Teaching Surgical Techniques and Procedures Using Advanced Educational Tools and Concepts

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New educational concepts and tools are being developed to remodel surgical education. This is, in part, being driven by changes in the public’s expectations of our profession along with new students seeking a different model of education. The explosion of new surgical procedures and technologies has amplified the importance of remodelling how we teach and train. At the heart of any educational experience should be a curriculum that is flexible enough to change with the content and educational tools available, but robust enough to deliver to the trainee the skills and foundation they need to safely and efficiently move through the complex medical education system that is evolving worldwide today. Here, we describe such a curriculum with great future promise to meet these expectations. [Asian J Surg 2005;28(3):159–62]

Key Words: surgical education

Introduction

For over a century, the training of surgeons around the world has followed the Halstedian Preceptorship model of training. Under this model, the surgeon trainee experiences “...the orderly exposure to graduated clinical experience in the operating room during several years of residency under the close tutelage of dedicated senior attending surgeons...”. This widely accepted and successful model led to the declaration that “the operating room is the surgeon’s classroom”. None trained in this era would argue against the success and strength of this model, and many of us struggle with any attempt to remodel or modify it. However, there are several forces mandating a change in this approach to surgical training.

In 2000, the Institute of Medicine released its report entitled To Err is Human: Building a Safer Health System. In this report, it was revealed that 44,000–98,000 Americans die in hospitals each year as a result of medical error, “More die from medical error than from highway accidents or breast cancer”. While not all errors were related to surgery, it is clear that since this report, the public will no longer accept any perception that errors in care are not being driven out of the system. This includes our training programmes, and the public increasingly rejects a training model that uses the operating room and real humans as the format for training.

With increasing demands for productivity among teaching faculty, the expanding field of information to be mastered by medical students and trainees, and average costs of operating theatre time of US$16.00/minute, the operating theatre is becoming a very expensive classroom. In a recent, as yet unpublished, study from our lab analysing the added time and resulting expense required when a trainee was the operating surgeon on a laparoscopic Nissen fundoplication and laparoscopic cholecystectomy (LC), it was found that the average cost to train someone in these procedures was more than US$65,000 over a 5-year training period, just based on the extra time required in the operating room.

Our trainees are changing. Many of our students, and perhaps for good reason, are rejecting the concept of spending 5 or more years working under the tutelage of a senior surgeon.
Most American medical students (83%) graduate with an average debt of US$95,000. General surgeons’ salaries in the USA are down 10%, while the salaries of what have been termed “lifestyle” specialties (e.g. radiology, ophthalmology, anaesthesiology, dermatology – ROADS) have risen nearly 100% in the past 5 years. Students are looking for accelerated training and, within the context of the new US 80-hour resident workweek, many feel that the Halstedian Preceptorship is too onerous and prolonged.

Finally, it is increasingly clear that in procedural-based specialties such as surgery, better skills translate into better surgery. In the first study of its kind assessing the impact of practice outside the operating theatre using a surgical simulator, surgeon trainees who were thus trained made fewer errors and completed the operation faster than those without such training.1 This study clearly demonstrated what the airline industry has understood for years, that when one prepares through practice using simulated experiences, one performs better when placed in the real-world situation.

All of these forces are impelling the discipline of surgery to remodel the Halstedian Preceptorship model of training to one that embraces new educational tools and concepts. It is clear that the operating theatre can no longer serve as the surgeon’s primary classroom for technical skills.

Lesson of minimally invasive surgery

Over a decade ago, we experienced the most significant change in general surgery in the preceding 20 years, LC. This new approach to a common general surgical procedure required new skills and anatomical understanding to perform an operation that was the mainstay of a general surgeon’s practice. These new skills were not intuitive, nor easily acquired, and as surgeons around the world shifted their technique to laparoscopic from open cholecystectomy, patients experienced the consequence of this new and counterintuitive procedure; injuries to the biliary system dramatically increased. Over the next few years, this same experience was to be reproduced as each new laparoscopic procedure was introduced and integrated into practice.

This manner of introducing a new procedure and skill set was not undertaken without some very serious consideration as to how to integrate these procedures in as safe a manner as possible, especially after the evolution of LC resulted in such a rise in serious complications. In fact, early after the introduction of LC, the promise of simulation and virtual reality was offered as the ultimate solution to safe teaching of new skills and techniques. For the next 10 years, most of the effort to realise the promise of simulation-based training was focused on the technology of virtual reality. After 10 years of some of the most impressive engineering medical education has seen, we still had no meaningful capability in virtual reality for general surgery training, and the first study of its kind demonstrating that training with a simulator outside the operating theatre could improve intraoperative skills was not accomplished until 2002.1 This study used a very basic and crude “simulator” that had absolutely no resemblance to reality: Minimally Invasive Surgery Trainer-Virtual Reality (MIST-VR; Mentic AB, Gothenburg, Sweden) (Figure 1).

Over the past 10 years, with some brilliant minds focused on bringing the model of the airline industry and virtual reality to surgical education, several important lessons have been learned (Table 1), and these are now informing our pursuit of a more efficient and effective model of surgical education.

