Designing and Validating a Customized Virtual Reality-Based Laparoscopic Skills Curriculum

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OBJECTIVE: We developed and instituted a laparoscopic skills curriculum based on a virtual reality simulator, LapSim (Surgical Science, Göteborg, Sweden). Our goal was to improve basic skills in our residents. The hypothesis of this study is that performance in our course will differentiate levels of experience in the training program, establishing construct validity for our curriculum.

DESIGN: We designed a novel curriculum that consisted of 17 practice modules and a 7-part examination. All residents who completed the curriculum successfully were included in this study. Performance to complete the examination was analyzed. Data were stratified by level of training.

SETTING: University surgical skill training laboratory.

PARTICIPANTS: In all, 29 residents of all levels of training and 3 attending surgeons completed the curriculum.

RESULTS: The average number of practice repetitions required was 243. To complete the examination component, junior residents (R1–R3) required more repetitions than senior residents (R4, R5), 28.3 versus 13.9, respectively ($p < 0.002$). Tasks on camera and instrument navigation as well as coordination did not reveal significant differences. The complex grasping task demonstrated significant differences in repetitions required for each level of training: 19.5 attempts for R1, 17.2 for R2, 13 for R3, 8.5 for R4, and 3 for R5 ($p < 0.04$). The 2 cutting drills, which required precise use of the left hand, required 7.9 repetitions for junior residents versus 2.7 for senior residents ($p < 0.009$). A clip application drill differentiated among junior residents with 39.4, 19.8, and 8.5 repetitions required for R1, R2, and R3, respectively ($p < 0.05$). Senior residents performed equivalent to attendings on this drill. A lifting and grasping drill differentiates among junior residents, senior residents, and attendings ($p < 0.03$).

CONCLUSIONS: Individual performance in our curriculum correlates with the level of training for many drills, which establishes construct validity for this curriculum. Noncontributory drills may need to be revised or removed from the curriculum. Successful completion of this curriculum may lead to improved resident technical performance. (J Surg 65: 413-417. © 2008 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: proficiency-based training, resident curriculum, surgical simulation, virtual reality

COMPETENCIES: Medical Knowledge, Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

Much has changed in surgical education since the days of William Stewart Halsted, MD. He established formal graduate surgical training in the United States as a system in which trainees are mentored in a hospital setting as they steadily gain surgical and patient care responsibility. As stated in the landmark paper, "The training of the surgeon," his system would "produce not only surgeons, but surgeons of the highest type."[1] Currently, the realities of medical and surgical training require a paradigm shift. Graduate surgical training now must conform to resident work-hour limits, the increased pressure for efficiency and volume in clinical practice for those who are teaching, and the development of new technologies and procedures that often have doubled the number of methods of performing a procedure and introduced new skills to be acquired. Minimally invasive surgical techniques clearly fit into the latter.

It is now widely accepted that skills training outside of the operating room is an essential part of residency, which is especially true for minimally invasive surgery (MIS). When compared with open surgery, MIS is more difficult to learn, more difficult to teach, and does not adapt well to old models of training. Furthermore, open surgery experience does not transfer to laparoscopy.[2] The challenge resides in the fact that MIS

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Presented at an Educational Workshop at the 2007 APDS Meeting in Washington, DC.

requires different skill sets from open surgery, which include ambidextrous coordination, appreciation of a 3-dimensional environment on a 2-dimensional screen, manipulation of delicate structures with limited tactile feedback, and use of instruments with limited degrees of freedom and unique features such as the fulcrum effect.

Various training methods and devices have been developed to replicate the laparoscopic environment. The most commonly used methods are "box trainers," virtual reality surgical simulators, and animal models. Each method has identifiable strengths and limitations with regard to utility, accurate representation of the surgical field and instrumentation, tracking of trainee performance, cost, availability, and maintenance requirements. From a surgical educator's perspective, the ideal training system develops basic skills that will be transferred to the operating room and provides a means of objective skill assessment.

Virtual reality surgical simulators are the tools that come closest to these goals. The concept of simulation in training has been used since the 1920s in pilot training. During the 80 years since then, these tools have been improved, and training curricula have been refined to the point that flight simulator experience is an acceptable substitute for flight time in training and recredential requirements of pilots. Virtual reality simulation in surgery is not yet as developed or integrated.

Seymour et al[3] were the first to demonstrate that completing a virtual-reality–based curriculum improves operating room performance. They also established the concept that performance, not fixed repetition, is the standard for skill development. Subsequent studies have validated several virtual reality simulators as tools that can teach laparoscopic psychomotor skills. The role of simulators in objective trainee assessment and in a structured curriculum is also becoming accepted.[4]

Multiple virtual reality surgical simulators are available on the market, each with its own advantages and disadvantages. The cost of acquisition is a universally shared disadvantage for most, but the design of the software for each allows variable degrees of customization by a program director. The LapSim (Surgical Science, Gothemberg, Sweden) simulates tasks required in MIS and has customizable difficulty and metrics. The tasks preinstalled in the device can be adjusted over a wide range of setups to help focus the training experience. Individual tasks can be combined into user-specific curricula to track an individual trainee's progression on the device and pattern of use. Previous work demonstrated that performance on LapSim drills can distinguish experts from novices.[5] Improvements in software and tasks now allow specific curriculum development that can be studied longitudinally.

A novel surgical simulation curriculum was designed at Yale University based on the LapSim exercises. We found that the preset simulator metrics and level designations provided by the manufacturer were not aligned with our goals. We also identified many quirks and tricks inherent in the simulations that did not correlate with surgical skills, but they were required to complete simulations on the preset settings. We endeavored to remove these issues from our curriculum.

The primary goal of the curriculum was to improve basic laparoscopic skills in our residents through a program that would allow independent practice. The drills were customized with special emphasis on 2-hand coordination, ambidextrous performance, and depth perception. Metrics and pass–fail settings were customized to emphasize task precision and efficiency. The curriculum was designed by, and the metrics were carefully set, based on the performance of an MIS fellowship-trained surgeon (A.J.D.).

The hypothesis of the study is that the customized Yale University basic laparoscopic skills curriculum can differentiate among years of experience, establishing construct validity for the curriculum.

METHODS

The Yale University basic laparoscopic skills curriculum consists of 17 practice modules and 7 examination modules. The initial practice drills were designed to familiarize users with the simulator. The drills become increasingly difficult as users advance into the curriculum. This difficulty is achieved by altering camera angles, minimizing the error tolerance, or altering the size of specific objects in some tasks. The practice modules are represented by camera navigation, instrument navigation, coordination, grasping, cutting, clip applying, lifting and grasping, and precision and speed, with most drills repeating at different levels of difficulty.

The examination modules include the same drills (except precision and speed) with slightly different parameters. Overall, most skills emphasize ambidextrous movements and hand–eye coordination. Practice modules may be repeated as many times as necessary to pass them, but all modules must be completed before a trainee can start the examination module. The participants had a maximum of 5 attempts at each examination component. Failure of any 1 component requires restarting the Yale University basic laparoscopic curriculum from the beginning and successfully completing all practice components before returning to the examination.

Overall, 32 participants at various levels of training completed the Yale University basic laparoscopy curriculum. None of the participants were involved in the design of the curriculum. The parameters analyzed included the individual performance of each trainee until successful completion of the examination. As the performance requirements for most of the parameters that the device tracks were carefully tied to passing or failing a drill, we found the number of repetitions each trainee required to reach this level of proficiency to be the most useful measure of performance relative to other trainees. We compared the total number of repetitions required for completion of the practice drills and examination drills with data stratified by level of training. Data analysis was performed with Student is *t*-test analysis of variance.