



Using Touch Surgery to Improve Surgical Education in Low- and Middle-Income Settings: A Randomized Control Trial

Citation

Taylor, Kathryn J. 2018. Using Touch Surgery to Improve Surgical Education in Low- and Middle-Income Settings: A Randomized Control Trial. Doctoral dissertation, Harvard Medical School.

Link

<http://nrs.harvard.edu/urn-3:HUL.InstRepos:41973491>

Terms of use

This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Other Posted Material (LAA), as set forth at

<https://harvardwiki.atlassian.net/wiki/external/NGY5NDE4ZjgzNTc5NDQzMGIzZWZhMGFIOWI2M2EwYTg>

Accessibility

<https://accessibility.huit.harvard.edu/digital-accessibility-policy>

Share Your Story

The Harvard community has made this article openly available.

Please share how this access benefits you. [Submit a story](#)

Improving Surgical Safety and Nontechnical Skills in Variable-Resource Contexts: A Novel Educational Curriculum

Yihan Lin, MD, MPH,^{*,†} John W. Scott, MD, MPH,^{*,‡,§,||} Sojung Yi, BA,^{*} Kathryn K. Taylor, BS,^{*} Georges Ntakiyiruta, MD,[¶] Faustin Ntiringanya, MD,[¶] Paulin Banguti, MD,[#] Steven Yule, PhD, MA, MSc,^{‡,||,*} and Robert Riviello, MD, MPH,^{*,‡,||,*}

^{*}Program in Global Surgery and Social Change, Harvard Medical School, Boston, Massachusetts; [†]Department of Surgery, University of Colorado School of Medicine, Denver, Colorado; [‡]Center for Surgery and Public Health, Harvard Medical School, Harvard T.H. Chan School of Public Health, Boston, Massachusetts; [§]Department of Surgery, Center for Surgery and Public Health, Brigham and Womens Hospital, Boston, Massachusetts; ^{||}Department of Surgery, Brigham and Womens Hospital, Boston, Massachusetts; [¶]Department of Surgery, University of Rwanda College of Medicine and Health Sciences, Kigali, Rwanda; [#]Department of Anesthesia, University of Rwanda College of Medicine and Health Sciences, Kigali, Rwanda; and ^{**}STRATUS Center for Medical Simulation, Brigham & Women's Hospital, Boston, Massachusetts

OBJECTIVE: A substantial proportion of adverse intra-operative events are attributed to failures in nontechnical skills. To strengthen these skills and improve surgical safety, the Non-Technical Skills for Surgeons (NOTSS) taxonomy was developed as a common framework. The NOTSS taxonomy was adapted for low- and middle-income countries, where variable resources pose a significant challenge to safe surgery. The NOTSS for variable-resource contexts (VRC) curriculum was developed and implemented in Rwanda, with the aim of enhancing knowledge and attitudes about nontechnical skills and promoting surgical safety.

DESIGN: The NOTSS-VRC curriculum was developed through a rigorous process of integrating contextually appropriate values. It was implemented as a 1-day training course for surgical and anesthesia postgraduate trainees. The curriculum comprises lectures, videos, and group discussions. A pretraining and posttraining questionnaire was administered to compare knowledge and attitudes regarding nontechnical skills, and their potential to improve surgical safety.

SETTING: The setting of this study was in the tertiary teaching hospital of Kigali, Rwanda.

PARTICIPANTS: Participants were residents of the University of Kigali. A total of 55 residents participated from general surgery (31.4%), obstetrics (25.5%), anesthesia (17.6%), and other surgical specialties (25.5%).

RESULTS: In a paired analysis, understanding of NOTSS improved significantly (55.6% precourse, 80.9% postcourse, $p < 0.01$). All residents reported that the course would improve their ability to provide safer patient care, and 97.4% believed developing nontechnical skills would improve patient outcomes.

CONCLUSIONS: Nontechnical skills must be highlighted in surgical training in low- and middle-income countries. The NOTSS-VRC curriculum can be implemented without additional technology or significant financial cost. Its deliberate design for resource-constrained settings allows it to be used both as an educational course and a quality improvement strategy. Our research demonstrates it is feasible to improve knowledge and attitudes about NOTSS through a 1-day course, and represents a novel approach to improving global surgical safety. (J Surg Ed ■■■■-■■■. ©2017 The Authors. Published by Elsevier Inc. on behalf of the Association of Program Directors in Surgery. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)).

