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### ► To cite this version:

J. Danion, C. Breque, D. Oriot, J.P. Faure, J.P. Richer. SimLife® technology in surgical training – a dynamic simulation model. *Journal of Visceral Surgery*, 2020, 157, pp.S117 - S122. 10.1016/j.jviscsurg.2020.02.013 . hal-03491017

**HAL Id: hal-03491017**

**<https://hal.science/hal-03491017>**

Submitted on 22 Aug 2022

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## Review

### **SimLife® technology in surgical training- a dynamic simulation model**

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**Declaration of links of interest:**

CB, DO, JPF, JPR have financial interests in SIMEDYS®

Keywords: Surgical simulation, SimLife.

**Summary:**

In initial surgical formation and continuing surgical education, simulation has become a compulsory technique. Just as becoming an airplane pilot requires skills, the acquisition of technical skills is essential to becoming a surgeon. The old apprenticeship model "I see, I do, and I teach" is no longer entirely compatible with the socio-economic constraints of the operating room, demands

for guaranteeing patient safety, and the compulsory reduction in resident working hours. We propose a new surgical simulation model, using cadavers donated to science that are rendered dynamic with pulsatile vascularization and ventilation. Such models are available for simulation of both open surgery and laparoscopy. Surgery on a human body donated to science makes it possible to accurately reproduce the hand gestures characteristic of surgical procedures. Learning in an appropriate and realistic simulation context increases the level of skills acquired by residents and reduces stress and anxiety when they come to perform real procedures.

### **Introduction:**

Modern practical training of surgeons must adapt to societal expectations and take into account the emergence of new pedagogical tools such as simulation while reconsidering the time-honored apprenticeship model. Thus, pre-clinical technical learning can begin "in the absence of the patient". This requires the use of realistic simulation models that allow learner immersion during initial training but are also applicable to continuing surgical education. However, the classic simulation models, in particular high-fidelity mannequins, while suitable for medical training and diagnosis, contain only computer and mechanical elements, and do not meet the anatomical and physiological specifications for the technical training of surgeons. The use of animal models poses ethical problems, and it has been abandoned for teaching in many countries. The human body donated to science remains the model closest to clinical reality. But until now this model remained inert without blood flow or ventilation. The Biomechanical Anatomy and Simulation laboratory of the Faculty of Medicine and Pharmacy at the University of Poitiers (ABS Lab) has developed a dynamic anatomical model. A fresh human body (emptied of its native blood, is frozen and can then be thawed for a training session. Obtained from the Gift of the Body to Science, the body is connected to a technical module which provides a pulsatile arterial vascularization with realistic color and warmth of the organs

thanks to warm simulated circulation and ventilation. This model is made available for practical training according to the principles of simulation teaching.

### **1 - Definition of SimLife technology.**

“SimLife” technology is based on (Figure 1):

- A fresh body from the Gift of the Body to Science. Cannulas are introduced into both femoral arteries and the left common carotid artery for circulatory input, and into both femoral veins and the left internal jugular vein for venous outflow. The distal limb vasculature can be excluded limiting vascularization to the trunk only, or one or two limbs can also be perfused. A pressure-recording catheter in the arterial system is inserted into the right common carotid artery and advanced to the aortic arch. A tracheostomy allows ventilation. A gastric tube allows aspiration of the stomach contents. Emptied of its native blood, the body is initially frozen and then thawed for eventual training use.
- A technical module that animates the body uses three synchronous pumps connected to arterial catheters (arterial revascularization by simulated blood at 37° C) and another pump asynchronous with the previous ones for ventilation. The blood substitute circulates in the arterial system in a pulsatile manner, recolors and rewarms the organs, restores venous pressure and is eliminated from the body *via* the venous catheters. A technician at the head of each model can mechanically modify the hemodynamic physiological data, correlated to the recordings of the pressures at the level of the right common carotid and to the modifications of the flow rates of the arterial pumps. The learner can see this data presented on an anesthesia monitor. The technical module (product called P4P "Pulse For Practice") was industrialized and marketed in the last quarter of 2018 by the SIMEDYS® company.
- An environment that simulates the operating room (OR): body draped for surgery, surgical instruments and coagulation devices, suction, *etc.*
- The specific development of surgery simulation based on the teaching principles defined by the French High Health Authority (HAS): prerequisite

learning, briefing, clinical scenario, grading of skills and learning, debriefing and corrective measures.

## **2 - Why was the SimLife® technology developed?**

The current evolution of educational principles in surgical training is a response to the increase in the number of students and to changes in the status of residents who are now considered postgraduate students, and also to the evolution of societal expectations.

The expected training of the future surgeon includes:

- Theoretical knowledge with permanent ongoing upgrading: knowledge of pathologies, knowledge of operating techniques and decisional algorithms, knowledge of the elements of post-operative monitoring;
- Gestural skills focused on the safe application of theoretical knowledge-- in other words, technical skills acquired during the apprenticeship learning phase.
- Communication skills, not only with the patient and their family, but also with the interdisciplinary and multi-professional medical and surgical team. The surgeon must develop leadership and management skills for crisis situations, *i.e.*, non-technical skills.

