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REVIEW ARTICLE

Simulation in surgery: opportunity or threat?

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The practice of surgery has undergone enormous changes over the past 20 years. The advent of minimally invasive surgery, in particular, has had a major impact on how surgeons operate. But much greater changes will inevitably occur during the years ahead. Developments in catheter-based interventions, natural orifice transluminal endoscopic surgery (NOTES) and robotic surgery are just some examples of how surgery is becoming increasingly technology based. These developments will have major implications for surgical training—not just for junior surgeons in training, but also for established surgeons who are already in practice. The skill sets which were traditionally acquired in surgical training will no longer sustain surgeons of the future throughout their professional lifetime. There will be a requirement to acquire new skill sets at regular intervals throughout a surgical career. But, just as importantly, surgeons of the future will also require training in the technology itself. All of this comes at a time when the traditional model of surgical training, i.e. the Halstead apprenticeship model is itself under significant threat.

The traditional model of surgical training (the apprenticeship model) employs the passage of time (i.e. years in training) and volume of experience (i.e. hours worked per week) as surrogate markers of competence. There is no formal assessment of technical proficiency at the end of training. However, there are several issues which challenge this traditional model of training, e.g. decreased duration of training, reduced working hours, technological advances, increasing sub-specialisation, and most importantly, changing public attitudes. It is no longer acceptable that surgical trainees practice their operative skills on patients. We need to develop a new model of surgical training which will enable our future surgeons to achieve expertise in a reduced period of time, despite the increasing use of complex technology in surgery.

The ultimate goal of training in operative surgery is to reach a state of expert performance. The importance of the concept of deliberate practice with structured feedback and coaching is well recognised in the psychology literature as an essential component of achieving expert performance [1, 2]. This concept has been extensively used in sports, music, aviation and many other areas where expert performance of a skill is demanded [3]. In surgery, the concept of deliberate practice with coaching and feedback has not been extensively employed because of a lack of available simulation material. During the past decade, however, there has been rapid progress in the area of surgical simulation, particularly in the area of virtual reality simulation. This opens the prospect of a new approach to learning and assessing surgical technical skills.

The history of simulation in surgical training is intimately linked to the name of Richard Satava [4]. In the early 1990s, he worked as programme manager in the Defense Advanced Research Projects Agency (DARPA) in Washington DC in addition to running a busy surgical practice. In this role, he was asked to apply top secret military technology to civilian healthcare. In 2001, Satava and a team at Yale University conducted a clinical trial in which surgical residents were randomised to train on VR or by traditional training. VR-trained residents were trained

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until they reached a proficiency level which was predefined. Experienced attending surgeons were assessed to objectively establish this proficiency level. In this double-blinded study, VR-trained residents performed their procedures 29% faster and made six times fewer intraoperative errors [5]. These findings have since been replicated [6, 7] and the American College of Surgeons has now embraced simulation as an integral part of twenty-first century surgical training [8]. Perhaps even more significantly, the Food and Drug Administration (FDA) in the United States has mandated that clinicians who perform carotid stenting should train to a defined level of proficiency on a simulator before they perform the procedure on a patient [9]. This mandate is likely to be a “tipping point” in surgical practice as it is the first time that clinicians have been required by law to demonstrate proficiency on a simulator prior to undertaking a procedure on a patient [10].

Simulation in surgery: opportunity?

There is little doubt that simulators allow surgeons to learn in new and more efficient ways. Surgeons in training can learn how to use the devices necessary to perform a procedure, the order in which they should (or should not) be used and can reach prescribed levels of proficiency before entering the operating room. This means that supervising consultants can be assured, from objective evidence, that the trainee has attained the prescribed level of proficiency and can therefore direct their attention to the more complex technological or behavioural aspects of the procedure [11]. From the trainees’ perspective, simulation has the advantage that they can acquire and refine their skills in a consequence-free environment. All trainees get exposure to the same cases and the level of difficulty can be adjusted as proficiency develops. More importantly, trainees can all be assessed on a standardised platform and measured objectively.