Correspondence: Inquiries to Yihan Lin, MD, MPH, Program in Global Surgery and Social Change, Harvard Medical School, 641 Huntington Avenue, Boston, MA 02116; e-mail: yihan.lin@mail.harvard.edu

KEY WORDS: quality, safety, surgical education, non-technical skills, global surgery

COMPETENCIES: Interpersonal and Communication Skills, Professionalism, Patient Care

INTRODUCTION

Five billion people do not have access to safe, timely, and affordable surgical care.¹ This need is concentrated primarily in low- and middle-income countries (LMICs), where poor infrastructure, inadequate service delivery, and insufficient workforce are common challenges to providing high-quality surgical care.² Governments and ministries of health are therefore working to scale up surgical infrastructure, services, capacity, and workforce in many of these countries. However, it is critical to simultaneously prioritize the development of novel strategies for improving surgical education, performance, and safety. These efforts must emphasize contemporary challenges, one of which is how to optimize surgical teamwork and reduce adverse events attributed to nontechnical skills.

Previous research has shown that nearly one-half of all errors in the operating room are owing to surgeon behavior and intraoperative decision-making.³ A study by Way et al.⁴ reported that the primary cause of bile duct injury during laparoscopic cholecystectomy was errors in perception, rather than technical errors. Analysis of adverse events in surgery owing to communication breakdown discovered that nearly half of information exchanged in the perioperative period was not fully transmitted.⁵ These findings challenged the traditional paradigm of surgical education, which principally emphasized technical expertise and cognitive knowledge. Translating the learning from these findings into formal teaching is crucial. Nontechnical skills must be developed and taught as an explicit, integral part of a robust education curriculum to prepare surgeons for safety-focused practice and ultimately, to address reduce surgical errors and their affect attributable to nontechnical skills.

The Non-Technical Skills for Surgeons (NOTSS) system is a behavioral assessment tool that describes the main observable nontechnical skills associated with good surgical practice. It is intended to observe, rate, and improve surgeons' behavior in the operating room in a structured, transparent manner. The NOTSS system comprises only behaviors that are directly observable or can be inferred through communication.⁶ They encompass both cognitive and social skills, which can be organized into a 3-level hierarchy consisting of categories (highest level), elements, and behaviors. The 4 key categories include: (1) situation awareness, (2) decision-making, (3) communication and teamwork, and (4) leadership (Appendix). Within each category are 3 corresponding elements and exemplary

behaviors that are intended to be indicative rather than comprehensive. This skills taxonomy thus provides a common language and systematic method for surgeons to evaluate, monitor, and strengthen nontechnical skills.

The NOTSS framework is especially relevant and valuable in variable-resource contexts (VRC), which are common in LMICs, where skills for managing inconsistent technology, infrastructure, and workforce are essential to providing safe surgery.^{7,8} Given that NOTSS and associated curricula were developed, piloted, validated, and implemented exclusively in high-income countries, its utility may be limited by lacking context-specific validity. As such, a novel educational tool was adapted from the original NOTSS system with a specific focus on the surgical environment of VRC. Developing the NOTSS-VRC tool in Rwanda consisted of a systematic literature review and extensive provider interviews of local "experts" in surgical care delivery.⁹ These interviews led to the identification of context-specific challenges, as well as the behaviors necessary to overcome them. The need for a video curriculum that accurately represents the local setting was also identified,¹⁰ as were contextually valid education paradigms to teach surgical providers in variable-resource environments effectively.

In response to this need, the present study aims to assess the effect of introducing NOTSS-VRC into the surgical education curriculum at a university residency program in a low-income country. Our objectives were to improve residents' knowledge of nontechnical skills, and raise awareness of the importance of these skills as a method for avoiding surgical adverse events.

