Creation, Implementation, and Assessment of a General Thoracic Surgery Simulation Course in Rwanda

Adriana G. Ramirez, MD, MPH, Nebil Nuradin, BS, Fidele Byiringiro, MBBS, Robinson Ssebuufu, MMed (Surgery), George J. Stukenborg, PhD, Georges Ntakiyiruta, MMed (Surgery), and Thomas M. Daniel, MD

Department of Surgery, University of Virginia, Charlottesville, Virginia; School of Medicine, University of Virginia, Charlottesville, Virginia; Department of Surgery, University of Rwanda, Kigali, Rwanda; Department of Surgery, Kampala International University Teaching Hospital, Western Campus, Ishaka-Bushenyi, Uganda; Department of Public Health Sciences, University of Virginia, Charlottesville, Virginia; and Ejo Heza Surgical Centre, Kigali City, Rwanda

Background. The primary objective was to provide proof of concept of conducting thoracic surgical simulation in a low-middle income country. Secondary objectives were to accelerate general thoracic surgery skills acquisition by general surgery residents and sustain simulation surgery teaching through a website, simulation models, and teaching of local faculty.

Methods. Five training models were created for use in a low-middle income country setting and implemented during on-site courses with Rwandan general surgery residents. A website <http://thoracicsurgeryeducation.com> was created as a supplement to the on-site teaching. All participants completed a course knowledge assessment before and after the simulation and feedback/confidence surveys. Descriptive and univariate analyses were performed on participants' responses.

Results. Twenty-three participants completed the simulation course. Eight (35%) had previous training with the course models. All training levels were represented. Participants reported higher rates of meaningful confidence, defined as moderate to complete on a Likert scale, for all simulated thoracic procedures ($p < 0.05$). The overall mean knowledge assessment score improved from 42.5% presimulation to 78.6% postsimulation, ($p < 0.0001$). When stratified by procedure, the mean scores for each simulated procedure showed statistically significant improvement, except for ruptured diaphragm repair ($p = 0.45$).

Conclusions. General thoracic surgery simulation provides a practical, inexpensive, and expedited learning experience in settings lacking experienced faculty and fellowship training opportunities. Resident feedback showed enhanced confidence and knowledge of thoracic procedures suggesting simulation surgery could be an effective tool in expanding the resident knowledge base and preparedness for performing clinically needed thoracic procedures. Repeated skills exposure remains a challenge for achieving sustainable progress.

(Ann Thorac Surg 2018;105:1842–50)

The global community has historically neglected access to surgical care and the burden of surgical disease. The current estimate of the global surgical disease burden—operations that would have a direct benefit on an individual's life or function but not performed—is approximately 33% of the total global burden of disease [1]. This translates into an additional 321.5 million operations needed annually [2]. According to a 2008 World Health Organization assessment, African countries have the highest rate of surgical disability–adjusted life-years compared with the rest of the world [3]. The World Health Organization developed a tiered system of prioritized surgical procedures to guide resource investment and focused largely on efforts to build capacity [4]. Thoracic surgery is considered a fourth-tier surgical concern. With much of the attention focused on access to procedures such as caesarian sections, long-bone fracture repairs, and laparotomies, an unintentional consequence has been a general neglect of surgical subspecialty care.

Rwanda is a land-locked Sub-Saharan African country with 50 full-time general surgeons for a population of 12 million people [5]. There are currently no full-time thoracic surgeons in Rwanda or general surgeons trained in basic thoracic surgery. To meet the need for

Accepted for publication Jan 15, 2018.

Presented at the Sixty-fourth Annual Meeting of the Southern Thoracic Surgical Association, San Antonio, TX, Nov 8–11, 2017.

Address correspondence to Dr Ramirez, Department of Surgery, University of Virginia School of Medicine, PO Box 800681, Charlottesville, VA 22908-0709; email: agr5e@virginia.edu.

The Appendices can be viewed in the online version of this article [https://doi.org/10.1016/j.athoracsur.2018.01.043] on http://www.annalsthoracicsurgery.org.

Published by Elsevier Inc.

0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2018.01.043

surgical conditions—among other health care workforce needs—Rwanda launched a 7-year project, the Rwanda Human Resources in Health Program, in 2012 [6]. The program has deployed more than 100 foreign faculty members to Rwanda during the past 5 years. Visiting faculty are encouraged to develop professional relationships with the local faculty and teach the teachers, who would then sustain the teaching after the visiting faculty left.

The most common general thoracic surgery procedures performed by the senior author (T.M.D.) during his 5-month experience operating with the Rwanda Human Resources in Health program were pulmonary decortication for mature postpneumonic empyemas, repair of esophageal perforation, biopsy of mediastinal masses, and repair of traumatic diaphragmatic perforation. Because thoracoscopic equipment is not currently available due to resource limitations, there is a reliance on open approaches often in a ventilated lung field because of the lack of single-lung ventilation capability.

