Objective assessment of surgical dexterity using simulators

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Surgical skill, like training for any craft, has traditionally been learnt as an apprenticeship. However, whereas carpenters learn on wood that is never displayed, operative training is done on real clinical cases. Over recent years surgical skills training laboratories have in part, replaced the apprenticeship. This article discusses some of the tools used within such laboratories to ensure optimal surgical performance.

THE PRESSURE TO CHANGE

The training of surgeons has traditionally been an apprenticeship. Trainees first observe surgical procedures, then assist, perform them under supervision and finally perform them alone. The ultimate aim of training is for the surgeon to be able to competently perform operations on real patients, so there can never be a total replacement for training on patients. Properly supervised, this is an efficient and safe method. However, there may be some skills that are better learnt outside the operating theatre in the training laboratory.

While people have discussed the possibility of learning skills at a site other than the operating theatre (Barnes, 1987), it was not really until the advent of minimal access surgery that the need for training laboratories to teach new techniques became fully apparent. Minimal access surgery poses several dexterity problems to the traditional surgeon and in the early days some mistakes were made as a result (Royston et al, 1994).

Minimal access therapy training units (MATTUs) were established throughout the UK in an attempt to teach surgeons the skills that are necessary to perform safe and successful laparoscopic surgery. These skills include the ability to operate in a three-dimensional environment while observing just a two-dimensional image, mastery of the fulcrum effect of the abdominal wall as the tool passes through it, and operating using very long tools, without the ability to use one's hands or gain the normal tactile feedback of open surgery.

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Mastering these skills on simulated models in the laboratory may enable surgeons to rapidly overcome many of these problems, allowing safer surgery, and learning curves for common procedures such as laparoscopic cholecystectomy have been well documented (Hunter, 1997).

Reduction in training time as a result of the Calman report (Calman et al, 1999) has created the need for rationalized training. In response, a number of skills training courses have emerged to train core skills for both basic and higher surgical trainees. In this way, it is felt that focused training can ensure a high standard of ability is achieved among trainees, and it is hoped that the skills learnt in the training laboratory can be transferred into everyday clinical practice. Such training schemes can ensure a required standard of achievement is maintained among all practitioners, and successful completion of such courses is now mandatory for admission to the Membership of the Royal College of Surgeons.

Other political pressures, particularly in the aftermath of the Bristol Children's Hospital Inquiry (Smith, 1998), and the increasingly litigious nature of society have reaffirmed the need for reliable and valid ways of training surgeons, both in and out of the operating theatre. A key part of training is assessment, and producing valid objective methods of assessing surgical performance has so far proved to be difficult. Methods of assessing surgical performance and skill have grown to be a major focus of research within our department and several others (*Figure 1*).

THE ACADEMICS RESPONSE TO THESE PRESSURES

Dexterity is only one of many skills that a surgeon needs to perform safe and competent surgery. It has been said that surgery is 75% decision making and 25% dexterity (Spencer, 1978). In addition to extensive knowledge of anatomy, pathophysiology and operative procedure, surgeons have to be decisive, work well leading a team, and be good at self-appraisal and audit. While many of these are currently examined extensively as part of the surgical accreditation process, the latter aspects, and particularly dexterity, remain unassessed among the majority of surgeons.

Figure 1. Equipment used for research into surgical dexterity.

Many groups have tried to produce an objective evaluation of surgical dexterity. Systems where trainees are assessed as they perform specific simulated procedures and manage simulated critical procedures have been shown to give a more accurate reflection of ability than a trainer's subjective evaluation (Faulkner et al, 1996). Such systems can achieve high inter-observer correlation, particularly in global ability scores rather than procedure-specific scores (Martin et al, 1997), but the systems are dependant on large numbers of pre-trained observers (Reznick et al, 1997).

Many other 'objective' systems have focused on time taken to perform a task (Rosser et al, 1997) but time is not necessarily a good discriminator, as a fast surgeon is not necessarily a good one.

Computer-based systems are being developed which might given additional information as to the dexterity of a surgeon when performing laboratory-based tasks (Hanna et al, 1996, 1998), and these have the advantage of being entirely objective. Such systems are largely based on assessing how a surgeon moves while performing a task.

Work at Imperial College has looked at motion analysis as a measure of dexterity, while performing a computer-based simulation of laparoscopic surgery (Taffinder et al, 1998a). A custom-built software package analyses the positional data produced by mechanical tracking devices as the simulated tools move to perform the task (*Figure 2*). This hardware and software combination, termed the Imperial College Surgical Assessment Device, produces raw motion analysis data.

Figure 2. The computer analyses the movements and allows comparative dexterity data to be fed back to the surgeon.

Motion psychology theory suggests that as a motor task is learnt, the operator becomes more efficient at performing the movement in terms of number and accuracy of movements (Rosenbaum, 1992). Applying motion analysis to computer-simulated laparoscopic surgery appears to produce valid measures by which to distinguish surgeons of differing skill and experience.

