Construct Validation of a Cost-Effective Vessel Ligation Benchtop Simulator

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OBJECTIVE: Many benchtop surgical simulators assess laparoscopic proficiency, yet few address core open surgical skills. The purpose of this study is to describe a cost-effective benchtop vessel ligation simulator and provide construct validation.

DESIGN: A prospective comparison of blinded proficiency assessments among participants performing a benchtop vessel ligation simulation task. Evaluations were performed using Objective Structured Assessments of Technical Skills.

SETTING: This study took place at the University of Virginia, School of Medicine: a large academic medical institution.

PARTICIPANTS: The participants included fourth-year medical students participating in a focused surgical elective course ($n = 16$), postgraduate year 2 to 3 surgery residents ($n = 6$), and surgical faculty ($n = 5$).

RESULTS: The total fixed costs of the vessel ligation simulator was $30. Flexible costs of operation were less than $0.20 per attempt. The median task-specific checklist scores among the medical students, residents, and faculty were 4.83, 7.33, and 7.67, respectively. Median global rating scores across the 3 groups were 2.29, 4.43, and 4.76, respectively. Significant proficiency differences were noted between the students and the residents/faculty for both the metrics ($p < 0.001$).

CONCLUSIONS: A cost-effective benchtop simulator can effectively measure proficiency with basic open surgical techniques such as vessel ligation. Among the junior surgical trainees, this tool can identify learning gaps and improve operative skills in a preclinical setting. (J Surg 72:381-386. © 2015 Association of Program Directors in Surgery Published by Elsevier Inc. All rights reserved.)

KEY WORDS: simulation, surgical education, surgical training, vascular surgery techniques

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

INTRODUCTION

The role of simulation training has expanded over the last decade, driven by scrutiny of surgical outcomes and reductions in operative experience due to work hour restrictions.[1] In addition to increasing exposure to advanced techniques, simulation can equip the junior-level residents with fundamental skills in open surgery.[2] Although most program directors see the value of a simulation laboratory, formal evaluations of basic skills are rare.[3] Furthermore, among medical students, simulation affords a low-stress environment in which fundamental proficiencies can be developed.[4] Acquiring these skills in a preclinical setting can enhance participation in the operating room, improve learning experiences, enhance mentoring, and nurture interests in surgical careers.[5,6] The last aim is becoming increasingly important, as the number of medical students interested in pursuing a surgical career has decreased.[7]

In response to these pressing needs, the American College of Surgeons and the Association of Program Directors in Surgery developed the surgical skills curriculum for residents. The first phase of this program addresses basic open techniques such as knot tying, suturing, and dissection.[8] However, without pragmatic and cost-effective simulators for these modules, the demand for practice and evaluation in a preclinical setting is unmet. Numerous studies have

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shown that low-fidelity and midfidelity benchtop simulators are as effective as expensive biological and virtual reality models.[9-12] Low fixed costs permit broad implementation, while low flexible costs facilitate repetitive self-practice.

Despite clear clinical relevance, an inexpensive benchtop simulator for open vessel ligation does not currently exist. Such a device would fill an important learning gap: most graduating medical students have minimal exposure to vessel ligation, yet junior surgery residents are expected to perform this task safely and efficiently in the operating room. The purpose of this study was to create a cost-effective vessel ligation simulator and demonstrate its construct validity as an evaluative tool. The study was designed to test the hypothesis that this tool could stratify between proficiency levels of graduating medical students, midlevel surgery residents, and experienced surgical faculty.

METHODS

Study Participants

Invitations for voluntary participation were extended to graduating fourth-year medical students enrolled in a focused, 2-week surgical elective near the end of the academic year. All the students had matched into residencies in surgical specialties. To better capture variations in skill level, no exclusion criteria relating to operative experience were instituted. Because open vessel ligation is a basic technique typically acquired in the first 1 to 2 years of residency, voluntary participants were also recruited among postgraduate year 1(PGY 1) general surgery interns during the first month of residency, PGY 2 to 3 general surgery residents, and experienced surgical faculty.

Before evaluation, each participant received verbal instruction regarding the steps involved in the stimulation task. The medical student participants were also provided with a video demonstration of the task, which they were expected to have reviewed before assessment. A review of this demonstration was not required for the resident and the faculty participants, given pre-existing clinical experience. To capture initial technical proficiency, the participants were not allowed to practice on the simulator before assessment.

Model Design

The vessel ligation simulator was designed with several objectives in mind. The aim was to replicate the process of controlling a section of vascularized tissue in a deep abdominal space. The model would ideally recreate the roles of both the primary surgeon and the surgical assistant. Budgetary parameters for construction were set to less than $100 per model. Finally, because the expected settings of implementation were preclinical evaluation and self-directed practice, the flexible costs of repetitive use were minimized.

With these goals in mind, a 4-sided box was created from pinewood to simulate a confined abdominal compartment, and a proprietary vessel-mounting device was secured to the base of the replicated surgical field. The total cost of simulator construction was $30 per model (Fig. 1). Several synthetic materials were tested as the simulated vessel, including Penrose drains, flexible intravenous tubing, and silicone tubing. Ultimately, disposable latex surgical gloves proved to be the most realistic substitute—glove fingers were deformable enough to clamp and tie, yet elastic enough to require steady tension for successful ligation. Mounting a glove in the simulator required less than 30 seconds and allowed for 2 ligation attempts. With expired gloves in constant abundance, flexible costs were reduced to solely

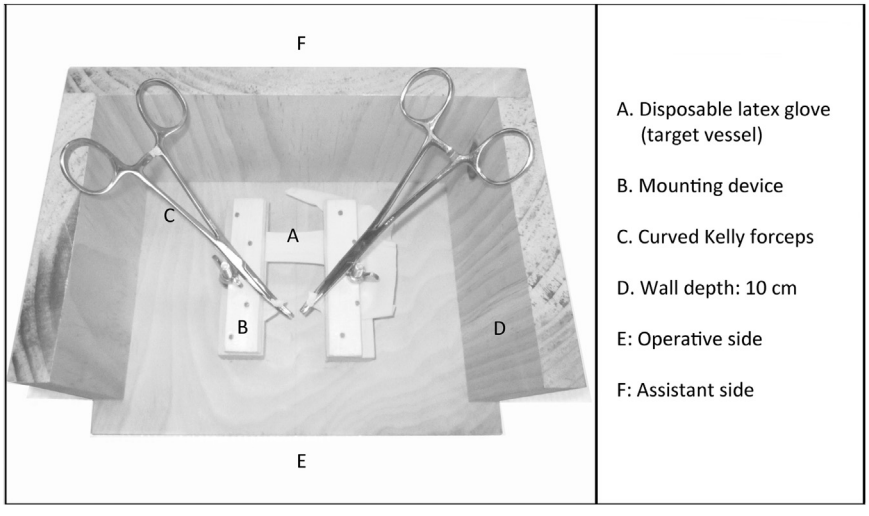

FIGURE 1. The Vessel Box training model. Participants obtain proximal and distal control of simulated vascularized tissue and perform suture tie ligation with the help of an assistant.