Table 1. Virtual reality surgical simulation: lessons learned over 10 years

| • Technology continues to change |
| • Content is everything |
| • Curriculum is debatable |
| • Does not need to be high-tech |
Curricular approach with proficiency-based progression

The foundation of an effective training programme is its curriculum. An appropriately conceived and constructed curriculum is the durable construct into which the evolving content can be laced. Technology, which has been the primary focus of efforts for the past decade, will only facilitate the execution of such a curriculum. Moore’s law (loosely interpreted, the processing capability of computers will double every 18 months) guarantees that by the time any technology has established itself as the centre of an educational programme, it will soon be outdated and ready to be replaced. This does not negate the role of technology in surgical education, it only helps us place it appropriately as a tool to help simplify and facilitate the execution of the curriculum.

Figure 2 depicts a programme for skills training that has the curriculum as its foundation, with the content tailored to the skills being taught and technology used to facilitate learning and assessing those skills so that the student can follow self-directed learning with objective assessment and progression to the next module. Such a curriculum seeks to realise the goals outlined in Table 2 and remembers the key elements in mastering and safely applying any procedure: knowledge, technical skill and judgement. Explicit within this approach is mastering the content of a given module before progressing to the next module. It is this mastery that ensures appropriate consolidation in the brain before progression, and uncluttered learning and building on prior experience in the next module.

Example of laparoscopic suturing

Suturing is an isolated skill, and is a very simple skill to build into this modular proficiency-based curriculum.

Module 1: Knowledge acquisition

In this module, the trainee reads a short article about the technique of needle manipulation, placing the suture through the tissue and tying a good knot. They also watch a video highlighting these steps. To demonstrate comprehension of the cognitive aspects of laparoscopic suturing, they must score 100% on a multiple-choice test on two separate occasions. Following this, they progress to Module 2.

Module 2: Psychomotor assessment and initial acquisition

Here, the trainee’s innate abilities are assessed using validated instruments that test perceptual, visuospatial and psychomotor ability (Pictorial Surface Orientation [PicSOr], MIST-VR). These assessments allow adjustments to Module 3 based on these innate abilities. The trainee is also introduced to the suturing models on which they will be training. These are...
physical models since there are, as yet, no good computer-based suturing trainers. They are also introduced to MIST-VR, the computer-based simulation tool, where they will master their basic laparoscopic manipulative skills. In Module 2, the trainees are explicitly told the criteria for progressing from Module 3 to Module 4. Module 2 typically requires an afternoon in the skills lab.

**Module 3: Integration of knowledge and psychomotor skills**
Put simply, Module 3 is where the trainee practises laparoscopic suturing. The training tools (i.e. the suturing model and MIST-VR) are available 24/7. In Module 2, the trainee was made aware of the criteria that will be used to determine when they have mastered this module and can progress to Module 4. The criterion for progression is determined by having attending surgeons proficient in laparoscopic suturing undergo assessment using all of the training models, and from this an “expert criterion level” is determined. A trainee’s achievement of this level of proficiency on two separate occasions is the basis for progression to the next module. The time needed for this module depends on the trainee’s abilities and the time they spend practising. Our own experience has revealed that every trainee eventually progresses, regardless of baseline abilities. Put differently, anyone can be trained to proficiency using this model, the difference is in how long it takes a given trainee to reach expert criterion levels.

**Module 4: Supervised real-world application**
In this module, the trainee and senior surgeon are in the operating room where the trainee is now allowed to apply newly acquired skills. Therefore, the new curriculum does not eliminate the operating theatre as the surgeon’s classroom, it only brings a better-prepared student to that classroom. It is in this module that the translation of a simulated training experience to better performance in the real clinical setting is both applied and tested. The trainee’s performance in the real-world setting is videotaped and assessed post hoc by a team of skilled examiners. For this methodology to work, errors in the real-world application of suturing must first be defined and carefully articulated so that trained examiners can use an error checklist to score performance. These error checklists are derived through regimented interviews with senior surgeons to define such errors. Two blinded reviewers grade videotapes to an inter-rater reliability of 0.8. Upon passing this real-world application, the trainee can matriculate from the curriculum. Put differently, they are “credentialled” in the skill being taught.

**Module 5: Mastery**
Module 5 implies that learning is never over, even when one has achieved objectively demonstrable proficiency with a skill. In laparoscopic suturing, the mastery module includes simulated experience of difficult situations. For example, a broken suture with a short tail before the final half-hitch has been thrown or suturing with camera angles and trocar angles that are at the extreme of what would be ideal. Again, Module 5 is ongoing and changes as new knowledge or skills relevant to the skill being mastered become available.

**Summary**
New educational concepts and tools are being developed to remodel surgical education driven, in part, by changes in the public’s expectations of our profession along with new students seeking a different model of education. The explosion of new surgical procedures and technologies has amplified the importance of remodelling teaching and training methods. The heart of any educational experience should be a curriculum that is flexible enough to change with the content and educational tools available, but robust enough to deliver the skills and foundation the trainee needs to safely and efficiently move through the complex medical education system that is evolving today.

**References**