

The need for simulation in surgical education in developing countries. The wind of change. Review article

Obada Hasan, Ahmed Ayaz, Muneeba Jessar, Charles Docherty, Pervaiz Hashmi

Abstract

Operative skills are the heart and soul of surgical practice. An extensive amount of literature has been devoted to the art and science of acquiring these skills which start by mastering basic skills until automaticity has been achieved. The current model of surgical education is purely based on sheer volume of patients, restrictions in the maximum number of working hours for trainees and increased pressures of operating room efficiency. This leads to limited teaching time. Adding to the scenario is the emphasis on patient safety and greater awareness of medico-legal consequences following medical errors. All this has significantly hampered the learning experience of surgical trainees and limited the expert surgeon's ability to fulfil trainees' learning needs during complex procedures. Thus, learning strategies outside the operating room were required to provide an ideal environment for learning without putting patients' health at risk. This has led to increased use of simulators in modern surgical training. The situation is even more worrisome in developing countries where the availability of these facilities is either extremely limited or non-existent. The current narrative review was planned to go over the importance of simulation in surgical education and to question its utility in developing countries.

Keywords: Simulation; surgery; training; education

Introduction

The current surgical training model goes back all the way to 1889 when Sir William Halsted introduced it at John Hopkins and revolutionised the way residents learn the intricate skills and technicalities of surgery.¹ It is based on an apprenticeship model where surgical residents and trainees learn by observing, assisting and finally taking over operative cases under the supervision of their mentors.² Over time, as the trainee comes across an assortment of clinical cases, he slowly starts

developing the necessary skills required for independent practice which hinges on extensive factual knowledge, sound clinical judgment and operative skill.³ Operative skills are the heart and soul of surgical practice. An extensive amount of literature has been devoted to the art and science of acquiring these skills which start by mastering basic skills until automaticity has been achieved in them. Then, the trainee looks to polish newer, more complex techniques until he reaches a stable level of expertise and maintains it throughout his career. Those experienced surgeons with consistently better outcomes than the inexperienced are known as "expert surgeons" and researches have revealed that these individuals display superior operative skills and diagnostic abilities compared to the non-experts.⁴ Behind that level of proficiency lie hours and hours of regular dedicated practice that refines motor skills and enhances precision. Over the years, however, due to alterations in the global healthcare system, this model did not seem to be as effective as it was in the past century. Since the current model is purely based on sheer volume of patients, restrictions in the maximum number of working hours for surgical trainees and increasing pressures of operating theatre (OT) efficiency have greatly limited teaching time. Moreover, special emphasis on patient safety and greater awareness of medico-legal consequences following medical errors have significantly hampered the learning experience of surgical trainees, and limited the expert surgeon's ability to fulfil trainees' learning needs during complex procedures.^{5,6} As a result, trainees are required to become proficient despite significantly decreased patient exposure and hands-on experience. Thus, the need for learning strategies outside the OT are required to provide an ideal environment for learning without putting patients' health at risk. This has led to increased use of simulators in modern surgical training.⁶ The situation is even more worrisome in the developing countries where the availability of these facilities is either extremely limited or non-existent. The current narrative review was planned to go over the importance of

Aga Khan University, Karachi, Pakistan.

Correspondence: Obada Hasan. e-mail: obada.husseinali@aku.edu

simulation in surgical training and to emphasise the need to integrate this technology into surgical practice in developing countries.

What is Simulation and why do we need it?

Fit and Posner have very adeptly explained the stages of motor skill acquisition.⁸ It starts with the cognitive phase in which a learner first learns the basic mechanics of a simple skill and gets familiarised with the different steps involved. For example, when learning how to tie a knot, one must first get acquainted with basic steps like holding the tie and placing the throws. Initial attempts would be incoherent and disjointed but would eventually improve with repetition and constant correction until the learner progresses to the next phase where all the steps are much more coordinated and focus shifts to achieving the task more sinuously with fewer interruptions. The final phase is where the learner automatically performs the task smoothly without pondering over individual steps. Once this automaticity is achieved, the trainer can concentrate on more complex parts of the procedure.¹

Many studies support the hypothesis that the more often a procedure is performed, the better becomes the outcome and lower gets the mortality. Although it seems logical to proclaim that regular practice is critical to better outcomes, performance does not just improve by sheer repetition of a task as explained by a number of studies showing variation in performance of different surgeons with a high volume of cases.⁹ Ericson in his landmark study states that maximal proficiency in any skill is not attained automatically by experience or number of hours devoted to practice but instead by a deliberate effort to improve. According to Ericson, the key to improving consistently is deliberate practice in which an individual focuses his efforts on a well-defined level-appropriate task with the sole purpose of improving performance, and gets expert feedback to allow for immediate error correction. He points out that the amount of time devoted to deliberate practice, rather than the time spent in surgery, is the most decisive factor in improving surgical skills as operative cases can be complicated and it is almost impossible to master a minor part of the operation.¹⁰

Simulation is the process of replicating real-life scenarios in a controlled environment. In surgical education, simulators are devices or models used by trainees to replicate real-life conditions and practice their skills safely without any risk to real patients. Learners can repeatedly

Table-1: Factors encouraging use of simulation in surgical education¹³.

