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Assistant Instructors Facilitate Simulation for Medical Students

Authors:

Yinin Hu, M.D.^a, Joanna Choi^a, Adela Mahmutovic^a, Helen Kim^a, Ivy A. Le^a, and Sara K. Rasmussen, M.D., Ph.D.^a

^aUniversity of Virginia School of Medicine, Department of Surgery, PO Box 800709, Charlottesville, VA 22908-0679

Abstract

Background—A procedural training protocol for medical students must be cognizant of faculty opportunity costs, which may preclude individually-supervised practice. Meanwhile, sporadic exposure in large group settings yields suboptimal proficiency. The purpose of this study is to assess the effectiveness of undergraduate assistant instructors in providing one-on-one simulation-based instruction for basic invasive techniques.

Materials and Methods—Investigators designed proficiency-based checklists by faculty consensus for three simulation tasks: orotracheal intubation, central venous catheterization (CVC), and suturing. Four undergraduate students were trained as instructors. Inter-rater agreement between instructors using the task checklists ranged from 0.754 to 0.866. Instructors conducted up to seven flexibly-scheduled, one-on-one practice sessions with clinically inexperienced medical student participants. Sessions were comprised of repetitive task attempts with an evaluation after every attempt. Upon completion of the training protocol, participants underwent evaluation by an experienced surgeon blinded to practice session performance. Study participants were surveyed to assess satisfaction.

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Corresponding Author: Sara Rasmussen, M.D., Ph.D. PO Box 800709 Charlottesville, VA 22908-0679 skr3f@virginia.edu P: 1-(434) 982-2796 F: 1-(434) 243-0036.

YH: yh9b@virginia.edu

JC: ic6ad@virginia.edu

AM: am6bd@virginia.edu

HK: hk3vh@virginia.edu

IAL: ial4zw@virginia.edu

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Mahmutovic, A: Analysis and interpretation, data collection, critical revision, and final approval Kim, H: Analysis and interpretation, data collection, critical revision, and final approval Le, IA: Analysis and interpretation, data collection, critical revision, and final approval Rasmussen, SK: Conception and design, analysis and interpretation, critical revision of the article, final approval, and obtaining funding

Results—Twenty-nine participants completed the study. Median total practice time was 8.75 hours (IQR 7.12-8.75). Post-test pass rates were 93% (26/28), 71% (20/28), and 68% (19/28) for suturing, intubation and CVC, respectively. Ninety-seven percent (27/28) of participants were satisfied with their experience and 62% (18/29) advocated for protocol adoption into the standard pre-clinical curriculum. Estimated cost saved by using student instructors, based on departmental collections for surgical faculty, was \$43,760.

Conclusions—Clinically-inexperienced assistants may be trained as instructors for basic simulation tasks with excellent inter-rater reliability. Deploying these assistant instructors makes effective, one-on-one technical training for pre-clinical medical students financially feasible.

Keywords

Surgical education; simulation; student; medical

INTRODUCTION

The Residency Review Committee mandates access to a surgical skills laboratory for all general surgery residents [1]. However, such regulations do not exist within medical student education. Despite gaps in competency [2], first-year residents are often called upon to perform invasive procedures on critically-ill patients. As a result, research on simulation-based training for medical students has increased exponentially [3]. Although surgery-specific “boot camps” are becoming widespread, care of surgical patients within academic centers often relies on non-categorical junior housestaff who did not have access to these opportunities [4, 5], and patients on non-surgical units similarly require invasive procedures. Thus, there is an impetus to provide simulation training to all medical students, regardless of specialty.

Due to clinical inexperience among medical students, repetitive and distributed practice over time confers superior skills retention [6]. Personalized feedback is also invaluable, leading to major demands on faculty time resources [7, 8]. Not surprisingly, the most universal barrier to high-throughput simulation instruction is the availability of teaching faculty [9]. Ancillary teaching assistants in baccalaureate programs allow faculty to focus on higher-level tasks such as curriculum design and student assessment [10-12]. There are concerns, however, regarding whether teaching assistants possess adequate confidence and expertise [13]. Within surgery, clinically-experienced “skills coaches” have shown promise in their ability to augment training [14, 15]. However, these costly personnel are impractical for high-throughput, one-on-one teaching of medical students. To date, the use of clinically-inexperienced, trained assistant instructors (TAI) in simulation training for medical students has not been explored. We hypothesize that undergraduate teaching assistants can provide cost-effective, high-throughput, one-on-one simulation training to medical students.