MATERIALS AND METHODS

Study Setting

This study involved faculty and residents from the University of Rwanda in Kigali. Rwanda is a low-income country in Sub-Saharan Africa, and is particularly well-suited for studying contextual challenges to providing safe surgical care in limited-resource settings that are common to most LMICs. At the time of study, there was a severe shortage of surgical providers in the country. An estimated 50 surgeons served a population of 11.5 million.¹¹ This ratio of 0.49 surgeons per 100,000 people contrasts with the minimum 20 surgeons per 100,000 people recommended by The Lancet Global Surgery Commission.¹ However, concerted efforts to strengthen and expand surgical training¹²⁻¹⁴ have led to an increase in the number of enrolled postgraduate surgical residents: from 15 in 2012, to 50 in 2016.¹⁵

Curriculum Design

The curriculum was based on original research identifying behaviors associated with nontechnical skills in VRC. Scott

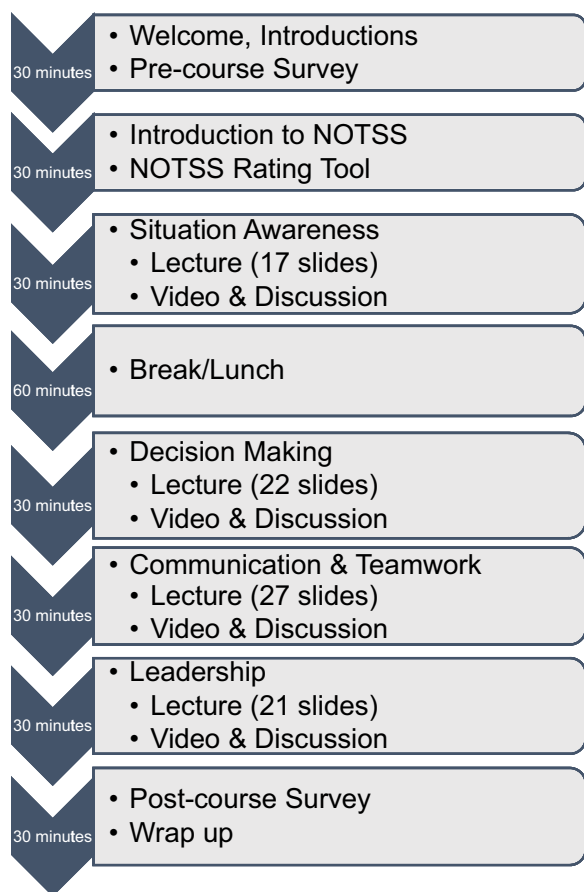


FIGURE 1. NOTSS-VRC curriculum overview.

et al.¹⁶ interviewed experts of surgical care delivery in Rwanda to determine a context-specific set of nontechnical skills that were unaccounted for in a model developed in high-income countries. Although the categories of nontechnical skills described in the original NOTSS taxonomy remained predominant, variability in both material and human resources resulted in unique contextual challenges which effected the ways that non-technical skills were used in this environment. Examples of effective and ineffective behaviors were collated into a NOTSS taxonomy that was specifically designed for VRCs. The curriculum consisted of teaching videos, didactic lectures, a NOTSS-VRC handbook, course evaluation, and was taught in small and large group discussions (Fig. 1), as described in detail later.

Teaching Videos

The NOTSS-VRC curriculum was based on simulated examples of operative situations emphasizing the importance of nontechnical skills to surgical care. A total of 4 videos were made based on scenarios identified as relevant and common in VRCs: delayed humeral fracture, abdominal pain with free air, significant liver trauma after a motor vehicle crash, and a cesarean delivery (Fig. 2). The simulated scenarios depict a regular day in a busy operating theater,

and portray characters in an operation including a surgeon, an anesthesia provider, a scrub nurse, and a circulating nurse. Each video focused on 1 of the 4 skill categories: situation awareness, decision making, communication and teamwork, and leadership. The videos contain examples of effective and ineffective behaviors from each member of the team. Although each video emphasizes a particular skill category, behaviors from each of the 4 categories are also represented in the scenarios and included in the accompanying faculty guide. The 2 of the videos highlight predominately ineffective behaviors for the NOTSS categories and elements, whereas 2 highlight predominately effective behaviors. Teaching notes for each case are also provided to help guide course instructors, and include information on the case background, key events of the case, examples of effective and ineffective behaviors, as well as key teaching points. These videos were filmed in Rwanda by a local film institute, with operating room nurses, surgical and anesthesia residents, and surgery faculty as actors in the videos. All videos were filmed in English, with English subtitles. The Table describes the videos including the introductory scenario, demonstrated behaviors during the video, as well as the goal and objectives of each teaching video.