Medico-legal consequences following medical errors, must have enough experience to practice
Advanced surgical techniques and procedures
Challenges in use of cadavers and animals
Emphasis on cost-effective and cost-conscious performance

practise techniques and sharpen their skills in an environment where errors can be made without serious consequences. The learners keep practicing until they achieve complete expertise in that skill and can then transfer that skillset to the operating room. As a result, surgical residents are fully prepared before even entering the OT, achieve proficiency with shorter leaning curves and perform surgeries more efficiently with better patient outcome and significantly less complication.¹¹

Seymour et al. went on to prove the effectiveness of simulation training by concluding that novice surgeons demonstrated diminished operative times and error rates for laparoscopic cholecystectomy after training on a virtual reality (VR) simulator compared to no training. Furthermore, in one randomised controlled trial (RCT), 20 surgical trainees were divided into two groups; one trained by VR-based simulation, and the other by traditional surgical training on a cadaveric porcine model. Simulation-based training reduced the learning curve significantly and resulted in fewer errors. It took only three surgical procedures for the simulation-trained group to achieve the same level of expertise that the non-simulation group took five surgeries for. The mean errors committed were six times less in the simulation-trained group. Moreover, the non-simulation trained group was five times more likely to injure the gallbladder or injure non-target tissue and nine times more likely to transiently fail to make progress.¹² Other factors that encourage the use of simulation in surgical education have also been cited in literature¹³ (Table 1).

Brief history of surgical simulation

The use of surgical simulation goes as far back as 500 BC. One of the first simulators were carvings made of materials that had the appearance, texture and general feel of human tissues.⁷ The first recorded surgical simulation was performed more than 2000 years ago where the Indians used leaf and clay models to visualise a forehead flap in nasal reconstruction surgery. Just like this, surgeons have

used various surgical simulation models over the years to sharpen their skills and practise without risking the life of patients. Over time, these models became more sophisticated and detailed with the resemblance to human anatomy the main priority. Some examples of these were wooden bench-top models, live animals and human cadavers.¹¹

For a long time, live animals were used as a form of surgical simulation as their anatomy closely resembled that of humans and they provided actual OT settings requiring trainees to not only improve their skills but also to deal with complications if they arise. This method remained popular for quite some time after which ethical issues arose regarding using live animals for simulation and it was banned in some countries.

A ground-breaking invention came in the 1980s when mannequins were first introduced. Mannequins were artificial human-like models that were used to teach anatomy and to assess basic clinical skills without the need of real patients. These mannequins evolved rapidly over time, becoming increasingly realistic and detailed. Now they come with in-built processors and computer software that allow them to mimic signs and symptoms of real patients with specific clinical conditions. The greatest revolution came in the 1990s with the emergence of VR. VR-based simulation systems are computer programmes containing virtual surgical procedures that trainees can perform via different tools and devices to sharpen their surgical skills. These tools are designed to resemble real-life instruments that are regularly used in OTs so that trainees get acquainted with them before even entering the OT. One of the first VR simulated surgeries to be performed comprised suturing, wound debridement and cholecystectomy. Various key points that are assessed objectively in simulation programmes have been described in literature¹⁴ (Table 2).

Table-2: Technical performance objective assessment in simulation programmes¹⁴.

Time in completing task
Extra unnecessary moves
Thermal damage to soft tissue
Damage to articular cartilage and nearby by structures
Hand and instrument distance travelled
Symmetry of suturing techniques

* May vary from software to software. Points mentioned for laparoscopic and arthroscopic procedures

Need for Simulation in developing countries

(A) Lack of access to surgical care

Currently, almost 5 billion people around the world do not have access to surgery, according to the landmark study conducted by the Lancet Commission on Global Surgery in which data was collected from 180 countries in the world representing 6.97 billion people, or 98% of the population.¹⁵ These figures portray a worrying picture in terms of availability of surgery around the world. The world's rural population is the most affected as this report suggests that more than 90% of the inhabitants of Africa and South Asia are deprived of basic surgical care. There is one surgeon per 250,000 people on average across Africa, and in the most rural areas, 2.5 million people are served by only one surgeon.¹⁶ More than 2 billion people are not able to receive surgical care due to a lack of OTs alone. To give a comparison, less than 5% of the people of Europe, Australia and high-income North America lack access to surgery.

