibility to schedule a training session with flexible schedules, just like a gymnasium.

Figure 3. Ex-vivo material used for laparoscopic training. Pig's intestines.
Source: elaborated by the authors.

2. Validated Surgical Simulation Training Programs

The program must be structured, setting clear objectives regarding the skills one wants the trainees to acquire by the end of the program, and offering the learner levels of difficulty that are challenging yet not overwhelming, adjusting the student's cognitive load (34). In this way, a learning curve may be established.

This program must use a previously validated assessment tool for the desired skill to be trained. An important aspect in the construction of a solid validity argument is the reliability of the scores obtained with an instrument (35). Reliability can be understood as the consistency of scores when an assessment is applied more than once on the same subject. To measure reliability in psychometric list of the items. Then, we would recommend evaluating with a panel of experts each of the identified items, with rounds using the Delphi methodology until stability in each of the criteria is reached. We suggest performing the necessary rounds to reach stability in all the criteria, and the literature recommends at least four rounds.

3. Expert feedback provider

Having an expert who can give feedback is the cornerstone of skill acquisition and the application of deliberate practice. Unfortunately, it is difficult to have an expert clinician with years of experience available, as they are generally a scarce and expensive resource for the health system, their schedules are restrictive, and they are rarely compatible with full-time teaching. In addition, they do not necessarily know how to provide effective feedback.

New technological solutions have enabled the massification of training, and the need has arisen to train more people in the competencies to deliver remote and asynchronous feedback when an on-site expert is not available.

Therefore, given the crucial importance of the fundamental third pillar of feedback, we believe that these experts can not only coach new trainers in the procedure, but train them in the delivery of effective feedback. These new trainers can be previous trainees, med school students or participants interested in education.

Thus, at our center we are training trainers to standardize laparoscopic instruction, developing a Train The Trainers course, and the people who are under training may vary: general surgeons, surgeons in training, general practitioners, veterinary surgeons, and even medical students.

Our experts in giving feedback have mastered the procedure, have previously completed the laparoscopic training programs, and have gone through a training process in identifying common errors and how to correct them. Also, we encourage the incorporation of the criteria for giving good quality and effective feedback to the trainee, which are: the feedback is formulated using non-judgmental and non-condescending language; takes into account the expected learning outcomes; it is based on direct observations of student performance; provides specific information; incorporates positive feedback reinforcing what the student did well; explains the gaps to achieve the performance standard; delivers constructive information; is based on how to improve; delivers precise and concrete suggestions for improvement: concludes with an action plan for the purpose of modifying or reinforcing an observed characteristic, and it links the feedback to future learning outcomes (37-39). In addition, regular meetings are held with the team to maintain ongoing training. Thus, new experts have learned how to give feedback effectively and join the network of expert feedback providers.

In our remote and asynchronous program, the learners must record their attempt and upload it to a digital platform where they can receive feedback from one of the expert feedback providers in the network within 72 hours, incorporating this valuable information before training again, as shown in the learning cycle of Figure 4. The feedback is specific, and the expert can select exactly the place in the video where the learner is making a mistake to send him/her inputs to improve his/her performance (21,23,40).

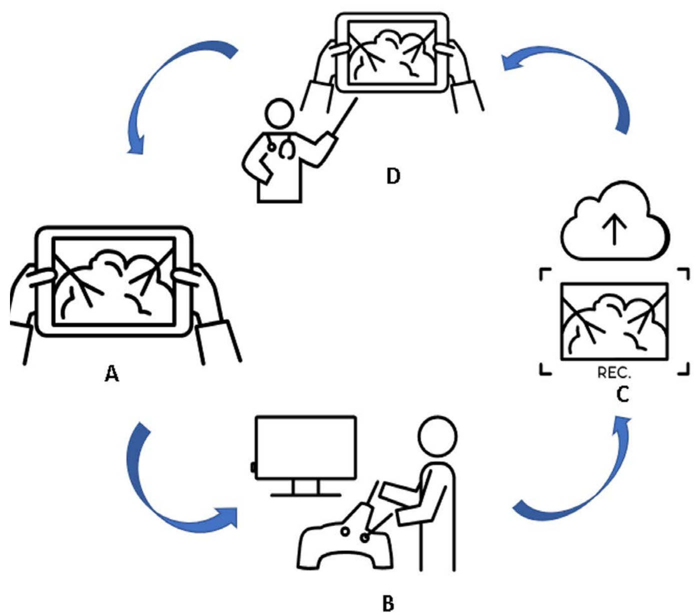

Figure 4. Learning cycle. **A.** The student reviews the tutorial. **B.** Student records him/herself performing the exercise for the first time. **C.** The expert feedback provider reviews the video and leaves accurate and specific feedback. **D.** The student reviews the feedback left by the expert, incorporates the feedback, and retrains through deliberate practice.
Source: elaborated by the authors.