Didactic Lectures

A lecture series was created for the curriculum and included an introduction to nontechnical surgical skills, an explanation of the NOTSS-VRC framework and rating tool, and a separate lecture for each of the 4 NOTSS-VRC skill



FIGURE 2. NOTSS-VRC video examples.

TABLE. Teaching Scenarios

Video Scenario	Key Teaching Surgeon Behaviors	NOTSS Teaching Objective
Laparotomy for suspected perforated gastric ulcer A 64-year-old man presents with abdominal pain and free air on his abdominal X-ray. The surgeons assume the cause is a perforated ulcer, but fail to consider recent unintended weight loss, cachexia, malaise, fatigue concerning for gastric cancer.	Arrives late, missing the preoperative briefing, and checklist. Does not seek to understand the patient's condition. Dismisses case information from anesthetist. Does not propose or discuss contingency plan. Does not help team anticipate consequences of a particular action. Has not asked to prepare an ICU bed.	Effective <i>situation awareness</i> requires developing and maintaining a dynamic awareness in the operating theater based on gathering data, understanding what that data mean, and thinking ahead about possibilities of what may happen next.
Delayed humeral fracture A 35-year-old presents in a delayed fashion with a humeral fracture requiring surgery. He undergoes open reduction and internal fixation. However, the initial pinning is unsuccessful and the plan changes to using plates.	Assesses risks and benefits of different options. Provides alternative plans in case potential problems arise during the operation. Guides the team to switch to an alternate through clear verbal directions. Discusses how patient consideration has been integrated into decisions.	Effective <i>decision making</i> involves skills for assessing the situation and reaching a judgment in order to select the appropriate course of action.
Laparotomy for trauma, bleeding liver A 25-year-old man presents after a motor vehicle crash with right upper quadrant abdominal pain. He is hypotensive and has peritonitis, raising concern for significant liver trauma. He is taken to the OR for an exploratory laparotomy.	Does not facilitate group communication in single language or conversation. Does not provide vocal updates about the progress of operation. Does not encourage team members to express their concerns or confusion about what is needed by the surgeon.	Effective <i>communication and teamwork</i> requires each team member to support all other team members, and ensures all participants have a shared understanding of the situation.
Cesarean delivery A 20-year-old woman who undergoes a successful Cesarean delivery. The consultant surgeon leaves the resident to finish the case. The resident encounters significant bleeding requiring her to call for help.	Encourages junior resident and student in their roles without overtaking the case. Does not act in a condescending manner by fostering confidence in junior surgeon to continue the operation and to fix the problem. Facilitates better control of case by applying compressive pressure to the bleed, thereby giving time for anesthetist to catch up with resuscitation.	Effective <i>leadership</i> includes providing direction for the team, upholding high clinical standards, and being considerate of individual skill levels and needs of members of the team.

ICU, intensive care unit; OR, operating room.

categories. The introduction to nontechnical skills introduces the concept that 50% of surgical errors in the operating room occur owing to breakdowns in nontechnical skills, and seeks to define optimal surgical performance. The lecture on NOTSS-VRC explained the skills taxonomy and purpose of the behavior assessment framework. Lectures on the 4 skills in the NOTSS taxonomy define key concepts and further explain specific elements related to each category. Effective and ineffective behaviors obtained through interviews and surgical team observations in Rwanda were included to provide concrete examples and embed the curriculum in local contextually appropriate surgical practice.

NOTSS-VRC Handbook

This handbook was prepared as part of the course materials. It was modified from the original NOTSS handbook to include the following sections: an introduction to NOTSS

and information for users, context-specific challenges and variability in low-resource settings and the adaptation to NOTSS-VRC, NOTSS skills taxonomy and effective and ineffective behaviors, and the NOTSS rating scale and rating tool. The exemplary behaviors were drawn from previous provider interviews and observations identifying context-specific behaviors for each of the NOTSS skills categories.⁹ The full original NOTSS curriculum, including the student and teacher handbooks, can be accessed on the following website: www.notss.org.

Course Evaluation Forms

An 18-item precourse and postcourse multiple choice questionnaire was administered to all participants to determine change in knowledge and attitudes about nontechnical skills, as well as participants' evaluation of the NOTSS-VRC course content. To assess knowledge, participants

were asked to identify either the category of nontechnical skill or an exemplary behavior from video. Attitudes regarding the importance of nontechnical skills and the content and structure of the NOTSS-VRC course were assessed using a 4-point Likert-type response scale (1 = strongly disagree to 4 = strongly agree). Space for free text was included and participants were encouraged to provide feedback in their own words.

