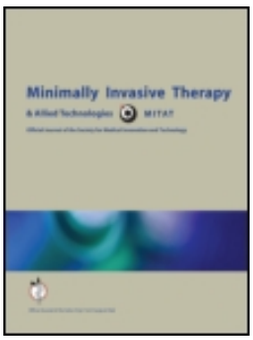

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M. Schijven & J. Jakimowicz

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Simulators, first experiences

M. Schijven and J. Jakimowicz

Department of Surgery, Catharina Hospital Eindhoven, Eindhoven, The Netherlands

Summary

It is increasingly being recognized that laparoscopic surgery poses specific strains on the surgical novice. Specific psychomotor skills are required, which cannot easily be acquired by extrapolation from open surgery. Also, limited teaching time in the strict surgical training curricula makes it difficult to acquire such skills. Two surgical simulation platforms, the Advanced Dundee Psychomotor Tester (ADEPT®), and the Xitact LS500®, are objects of study in our hospital for the training and objective assessment of laparoscopic task performance. Multiple validation studies, both at our center and at other institutions, are ongoing. Face-construct and content validity of the two systems under investigation have been established at our skills laboratory. This article highlights the most important findings of our studies using simulative surgical lapraoscopic technologies.

Keywords

virtual reality, validation, laparoscopy

Introduction

In recent years, laparoscopic cholecystectomy has replaced open cholecystectomy as treatment-of choice for symptomatic cholelithiasis. Since the laparoscopic technique requires different psychomotor abilities and skills, skills needed to perform laparoscopic surgery safely cannot be extrapolated from skills acquired from performing open surgery. At present, surgical residents-in-training are introduced to laparoscopic surgery mainly by the classic surgical apprenticeship, that is, they are guided by an expert surgeon in the operation theatre whilst performing hands-on surgery. Interestingly, there are no standards that must be met by a surgeon to practice laparoscopic surgery safely [1]. Moreover, there is no agreement on the method or means with which to measure laparoscopic surgery objectively. There is agreement, however, on the issue that no surgeon should undertake any operative procedure unless competent to do so [2]. As competency can only be acquired through practice, this poses an interesting dilemma for the surgical community.

One way to get acquainted with a surgical procedure safely, i.e., not in a patient context, is by means of creating an alternative, equally informative and effective teaching setting. Surgical skills laboratories may play an important role in the acquisition of skill in minimal access surgery, e.g. in laparoscopic / endoscopic surgery, and nowadays surgical curricula should contain a minimal access skills training program [3, 4]. New technologies, such as virtual reality surgical simulators and other objective methods of assessment, e.g. endoscopic psychomotor testers, are promising equipment for the improvement and evaluation of a physician's endoscopic level-of-skill.

In our hospital, a research-line was set up to investigate the dynamic process and the pitfalls concerning acquisition, integration and evaluation of minimal access surgical skill in the surgical curriculum. The Advanced Dundee Psychomotor Tester (ADEPT) and the Xitact LS500 laparoscopic cholecystectomy virtual reality simulation platform are means and object of study [5, 6].

ADEPT is a computer-controlled device, developed by the Ninewells Hospital, University of Dundee, for the objective evaluation of endoscopic task

Correspondence: M.P. Schijven, *Dept. of Surgery, Catharina Hospital Eindhoven, Michelangelolaan 2, P.O. Box 1350, NL-5602 ZA Eindhoven, The Netherlands. Tel: +31 40 2397150. Fax: +31 40 2443370. E-mail: mschijv@zonnet.nl.*

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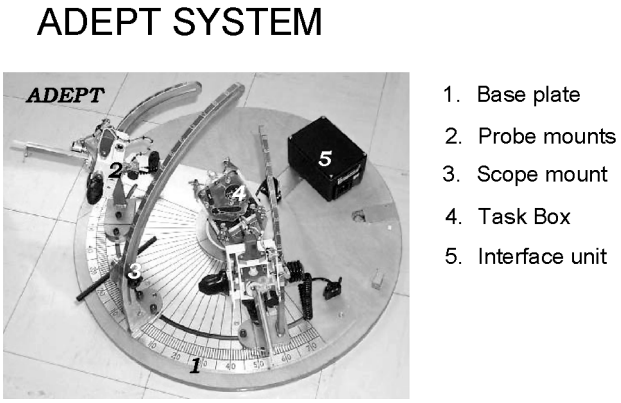

Figure 1. Advanced Dundee Psychomotor Tester.

performance [7]. The system has proven its value and been used in various research protocols [8–10] by the Cuschieri research group at Dundee. The Xitact LS500 was developed by Xitact SA, Morges Switzerland and is a relative new virtual reality laparoscopic cholecystectomy simulator. Xitact has been part of our skills laboratory since its early developmental stage [11].

This article reflects our first experiences with both ADEPT and Xitact LS500.

Materials & methods

Equipment

ADEPT's hardware (Figure 1) consists of a dual gimbal mechanism that accepts standard endoscopic instruments and -camera for bilateral manipulation in a defined 3D workspace. A task box is placed on the isocenter of the device. This box comprises five different target tasks, based on the main actions involved in endoscopic manipulation. ADEPT is linked to a standard PC for task instruction and storage of data.

The Xitact LS500 laparoscopy platform (Figure 2) is a modular virtual reality training platform, currently featuring peritoneal dissection and the clip-and-cut task of laparoscopic cholecystectomy. The simulator was developed by soft- and hardware engineers, working together with an advisory board of well-known and experienced laparoscopic surgeons. The simulator is a hybrid, combining a physical object containing the mechanical hardware, the OpTable, e.g. the virtual abdomen, with a computer providing the virtual reality visual scenery and haptic feedback. The computer assigns tailored curricula and stores sets of data of the participants.