To address the gaps in thoracic surgery education, a simulation general thoracic surgery course was developed to expose local residents and faculty to basic thoracic skills, and an online simulation website was created to supplement the hands-on teaching. The study's objectives were (1) to provide proof of concept and feasibility of conducting thoracic surgical simulation in a resource limited setting, (2) to accelerate the acquisition of needed thoracic surgery skills, as measured by assessment of confidence level and content knowledge, by offering general surgery residents a 2-hour course using inexpensive simulation models, and (3) to sustain the teaching and performance of thoracic surgery in Rwanda by supplementing the simulation with an online website, providing models, and teaching of the local faculty.

Material and Methods

Site Selection

The two sites for the simulation thoracic surgery course were the university teaching hospital in the capital city of Kigali and in the university teaching hospital in the small provincial town of Butare (Huye). The sites were selected based on convenience for participants, access to laboratory space, and status as national referral centers equipped with appropriate preoperative and postoperative services and blood banking capability.

Criteria Used in Creating the Simulation Thoracic Surgery Models

Because the models were designed for use in low-middle income countries, the following criteria guided their creation:

- Components were inexpensive (see Appendix 4) and made of materials that were readily available materials online or locally in North America.
- Models could be built using ordinary tools and minimal expertise.
- Models did not require electricity to function.
- Models used only standard operating room instruments and equipment.
- Minimal setting requirements for using the models were a room with a table, overhead lighting, a sink with running water, and detergent.
- Models could incorporate locally acquired animal mediastinal tissue (goat or pig).
- Models met the transportable size and weight criteria for air transportation.

Model Selection and Description

Five exercises were chosen for the thoracic surgery course described below. Two of the exercises incorporated locally acquired mediastinal goat tissue.

The thoracotomy positioning exercise used a full-body skeleton model placed in lateral decubitus and stabilized with a technique involving Kerlix Gauze Rolls (Covidien AG, Mansfield, MA) wrapped around rolled blankets placed anterior and posterior to the skeleton's chest in addition to hip stabilization with wide tape. Appropriate padding and support of all extremities and the neck and all pressure areas was achieved with pillows and egg crating materials (Fig 1).

In the performance of a posterolateral thoracotomy, the left-side scapular bolts of the skeleton model were removed to allow more natural scapular and rib mobility. Chest wall muscles were simulated with bubble wrap covered with white elastic foam tape and attached to the rib cage for repeat use with VELCRO Brand Sticky Back (Velcro Group Corporation, Boston, MA) or other self-adhesive hook and loop strips (Fig 2).

The decortication exercise used the hemithorax of a chest manikin cut along the sagittal plane with an ellipse of manikin cut out to simulate a posterolateral incision. The model was adapted from the Thoracic Surgery Directors Association Boot Camp (R. Feins, personal communication, August 14, 2012).

For the chest wall decortication exercise, polyethylene tubing attached with bolts to the chest manikin was used to simulate the aortic arch and descending aorta. Half of a rubber football bolted to the inferior end of the manikin simulated the diaphragm. The "peel" of the organized

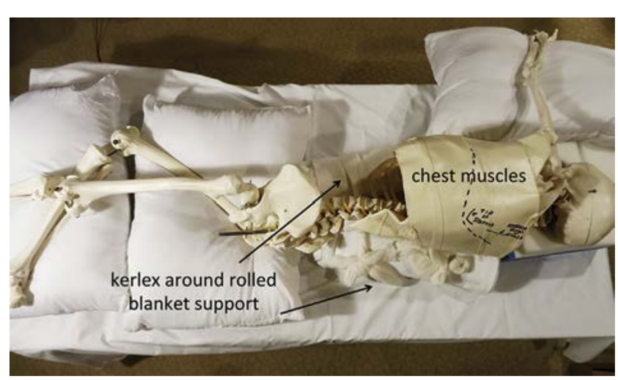

Fig 1. Skeleton model used in the thoracotomy positioning exercise.

CONGENITAL HEART

Fig 2. Demonstration of the technique for identifying the subscapular first rib.

empyema lining the diaphragm, aorta and chest wall was simulated using oil-based nonhardening clay, a feature that allowed for multiple repetitions (Fig 3A) The visceral pleura decortication model used a small foam football simulating the trapped lung. It was covered with a layer of clear plastic tape to mimic the pleural surface and wrapped with multiple layers of white elastic foam tape to simulate the organized empyema layer seen in a late-stage organizing empyema (Fig 3A, 3B).

The model for repair of a diaphragmatic rupture or laceration used a fresh goat mediastinal tissue block with its attached diaphragm (Fig 4). Incorporating the manikin allowed the exercise to be performed with an intrathoracic approach vs an intraabdominal approach.

The acute esophageal perforation repair exercise used the fresh goat mediastinal tissue block secured on a cutting board and the left-sided chest manikin placed over it. Intubating the goat left main bronchus heightened simulation reality with hand ventilation of the left lung, because selective lung isolation is often not available in the Rwandan operating theater. A large green rubber bougie was used to intubate the esophagus to easily distinguish location of lumen, extent of perforation, and adequacy of closure (Fig 5).

During initial model implementation, comments were obtained from residents and faculty at the University of Rwanda. This feedback was used for additional revision of the exercises and course restructuring. The resulting version of the simulation experience can be found on the website <http://thoracicsurgeryeducation.com> that was created to describe the assembly of the models and to provide a step-by-step supplement to the on-site teaching.