Curriculum Implementation

NOTSS-VRC was held as a 1-day training course at the University of Rwanda on October 7, 2017, for all Rwandan postgraduate trainees (residents) in anesthesia and all surgical subspecialties, including: general surgery, orthopedic surgery, obstetrics/gynecology, urology, otolaryngology, and neurosurgery. This date was chosen as it was close to the beginning of the academic year, therefore all new interns would be able to participate. The curriculum consisted of didactic lectures, teaching videos, and small and large group discussions (Fig. 1). The NOTSS-VRC handbook was distributed to all participants.

Selected surgical and anesthesia faculty presented lectures on each of the 4 categories of nontechnical skills, followed by the corresponding Rwandan teaching video. Participants were then divided into small groups (approximately 7-8 per group) with residents from different departments and an advising faculty to encourage a multidisciplinary discussion of the teaching videos. Group discussions were facilitated by a discussion leader who was oriented before the course and provided with a faculty guide including teaching notes for each of the 4 videos. The small groups reviewed essential teaching points identified by NOTSS experts before the course. Following these small breakout groups, the lecturer facilitated a large group discussion to synthesize summative reflections. The course evaluation forms were administered immediately before and after the curriculum was taught.

All statistical analysis was performed using STATA v12.0. We described participants' demographics, attitudes toward nontechnical skills, and course evaluations using means for continuous data, and percentages for categorical data. We evaluated the change in knowledge of nontechnical skills using a 2-sided paired *t*-test, with $\alpha = 0.05$.

Institutional Approval

Ethical approval for the study was obtained from the National Health Research Committee with Ref: NHRC/2014/PROT/0130, and the Rwanda National Ethics Committee with Ref: 214/RNEC/2014. Additional institutional approval was acquired from the University of Rwanda College of Medicine and Health Sciences Teaching Hospital Ref: EC/CHUK/018/14 with successful renewal of institutional review board as EC/CHUK/094/2016.

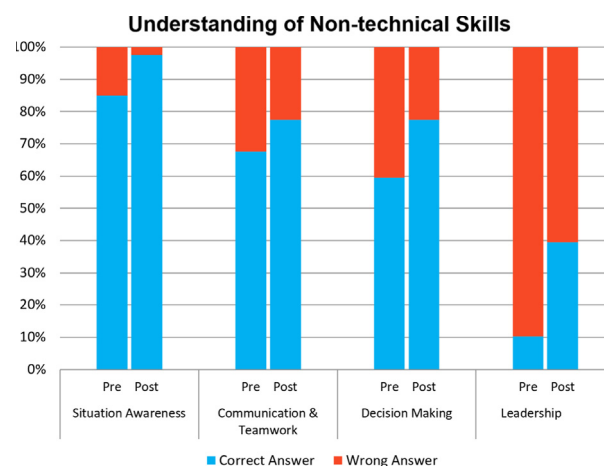
RESULTS

A total of 55 residents participated in the course. Residents were from the following specialty training programs: general surgery (31.4%), obstetrics and gynecology (25.5%), anesthesia (17.6%), and other surgical specialties (25.5%). The mean age was 31 years, with 84.3% male participants. Out of the residents who identified their postgraduate year (PGY), 25 residents were PGY-1 (49.0%), 10 residents were PGY-2 (19.6%), 8 residents were PGY-3 (15.5%), 7 residents were PGY-4 (13.7%), and 1 resident was PGY-6 (2.0%).

Participants' knowledge of nontechnical skills improved during the course. Before undergoing the program, residents posted an average score of 55.6% on questions that asked them to identify nontechnical skills. In a 2-tailed paired *t*-test analysis, this score increased significantly to 80.9% after the course ($p < 0.01$) (Fig. 3). All course participants stated that the training session was "enjoyable, practical, and informative" for teaching them to provide safer care (Fig. 4).