Figure 2. Xitact LS500.

Studies

ADEPT was used to assess the following research questions:

- Are surgeons good estimators of their own performance?
- Do surgeons perceive ADEPT to be a valid instrument in measuring laparoscopic skills?
- Does performance on ADEPT reflect innate psychomotor ability?

Forty-five subjects, all surgeons with varying laparoscopic experience but without experience on ADEPT were assigned to perform two runs of five randomly assigned tasks on ADEPT. Execution time, successful completion, total plate error time (haptic parameter) and total probe error time (haptic parameter) were recorded. End parameters of study were perfect plate task runs, perfect probe task runs, and full perfect task run. Subjects filled in a questionnaire on demographics, the face validity of the system and their subjective estimate of performance.

On Xitact, multiple validation studies were performed, assessing the aspect of face-, expert-, referent-, concurrent- and construct validity of the over-all simulation and of specific laparoscopic tasks. Research questions were:

- To what extent does the Xitact simulate what it is supposed to represent, i.e. laparoscopic cholecystectomy?
- For the clip-cut scenario, it was hypothesized that
  - performance scores among experts in clinical laparoscopy should be significantly higher than scores of novices;
  - performance scores should be related to the clinical experience of the participant and that
  - performance scores should improve over runs of the clip-cut task.

An expert group of 33 experienced laparoscopic surgeons (>100 laparoscopic cholecystecomies) was compared with a referent group having performed less than 100 laparoscopic cholecystectomies for the face-validity study. For the clip-cut scenario, two groups of 37 experts (>100 laparoscopic cholecystectomies) and 37 novices (no experience) were formed.

Results

On ADEPT, it was clear that surgeons were no good estimators of their own performance score (as measured on a Visual-Analogue Scale). For purpose of the study, a summative score (SUM-score) was computed, integrating the various end-parameters into one weighted, normally distributed reliable performance score. Interestingly, SUM scores could not be predicted by knowing the self-reported VAS score. Face validity on ADEPT was previously established by others [12]. Our study showed ADEPT's internal validity to be high, and for external validity. It had previously been shown that ADEPT strongly correlates with clinical competence [13]. In our study, however, experienced surgeons on the whole did not perform worse or better than inexperienced surgeons.

The third research question in the ADEPT study addressed the issue whether or not ADEPT reflects innate ability. Macmillan and Cuschieri have previously shown that ADEPT is a system able to identify aspects of performance that do not seem to improve with practice [13]. In our study, analysing two runs of five tasks, there was a concordance of 72% between runs, meaning that scores seem to be relatively independent of laparoscopic experience and stable over runs. However, some training effect took place since number of successful tasks and time are rated higher among second run statistics [5].

The Xitact LS500 is considered to be quite similar to the laparoscopic cholecystectomy environment, as both expert- and resident opinion agree that scenery and haptics are approaching reality. Most importantly, there appears to be no significant difference between the means of both groups on all sixteen face-validity questions, indicating a favourable and uniform opinion on both the 'consumer' group and the 'teacher / buyer' group. The majority of respondents feel Xitact could become a useful tool in teaching and monitoring progress in laparoscopy. Since the scenery of Xitact has improved over the last year, resulting from evolving software development and attention to user's feedback, the face-validity of the system was rated even higher in the clip-and-cut construct validity study. Again, for research purposes, a validated SUM score was computed here, assigning a score for every possible outcome of the simulation, weighing some faults or sequence of faulty actions heavier than others. Experts do indeed score significantly higher than novices, and also their confidence intervals around the scores are smaller (indicative for less variation e.g. a more stable / experienced group). Performance scores also seem to be related to the clinical laparoscopic experience of the participant. And lastly, performance scores of both experts and novices improve over runs. Thus, the assumption must be that the Xitact LS500 laparoscopy simulator does in fact adequately mimick the surgical procedure of clipping and cutting of the cystic duct and — artery during the laparoscopic cholecystectomy.

Discussion

It is a fact that the endoscopic setting of ADEPT is not similar to the clinical laparoscopic situation. In contrast to Xitact, ADEPT is a pure *psychomotor* tester, focussing on only one aspect of the complex area of interacting determinants (cognitions, skills and abilities) that make up a surgeon. This might explain why experienced surgeons did not perform any better. In fact, ADEPT seems to be able to exclude experience in laparoscopic surgery as a determinant of importance in assessing pure psychomotor abilities. Xitact, on the other hand, does account for factors such as knowledge and previous laparoscopic experience since its tasks are similar to a clinical situation. Performance scores on Xitact are able to differentiate between groups with different levels of experience. Xitact's environment does indeed mimick a clinical laparoscopic situation. This is reflected by high face- expert and referent opinion considering the VR simulation, e.g. its validity. The uniformity in judgement is important

since it indicates acceptance for both potential trainers and trainees.

Both on ADEPT and Xitact LS500, it seems to be difficult for participants to estimate performance. In fact, because this seems to be so difficult, the need for objective scoring systems to evaluate endoscopic task performance is obvious.

The greatest advantage of virtual reality medical simulation is the opportunity to try and fail without consequence for the patient [14]. The importance of validation is eminent, to prove its usefulness, its capacity as both a training and an assessment tool, and also for its positioning on the VR simulator market. Many simulators are out there, some validated, some not, and each with its own areas of main interest. However, there is agreement on certain features: the importance of force-feedback and stability of the VR scenery, the modularity of the system, the gradual increase in difficulty, the ability to build specific curricula and the ability to export data. These features are thus integrated into most simulators.

Almost all companies acknowledge the need for proper validation of their system and therefore, increasing interest in these types of studies is reflected in the current literature. In our opinion, it cannot be stressed enough that there is much to gain from input from both the clinical surgical field and the medical engineering and software development into simulation development.

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