METHODS

Simulation Design

Through collaboration between the Departments of Anesthesiology and Surgery, three simulation tasks were designed: orotracheal intubation, basic surgical suturing, and

subclavian central venous catheterization (CVC). The intubation task involved one-person bag-valve-mask ventilation followed by direct laryngoscopy and orotracheal intubation with an 8 mm endotracheal tube, all performed using an Airway Management Trainer (Laerdal, Stavanger, Norway). To facilitate instructor evaluation, participants used the C-MAC video laryngoscope (Karl Storz, El Segundo, CA) with a #2 Macintosh blade. However, the participant was not permitted to view the output monitor. The surgical suturing task involved approximating two pliable, vertically-oriented surfaces 1 cm apart using three figure-of-eight stitches comprised of 2-0 multifilament silk suture (Hefei Fast Nonwoven Products Co., Ltd., Anhui, China). These were each secured using a two-handed tie, an instrument tie, and a one-handed tie. The CVC task involved a manikin-based simulator (CentralLineMan, SimuLab, Seattle, WA) and the sterile placement of a right subclavian central venous line using a single-lumen catheter kit (Sim*Cath, Sim*Vivo, Essex, NY) without ultrasound guidance. Participants were required to identify anatomic landmarks, cannulate the subclavian vein, utilize sterile Seldinger technique, check placement using a sterile flush, and request a chest radiograph.

Assessment checklists were defined through expert consensus based on task-specific Objective Structured Assessment of Technical Skills (OSATS) [16-19], modified to incorporate greater detail (Table 1). To facilitate scoring, checklist items were assigned point values, and a minimum score was defined such that inability to correctly perform several minor steps or one critical step resulted in failure.

Selection of Teaching Assistants

Trained assistant instructor opportunities were extended to premedical undergraduates at the University of Virginia. The TAI position was described as an opportunity to learn and then teach basic, simulation-based tasks to medical students. Expected time commitment per instructor was 60 hours distributed over two months, and instructors were each reimbursed \$500. Four TAI's were selected out of 34 applicants based on schedule flexibility and interest in teaching. Once accepted, TAI's received individualized training in the three study tasks by one surgical faculty member. Following repetitive practice under the guidance of one surgery resident, each TAI was tested by the supervising faculty member using the task-specific checklists to verify proficiency. Total training time ranged between 4 and 6 hours per TAI distributed over two weeks, depending on rate of learning. The TAI's were then trained to administer these checklists, and inter-rater reliability was assessed through simultaneous observation by TAI's of ten repeated attempts of each task. Using these methods, intraclass correlation coefficients were 0.866, 0.754, and 0.763 for suturing, intubation, and CVC, respectively.

Medical Student Curriculum

Volunteer participants were recruited from the first- and second-year medical school classes. Because an existing survey had identified that only 1-3% of the students in these classes have had prior experience in the simulation tasks, pre-testing was not performed. Participants underwent a 2 hour orientation addressing basic concepts and proper technique, along with instructional videos for review. Following orientation, each participant was given a schedule of one-on-one practice sessions proctored by TAI's and tailored to the availability

of participants (Figure 1). Instructor assignments were rotated weekly to minimize scoring bias. Participants attended between 5 and 7 practice sessions distributed over seven weeks, and each session lasted 45 to 75 minutes. No more than one session was allowed per participant, per week. Sessions involved repetitive attempts at the simulation tasks, with a TAI-administered checklist evaluation and feedback regarding deficiencies following every task attempt.

Upon completion of the study curriculum, each participant underwent post-testing under direct observation by a single surgical faculty member blinded to practice session performance. Post-tests were comprised of three attempts at each task without feedback between attempts, and the top two scores were recorded for analysis. Finally, a survey was administered to determine participants' perceptions of the TAI's abilities and of the training curriculum as a whole.