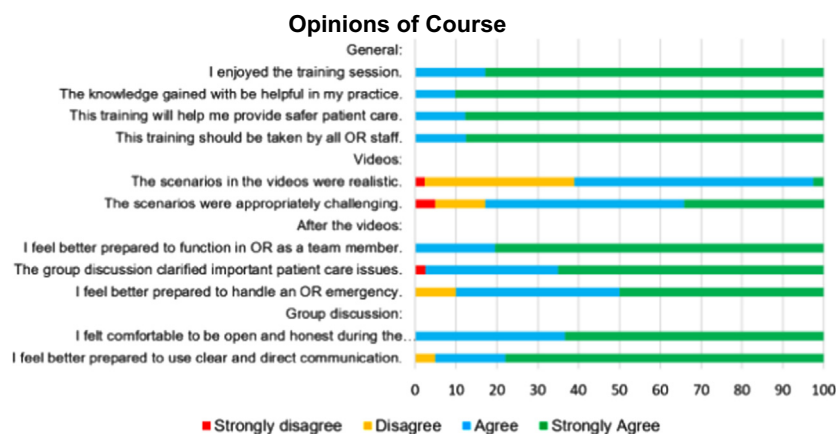
Residents' awareness about nontechnical skills was very positive both before and after the course. There was a high level of agreement to the following statement: "Nontechnical skills will lead to better patient outcomes" (precourse: $n = 52$: 95.12%, postcourse: $n = 50$: 92.50%; $p = 0.57$). Before the course, 90.2% ($n = 49$) disagreed with the following statement: "It is too much trouble to attend sessions on nontechnical skills," with 100% disagreement postcourse ($p = 0.18$). A total of 95.1% ($n = 52$) agreed with the following statement after the course: "Learning nontechnical skills has helped or will help my team-working skills".

An inductive approach was used for analysis conducted on the free-response feedback (Fig. 4). Each participant had an opportunity to provide free-response feedback of "things the training program did well" and "things the training



*Participants' pre- and post-curriculum scores were compared using a paired *t*-test, blocking for each responder. The post-curriculum scores were significantly higher than the pre-curriculum scores (90% CI [-1.03, -0.26], $p < 0.01$).

FIGURE 3. Resident understanding of nontechnical skills.



Free-response Feedback

Themes	Examples
Engage participants through small group discussions and interactive lectures	"Teaching tools were good and useful to understand[ing] the NOTSS skills"
Provide contextually appropriate and relevant examples	"Videos were realistic [and] suited to Rwandan challenges."
Encourage personal reflection	"It made me realize the importance of little things that can be of utmost importance for patient care."
Integrate entire operating team in the NOTSS training	"Invite all OR team to the next session for better discussion"
Offer course more often	"Repeat training each year," "Provide refresher," "Do course twice a year."

FIGURE 4. NOTSS-VRC course feedback.

program should improve." Out of 55 participants, 43 provided feedback documenting "things the training program did well." Patterns that emerged from the responses were organized into broader themes regarding: teaching style, teaching materials, relevance to Rwanda, course pace, details of the event space, and opportunity for personal reflection. Most (65.1%) of responses indicated that the teaching style ("group discussions," and "interactive lectures") were "engaging," "effective," or "good." Almost half (46.5%) of responses highlighted the teaching materials (handouts with NOTSS taxonomy and rating tool) as being "clear," "helpful," or "well-prepared." Multiple participants specifically commented on the contextually appropriate videos featuring Rwandan surgical staff, materials, and common cases.

Out of 56 participants, 38 provided free-response feedback documenting "things the training program should improve." Analysis of these responses revealed several themes: expanding the course to include other members of the operating team; extending the course either in duration or frequency; and the working environment of the course. More than half of the participants who provided feedback suggested teaching the NOTSS-VRC training to

other clinical providers (e.g., nurses, anesthesia technicians, other consultants, and heads of departments). Half of these responses specified that inviting other staff from the operating room and the rest of the hospital would "improve" the discussions. Almost 40% of the feedback also indicated an interest in extending the course to 2 days, offering the course each year, or providing the option to attend twice a year.

DISCUSSION

We developed and implemented the first nontechnical skills curriculum designed specifically for a VRC, maximizing the relevance of the NOTSS-VRC curriculum to front-line providers in LMICs. Our study also shows that it is feasible to teach the NOTSS-VRC curriculum in a 1-day course. After the course, participants exhibited an improved understanding of nontechnical skills. This improvement was measured by their ability to recognize nontechnical skills in a postcourse evaluation. The NOTSS curriculum serves as an effective introduction to sensitize and orient residents to recognize and develop their nontechnical skills. We

demonstrated strong interest for the contextual relevance of the NOTSS-VRC curriculum in Rwanda. Settings with variable resources present many challenges⁹ and thus it stands to reason that providers in this setting are interested in strategies to maximize surgical safety and patient outcomes despite these challenges.