The shift in the constraints of surgical training results from reduction in the duration of clinical training for future surgeons (compulsory rest time and organization of simulation models for training), the amplification of medico-legal and economic pressure on the surgical and hospital world (profitability), the explosion of digital resources, and changing societal expectations (summed up by the HAS's dictum: "never perform a procedure for the first time on a real patient"). The Order of April 21, 2017 relating to knowledge, skills and training models for Diplomas of Specialized Studies (DES) during the third cycle of medical studies has mandated the transition from acquisition of knowledge towards the acquisition of skills.

This evolution currently requires a rethinking of the apprenticeship of future surgeons and other interventionists, some of which can take place "at a distance

from the patient", using virtual models organized at both the national and international level and at a time when there is major technological change in surgery (1,2). The best learning modality is one where learners actively participate, driving and facilitating their own training (3,4). Simulation teaching has therefore established itself as an essential tool in the practical training of all health professions by specifying the "objectives to be mastered", and not the "objectives to be taught", according to processes inspired by theories of social constructivism or cognitivism (5-8).

### **3 - How does SimLife® technology meet the expectations of surgical training?**

#### *3a - The specific characteristics of surgical apprenticeship*

The surgeon's technical training in the operating room should prepare him or her to manage not only foreseen events but also unforeseen events (9).

Predictable management refers to:

- The acquisition of basic skills such as: dissection (knowledge and recognition of anatomy by its structure, color, heat, movement and discovery of cleavage planes), resection (vascular control, recognition of vascularized or devitalized tissue, and application of carcinological rules), and the techniques and rules of suturing (manipulation of instruments, taking into account the nature and quality of tissues).
- The application of technical algorithms: hierarchy and chronology of surgical procedural steps, application of rules for drain placement.
- The oversight and management of the surgical team in the operating room and recognition of when one should call for help.
- Committing all of this learning to memory (encoding, consolidation, storage and retrieval) is the challenge of training the surgeon. To develop the sensory, motor and psychic processes that are at work in surgery requires a simulation model of

great fidelity in order to bring into play working memory (short-term memory) and procedural memory through the repetition of the tasks (long-term memory).

Procedural memory (implicit memory) is the unconscious repercussion of experience that permits the apprentice surgeon to progress along the learning curve of procedures and further promotes continuous performance improvement through repetition. While the initial learning is conscious, the subsequent implementation of acquired skills will become more automatic and less conscious provided that the fidelity of the simulated situation and the context are identical to that of the learning goal.

Management of unexpected events requires

- control of operator stress
- analysis of the event in real time
- speed and adequacy of the response
- the management of unforeseen events involves episodic memory--long-term memory (explicit memory related to the limbic system and to the hippocampus that open on the different parts of the cortex, in particular the frontal cortex). This episodic memory is that of actual personal experiences lived in a determined place and at a time and in a precise context. The ability to access memory of the solutions applied to similar experiences and contexts as those currently confronting the surgeon makes it possible to respond analogously to the current situation (10).

### *3b - Realism and fidelity in simulation*

Kirkpatrick's (1959) training evaluation model constitutes a reference in the educational scientific literature (11,12).

In Kirkpatrick's pyramidal representation of four progressive levels of the success of training programs, the first level (reaction/satisfaction) explores the trainee's' feelings, perceptions and satisfaction, encouraging them to adhere to this training. This satisfaction is largely linked to the realism of the chosen model but

also to the fidelity (perception of authenticity) of the simulation sessions for the intended learning. The second level (learning) assesses the gain in knowledge and practical skills brought about by the training program. The third level (behaviors) explores the transfer of learning outcomes through positive changes in practice and behavior that the learner generates. The last level (results) is more difficult to assess or measure and concerns the impact of training on improving clinical results, particularly morbidity and mortality and organizational results (13).

Fidelity refers to the degree to which a simulation imitates reality in all its characteristics allowing true immersion of the learner (14). There are several dimensions to fidelity, some of which are essential in surgical simulation:

- physical fidelity in reference to the degree with which the simulator reproduces the morphological aspect and variations in reality,
- physiological or functional fidelity which characterizes the dynamic behavior of the simulator compared to reality,
- environmental fidelity referring to the degree to which the simulator and its environment allow a duration of action and the use of equipment consistent with reality and reproduce real visual and sensory signals,
- finally, psychological fidelity refers to the degree to which the participant accepts the simulation as a valid representation of reality.

The learner's immersion in the scenario appears essential for simulation to be effective of the training (Kirkpatrick level one) (12-15).