Analyses

Personnel costs were calculated based on the median annual collection by clinical surgical faculty at our institution, equating to \$571,631 or 9466 relative value units (RVU). Assuming a 55-hour work week, this translated to \$208 or 3.31 RVU per hour. An alternative cost analysis is also presented based on the 2011 national median academic surgeon salary of \$210,000 [20], translating to an hourly wage of approximately \$76. Comparisons of performance were assessed using Wilcoxon signed-rank test. Multivariate linear regression was performed to assess predictors of post-test performance, limited by study size to three predictors: student class, gender, and number of practice attempts. All data were analyzed using SAS statistical software (version 9.3; SAS Institute, Inc). This study was deemed exempt by the University of Virginia Institutional Review Board (IRB-SBS protocol #2013-0246-00).

RESULTS

Thirty medical school students were enrolled, of which 29 completed all requisite practice sessions. One participant was excluded due to unintentional un-blinding. Participants were comprised of 10 first-year and 19 second-year students, and 69% (20/29) were male. Median age was 21 years (interquartile range, IQR, 20-22). No participant had pre-existing exposure to CVC or intubation, and only one had exposure to suturing. Median total practice time was 8.75 hours per participant (IQR 7.12 – 8.75), and most practice sessions took place during evenings and over weekends. Participants completed a median of 25 suturing tasks (IQR 22.5 – 28), 12 intubations (IQR 9 – 14), and 9 CVC's (IQR 6-11). With only the orientation session and instructional videos for guidance, 0% (0/29), 17.2% (5/29), and 13.8% (4/29) of participants passed two of their first three practice session attempts at suturing, intubation, and CVC, respectively. By comparison, 93.1% (27/29), 72.4% (21/29), and 69.0% (20/29) of participants passed two out of three attempts during post-testing (Figure 2a). Checklist performance scores for all three tasks increased significantly between the initial practice attempts and the post-test evaluations (Figure 2b). Comparing post-test scores with scores from the final two practice session attempts revealed intraclass correlation coefficients of 0.723, 0.769, and 0.532 for suturing, intubation, and CVC, respectively.

Common deductions on post-testing for intubation were for air leaks during bag-valve-mask ventilation or suboptimal visualization of the true vocal cords. Despite this, all participants successfully inserted the endotracheal tube during post-testing. Deductions for CVC were most commonly for improper identification of anatomic landmarks. Under multivariate analysis, there were no significant associations between post-test performance and volume of practice attempts, student class, or gender (data not shown).

Participants were surveyed after post-testing. Satisfaction was determined by a response of 4 or 5 on a five-point Likert scale. Ninety-seven percent (28/29) of participants were satisfied with the simulation curriculum and 93% (27/29) would recommend enrollment to their peers. Sixty-two percent (18/29) endorsed adopting the study curriculum as a required component of preclinical training, while 31% (9/29) suggested adoption as an elective. Of note, 90% (26/29) participants expressed feeling anxiety during post-testing. Eighty-two percent of participants found the TAI's knowledgeable (24/29), however, 38% of participants (11/29) noticed minor inconsistencies in technique between TAI's during practice sessions. Encouragingly, 90% (26/29) of participants expressed an increased interest in surgery or surgical subspecialties as a result of study participation.

The total cost for the curriculum was \$18,435 (Table 2). This included \$9900 of fixed, overhead material costs comprised of the training models and video laryngoscope. Personnel costs, based on median departmental institutional collections, were comprised of \$4160 in faculty costs (66.2 RVU) and \$2000 in TAI compensation. Trained assistant instructors supervised a combined 220 hours of one-on-one practice sessions. Compared to faculty-supervised practice, implementing TAI proctoring resulted in net savings of \$43,760 in institutional collections. For a medical school class of 140 students, the projected savings of the TAI protocol would be \$211,255 per year. When using faculty salary rather than institutional collections as the benchmark for opportunity cost, the corresponding projected cost savings is \$71,062. Notably, despite substantial time commitment, all four TAI's expressed interest in repeating the curriculum, citing the exposure to clinically-relevant experiences as the prime reason for participation.