However, these skills require constant and deliberate practice for improvement,¹⁷ an observation supported by feedback given by our course participants requesting an increase in the frequency of the curriculum delivery. The faculty members of the University of Rwanda have expressed a commitment to provide this course as a fixed component of the orientation curriculum in subsequent years, such that all new residents are familiar with NOTSS from the beginning of their training and may invest in developing their nontechnical skills. Discussions are underway to identify other midyear opportunities for refresher courses.

Another common feedback was the request to integrate other staff from the operating theater in the NOTSS training. This view is likely a reflection of the participants' understanding that surgical delivery occurs within the context of a team, and that effective nontechnical skills in all team members are necessary for optimal performance. This suggestion provides an opportunity to expand training to be more inclusive and multidisciplinary in the future. Thus, identified next steps include: (1) modification to the curriculum to define unique anesthesia and nursing aspects of the NOTSS-VRC curriculum, and (2) delivering courses for University of Rwanda faculty and ministry of health consultant surgery and anesthesia providers, likely in conjunction with the Rwanda Surgical Society. Finally, the teaching faculty identified the relevance of training practitioners at decentralized locations, and thus courses aimed at surgical teams in rural district hospitals (which include general practitioners, anesthesia technicians, and general nurses) will be developed.

We anticipate continued iterative development of the NOTSS curriculum. Course feedback will be integrated into a modified curriculum, before being delivered to more providers. The results of this study indicate that although the course is effective in introducing NOTSS concepts, there is a need for increased training opportunities and an expanded curriculum to include other staff from the operating room. Incorporating these data to improve the course is crucial to ensuring that the curriculum continues to grow in context. Although the NOTSS taxonomy and rating tool may remain constant, the next steps are to continue enhancing the behaviors specific to this environment, before expanding the curricular target.

Our findings should be interpreted in relation to the study's limitations. Before the development of this NOTSS-VRC, the NOTSS curriculum was only available in

high-income countries with relatively less resource variability. Lack of contextual adaptation may have contributed to the curriculum not being used for the surgical settings of LMICs. Likewise, this curriculum is intended for any VRC. However, we recognize that "variable-resource contexts" represent a very broad geographic distribution globally. As NOTSS-VRC was developed primarily in Rwanda, users in other countries and continents may not find the setting-specific videos as relevant or accessible as our study population. Despite this perceived limitation, we believe that the contextual challenges identified are still highly relevant to hospitals in LMICs. Additionally, the NOTSS curricula have previously been slightly modified to the country in which they are being taught.^{8,18} Clarifying the steps required to develop this NOTSS-VRC course is intended to help other settings tailor the curriculum according to their local contexts. Therefore, these findings and the utility of this curriculum should still be generalizable across a wide range of surgical delivery systems.

Additionally, this study demonstrates effective knowledge transfer, but the effect on changes in behavior and clinical outcomes remains to be measured. Future work will assess whether the usage of this curriculum in surgical safety education has an effect on surgical outcomes. Ongoing longitudinal assessment would also be an ideal method to demonstrate the achievement and maintenance of nontechnical skills competence, as the learners progress through the various stages of training. The NOTSS-VRC curriculum thus serves as a novel method to improve residents' cognitive knowledge of nontechnical skills, as well as to reinforce their perception of the importance of these skills as a strategy for decreasing surgical errors.

CONCLUSION

Nontechnical skills in surgery are an essential aspect of every surgical curriculum. Although many features of surgical education and health systems require significant material or financial investments, the NOTSS-VRC curriculum can be implemented immediately without the need for additional technology or significant financial cost. Its deliberate design for resource-constrained settings allows it to be used readily both as an educational course and as a quality improvement strategy. This tool may then be used as a model for other settings across the world with similar variability in resources. The NOTSS-VRC course is an effective method for introducing and orienting trainees to identify and strengthen their nontechnical skills. Ultimately, NOTSS-VRC aims to incorporate nontechnical skills as a key component of surgical education and as a novel method for improving surgical safety globally.

