Assessment of Procedural Skills Using Virtual Simulation Remains a Challenge

Siska Van Bruwaene, PhD,*† Marlies P. Schijven, PhD,‡ and Marc Miserez, PhD*§

*Center for Surgical Technologies, Leuven, Belgium; †Department of Urology, University Hospitals, Leuven, Belgium; ‡Department of Surgery, Academic Medical Center, Amsterdam, The Netherlands; and §Department of Abdominal Surgery, University Hospitals, Leuven, Belgium

OBJECTIVE: The LAP Mentor is a procedural simulator that provides a stepwise training for laparoscopic cholecystectomy. This study addresses its "construct" validity that is present when a simulator is able to discriminate between persons with known differences in performance level on the laparoscopic cholecystectomy in real life.

DESIGN: Three groups with different skill levels performed 2 trials of 4 distinct parts of the cholecystectomy procedure (cholecystectomy exercises) and 1 full procedure on the LAP Mentor. Assessment parameters concerning the quantity and the quality of performance were compared between groups using the Kruskal-Wallis and Mann-Whitney *U* tests.

SETTING: The entire research was performed in the Center for Surgical Technologies, Leuven, Belgium.

PARTICIPANTS: For study purposes, 5 expert abdominal laparoscopists (>100 laparoscopic cholecystectomies performed), 11 surgical residents (10-30 cholecystectomies performed), and 10 novices (minimal laparoscopic experience) were recruited.

RESULTS: With regard to the quantity of performance (time needed and number of movements), the experts showed significantly better results compared with the novices in the cholecystectomy exercises. Only in the full procedure, the results of all the parameters (except speed) were significantly different between the 3 groups, with the best results observed for the experts and worst for the novices. With respect to quality of performance, only the parameter "accuracy rate of dissection" in exercise 3 showed significantly better performance by the experts.

CONCLUSIONS: Only the full procedure of the LAP Mentor procedural simulator has enough discriminative power to claim construct validity. However, the lack of quality control, which is indispensible in the evaluation of procedural skills, makes it currently unsuited for the assessment of procedural laparoscopic skills. The role of the simulator in a training context remains to be elucidated. (J Surg 71:654-661. © 2014 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: laparoscopy, virtual simulation, construct, validation, LAP Mentor, assessment

COMPETENCIES: Patient Care, Professionalism, Practice-Based Learning and Improvement

INTRODUCTION

"See one, do one, teach one" has been the cornerstone of surgical training programs for years. However, with the advent of minimally invasive surgery, technical demands on surgeons have increased, whereas at the same time, training opportunities in the operating theater have diminished because of problems, such as restricted work-hour regulations, legal issues, and time pressure. These changes have created the need for supplementary skills training in a safe laboratory environment where surgical simulation permits learning through "trial and error" without endangering patients' lives. Virtual reality (VR) as a training model is an upcoming tool in these surgical training programs.[1-3]

For basic laparoscopic skills, as well as for more advanced laparoscopic skills, such as suturing and knot tying, the role of the virtual simulators is still under debate. More robust and inexpensive video trainers are both seen as equally effective[3-5] or even superior[6] and apparently more appealing and realistic to the trainees.[4-7] In the more advanced stages of laparoscopy training, focus shifts toward procedural dissection skills. The current training models include live anesthetized animals and animate cadavers that are costly,

The purchase of the LAP Mentor virtual trainer by the Center of Surgical Technologies, Leuven, was partially sponsored by Ethicon Inc (Johnson & Johnson medical). This funding was completely independent from this study and did not influence its results. Drs Van Bruwaene, Schijven, and Miserez have no conflicts of interest or other financial ties to disclose.

Correspondence: Inquiries to Siska Van Bruwaene, MD, PhD, Parijsstraat 1, Vlezenbeek 1602, Belgium; fax: (032) 568-0132; e-mail: siska.vanbruwaene@gmail.com

  1931-7204/$30.00
http://dx.doi.org/10.1016/j.jsurg.2014.01.005

require complex infrastructures, differ from human anatomy, and suffer from both ethical and hygienic drawbacks.[3-8] Therefore,VR simulation seems to be an appealing alternative as a training model.