Course Objectives

A 2-hour course with 1-on-2 instruction by a senior thoracic surgeon was devised and aimed at introducing residents and faculty to the following essential skills:

During the thoracotomy positioning exercise, participants learned proper lateral decubitus positioning of a patient with appropriate padding, stabilization techniques, and optimal operating room table bend for exposure. In the performance of a posterolateral thoracotomy exercise, participants were taught proper chest wall dissection, rib exposure, and identification of the correct rib space to enter the chest. Rib resection was taught as an alternative way to enter the chest when appropriate. Proper technique of the insertion and positioning of chest tubes after a thoracotomy was reviewed as well as the techniques of closing a thoracotomy incision.

For the decortication exercise, the proper dissection technique to remove the mature vascularized fibrous rind from the parietal and visceral surfaces of the lung and chest wall in late-stage empyema was demonstrated. Proper technique after inadvertent puncture of lung parenchyma during decortication was demonstrated to avoid further pleural injury.

During the ruptured diaphragm repair exercise, participants were taught suture selection and closure technique for a diaphragm laceration. The objectives for repair of an acute esophageal perforation exercise were to learn adequate proximal and distal exposure of the full length of the submucosal and mucosal tear of the esophagus as well as proper approximation of the mucosal/submucosal layer and separately, the muscular layer in a setting requiring lung retraction for exposure due to a lack of lung isolation. Participants also gained practice tying in a deep chest cavity.

Implementation of the Simulation Surgery Course

Local senior Rwandan leadership was engaged throughout the study design, planning, and implementation phases of the study. Institutional Review Board approval was obtained at the University of Virginia (UVA) (#2016-0105-00), University Teaching Hospital of Kigali (EC/CHUK/0101/2016), and University Teaching Hospital of Butare (Ref #: CHUB/DG/SA/6/845/2016). All participants provided verbal and written consent before the start of the simulation course.

The simulation course was conducted at the 2 Rwandan teaching hospitals during a 2-week period in May and June 2016. All surgical residents and faculty at the University of Rwanda were eligible and recruited to participate in the thoracic skills course. Participants were provided with access to the website or an on-site hard-copy of the simulation manual.

Participant information was collected for basic demographic information as well as their level of training and prior thoracic operative experience or simulation experience. A survey before and after the simulation course was administered to assess the participant's confidence level and knowledge content of the simulated thoracic surgical procedures (Appendices 1, 2, and 3). Confidence level was reported on a standard Likert scale. Meaningful confidence was defined as moderate to complete confidence for the purposes of analysis. The knowledge assessment contained questions relevant to each simulated procedure covering key teaching points discussed during the simulation. The maximum score of

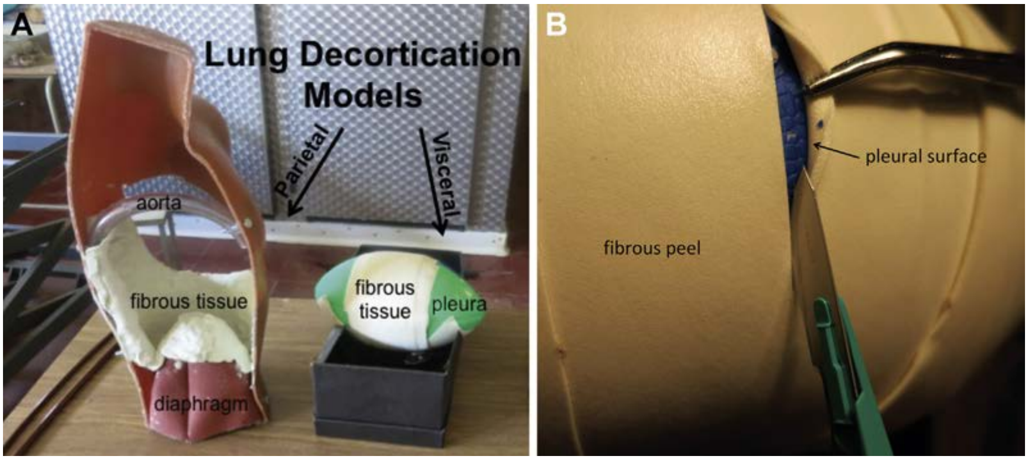

Fig 3. Decortication exercise. (A) Parietal and visceral pleura decortication models. (B) Visceral pleura decortication on football and intact underlying "pleura."

the knowledge assessment was 14 points, which was translated into a total percentage out of 100. In addition, participants provided feedback using a modified version of the Michigan Standard Simulation Experience Scale survey on the course's content and utility. Structured statements were given on a Likert scale, and participants chose from the following options: strongly disagree, disagree, neutral/don't know, agree, and strongly agree, Additional open-ended questions covered participant perceptions of ongoing barriers in translating skills to practice and further improvements needed to the simulation course [7].

