Development of a Web-Based Laparoscopic Technical Skills Assessment and Testing Instrument: A Pilot Study

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OBJECTIVE: Current surgical training programs rely heavily on subjective assessments to measure operative proficiency, despite heavy emphasis on standardized testing as a means to rank scholastic ability. A compact laparoscopic simulator was developed with the intention to create a technical skill evaluation system that resembles standardized testing to provide the user with real-time percentile scores in a variety of skill metrics. The calculation of percentiles is only accurate if the pool of scores resembles a specific distribution (e.g., normal or log-normal distribution). We hypothesize that the grading measures provided by the simulator will follow normal or log-normal distributions.

MATERIALS AND METHODS: A total of 29 surgical trainees with varying levels of laparoscopic experience were surveyed regarding their current training, proficiencies, and experience with the Fundamentals of Laparoscopic Surgery curriculum and then asked to perform a standard peg-transfer task 5 times. A proprietary device placed along the trocars of a laparoscopic box trainer was used to gather data that, when subjected to unique algorithms, gave real-time, web-based feedback to trainees on the following metrics: volume of instrument use, economy of movement, angular instrument path, instrument rotation, bimanual coordination, smoothness, time to task completion, and depth perception. Numerical data were plotted on a frequency histogram. Minitab software was used to identify if individual metrics fit a standard distribution curve. Analysis of variance was used to differentiate among 3 established physician skill levels, as a means of assessing construct validity.

RESULTS: In the goodness-of-fit tests performed, angular path, depth perception, rotation, and smoothness were found to best fit a log-normal distribution ($p > 0.1$). Bimanual coordination was found to fit a normal distribution ($p \geq 0.067$). However, both normal and log-normal distributions were rejected ($p \leq 0.01$) for the metrics of time, volume, and economy of movement. After separating participants into 3 groups based on level of experience with the Fundamentals of Laparoscopic Surgery curriculum, analysis of variance showed significant differences among all group means across the 5 metrics (i.e., angular path, depth perception, rotation, smoothness, and bimanual coordination; $p \leq 0.023$).

CONCLUSION: A proprietary device provided quantitative assessment of laparoscopic skills, which can be used to differentiate among skill levels. Of the 8 tested metrics, 5 fit a normal or log-normal distribution, meaning the scores can statistically be ranked by percentile. Time, volume, and economy of movement did not fit desired distributions. The grading system proved to have construct validity, indicating it may be useful in the longitudinal assessment of laparoscopic skills of surgical trainees. (J Surg 71:e73-e78. © 2014 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: FLS, laparoscopic simulation, technical skills, surgical education, motion analysis

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

INTRODUCTION

In response to concerns for patient safety, duty-hour restrictions, and cost containment, surgical simulation has become an increasingly important adjunct to graduate surgical education over the past 2 decades. Its role has grown to the point that many educators feel it should become integrated into training programs as a standard requirement.[1] In the domain of laparoscopic surgery,

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available technical skills simulation platforms now range in complexity from simple "open" and laparoscopic suture laboratories to the more complex and, quite often, expensive computer-based systems. One such validated, cost-effective tool used to teach and measure laparoscopic skills is the box trainer used in the McGill Inanimate Systems for Training and Evaluation of Laparoscopic Skills system.[2-4] Numerous studies have correlated performance and practice using the box trainer with increased operative proficiency to the point that its exercises are now incorporated into the Fundamental of Laparoscopic Surgery (FLS) skills course and its companion written/practical examination, in which the American Board of Surgery (ABS) now requires a passing performance by surgical trainees to be eligible for the qualifying examination.[5]

Among the critical elements of a successful simulation platform in terms of resident education and training is the need to provide immediate and objective performance feedback that the user/resident can use to enhance their skill set, unlike a videotaping session offered by a swing coach in golf. In laparoscopy, complex hand gestures that may be difficult to characterize by the naked eye in an open, freestyle simulation experience can be readily broken into basic movements owing to fact that the instruments used are fixed in position.[6] As such, these gestures/movements can be recorded and translated into data points, normalized, and immediately returned to the user to provide an objective assessment of their skill set—and offer suggestions as to how the user might go about improving those movements that fall below a set standard.

We have developed a compact and cost-effective simulator that, when placed on top of any existing box trainer, was hypothesized to provide real-time numerical gesture analysis feedback to users in the form of percentile scores. To define feasibility, validity, and reliability, a pilot study was completed to determine whether the movement data collected resembles a known specific (e.g., normal or log normal) distribution. To the extent that each gesture movement does follow a standard distribution, we then set out to define how users of varying expertise could be differentiated through this form of gesture analysis.

METHODOLOGY

Instrument Development

The device consists of a mat that sits on top of any standard box trainer (Fig. 1). Embedded in the mat are trocars that consist of 2 sensors that measure the movement of a laparoscopic instrument placed into that trocar. A dual-axis accelerometer measures the side-to-side and forward-to-back tilt of the instrument whereas an optical mouse sensor measures the clockwise and counterclockwise rotation as well as the in and out insertions of the instrument. In the device, 2 USB ports connect to a webcam and to the sensor's motherboard that relays information to a standard computer.

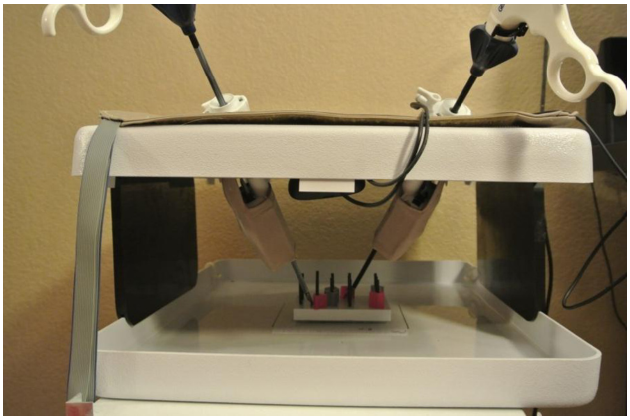

FIGURE 1. Design of simulator. Mat sits atop a box trainer. The trocars hold sensor, which relay motion data to a computer. A webcam (not pictured) is used to display exercise.

The following metrics were measured: (1) volume of instrument use, indicating the cubic area of space occupied by the instruments during task completion; (2) economy of movement, the ratio of total instrument path to the shortest path distance possible; (3) angular path, which describes the angular movement of the instrument; (4) instrument rotation; (5) bimanual coordination, which is the percentage of motion of each hand during task completion; (6) smoothness, which uses velocity to define how smooth (or jerky) the tip of the instrument is moving during task completion; (7) time to task completion; and (8) depth perception. Proprietary algorithms were then used to formulate each metric in line with previously established methodology.[7] The individual movement metric data obtained during the completion of a standardized laparoscopic exercise are uploaded through a website (http://www.med3dtracker.com), analyzed, and returned immediately to the user at the end of each trial or session.

Study Group

A total of 29 surgeons from Carilion Roanoke Memorial Hospital, which serves as the tertiary care medical center for Virginia Tech Carilion School of Medicine, were voluntarily recruited for this institutional review board–approved study. Participants were first asked to complete an online survey designed to define their current level of training/experience, their technical proficiencies, and their experience with the FLS curriculum. Based on this information, participants were assigned to 1 of 3 groups: novice, intermediate, and expert. They were assigned to the expert group ($n = 6$) if they had passed FLS or were current practicing minimally invasive surgeons. The intermediate group ($n = 11$) consisted of participants with some exposure to FLS training, whereas the novice group ($n = 12$) consisted of participants who had no prior FLS exposure.