The feedback provided is expected to be aligned to a benchmark of standard performance, which should also be reflected in the evaluation. Therefore, every time a student receives a lower score on the assessment, it should be adequately justified through the appropriate feedback input, providing information on what he/she missed to reach the maximum score. This will help the student get closer to the expected performance standard on the next attempt.

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What have we learned over the past twelve years about simulated laparoscopic training

After two years of work, in 2012 our team published an experimental study in which we designed a second pillar, a simulated laparoscopic training program, and compared first year surgery residents (PGY-1) who underwent 14 sessions of lab-training, general surgeons graduated from traditional programs with no simulation and experts in laparoscopic surgery with years of experience. We thereafter confirmed that there was an effective transfer of skills using a porcine model (predictive validity) and the results showed better performance in the PGY-1 group with simulated training than in the general surgeon group without simulated training. The PGY-1 results were comparable to those of the experts in terms of quality, and the trained group significantly improved their efficiency of movements (36).

Then, because this program was validated only in porcine models, it was necessary to know if these acquired skills would be transferred to the intraoperative environment with real patients: predictive validity. A group of PGY-1 trained with the advanced simulated laparoscopic training was compared to a group of general surgeons with no prior simulated training but who had completed a traditional 5-year general surgery residency program. The results were unquestionable, given that intraoperatively the best performance from the group of general surgeons had lower scores than the worst performance from the PGY-1 group trained with simulation but without previous advanced laparoscopic clinical practice (17).

Until 2018, the training modality corresponded to only in-person training at our Simulation Center. The facility includes access to high definition camera laparoscopic simulators, and expert trainers who can provide face-to-face feedback, in a gymnasium modality, allowing trainees to go at their own pace (28,40).

An attempt was made to scale the training, using only video tutorials so that the students could independently develop their laparoscopic practice (22). However, this was not enough to achieve comparable development of skills because a key element was missing: effective feedback (the third pillar).

Years later, with the support of a grant from the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES), a training program was developed that would incorporate the development of a digital platform that could deliver remote and asynchronous feedback to assist with "the third pillar" simulation centers around Chile and Latin America. The in-person and remote-and-asynchronous modalities were compared and there was no significant difference in the acquisition of skills. This new modality provided the potential to take advantage of all the features of having a remote and asynchronous training program and was key to continue training during the years of the COVID-19 pandemic (23).

Subsequently, we have shown that it is possible to scale up the remote and asynchronous training modality to more than 14 centers in more than 8 countries, developing a centralized network of experts to provide feedback (40).

What does the article contribute?

- It is not necessary to have the latest technology for training with deliberate practice.
- A framework is proposed for developing and implementing a new simulated training program based on three pillars: The hardware and infrastructure (what to train with), the training program (what to do), and providing feedback (how to improve).

Conclusions

Simulated training has become essential for skills training, and the best results have been obtained when using deliberate practice and the mastery learning paradigm because it can shorten the learning curve.

Three pillars are essential for developing a simulated training program: the hardware or infrastructure that will be used to train the skill, a structured and validated program with progressive difficulty, and an expert who can provide specific feedback to allow for deliberate practice until mastery has been achieved.

It is understandable that there may be limitations in trying to develop these recommendations and that they may not be applicable in all settings, but modifications are possible depending on each center's needs and resources.

Conflict of Interest

Julian Varas is the Founder of Training Competence, an official spinoff startup from the Pontificia Universidad Católica de Chile. Valentina Durán, María Inés Gaete and Francisca Belmar are consultants of this startup. Training Competence and the Pontificia Universidad Católica de Chile are the owners of the rights and distribution of the LAPP platform used for the assessment in this study. Isabella Montero, Mariana Miguieles and Brandon

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