(B) Lack of training facilities

One of the main challenges in providing surgical care in these areas is the relatively small number of skilled surgeons there. It is a known fact that most of these low-income countries have poor access to healthcare, but even when healthcare is accessible, there is still a dearth of well-trained surgeons, especially in specialised surgical fields like laparoscopy. Training facilities, such as simulation models and computer-based programmes, for these surgical procedures are not available in most of these areas, negatively impacting the required surgical training necessary for providing surgical care.¹⁷ Local novice surgeons then prefer travelling to other countries where advanced facilities and resources are available for specialised training. Unfortunately, only a handful of them can opt for this route due to the high cost of travelling and living there, political will, visa issues and strict regulations for hands-on training. Very few trainees are able to complete their training abroad and even fewer decide to return to their home country after experiencing the bells and whistles, generous pay-scale and lavish lifestyle of those countries abroad.

(C) Increased peri-operative complications

A paucity of skilled surgeons brings with it dire consequences. It has been reported that the peri-operative death rate is as high as 10% in these countries compared

to a meagre 0.4% in the developed world.¹⁸ In areas where clean water is scarce and availability of blood banks are insufficient, the magnitude of these surgical complications are more marked.¹⁹ The increased number of complications led to slow recovery and increased length of hospital stay for these patients which adds burden to the relatively small number of hospital beds available. Discharging these patients early is risky as most homes do not have the luxury of clean water and they have no other appropriate place to get through the recovery phase. Beds are always in high demand as many pre-op patients get pre-admitted as they come from far-flung areas to reach surgical care or need some time to arrange the financial means for surgery.

Additionally, there is usually just one bread-earner in the entire family and a prolonged hospitalisation could prove to be catastrophic for the entire household. Most workers and employees rarely have any financial security as they live hand-to-mouth with very little savings or investments. Sick leave is not an option and every day spent in hospital would mean no income for that day. Also, in most patriarchal families, a suitable replacement for the earning member would be difficult to find due to cultural issues. Moreover, the financial burden of surgical care is even more pronounced in developing countries as all healthcare related expenses are paid out of pocket with no facility of instalments or loans. Families are then forced to sell all their assets or gather money by borrowing from friends and family for which it would take several years to repay. Nursing care is routinely provided by other family members in the house and this results in decreased attention to childcare and reduced earning capacity.

(D) Benefits of Surgical Simulation in developing countries

Introducing surgical simulation facilities in developing countries is a promising solution to address the above-mentioned problems. The aim of these facilities would be to develop mastery in surgical skills aimed at increasing availability of trained surgeons and improving quality of surgical care (Figure 1). This would eventually result in better patient outcomes and a significantly reduced financial burden on an already economically strained population.

Although surgical simulation has been in use in developed countries for many years and several studies have proved its effectiveness in training surgical residents with reduced



Figure-1: Orthopaedic surgical trainee learning the basics and principles of shoulder arthroscopy under supervision of an orthopaedic surgeon and expert in sports medicine. Such advanced procedure was difficult to learn and practise during residency training programmes.

learning curves and fewer errors, data regarding utilisation of this technology in developing countries is scanty.²⁰ Very little is known of the efficacy of surgical simulation in these areas and even less about how they can be implemented there.

Okrañec et al. conducted a three-day surgical simulation course in Botswana, and after comparing results, proved that a feasible simulation solution can bring significant improvements in the surgical skills of trainees.² Additionally, even though the use of simulation is extremely limited in the postgraduate curriculum, individual surgical simulation courses intended to teach specific skills have been found to be as fruitful by Tansley et al. in Rwanda.²⁰

They established the importance of such locally taught programmes in low-income countries, proving that the benefits of surgical simulation extend to training programmes in Rwanda and potentially other developing countries. Similar results have been documented in Nicaragua, Tanzania, Kenya and Madagascar. Some recent studies in developing countries showed positive results after the use of surgical simulation training (Table- 3)^{16,17,21,30}.