Statistical Analysis

Participants who were previously involved in the beta testing of the thoracic simulation models were considered repeat participants. The rest of the participants were considered simulation-naïve participants for the purposes of the analysis. Junior-level residents were defined as postgraduate year (PGY) 1 and PGY2, and senior-level residents were PGY3 and PGY4. Descriptive statistics were performed comparing participant demographics and other baseline characteristics using one-sample Student *t* tests and χ^2 tests.

Paired Student *t* tests and Fisher exact tests were used to compare presimulation and postsimulation responses in the knowledge assessment and proportions of meaningful confidence reported, respectively. Presimulation knowledge mean scores between repeat participants and simulation-naïve participants were compared as well as between junior and senior level residents using a two-sample Student *t* test. Analyses were performed using Stata/SE 15.0 software (StataCorp, College Station, TX). Significance was defined as a *p* value of less than 0.05.

Results

A total of 23 general surgery residents completed the simulation course; of which, 8 participants (35%) had been previously exposed to the simulation models during the course development. The participants were an average age of 31 years (range, 28 to 34 years), and 21 of 23 (91%) were men.

All training levels were represented in our study: 9 PGY1, 7 PGY2, 2 PGY3, and 5 PGY4. Most participants reported little to no experience performing thoracotomies (defined as less than 5 thoracotomies) and limited interaction with thoracic surgical patients (defined as less than

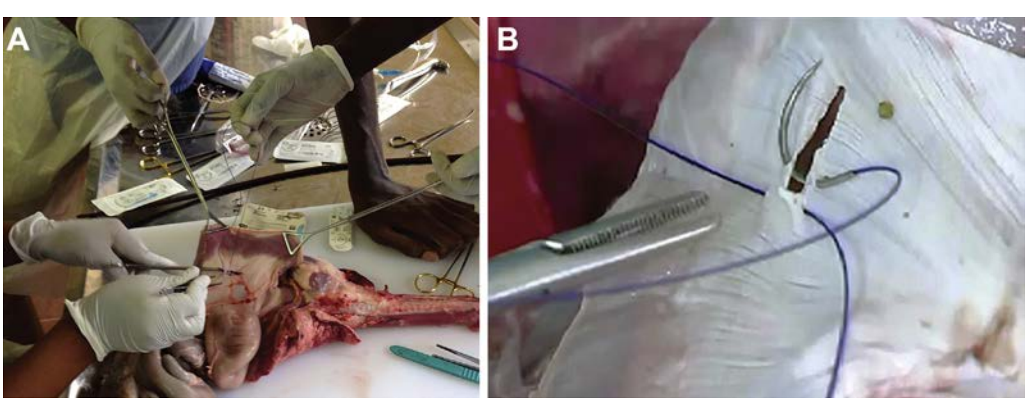

Fig 4. Suture repair of diaphragmatic laceration. (A) Start of interrupted horizontal mattress stitches repair. (B) Magnification of suture technique.

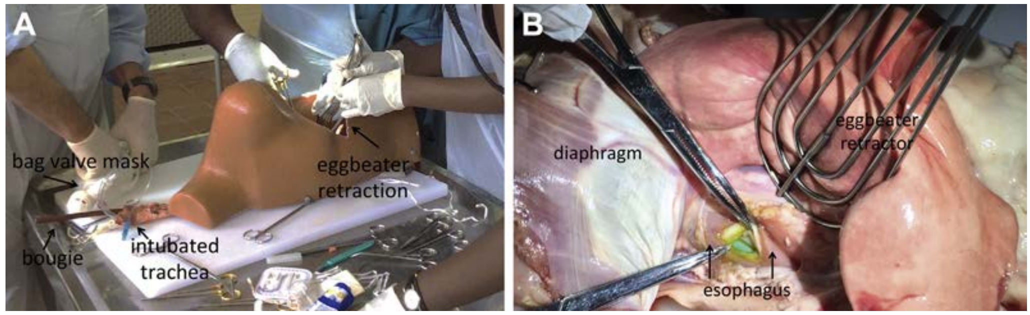

Fig 5. Exercise to repair acute esophageal perforation. (A) External view of simulation in progress with Rwandan residents and faculty facilitator instruction. (B) View of esophageal laceration through thoracotomy incision.

5 patients per month), 19 of 23 (83%) and 15 of 23 (65%), respectively. However, 17 of 23 (74%) reported that they expect to perform some basic thoracic procedures in their future practice.

Table 1 summarizes meaningful confidence reported before and after the simulation course. Participants reported improved confidence in performing each of the five thoracic surgical procedures (all $p < 0.05$).

Figure 6 shows the mean scores and standard errors from the knowledge assessment questionnaire before and after the simulation course. Postsimulation course scores were uniformly higher, with significant increases in mean scores ($p < 0.0001$) for all simulated procedures, except for ruptured diaphragm repair ($p = 0.45$). The overall mean knowledge score gain between the presimulation and postsimulation course assessment was 36% (42.5% vs 78.6%, $p < 0.0001$). The presimulation knowledge scores were 11.4% higher on average for the repeat simulation participants compared with the simulation-naïve participants ($p = 0.02$). Repeat participants were also more senior-level residents. When level of training and precourse assessment mean scores were compared, senior-level residents scored 12.9% higher than junior-level residents ($p = 0.01$).