DISCUSSION

By implementing TAI's to proctor practice sessions, we demonstrate a cost-effective, high-throughput method of extending in-depth simulation to preclinical novice trainees. Timing the protocol within the preclinical setting allows exposure to invasive tasks prior to clinical rotations, thus promoting active participation during clerkships and sub-internships. Because basic invasive procedures are performed by residents in nearly all medical specialties, simulation training among students disseminates a baseline proficiency level upon which clinical expertise may be built in a responsible and safe manner. Importantly, one-on-one faculty mentorship retains a role within this model as a means by which students with an elevated baseline competency level may receive more personalized, in depth feedback for further technical insight.

After completing our study, 93.1%, 72.4%, and 69.0% of students attained proficiency in basic suturing, intubation, and CVC, respectively. Among a minority of participants,

deficiencies persisted for certain techniques, such as single-person bag-valve-mask ventilation and sustained vocal cord visualization. Comparing favorably to existing studies of simulated intubation [21], all participants were able to successfully intubate the trachea using direct laryngoscopy during post-testing. The high rate of success among our participants may be attributable to repetitive, distributed practice and the use of video laryngoscopy as a tool for formative feedback [22]. Simulation-based CVC courses have been shown to reduce catheter-associated bloodstream infections in a cost-effective manner [23-25]. Our results highlight the intricacies of this procedure. Common errors were improper angling of the introducer needle and suboptimal insertion landmarks. Although these deficiencies may be due to the simulation model, a contributing factor may be inconsistencies in technical instruction between TAI's, which were noticed by a minority of participants. We maintain that it is important for all participants trained in simulation to undergo further observation at the bedside for full preparation. For all three tasks, we anticipate that higher post-test pass-rates may be achieved by implementing a mid-curriculum TAI refresher course to reinforce TAI teaching methods and adopting blinded, video-assisted post-testing to reduce participant anxiety. The purpose of our intervention was not to credential students for these invasive procedures. Rather, we sought to provide early exposure in order to promote hands-on learning during clerkships while minimizing risks to patient safety and impedance to workflow. Promisingly, all students demonstrated knowledge of the procedure's sequence of steps and safety measures during post-testing.

For many basic simulation techniques, the predominant cost of training originates from instructor supervision [25, 26]. Foregone hospital collections represent the true opportunity cost of time dedicated to training medical students. Simply put, the time investment required for high-throughput, one-on-one faculty supervision is impractical for simulation training, and institutions cannot afford to compensate faculty for simulation instruction at the same rate as it does for research and clinical pursuits. Employment of TAI's offers substantial cost savings, such that in-depth simulation opportunities may be offered to the entire medical student body rather than to selective surgical boot camps. These reduced personnel costs also allow channeling of resources to equipment costs, which may include a video laryngoscope, standardized suture, and high-fidelity manikins. In prior studies, surgical and veterinary technicians have been effectively implemented in both instructive and evaluative settings (14, 15). To our knowledge, the present study is the first to employ undergraduate students as assistant instructors. Due to the lack of contextual experience among TAI's, our study used task-specific checklists in lieu of more subjective global rating scores. In doing so, evaluations by TAI's attained excellent inter-rater agreement, ensuring consistent teaching throughout practice sessions.

Beyond cost-savings and resource allocation, the greatest advantage of implementing a TAI paradigm may be an intangible one: the promotion of medical and surgical interest at multiple levels. High-achieving college students are drawn to medical careers through TAI experiences, and are exposed to peer mentorship from medical student participants. Meanwhile, participants become exposed to procedure-based medicine at a preclinical level, and interest in surgery is broadly cultivated prior to clerkship experiences. We expect this interest to be further refined during clerkships, as faculty and residents are likely to provide

superior mentorship if they are confident that students have already achieved a baseline level of competence.

Despite its prospective design, the present study did not include a control group. Thus, the superiority of a TAI protocol over an equal volume of independent practice or several faculty-led group teaching sessions is unconfirmed. However, given that initial CVC attempts required an average of 8 minutes to complete, group-based practice would have required over 15 faculty-hours to achieve less than half the per-student practice volume for CVC training alone. Although independent practice in high-fidelity virtual reality laparoscopy and endoscopy has comparable efficacy to proctored methods [27], such evidence does not exist for open, bench-top simulation. Second, although comparing participants' final practice session scores and post-test scores revealed excellent agreement for suturing and intubation, intraclass correlation was only moderate for CVC. This suggests either that TAI's could benefit from additional training on the evaluation metric for CVC, or that participants performed differently during practice than during post-testing for this task. We believe that both factors contributed, as 90% of participants reported anxiety during testing. Finally, we encouraged high-repetition practice rather than prolonged demonstrations in order to maximize the utility of objective checklists and minimize reliance on subjective feedback. The comparative effectiveness of repetition versus didactic teaching is unclear, and will require well-designed, randomized studies in the future.

