Virtual reality computer simulation

An objective method for the evaluation of laparoscopic surgical skills

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Abstract

Background: Objective assessment of psychomotor skills should be an essential component of a modern surgical training program. There are computer systems that can be used for this purpose, but their wide application is not yet generally accepted. The aim of this study was to validate the role of virtual reality computer simulation as a method for evaluating surgical laparoscopic skills.

Methods: The study included 14 surgical residents. On day 1, they performed two runs of all six tasks on the Minimally Invasive Surgical Trainer, Virtual Reality (MIST-VR). On day 2, they performed a laparoscopic cholecystectomy on living pigs; afterward, they were tested again on the MIST-VR. A group of experienced surgeons evaluated the trainees' performance on the animal operation, giving scores for total performance error and economy of motion. During the tasks on the MIST-VR, errors and noneconomy of movements for the left and right hand were also recorded.

Results: There were significant correlations between error scores in vivo and three of the six in vitro tasks \((p < 0.05)\). In vivo economy scores correlated significantly with non-economy right-hand scores for five of the six tasks and with non-economy left-hand scores for one of the six tasks \((p < 0.05)\).

Conclusion: In this study, laparoscopic performance in the animal model correlated significantly with performance on the computer simulator. Thus, the computer model seems to be a promising objective method for the assessment of laparoscopic psychomotor skills.

Key words: Surgical education — Laparoscopic training — Computer simulation — Virtual reality

Laparoscopic surgery is difficult to perform. Extensive training is needed to master the fine motor skills and hand-eye coordination necessary to operate safely. Assessing the surgeon early in the training course to ensure that a satisfactory outcome can be anticipated should be a requisite component of the residency program. If insufficient performance is detected early in the surgeon's career, he or she could receive professional guidance toward other specialties or operative procedures, thus potentially averting complications in the future.

There are computer systems that can provide unbiased, objective, and easily applicable measurements of laparoscopic performance, but their wide application in surgical training programs is not yet generally accepted. These systems would have a great beneficial effect on education and may even provide a benchmark for future certification [2]. The purpose of the present study was to validate the Minimally Invasive Surgical Trainer, Virtual Reality (MIST-VR) as an objective method for assessing laparoscopic surgical skills.

Materials and methods

The data were collected at a 2-day course in laparoscopic technique for surgical residents. Fourteen participants (13 male, 1 female) with similar limited experience in endoscopic surgery (<10 cholecystectomies) took part in the study. All were right-hand-dominant individuals. On day 1, all trainees made two runs of all six tasks on the MIST-VR. On day 2, they performed a laparoscopic cholecystectomy on living pigs; afterward, they were tested again on the MIST-VR.

Laparoscopic skills in vitro were measured objectively by performing the six tasks on the MIST-VR system (Virtual Presence Ltd., London, England). The system is based on a PC and configured with a Pentium 200-MHz processor, 32 MB of RAM, a 1.6-GB hard drive, a Matrox Mystique 4-MB video card, and a 17-in monitor. It is linked to a frame containing two laparoscopic instruments and a diathermy pedal. Movement of the instruments is translated as a real-time graphical display. An accurately scaled operating volume of 10 cm³ is represented as a three-dimensional cube on the computer screen. Targets appear randomly within the operating volume according to the task and can be "grasped" and "manipulated" [5].

The six tasks are of progressive complexity. All of them begin with...
bilateral movements to touch a virtual sphere with the tips of the virtual instruments. For task one, the trainee is required to grasp a virtual sphere and place it in a virtual box. As with all tasks, it is repeated twice for each hand. In the second task, the virtual sphere is grasped, transferred between instruments, and then placed in the box. Task three consists of alternately grasping the segments of a virtual pipe. Task four requires the trainee to withdraw, and reinsert this instrument, and once again touch the sphere. In the fifth task, once the virtual sphere has been grasped, three plates appear on the surface of the sphere, 90° apart; they are then touched by the other instrument and, using the pedal, removed using virtual diathermy. Task six combines the actions of tasks four and five with the aim of diathermying the plates while holding the sphere in the virtual box. During the tasks, errors (number of movements away from the target), non-economy of motion for each hand (actual path length/ideal path length), and operation time are calculated and recorded.

Laparoscopic skill in vivo was assessed with a laparoscopic cholecystectomy on anesthetized pigs (Danish Landrace) using conventional laparoscopic equipment. A group of three experienced laparoscopic surgeons observed and evaluated the performance of the trainees according to predefined objective criteria, such as coordination (0 = poor, 1 = satisfactory, 2 = good, 3 = excellent), confidence of movements (0 = poor, 1 = satisfactory, 2 = good, 3 = excellent), bleeding (0 = no, 1 = yes), gallbladder perforation (0 = no, 1 = yes), and deep lesions (0 = no, 1 = yes). Coordination and confidence of movements were considered to be parameters comparable with accuracy/economy from the simulator test; bleeding, gallbladder perforation, and deep lesions were considered to be error parameters. The sum of coordination and confidence values formed the total economy score; the sum of bleeding, gallbladder perforation, and deep lesions formed the total error score.

Economy and error scores from the in vivo test were correlated with non-economy of the left/right hand and error values from the computer simulator. The total economy score from the pig operation was compared with both non-economy left- and right-hand scores from the third test session on the computer simulator. Similarly, the total error score calculated during the animal operation was compared with the error score from the third repetition of the virtual procedure. Spearman’s test was used to determine the correlation between in vivo and in vitro scores. Values are given as median (range) unless otherwise stated.

The study protocol was approved by the local ethics committee, and participants were enrolled after giving their informed consent.

Results

The values from the animal operation and the third session of the sixth MIST-VR task are presented in Table 1. Significant correlations were demonstrated between the error scores from the animal cholecystectomy and three of the six virtual laparoscopic tasks: task 2 ($r_s = 0.7, p = 0.012$), task 4 ($r_s = 0.5, p = 0.049$), and task 6 ($r_s = 0.6, p = 0.038$).

There were significant correlations between the economy score from the animal procedure and the non-economy of motion scores for the right hand in five of the six simulator tasks: task 1 ($r_s = 0.6, p = 0.034$), task 2 ($r_s = 0.6, p = 0.014$), task 4 ($r_s = 0.6, p = 0.018$), task 5 ($r_s = 0.8, p = 0.001$), and task 6 ($r_s = 0.6, p = 0.022$). For the left hand, correlation was demonstrated in only one of the six tasks, task 6 ($r_s = 0.8, p = 0.001$).

Scatterplots of values from the animal operation and the third session of task 6, which is the most complex task and includes elements from most of the other tasks, are given in Figs. 1, 2, and 3.

Discussion

The training of laparoscopic surgeons is a subject of extensive debate. Reports of serious complications have stressed the importance of receiving adequate training and evaluation before attempting surgical procedures with patients. The airline industry, which also relies on technical performance, requires pilot trainees to undergo and successfully manage exhaustive exercises on flight simulators prior to performing real flights. There is increasing consensus that a similar philosophy should be applied in surgical education [1, 3, 6].

In current practice, the assessment of surgical skills is often unstructured, subjective, and may even be biased. A generally accepted standardized, objective, and valid method for the quantitative measurement of laparoscopic operative skills does not exist [3]. However, recent developments in computer technology have produced virtual reality simulators that may offer optimal conditions for the training and evaluation of laparoscopic skills. The computer models allow the trainee to practice realistically complicated maneuvers without treating actual patients. Furthermore, the trainee’s performance is not affected by anatomic variations or the physiologic responses found in animals, and the scenario for testing is easily reproducible.

When we compared the error scores for the animal model with those from the MIST-VR, we found significant