On the postsimulation knowledge assessment, all training levels demonstrated improvement, with the greatest increase in scores made by more junior-level learners, 38.6% presimulation vs 78.1% postsimulation. No difference was detected in the postsimulation mean knowledge scores between repeat participants vs simulation-naïve participants or by PGY level. In addition, there was no difference in reported confidence level presimulation or postsimulation between simulation-naïve participants and repeat participants or by PGY level.

Responses from the Michigan Standard Simulation Experience Scale survey are summarized in Figure 7. Overall, participants had overwhelmingly positive remarks toward the simulation course. Participants most frequently reported feeling more comfortable with thoracic conditions after the simulation, found the simulation useful, or appreciated its educational value and demystifying capability for thoracic surgery. When asked the reason for attending the course, the most common responses were related to an interest in skill acquisition or to increase their knowledge of thoracic conditions. The most common suggestions for improvement were increasing practice time and the need for repeated thoracic experiences.

Finally, participants were asked about existing challenges to providing thoracic surgical care. The most frequent responses included a lack of instruction/mentoring and sufficient cases, lack of thoracic-specific instruments and equipment, limited intensive care unit capability, and lack of thoracic-trained anesthesia providers and techniques.

Table 1. Participants Reporting Meaningful Confidence[a] Before and Immediately After the Course for Each Simulated Procedure

	Participant, No. (%)		
Simulated Procedure	Before	After	p Value
Thoracotomy positioning	8 (35)	23 (100)	<0.01
Performance of a thoracotomy	6 (26)	21 (91)	<0.01
Ruptured diaphragm repair	3 (13)	21 (91)	0.02
Lung decortication	3 (13)	20 (87)	<0.01
Esophageal perforation repair	1 (4)	17 (78)	0.01

[a] Meaningful confidence is defined as moderate or complete confidence indicated on a Likert scale.

Comment

The objectives to successfully create, transport, and implement a general thoracic skills simulation course in Rwanda were met. The general surgeons' confidence was assessed in performing five thoracic surgery procedures that are commonly needed in their clinical practice. Participant feedback showed enhanced confidence in performance of thoracic procedures. Participants' knowledge assessment scores improved uniformly, and simulation-naïve participants attained equally high scores as repeat participants postsimulation. These results suggest that simulation surgery could be an effective tool to expand the resident knowledge base and preparedness for performing clinically needed thoracic procedures.

The feedback received and confidence in performance of the skills is in line with similar studies on the perception of simulation and preparation in cardiothoracic

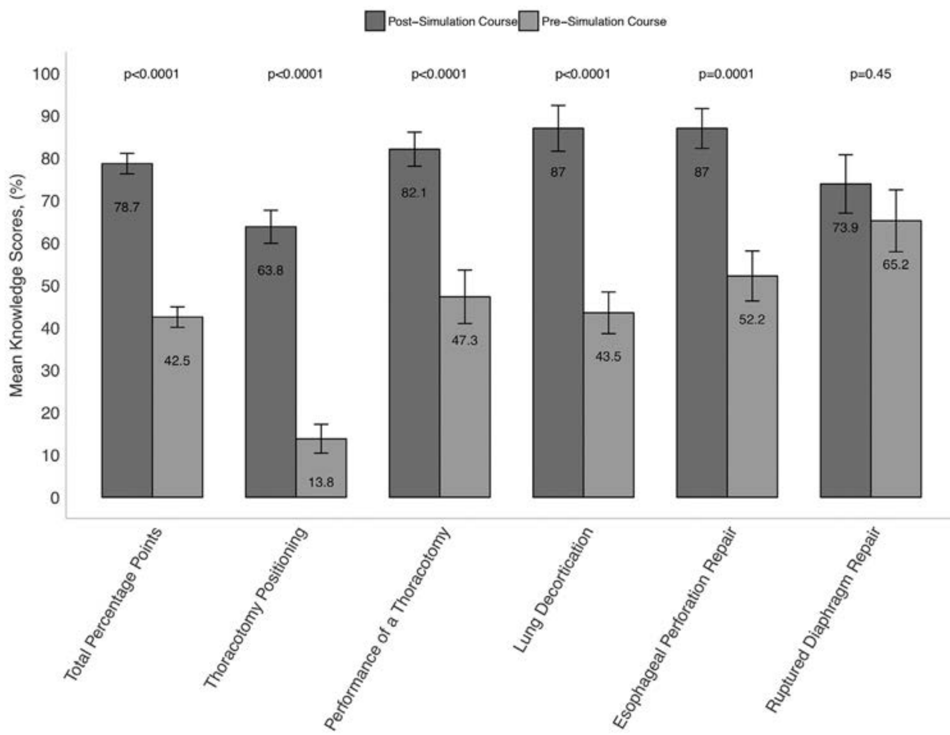

Fig 6. Mean scores and SEs (range bars) for the knowledge assessment questionnaire before and after the simulation course.

trainees in the United States [8]. Together, these met objectives provide proof of concept and feasibility of conducting a simulation experience in general thoracic surgery in a limited-resource setting that lacks experienced faculty and subspecialty fellowship training opportunities.