Next to important logistic advantages, the virtual simulators offer automated scoring with numerous computer-based metrics. These could be used for assessment of procedural laparoscopic skills, replacing the laborious and subjective rating by experts during live or videotaped procedures.[9] However, to allow for valid assessment, these parameters must correctly reflect the actual operative skill of the trainee. This so-called concept of construct validity is present when the simulator is indeed able to discriminate between persons with known differences in performance level on the simulated skill, the laparoscopic cholecystectomy, in real life.[10,11]

The LAP Mentor (Simbionix, Cleveland) is a laparoscopic virtual simulator that, next to basic laparoscopic skills, suturing, and knot tying, provides a structured stepwise training program for the laparoscopic cholecystectomy. This training program consists of 4 cholecystectomy exercises, representing 4 distinct parts of the procedure to ensure a stepwise acquisition of the technique. They focus on the dissection of the Calot triangle, clipping and cutting of the cystic artery and duct, and the dissection of the gall bladder from the liver bed. Furthermore, 6 full cholecystectomy procedures, each with specific patient characteristics (i.e., short cystic duct and variations in cystic artery position), are provided. For every exercise and for the full procedures, several assessment parameters are measured simultaneously.[12,13] Construct validity of this procedural part of the LAP Mentor was addressed in only a single previous study.[13] Discriminative power between groups was found to be limited, and data clearly showed a lack of quality control. When aiming for the assessment of surgical skills, stronger validity evidence is needed. Therefore, the present study verifies the construct validity of the "cholecystectomy" module of the LAP Mentor virtual simulator.

MATERIAL AND METHODS

Subjects

For study purposes, 26 participants were recruited. Of these subjects, 5 were expert abdominal laparoscopists (> 100 laparoscopic cholecystectomies performed), 11 were surgical residents in training (10-30 cholecystectomies performed), and 10 were nonsurgical residents in training (novices with minimal laparoscopic experience). All participating surgical residents were in their second or third year of training. All the novice participants had previously attended several human cholecystectomies. Therefore, adequate cognitive procedural input was guaranteed, and all had some experience with laparoscopic equipment. None of the subjects had previous experience with the LAP Mentor virtual simulator. The nature of the study was explained to all the subjects before enrollment, and informed consent was obtained from all the subjects.

LAP Mentor Virtual Simulator

The LAP Mentor is a computer-based VR simulator for learning laparoscopic skills, featuring 2 mock working instruments and a camera. Instrument and camera movements are translated into a virtual surgical environment, including haptic feedback, and displayed through a 17-in. flat liquid crystal display. The laparoscopic cholecystectomy is separated into 4 distinct parts of the cholecystectomy procedure (cholecystectomy exercises) to ensure a stepwise acquisition of the technique (Fig. 1). Furthermore, 6 full procedures are available of which only the first one was used for this study. Colored structures guide the trainee during the procedural exercise but are not provided during the full procedures. Diathermy, graspers, endoscissors, and a clip applier are available for use.[12,13]

Performance Evaluation

The quantitative parameters are measured in all exercises, as well as during the full procedures: total time needed to perform the exercise, the number of movements of the right and left hand, total path length of the right and left hand, and average speed of the right and left hand. For each of these motion parameters, a composite score for both hands (sum for "movements" and "path length"; average for "speed") was calculated so as to exclude the effect of dexterity (hand dominance) on performance scores.

The parameters assessing quality of performance are different for each exercise. All these parameters indicate better performance with a higher value. In the first exercise (Fig. 1A), the trainer provides the accuracy rate of clipping and cutting, that is, the percentage of clips and cutting maneuvers performed on the marked lines. In the second exercise (Fig. 1B), the trainer provides a safe clipping distance, that is, the distance between the proximal and the distal clip on the cystic artery and duct, and a safe cutting distance, that is, the distance between the division and the closest clip, either proximal or distal. A third distance that is measured by the trainer, between the distal clip and the infundibulum, seemed clinically irrelevant and was not used in this study. The safe clipping and cutting distance were summed for further calculations and called the safety parameter of clipping and cutting (measured in mm). In the third exercise (Fig. 1C), the trainer provides 4 independent quality parameters: the accuracy rate of dissection, that is, the percentage of time cautery is performed within the correct area (indicated with a blue color on the screen), which decreased when cautery is performed in the area of the common bile duct or hepatic artery; the efficiency rate of cautery, that is, the percentage of time cautery is applied in actual contact with the adhesions; the safety rate of cautery,