ORIGINAL REPORT

Mastery-Based Virtual Reality Robotic Simulation Curriculum: The First Step Toward Operative Robotic Proficiency☆,☆☆

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OBJECTIVE: Hepatobiliary surgery is a highly complex, low-volume specialty with long learning curves necessary to achieve optimal outcomes. This creates significant challenges in both training and measuring surgical proficiency. We hypothesize that a virtual reality curriculum with mastery-based simulation is a valid tool to train fellows toward operative proficiency. This study evaluates the content and predictive validity of robotic simulation curriculum as a first step toward developing a comprehensive, proficiency-based pathway.

DESIGN: A mastery-based simulation curriculum was performed in a virtual reality environment. A pretest/posttest experimental design used both virtual reality and inanimate environments to evaluate improvement. Participants self-reported previous robotic experience and assessed the curriculum by rating modules based on difficulty and utility.

SETTING: This study was conducted at the University of Pittsburgh Medical Center (Pittsburgh, PA), a tertiary care academic teaching hospital.

PARTICIPANTS: A total of 17 surgical oncology fellows enrolled in the curriculum, 16 (94%) completed.

RESULTS: Of 16 fellows who completed the curriculum, 4 fellows (25%) achieved mastery on all 24 modules; on average, fellows mastered 86% of the modules. Following curriculum completion, individual test scores improved ($p < 0.0001$). An average of 2.4 attempts was necessary to master each module (range: 1-17). Median time spent completing the curriculum was 4.2 hours (range: 1.1-6.6). Total 8 (50%) fellows continued practicing modules beyond mastery. Survey results show that "needle driving" and "endowrist 2" modules were perceived as most difficult although "needle driving" modules were most useful. Overall, 15 (94%) fellows perceived improvement in robotic skills after completing the curriculum.

CONCLUSIONS: In a cohort of board-certified general surgeons who are novices in robotic surgery, a mastery-based simulation curriculum demonstrated internal validity with overall score improvement. Time to complete the curriculum was manageable. (J Surg Ed ■:■■■-■■■. Published by Elsevier Inc on behalf of the Association of Program Directors in Surgery)

KEY WORDS: surgical education, robotic simulation, mastery-based curriculum, surgical proficiency

COMPETENCIES: Practice-Based Learning and Improvement, Professionalism

INTRODUCTION

Complex surgical oncology presents a significant challenge to training surgeons to optimal performance, particularly in pancreatic resections. For open pancreaticoduodenectomy, the number of cases necessary to achieve optimal outcomes, or the "learning curve," reaches more than 60 cases, a daunting number when one considers that even by the end of fellowship, a surgeon likely encounters about half of this case volume.[1] The recent introduction of minimally invasive surgical approaches to this field further exacerbates this problem. Many have raised concerns regarding patient safety and operative outcomes.[2] Recent evidence shows that

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surgical skill and efficiency leads to improved patient outcomes.[3] The need for a structured robotic training curriculum outside of the operating room that maximizes surgeon preparedness so that surgeons can more efficiently attain operative proficiency (and optimal outcomes) is widely noted; however, one currently does not exist.[2,4-6]

Multiple robotic virtual reality surgical skill simulators are commercially available. Numerous studies show that robotic virtual reality simulation has face validity (simulator use mirrors console use) and construct validity (simulator scoring discriminates novices from experts).[7] However, the question of how to use these findings to create a program leading to improved operative performance remains unanswered. Studies show that mastery learning, or proficiency-based training, is a very effective education strategy, more so than time or frequency-based styles.[8,9] Ultimately, virtual reality simulation and its application to basic robotic technical skills is only one component to determining operative proficiency, and eventually, one's learning curve.[10,11]