For more senior surgeons who wish to learn how to perform a new procedure (e.g. carotid stenting), simulation affords the opportunity to acquire the skills in a safe environment. As surgical practice becomes more and more technology dependent, this will become increasingly important [12]. Simulation will also make it possible to develop and perfect new high risk procedures such as those for acute stroke intervention. The main obstacle for training clinicians in acute stroke intervention is that the only training model currently available is the brain of a very ill and unstable patient. Few neurosurgeons or interventional neuroradiologists would take the risk of allowing a trainee to work on the brain of such a patient. However, the use of simulation gives quantitative evidence of the skill set of the trainee and this will support the decision as to whether a trainee is sufficiently skilled to intervene in such a situation. Furthermore, some of the more sophisticated full physics VR simulators currently available for neuro-interventional procedures are capable of simulating patient-specific data, which have been captured from real time imaging in the catheter laboratory [13]. The use of such patient-specific data for deliberate practice in surgery will have enormous implications for high technology interventions such as NOTES and robotic surgery. We foresee a time when all surgical procedures will have the potential to be captured and downloaded to a simulator which will give trainees the opportunity to perform cases which they might not have otherwise encountered.

Simulation in surgery: threat?

Many surgeons believe that simulations will be used for re-credentialing and this is almost certainly going to happen [14]. VR simulation has the advantage of being consistent, objective and transparent. The vast majority of surgeons have nothing to fear from an objective assessment of their procedural skills. Some surgeons maintain that technical or procedural skills are only a small part of what makes a competent surgeon. This is undoubtedly true and the behavioural or human factors component of surgical practice is equally important [15]. However, as surgery becomes increasingly technology based, the technical skills required for future surgeons will be critically important and there will be a requirement to verify these skills objectively [16].

Simulation has already been used for proficiency-based progression for carotid artery stenting and this is likely to be become more common in the future. It will almost certainly be utilised by government agencies responsible for quality assurance in medicine. This approach reassures these organisations as well as patients that the surgeon has at least sufficient skills to perform an operation safely. In the United States, organisations such as Partners Healthcare in the Harvard hospital system have reduced the insurance premiums of physicians who have undergone a simulation course. This type of approach is likely to become more common in the future. However, it is likely that simply attending a simulation course will not suffice and clinicians will be required to demonstrate that they can perform to a specified proficiency level [11]. The specified proficiency levels will need to be defined and quantified, based on the performance of the “average” safe practising surgeon or physician. This means that the majority of surgeons would have little difficulty meeting this performance criterion [17].

Just as simulation allows surgeons to acquire skills to perform a new procedure or perform an established

Fig. 1 Surgical simulation laboratory at Royal College of Surgeons inIreland

procedure with a new device, this resource is also available to other specialities within medicine. The clearest example of this is carotid artery stenting [9]. Vascular surgeons have performed carotid endarterectomy for decades [18]. However, with the advent of carotid artery stenting, other disciplines (e.g. interventional cardiology and interventional radiology) have started performing the procedure [19, 20]. Some of these interventionists acquired their skills on a simulator, and as a result, there has been a significant reduction in the number of carotid endarterectomy procedures performed in the United States. This type of development is likely to become more common in the future when other physician groups compete to perform new procedures which have traditionally been performed by surgeons. The next confrontation is likely to occur over natural orifice transluminal endoscopic surgery (NOTES). It is clear that simulation will result in blurring of the boundaries between interventional disciplines [9].

Simulation at the National Surgical Training Centre, RCSI

The Royal College of Surgeons in Ireland has been an early and enthusiastic adopter of simulation. At the National Surgical Training Centre in RCSI there has been a heavy investment in simulation, including virtual reality simulation. A syllabus for operative surgery has been developed in General Surgery and this syllabus is divided into modules. All trainees in General Surgery attend the National Surgical Training Centre for six full days each year (Fig. 1) and receive intensive "hands-on" training in surgical techniques and procedures using bench models and virtual reality simulators. There is a high tutor-to-trainee ratio during these technical skills training days and trainees receive individual attention. In many cases, low fidelity bench models are sufficient for training purposes, thus reducing cost (Fig. 2). But state-of-the-art VR simulators are used for teaching endoscopic and laparoscopic procedures, and these simulators allow objective assessment of trainee performance (Fig. 3). This approach has allowed standardisation of technical skills, training and assessment of all trainees across Ireland. More recently, we have developed a mobile surgical skills training unit, based in an articulated truck which travels to hospitals around Ireland (Fig. 4). This has greatly facilitated delivery of surgical skills training at a local level.