The objective to create continual teaching by local general surgery faculty using the simulation models created was met initially but not sustained. Rwandan faculty successfully led a simulation course, which was supplemented by interactive instruction originating from the UVA Office of Telemedicine. The subsequent lack of sustainability was primarily due to internal shifting of senior leadership during which 2 local faculty champions of simulation surgery left the University of Rwanda. Without a local committed faculty, we believe opportunities for further exposure to the field must rely on experienced visiting surgeons on short-term simulation and clinical teaching trips, in the hopes of raising interest in residents to pursue advanced training.

Currently the model being used by visiting anesthesiology faculty in Rwanda is 1-month rotations accompanied by a senior anesthesia resident. Canadian Anesthesiologists' Society International Education Foundation is collaborating with several North American anesthesiology societies, which allows for a constant visiting anesthesiology presence at the University of Rwanda.

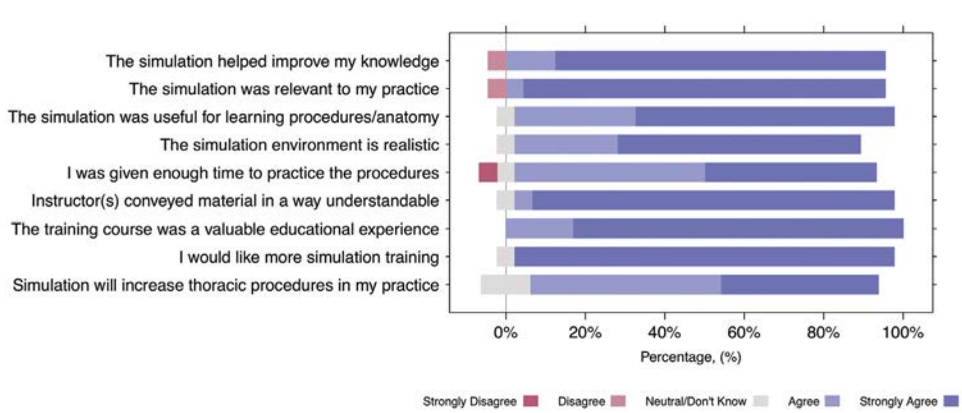

Fig 7. Participant response to feedback questionnaire. The vertical line denotes negative responses to the left and positive responses to the right.

The lack of exposure to thoracic surgery is multifactorial in this context. The objective to create a demand for sustained teaching of a simulation thoracic surgery workshop was also made more difficult to achieve by the current low incidence of patient referrals with operable general thoracic surgery conditions such as chronic empyema and acute esophageal perforation. It is hoped that the Rwandan health care system will increase referral of patients with thoracic conditions now that there is a practical and inexpensive way to teach their general surgery faculty and residents basic thoracic surgery skills for conditions commonly seen. However, this remains to be determined.

It remains our opinion, based on this experience, that sustainable simulation thoracic surgery teaching of general surgery residents in Rwanda can only be achieved by repeated systematic teaching visits of 2 to 4 weeks' duration by experienced thoracic surgeons. This relatively short time commitment—using the preexisting simulation models left in place—would allow excellent simulation-based instruction of local faculty and residents. It would also allow time for the development of professional relationships with the local Rwandan faculty and subsequent participation in clinical conferences and operative cases.

The use of simulation for skill acquisition is increasing in Africa. The focus has largely been on laparoscopic training [9–11] and trauma [12, 13]. To our knowledge, this study represents the first time that general thoracic skills simulated teaching has been offered to a cohort of general surgery residents in the region. Using simulation to augment technical and nontechnical skills is a well-established part of the training for Rwandan surgical residents and medical students. Our study showed 15 of 23 participants (65%) had prior simulation-based training. This is reflective of previous investments in educational collaborations between Rwanda and various foreign academic institutions [14–16]. A key component of this training has been to use simulation as an educational platform leading to the creation of dedicated facility and curriculum building that integrates simulated opportunities. As such, we were able to directly build on the resources locally available.

For surgical residents and faculty, simulation has focused on general surgery skills, including trauma and standard suturing exercises such as performance of an end-to-end ileostomy anastomosis. Similar to Tansley and colleagues [17], our study showed that junior-level participants achieved the most gains on knowledge assessment compared with more senior-level participants. To what extent prior thoracic surgery simulation plays a role in this discrepancy in our study is unclear, because senior-level participants were also more likely to have previously completed our course.

Limitations

Several limitations are associated with our study. We did not perform a delayed assessment of knowledge or procedural skill retention beyond immediate assessment after the course. The thoracic surgical caseload is limited for reasons discussed previously; thus, we were unable to assess the simulation course's procedures against operative performance. Participant surveys were used to collect most of our data, which has inherent biases such as recall bias or testing threat.

Future Considerations

In addition to gaps in technical expertise, participant narratives elucidated additional barriers to surgical treatment for thoracic conditions, highlighting the resource differences and multidisciplinary care of thoracic patients. Understanding the resident and faculty interest in general thoracic skills through engagement in an intensive simulation course is part of the beginning of building an investment case for thoracic surgery in Rwanda. To complete the picture, further information is needed on prevalence of thoracic conditions, baseline operative volumes, and detailed assessments of equipment needs, preoperative evaluation deficiencies, and postoperative care challenges.