Concomitant with the increasing popularity of robotic surgery in urology and gynecology over the past decade, multiple studies have shown that those who participate in simulation preparatory work perform better on robotic task testing than those who have not participated.[7,12,13] Despite these findings, a clearly validated, reproducible curriculum for obtaining robotic surgical proficiency has not been established for residents, fellows, or established surgeons to learn this new, widely implemented technique. Recently, the fundamentals skills of robotic surgery (FSRS) have been developed and validated for use in simulation-based robotic curriculum for basic robotic skills in a multi-institutional randomized trial after many years of development.[14,15] Next, we must determine how virtual reality robotic simulation and basic robotic skills apply to content validity (technical skill) or predictive validity (operative ability).[16]

The goal of this study was to assess the implementation of a proficiency-based robotic simulation curriculum for surgical oncology fellows using a pretest/posttest quasiexperimental design. We asked whether we could measure and stratify robotic simulation performance and improve performance after instituting a curriculum as an intervention. Ultimately, we aim to determine whether performance in a simulation environment predicts and correlates with performance in an inanimate and then operative environment. We hypothesize that objective and subjective improvement in robotic skills would be measureable after a robotic simulation curriculum. Additionally, we feel the time for trainees would be feasible in a rigorous training environment and, ultimately, performance in simulation would correlate to performance in an inanimate and operative environment.

MATERIALS AND METHODS

On July 1, 2013, a robot curriculum (Fig. 1) was established for surgical oncology fellows at the University

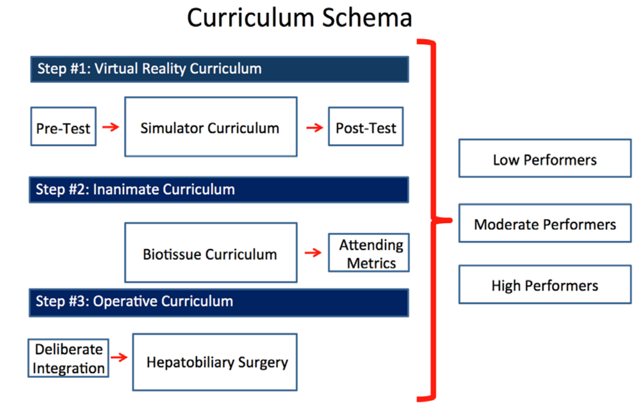

FIGURE 1. Schema of the 3-step robotic curriculum. This work represents preliminary analysis of Step 1 virtual reality mastery simulation curriculum. In each step, learners are stratified into high, moderate, and low performers for corollary studies.

of Pittsburgh Medical Center (UPMC) and by December 31, 2014, 3 classes of fellows matriculated through Step 1: virtual reality curriculum, representing the first phase of our pilot study and the focus of this article. The Step 2: biotissue curriculum uses bioartificial materials fashioned like organs (LifeLike BioTissue Inc., London, ON). This step would be assessed independently of Step 1, for they represent a new level in the trainee's progress toward operative proficiency, and would be reported in a later study. This was an exempt study approved by the Institutional Review Board at UPMC (IRB PRO13100295).

A Pretest/Posttest Quasiexperimental Design Was Used to Evaluate Both the Fellows and the Simulation Curriculum

Fellows completed the same 4 virtual reality tasks (match box 3 [MB3], ring and rail 2 [RR2], tubes, and continuous suture [CS]) and 3 inanimate tasks (ring rollercoaster 4 [RR4], around the world [ATW], and interrupted suture [IS] in both the pretests and the posttests) (Table 1).[17] Scoring from MB3, RR2, and tubes was downloaded directly from the simulator. Participants can achieve maximum scores of 100 per drill, 300 cumulative. These drills were picked for 2 reasons. The first was that the first author performed the curriculum described in the next paragraph, and these took the longest to master. Additionally, the scores from all simulator drills were downloaded, and these drills had lower scores than the ones within the curriculum. It was determined that these would be more likely to differentiate a difference between the pretest and posttest scores if one exists.

Two graders scored the inanimate tasks (CS, RR4, and ATW) and IS through video analysis using the objective structured assessment of technical skills (OSATS).[3,7-19] Graders evaluated the videos based on time, errors (drops, accuracy, torn suture, torn/dislocated equipment, instrument collisions, granny