CONCLUSIONS

Overall, trained teaching assistants permit what has thus far been unattainable for simulation training: flexibly-scheduled, proctored, individual practice sessions offered in a cost-effective, high-throughput curriculum, with educational and experiential benefits reaped at multiple levels of learning. By diverting resources from protected time for faculty and technicians to purchasing high-fidelity equipment, this novel approach facilitates a superior simulation experience. Extending this experience to a wide population of medical students will improve the quality of care provided by categorical and non-categorical housestaff alike.

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Figure 1.
Simulation curriculum design, incorporating trained assistant instructors (TAI).

Figure 2.

Post-test performance. a) Pass rate among student participants: 93.1%, 72.4%, and 69.0% for suturing, intubation, and central venous catheterization (CVC), respectively. Passing score requirement shown as dashed line. b) Improvement in composite scores from 2 task attempts between the initial practice session and post-testing, shown as positive difference ().

Table 1

Objective checklist criteria for simulation tasks

Basic Suturing				Pass: 32/36
<u>Overall Technique</u>		<u>Instrument Tie</u>		
Does not grasp needle with hand	3	Tail length 2 cm		1
Loads needle 90°, past mid-arch	1	Grasps tail at distal 1/2 cm		1
Turns needle through tissue	1	First knot is surgeon's knot		1
3 targets missed (12 total)	3	Flat knots (crosses hands)		1
Needle free when tying	1	No air knot		5
Needle does not pass through knot	1			
<u>Two-Handed Tie</u>		<u>One-Handed Tie</u>		
First knot is surgeon's knot	1	Pushes knots down with 1st finger		1
Flat knots (crosses hands)	1	Alternates knots appropriately		1
Alternates knots appropriately	1	Does not drop suture		1
Does not drop suture	1	No air knot		5
No air knot	5			

Intubation				Pass: 16/18
<u>Bag-Mask</u>		<u>Intubation</u>		
Adequate Seal	3	Tube assembly		2
Jaw thrust performed	1	Teeth protected		1
Proper ventilation (12 bpm)	1	Handle traction toward ceiling		2
		Vocal cords visualized		3
<u>Verification</u>				
Carbon dioxide indicator	1	Stylet removed		1
Bilateral chest rise	1	Cuff inflated		1
Bilateral auscultation	1			

Central Venous Catheterization				Pass: 32/36
<u>Preparation</u>		<u>Catheterization</u>		
Lay out catheter kit in order of use	1	Appropriate anatomic landmark		2
Pre-flush catheter	2	Flat angulation during cannulation		3
Trendelenberg position	4	Successful cannulation		6
Local anesthetic with 22-gauge	1	Notes non-pulsatile flashback		2
		Wire orientation (curve caudal)		1
		Wire insertion with oscillation		1
<u>Placement Check</u>				
Aspirate, then flush check catheter	2	One hand on wire at all times		1
No sterility break or bent wire	5	Incision (blade away from wire)		1
Request for chest radiography	2	Dilator insertion with oscillation		1
		Catheterization with hand on wire		1

Table 2

Curriculum costs

Personnel	Hours	Cost
Surgical Faculty		
Assistant instructor training	6	1,248
Participant post-tests	14	2,912
Surgery Resident	16	-
Assistant instructors (4)	220	2000

Material Costs	Quantity	Cost
Central venous catheter		
Manikin	1	2000
Replacement tissue	4	1700
Catheter insertion kits	25	300
Intubation		
Manikin	1	1800
Video laryngoscope	1	6100
Endotracheal tube, bag-mask	2	100
Suturing		
2-0 Silk suture	1000	175
Surgical instrument set	5	100
Total Cost		18,435