Utilizing similar mechanical tracking devices, it has been possible to perform motion analysis on surgeons of varying experience as they perform simple physical simulations of laparoscopic surgery, such as pulling and cutting pieces of thread, or more complex tasks such as laparoscopic suturing. The measures produced appear to be valid reflections of laparoscopic skill, including number of movements, distance travelled, speed of tool movement and time taken (Taffinder et al, 1999).

Mechanical trackers limit the freedom of movement, and so recent research has focused on electromagnetic trackers. As trackers attached to the surgeon's hands (*Figure 3*) move within an electromagnetic field which is induced by a field box sitting on the patients abdomen, their three-dimensional position in space can be recorded at a rate of 20 Hz.

The trackers are free to move anywhere, and can be placed under a surgeon's gloves as he/she performs real surgery in the operating theatre (*Figure 4*) or complex simulated tasks in the laboratory (*Figures 5a* and *b*). Similar software allows calculation of criteria of movement analysis. Based on a laboratory model of an entire surgical procedure, the criteria appear to be valid judges of dexterity (Smith et al, 1999a).

Figure 3. Trackers on a surgeons hand.

THE ROLE OF OBJECTIVE EVALUATION

The value of such systems that can objectively assess surgical dexterity may be widespread. The influence of environmental factors on dexterity, such as the detriment caused by sleep deprivation, can be demonstrated (Taffinder et al, 1998b), and the effect of alcohol is currently under investigation.

The effect of training courses on dexterity has been demonstrated

Figure 4. Trackers in use in theatre.

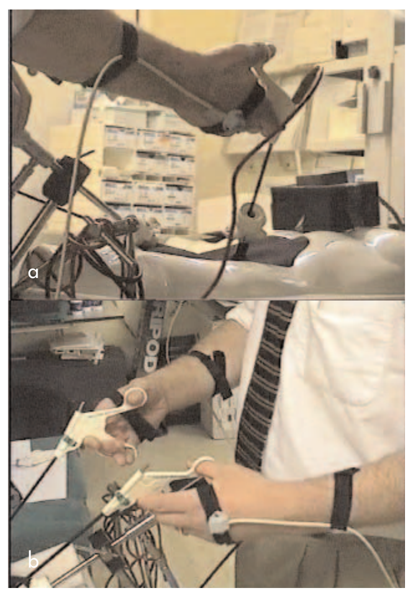

Figure 5. a and b. Trackers in use with simulators in the laboratory.

(Smith et al, 1999b), and the value of new training tools such as virtual reality simulations can be investigated (Smith et al, 1999c).

As new technology and computer-based simulation comes to the forefront of surgical training, tools such as this will be invaluable. By assessing performance in real surgery, we can define what it is that a good surgeon does, and contrast that with what a less experienced one does. The building bricks of good practice ascertained from studies in theatre can be built into computer simulations, allowing people to be trained to the same criteria in a simulated environment as they are in real surgery.

One value of such tools may come when assessing junior doctors who are embarking on surgical training. The potential exists to perform some form of aptitude testing, looking for those who might excel, those who need training, and those who despite training might never achieve an adequate level of performance. In this way, training could be focused for an individual, with the aim of helping one person achieve their maximal level of performance in the most efficient manner.

Results from such systems might help career guidance, and save time and money being spent on wasted or inappropriate training for an individual. Previous attempts at aptitude testing for surgical trainees have been inconclusive (Graham and Deary, 1991), but tools such as these might provide more evidence to increase the value of predictive assessment.

Whether such tools will play a major role in the revalidation and self-regulation of surgeons remains to be seen. Although dexterity is only a minor part of surgical skill as a whole, it is nonetheless of paramount importance. A surgeon with excellent knowledge and judgment may have a significant problem with manual dexterity. Hence, if improved audit highlights underperformance in an individual, such tools may be of value in highlighting what specific aspects of their practice might benefit from retraining.

CONCLUSION

Motion analysis is certainly not the panacea for all problems that currently exist in the assessment and maintenance of good surgical practice, but it may be a valuable tool to help guide training, simulation and assessment methods. Ongoing work augmenting the motion analysis with rigorous video analysis may produce a more powerful tool, allowing the combination of quality analysis with the quantitative analysis that motion analysis provides.

The ultimate goal of such research is to correlate these computer-generated scores of skill with patient outcome. Such research will be costly in terms of both money and time, but is vital to confirm beyond doubt the place of such analysis. It is only at that point that surgeons can confidently know that training and assessment in a simulated environment really can make a difference to patient outcomes. **HM**

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KEY POINTS

- Surgical training has moved away from a traditional apprenticeship.
- Surgical skills laboratories can replace some aspects of traditional training.
- Such laboratories may be the forum for assessment as well as training.
- Motion analysis using the Imperial College Surgical Assessment Device can be of value in both the laboratory and the operating theatre.