We have now developed the methodology for standardised assessments of technical skills, and all trainees are assessed on a standardised platform [21]. Over the past

Fig. 2 Simple bench models for teaching basic surgical tasks

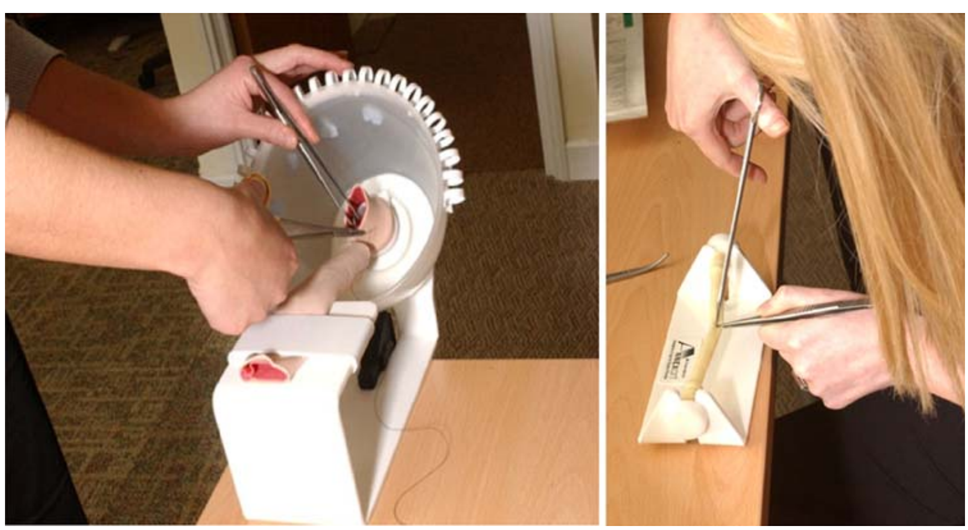

Fig. 3 Virtual reality simulator for teaching advanced laparoscopic skills

4 years we have used standardised assessment of surgical technical skills in selection for Higher Surgical Training in General Surgery and also in some of the other specialities. Of course, training in a surgical skills laboratory can never replace training in the operating theatre but the use of simulation in the skills laboratory allows trainees to become "pre-trained novices" and so to use their scarce operating theatre time more efficiently and more safely.

Another important feature of simulation in training is that it facilitates team training. Proficiency in technical skills is just one aspect of surgical competence. It is abundantly clear that non-technical personal skills are just as important in surgical practice. These human factor skills—teamwork, communication skills, leadership, crisis management—can quite easily be taught in a simulation laboratory with involvement of the other key members of the core surgical team (Fig. 5). This type of team training exercise is likely to play an increasingly important role in twenty-first century surgical training.

Simulation: the future

The best developed simulations in surgery have been deployed for image-guided procedures such as laparoscopic surgery and endoscopic or endovascular procedures. However, these types of intervention represent a minority of the ways in which surgeons operate. The majority of surgical procedures are still performed using an open incision. There is a real need for surgery to develop a virtual reality simulator for such open surgical procedures. Cooperative ventures with software designers in the gaming industry will undoubtedly yield significant advances in the years ahead [22]. Indeed there have been some studies which suggest that surgical trainees who are "proficient" with interactive DVD games may perform better on surgical simulators [22, 23].

Developments in surgical simulation unfortunately come at a high cost. The costs of simulation will undoubtedly reduce in the years ahead, but currently, cost is a major impediment to the advancement of simulation in surgical training. Despite this, RCSI continues to make a significant financial investment in surgical simulation and is about to build a multi-million euro state of the art National Surgical Training Centre which will be largely based around simulation.

Fig. 4 Mobile surgical skills training unit

Fig.5 Team training exercise in simulation laboratory

Simulation has enormous potential as a tool for the delivery of an evidence-based curriculum which allows surgical training programmes to deliver and to quality-assure surgical skills training. It also allows experienced surgeons to develop expertise in new procedures or in the use of new devices. Simulation has the ability to objectively measure and validate technical skills which have been trained to a quantitatively established proficiency level.

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