The authors extend special appreciation to Dr John Hanks for his supervisory role during field collection, Drs Christian Ngarambe, Ahmed Kiswezi, and Didace Mugisa for their assistance as ancillary teaching staff, and Florence Mukakabano for technical support and use of the simulation center at University Teaching Hospital of Kigali. The authors also recognize the Rwanda Human Resources for Health Program (T.M.D.) for its initial investment in facilitating collaborative education and cultivating the development of educational simulation experiences. This work was supported by grant T32-HL-007849 (A.G.R.) from the National Heart, Lung, and Blood Institute of the National Institutes of Health. Institutional support from the UVA Center for Global Health (A.G.R. and N.N.) and the UVA Medical School Foundation Surgery Education Project in Rwanda (T.M.D.) provided financial support to cover the cost of the simulation models and travel expenses to Rwanda for the United States–based researchers.

References

1. Rose J, Weiser TG, Hider P, Wilson L, Gruen RL, Bickler SW. Estimated need for surgery worldwide based on prevalence of diseases: a modelling strategy for the WHO Global Health Estimate. Lancet Glob Health 2015;3(Suppl 2):S13–20.
2. Meara JG, Leather AJM, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. Lancet 2015;386:569–624.
3. Ozgediz D, Riviello R. The "other" neglected diseases in global public health: surgical conditions in sub-Saharan Africa. PLoS Med 2008;5:e121.
4. World Health Organization. Global Initiative for Emergency and Essential Surgical Care (GIEESC). Available at http://www.who.int/surgery/globalinitiative/en/. Accessed February 21, 2017.
5. Petroze RT, Nzayisenga A, Rusanganwa V, Ntakiyiruta G, Calland JF. Comprehensive national analysis of emergency and essential surgical capacity in Rwanda. Br J Surg 2012;99:436–43.
6. Binagwaho A, Kyamanywa P, Farmer PE, et al. The Human Resources for Health Program in Rwanda—a new partnership. N Engl J Med 2013;369:2054–9.

7. Seagull FJ, Rooney DM. Filling a void: developing a standard subjective assessment tool for surgical simulation through focused review of current practices. Surgery 2014;156:718–22.
8. Odell DD, Macke RA, Tchantchaleishvili V, et al. Resident perception of technical skills education and preparation for independent practice. Ann Thorac Surg 2015;100:2305–13.
9. Okrainec A, Smith L, Azzie G. Surgical simulation in Africa: the feasibility and impact of a 3-day fundamentals of laparoscopic surgery course. Surg Endosc 2009;23:2493–8.
10. Long KL, Spears C, Kenady DE, Roth JS. Implementation of a low-cost laparoscopic skills curriculum in a third-world setting. J Surg Educ 2014;71:860–4.
11. Morrow E, Bekele A, Tegegne A, et al. Laparoscopic simulation for surgical residents in Ethiopia: course development and results. Am J Surg 2016;212:645–8.
12. Jacobs L, Burns K, Luk S, Hull S. Advanced trauma operative management course: participant survey. World J Surg 2010;34:164–8.
13. Petroze RT, Byiringiro JC, Ntakiyiruta G, et al. Can focused trauma education initiatives reduce mortality or improve resource utilization in a low-resource setting? World J Surg 2015;39:926–33.
14. Livingston P, Bailey J, Ntakiyiruta G, Mukwesi C, Whynot S, Brindley P. Development of a simulation and skills centre in East Africa: a Rwandan-Canadian partnership. Pan Afr Med J 2014;17:315.
15. Deckelbaum DL, Gosselin-Tardif A, Ntakiyiruta G, et al. An innovative paradigm for surgical education programs in resource-limited settings. Can J Surg 2014;57:298–9.
16. Riviello R, Ozgediz D, Hsia RY, Azzie G, Newton M, Tarpley J. Role of collaborative academic partnerships in surgical training, education, and provision. World J Surg 2010;34:459–65.
17. Tansley G, Bailey JG, Gu Y, et al. Efficacy of surgical simulation training in a low-income country. World J Surg 2016;40:2643–9.

INVITED COMMENTARY

It has long been known that surgical simulation is beneficial in the education of trainees. Laparoscopic simulation can predict intraoperative surgical performance in general surgery residents [1]. In addition, structured boot camps for postgraduate year one (PGY-1) residents correlate with improved higher American Board of Surgery In-Training Examination scores and residents' performance in validated measurements of technical skills [2]. The same is true for simulation in cardiothoracic surgical education. Feins and associates [3] demonstrated that first year residents completing cardiac surgery training modules, simulating such procedures as initiation and management of cardiopulmonary bypass, aortic valve surgery, and coronary artery bypass grafting, improved their performance in component tasks with simulation-based training. The data in support of simulation training in surgical education led the Accreditation Council for Graduate Medical Education in 2008 to mandate that all surgery residencies build a cogent simulation program into their curriculum. For cardiothoracic surgery trainees beginning residency on or after July 1, 2017, 20 hours of simulation are required [4].