APPENDIX: NOTSS TAXONOMY

Category	Elements
Situation awareness	<ul style="list-style-type: none"> ● Gathering information ● Understanding information
Decision making	<ul style="list-style-type: none"> ● Projecting and anticipating future state ● Considering options ● Selecting and communicating options ● Implementing and reviewing decisions
Communication and teamwork	<ul style="list-style-type: none"> ● Exchanging information ● Establishing a shared understanding ● Co-ordinating team activities
Leadership	<ul style="list-style-type: none"> ● Setting and maintaining standards ● Supporting others ● Coping with pressure

REFERENCES

1. Meara J, Leather A, Hagander L, et al. Global surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015;386(9993):569-624.
2. Debas H, Donkor P, Gawande A, Jamison D, Kruk M, Mock C. Disease Control Priorities, Volume 1, Essential Surgery. 3rd ed. Washington, DC: World Bank Publications; 2015.
3. Gawande A, Zinner M, Studdert D, Brennan T. Analysis of errors reported by surgeons at three teaching hospitals. *Surgery*. 2003;133(6):614-621.
4. Way LW, Stewart L, Gantert W, et al. Causes and prevention of laparoscopic bile duct injuries: an analysis of 252 cases from a human factors and cognitive psychology perspective. *Ann Surg*. 2003;237(4):460-469.
5. Greenberg C, Regenbogen S, Studdert D, et al. Patterns of communication breakdowns resulting in injury to surgical patients. *J Am Coll Surg*. 2007;204(4):533-540.
6. Yule S, Flin R, Paterson-Brown S, Maran N, Rowley D. Development of a rating system for surgeons' non-technical skills. *Med Educ*. 2006;40(11):1098-1104.
7. Mutabdzic D, Bedada AG, Bakanisi B, Motsumi J, Azzie G. Designing a contextually appropriate surgical training program in low-resource settings: the Botswana experience. *World J Surg*. 2013;37(7):1486-1491.
8. Scott JW, Morales DR, McRitchie A, Riviello R, Smink D, Yule S. Non-technical skills and health care provision in low- and middle-income countries: a systemic review. *Med Educ*. 2016;50(4):441-455.
9. Scott JW, Lin Y, Ntakiyiruta G, et al. Contextual challenges to safe surgery in a resource-limited setting: a multi-center, multi-professional qualitative study. *Ann Surg*. 2017 [Epub ahead of print].
10. Lin Y, Scott JW, Mutabazi Z, et al. Strong support for a context-specific curriculum on non-technical skills for surgeons. *East Cent Afr J Surg*. 2016;21(3):3-5.
11. Petroze R, Nzayisenga A, Rusanganwa V, Ntakiyiruta G, Calland J. Comprehensive national analysis of emergency and essential surgical capacity in Rwanda. *Br J Surg*. 2012;99(3):436-443.
12. Binagwaho A, Farmer P, Nsanzimana S, et al. Rwanda 20 years on: investing in life. *Lancet*. 2014;384(9940):371-375.
13. Cancedda C, Farmer P, Kyamanywa P, et al. Enhancing formal educational and in-service training programs in rural Rwanda: a partnership among the public sector, a nongovernmental organization, and academia. *Acad Med*. 2014;89(8):1117-1124.
14. Cancedda C, Riviello R, Wilson K, et al. Building workforce capacity abroad while strengthening global health programs at home: participation of seven Harvard-affiliated institutions in a health professional training initiative in Rwanda. *Acad Med*. 2017 [Epub ahead of print].
15. Rickard J, Ssebuufu R, Kyamanywa P, Ntakiyiruta G. Scaling up a surgical residency program in Rwanda. *East Cent Afr J Surg*. 2016;21(1):11-23.
16. Scott JW, Ntakiyiruta G, Mutabazi Z, Smink DS. Identifying the unique non-technical skills used by surgeons operating in low and middle income contexts [abstract]. *J Am Coll Surg*. 2015;221(4):S87.
17. Ericsson K. Deliberate practice and acquisition of expert performance: a general overview. *Acad Emerg Med*. 2018;15(11):988-994.
18. Spanager L, Lyk-Jensen H, Dieckmann P, Wettergren A, Rosenberg J, Ostergaard D. Customization of a tool to assess Danish surgeons' non-technical skills in the operating room. *Danish Med J*. 2012;59(11):A4526.