Admittedly, the relationship between learner satisfaction and the gain in competence engendered by the learning experience has not been clearly established and is still debated in the literature (14,16,17). However, the analysis of learner satisfaction makes it possible to assess the effectiveness of a model for training. It is thus demonstrated that the positive experiences of a training experience that engages the attention of students involved in their learning program, have a beneficial effect on the attitudes and behavior of the learners with a strong adhesion not only to the session but also to the whole training



program, engaging them in their learning process (14). This level 1 of student satisfaction according to Kirkpatrick, has been validated for the SimLife® technology, which represents an anesthetized patient in the operating room (18).

### *3c - The place of SimLife® as a model in surgical simulation*

Computer-rich high-fidelity mannequins have not yet been designed for surgical training. Despite their appearance, synthetic patient simulators (SynDaver® type) are not completely suitable for learning the hierarchy of intracorporeal technical gestures in surgery; they lack realism and anatomical variations (18,19). Virtual reality and/or augmented reality simulators, a notable evolution of procedural simulators, have shown their effectiveness for some videoscopic surgical training (10, 20, 21,22). But they are expensive to purchase and maintain, of uneven visual quality, and often present stereotypical scenarios without haptic feedback for certain devices; they are often used without debriefing (22).

Robotic surgery simulators seem to show a benefit in surgical learning, but their availability is limited; they are located only in reference centers and demand the physical presence of the apprentice surgeon for training on stereotypical scenarios. They, too, have a high purchase and maintenance cost (19). Animal models are mainly intended for experimental surgery and basic research. However, they have been used as an educational model for surgical training (23,24). Their use is very strictly regulated and requires an expensive and suitable infrastructure. Animal models have been largely abandoned as an educational model in English-speaking countries for ethical and health safety reasons (19).

The body donated to science therefore appears closest to clinical reality and some feel that it remains one of the most suitable models for technical surgical training (25-28). In surgical training programs, it constitutes a high-fidelity model for the haptic feedback of surgical procedures (29-31). Since the first technical realization of a circulating body in 2001 by Garrett, the description of such innovations has been scantily reported in the international literature (32).

Existing models, mainly in North America (USA), revascularize a device or a part of the body. The vascularization is not always pulsatile, and ventilation is not present. These models have no possibilities for hemodynamic or ventilatory adaptative scenarios, neither in the context of the proposed surgery nor to simulate accidental events that may occur during an operative session (33-39).

#### **4 - The place of SimLife® technology in surgical training**

*4a - The SimLife® technology is suitable for all levels of resident training in surgical specialties, to implement the reform of the third cycle of medical studies. Surgical training on this high fidelity model using a body donated to science helps to improve the self-confidence of the future surgeon and shorten the learning curve (40).*

In the operating room, around the anesthetized patient, the operator is typically accompanied by an assistant and a scrub nurse. In our experience of Simlife® technology, the first-year resident phase plays the role of the scrub nurse, the junior resident that of the surgical assistant, and the senior resident that of the operating surgeon. But these roles can be interchanged. A senior surgeon acts as facilitator to assure the smooth running of the scenario. In addition to his/her own technical surgical training, the future surgeon must learn how to assist another operator and how to function as a team leader; this requires the development of situational awareness, fellowship and leadership.

*4b - The SimLife® technology lends itself particularly well to multidisciplinary and multi-professional training in crisis resource management.*

Anesthesiology team can participate in the training, as well as a circulating nurse and all the other participants typically found in the operating room environment. Unexpected or catastrophic events can be introduced into the scenario (hemorrhagic shock or gas embolism during hepatic surgery, for example); the response can then be analyzed during debriefing to assess

individual responses, team work, management of human and material resources, communication, problem solving and crisis management.

#### *4c – SimLife® technology is suitable for assessment and certification*

The development of a national surgical training network based on the SimLife® model ("SimLife® net") has initiated collegial work in many surgical specialties: standardization of good surgical practices, creation of scenarios and assessment scales. This developing network was awarded the 2016 Call for Expressions of Interest by the French Ministry of National Education, Higher Education and Research (AMI 2016 from MENESR) (41). It has received the support of many learned societies including the National Academy of Surgery. Scenarios using SimLife® technology and the assessment measures thus created and validated at the national level will lay the foundations for certification in surgery.

#### *4d – SimLife® technology lends itself to research*

The development of the national surgical training network using SimLife® technology requires the creation of shared and standardized scenarios using the nominal group process and the development of evaluation measures. These tools will be published in order to be disseminated, since no simulation teaching occurs without evaluation measures (42).

Operator experience leads to decreased stress (43). At our center, work is underway to assess the impact of simulation training with SimLife® technology and its repetition on residents' stress as they learn, but also subsequently in the operating room.

## **Conclusion**

The current national university diffusion of Simlife® technology and the national "SimLife® net" network allow us to envisage the standardization of practical

surgical training in shared high-quality simulation. SimLife® technology provides a strong educational response to societal demand for the acquisition of preclinical skills respecting "never on a real patient the first time".

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**Fig. 1: Schema of global vascular and ventilatory access sites of SIMLife (right side) and the connections with SimLife® technical system (left side)**