Mandating simulation training for our trainees is admirable, but at what cost? Literally speaking, at what cost? Surgical simulation, whether it is high or medium fidelity, is expensive. Using a high-fidelity simulator to train surgery residents in endoscopy, Raque and colleagues [5] found an average cost per resident of $715 over 6 years. Building a simulation program modeled on the American College of Surgeons/Association of Program Directors in Surgery Skills Curriculum can cost more than $22,000 [6]. In this issue of *The Annals of Thoracic Surgery*, Ramirez and colleagues [7] present a general thoracic surgery simulation course, developed at an American academic program, that was specifically to be implemented in a low-resource university setting in Rwanda. The authors' curriculum consisted of basic open thoracic surgical procedures, ranging from positioning and posterolateral thoracotomy to performing a lung decortication. The simulation components were inexpensive (including tools such as a teaching skeleton and a football), did not require electricity, were easily built, and used standard operating room equipment. In addition, the exercises were paired with an online resource (http://thoracicsurgeryeducation.com) that provided guidance on model assembly and supplemented on-site instruction. For a minimal cost, the authors were able to demonstrate the successful implementation of a low-fidelity simulation curriculum for thoracic surgery trainees in a low-resource setting, leading to improved participant confidence and knowledge attainment.

This study by Ramirez and colleagues [7], which was intended for global health and the benefit of training programs in low-resource nations, may be translatable to low-resource residency programs in this country. First year cardiothoracic surgery residents, whether they are PGY-1 residents in an integrative program or PGY-6 residents in an independent program, have less and less exposure to thoracic surgery before starting their training. Low-fidelity simulation, as described by Ramirez and associates [7], could provide a curriculum of modest "suspension of disbelief" that would be introductory to the specialty. Combining with other lean cost strategies, such as the use of low-fidelity vascular models and task shifting faculty time from traditional curriculum didactics to simulation, may help make the required simulation training in residencies affordable [8, 9]. The low-cost model described by Ramirez and colleagues [7] may prove beneficial not only to learners already in residency programs, but also to prospective students who are seeking an introduction to our specialty. Surgical skills courses increase medical students' interest in thoracic surgery [10]. One can see modestly resourced surgery interest groups in US medical schools adopting this curriculum to the benefit of their members.

The cost of educating trainees can be incredible, but the value of surgical simulation to learners is accepted. In addition, the requirements of the Accreditation Council

0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2018.03.036

for Graduate Medical Education for a developed simulation curriculum in accredited residency programs necessitate that those programs find ways to mitigate the cost barrier. Perhaps program directors and other education leaders can take insight from the strategies of surgical volunteerism and global health and translate those lessons of cost efficiency to their own resource-challenged learning environments.

David Tom Cooke, MD

Section of General Thoracic Surgery
UC Davis Medical Center
2221 Stockton Blvd, Ste 2117
Sacramento, CA 95817
email: dtcooke@ucdavis.edu

References

1. Steigerwald SN, Park J, Hardy KM, Gillman LM, Vergis AS. Does laparoscopic simulation predict intraoperative performance? A comparison between the Fundamentals of Laparoscopic Surgery and LapVR evaluation metrics. Am J Surg 2015;209:34–9.
2. Fernandez GL, Page DW, Coe NP, et al. Boot cAMP: educational outcomes after 4 successive years of preparatory simulation-based training at onset of internship. J Surg Educ 2012;69:242–8.
3. Feins RH, Burkhart HM, Conte JV, et al. Simulation-based training in cardiac surgery. Ann Thorac Surg 2017;103:312–21.
4. Review Committee for Thoracic Surgery. Case Requirements for Residents Beginning on or After July 1, 2017. Available at http://www.acgme.org/Portals/0/PFAssets/ProgramResources/CaseRequirementsForResidentsBeginningJuly2017.pdf?ver=2017-03-30-141914-970. Accessed March 4, 2018.
5. Raque J, Goble A, Jones VM, Waldman LE, Sutton E. The relationship of endoscopic proficiency to educational expense for virtual reality simulator training amongst surgical trainees. Am Surg 2015;81:747–52.
6. Pentiak PA, Schuch-Miller D, Streetman RT, et al. Barriers to adoption of the surgical resident skills curriculum of the American College of Surgeons/Association of Program Directors in Surgery. Surgery 2013;154:23–8.
7. Ramirez AG, Nuradin N, Byiringiro F, et al. Creation, implementation, and assessment of a general thoracic surgery simulation course in Rwanda. Ann Thorac Surg 2018;105:1842–50.
8. Helder MR, Rowse PG, Ruparel RK, et al. Basic cardiac surgery skills on sale for $22.50: an aortic anastomosis simulation curriculum. Ann Thorac Surg 2016;101:316–22; discussion 322.
9. Calhoon JH, Baisden C, Holler B, et al. Thoracic surgical resident education: a costly endeavor. Ann Thorac Surg 2014;98:2012–4; discussion 2014–5.
10. Tesche LJ, Feins RH, Dedmon MM, et al. Simulation experience enhances medical students' interest in cardiothoracic surgery. Ann Thorac Surg 2010;90:1967–73; discussion 1973–4.