Figure-2: Different simulators: A: LapSim (Laparoscopy Simulator). B: VirtaMed (Urology Simulator). C: Immersive Touch (Neurosurgery Simulator). D: VOXEL-MAN (ENT Simulator). E: SonoSim (Ultrasound Simulator). F: Dental Simulation Lab.

considerable number of medical students to pursue surgery in the future. One of the reasons very few students choose surgery as a specialty is because of the lack of exposure which results in them being overwhelmed with the amount of necessary expertise required and the notion that their skill level is below par; hence they avoid choosing a field they think they cannot be proficient in. A feeling of incompetence plays a significant role in career selection, and many students described the field as something that was unachievable for them because the technical expertise was impossible to attain. Once they get acquainted with surgical procedures at a junior level via simulation, they will be able to become proficient in the basic skills required to be a surgeon and eventually consider surgery as a

Table-3: Recent studies conducted in developing countries proving benefits of surgical simulation

Author	Year of study	Country
Tache et al. ²¹	2009	Tanzania
Dorman et al. ²²	2009	Ethiopia
Okraïnec et al. ²³	2009	Botswana
Jacobs et al. ²⁴	2010	Ghana
Biyani et al. ²⁵	2013	Ethiopia
Long et al. ¹⁶	2014	Kenya
Beard et al. ²⁶	2014	Tanzania
Dreyer et al. ²⁷	2014	Zambia
Livingston et al. ²⁸	2014	Rwanda
Weit et al. ¹⁷	2016	Nicaragua
Tansley et al. ²⁰	2016	Rwanda
Campain et al. ²⁹	2016	Africa
Ghesquire et al. ³⁰	2018	Madagascar

career choice.²¹ Introducing surgical simulation in the medical school curriculum in developing countries would be a great addition and could prove to be a vital by increasing the number of locally trained surgeons in low-income countries in the future. Different specialties' simulators are introduced (Figure 2).

(E)"There ain't no such thing as a free lunch"

On the contrary, there are a few questions to be answered. Firstly, is some care or less-than-optimal care better than no care at all? To elaborate on this, it is important to realise that simulation can use valuable professional time, consumables and fixed assets that depreciate through time; all of this carries a cost. In the context of limited budgets and very scarce expertise and equipment, rather than learners practising on simulators, couldn't they learn using the same equipment on patients even at the risk of error? In the West, this argument is strongly in favour of simulated practice to develop competence before practising with patients because investing to avoid possible harm or negligence and subsequent lawsuits makes this financially sensible. But in the developing world illiteracy rates are high, people are very needy, grateful for small mercies, and likely to be unaware that medical errors happen frequently and are avoidable. The financial impact of medical error is therefore much, much less, and may go unreported. In addition, the ethics may be more favourable towards providing less-than-perfect care if the option is no care whatsoever for people in extreme poverty. This argument swings in the opposite direction if more harm than good is done by less-than-perfect medical intervention compared to no care. Thus, in the developing world, with extreme shortages a part of everyday life, there is little pressure for learners, or institutions, to ensure a level of competence before learners are let loose on patients. A second consideration is the opportunity cost. Instead of investing millions of dollars in simulation centres and even more on high-fidelity simulators, what healthcare benefits could be gained in the poorer areas of a developing country just by providing sustainable clean drinking water, or vaccinations, or anti-malarial drugs? Similarly, simulation centres have authentic clinical environments fully equipped to clinical standards. Could more benefit be gained through using this investment to provide actual care to real people, and not mannequins? In an ideal world, choosing where to devote resources wouldn't be

an issue, but these difficult choices are often necessary. Compounding this is that nowadays in any developing country there are diseases of affluence as well as diseases of poverty so a whole range of top specialists, such as interventional cardiologists, require to be trained, optimally utilising high-fidelity simulators. To make rational choices as to where to invest in this complex situation, there needs to be an economic evaluation of the impact of simulation, and its viable alternatives. There are so many assumptions on the benefits of clinical simulation, some of which have been confirmed, but very few comparative analyses on the alternatives exist. Many novice surgeons have benefited from stand-alone training courses, but to harness technology's full potential, it should be integrated into the under-graduate and post-graduate curriculum. As stated very adeptly by Satava: "It's not the simulator, it's the curriculum"³¹.

Conclusion

Simulation fills an irreplaceable gap in the teaching of surgical skills with its effectiveness having been proved on numerous occasions. It provides a safe learning environment for trainees to refine their skills and prepare for the real world without the fear of the consequences. Although a lot of work and progress is being done to implement this technology into the postgraduate curricula in the developed countries, the availability in developing countries is below par leading to severe consequences in quality of surgical care provided. Policy-makers, surgeons and medical educators must work together and use this innovation to overcome the challenges faced in surgical care delivery in developing countries. There should be an economic evaluation of the impact of simulation to decide its cost-effectiveness in our part of the world.

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