OPEN

Feasibility of an Interprofessional, Simulation-Based Curriculum to Improve Teamwork Skills, Clinical Skills, and Knowledge of Undergraduate Medical and Nursing Students in Uganda

A Cohort Study

Santorino Data, MMed, Pediatrics and Child Health;

Mirette M. Dubé, MSc;

Francis Bajunirwe, PhD;

Catherine Kyakwera, MMed, Pediatrics and Child Health;

Traci Robinson, BN;

Josephine N. Najjuma, MNS;

Moses Cherop, MBChB;

Lenard Abesiga, MMed, Obstetrics;

Tamara Namata, MBChB;

Jennifer L. Brenner, MD;

Nalini Singhal, MD;

Margaret Twine, MBChB;

Ian Wishart, MD;

Heather MacIntosh, MPA;

Adam Cheng, MD

Introduction: Many deaths in Sub-Saharan Africa are preventable with provision of skilled healthcare. Unfortunately, skills decay after training. We determined the feasibility of implementing an interprofessional (IP) simulation-based educational curriculum in Uganda and evaluated the possible impact of this curriculum on teamwork, clinical skills (CSs), and knowledge among undergraduate medical and nursing students.
Methods: We conducted a prospective cohort study over 10 months. Students were divided into 4 cohorts based on clinical rotations and exposed to rotation-specific simulation scenarios at baseline, 1 month, and 10 months. We measured clinical teamwork scores (CTSs) at baseline and 10 months; CSs at baseline and 10 months, and knowledge scores (KSs) at baseline, 1 month, and 10 months. We used paired *t* tests to compare mean CTSs and KSs, as well as Wilcoxon rank sum test to compare group CS scores.
Results: One hundred five students (21 teams) participated in standardized simulation scenarios. We successfully implemented the IP, simulation-based curriculum. Teamwork skills improved from baseline to 10 months when participants were exposed to: (*a*) similar scenario to baseline {baseline mean CTS = 55.9% [standard deviation (SD) = 14.4]; 10-month mean CTS = 88.6%; SD = 8.5, $P = 0.001$}, and (*b*) a different scenario to baseline [baseline mean CTS = 55.9% (SD = 14.4); 10-month CTS = 77.8% (SD = 20.1), $P = 0.01$]. All scenario-specific CS scores showed no improvement at 10 months compared with baseline. Knowledge was retained in all scenarios at 10 months.
Conclusions: An IP, simulation-based undergraduate curriculum is feasible to implement in a low-resource setting and may contribute to gains in knowledge and teamwork skills.
(*Sim Healthcare* 00:00–00, 2020)

Key Words: Interprofessional simulation, teamwork, clinical skills, Uganda, Africa.

Many deaths in Sub-Saharan Africa are preventable.[1–4] Preventable deaths are particularly an issue in Uganda, where maternal mortality is among the highest in the world (336 maternal deaths per 100,000)[5] and where the highest burden of deaths under the age of 5 years occurs in the neonatal period.[6] These deaths are often from preventable causes such as hemorrhage, sepsis, intrapartum hypoxic events, and preterm complications.[3,7,8] Skilled birth attendants and healthcare professionals

From the Mbarara University of Science and Technology (S.D., F.B., C.K., N.N.J., C.M., L. A., T.N., M.T.), Mbarara, Uganda; KidSIM Simulation Program (M.D., T.R., I.W., A.C.), Alberta Children's Hospital; and Department of Pediatrics (J.L.B., N.S., I.W., A.C.), and Global Health and International Partnerships (H.M.), Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada.

Correspondence to: Santorino Data, MMed, Pediatrics and Child Health, Department of Pediatrics and Child Health, Center for Innovation and Technology Transfer, Mbarara University of Science and Technology, Plot 8 - 18, Mbarara - Kabale Road P.O Box 1410, Mbarara, Uganda (e-mail: sdata@must.ac.ug; boymukedata@gmail.com).

The authors declare no conflict of interest.

Supported by the Laerdal Foundation for Acute Medicine (Grant Number: 40162), the Elma Foundation (Grant Number: 16-F0021), and the International Development Research Center, Canada (Grant Number: 108217-001).

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.simulationinhealthcare.com).

DOI: 10.1097/SIH.0000000000000531

can potentially reduce the rate of maternal and newborn deaths.[3,7,8]

Clinical skills (CSs) have been proven to decay over time unless systematic exposure to routine practice and feedback is implemented.[9–15] Simulation training, when conducted with opportunity for repetitive practice in a team-based environment, improves clinical performance and teamwork skills in many clinical areas.[16–23] Many Ugandan undergraduate health professionals seldom have opportunity to practice in an interprofessional (IP), simulation-based environment. Furthermore, few African medical and/or nursing schools have implemented IP, simulation-based training into their curricula. This contributes to suboptimal team-based clinical care upon entry into clinical practice. It is unknown whether the implementation of an IP, simulation-based education for undergraduate nursing and medical students is feasible in a limited resource setting.

In this study, we aimed to evaluate the feasibility of implementing an undergraduate IP, simulation-based curriculum and to describe the possible impact of this curriculum on teamwork skills, CSs, and knowledge as measured at baseline, 1 month, and 10 months among a cohort of medical and nursing students in Uganda. We also aimed to determine whether teamwork skills were transferable across different clinical scenarios by the end of the curriculum.

METHODS

We used departmental faculty to identify both emergent and routine cases common to the Departments of Pediatrics, Internal Medicine, Obstetrics, and Surgery at the Mbarara University of Science and Technology (MUST) in southwestern Uganda that were developed into simulation case scenarios. The MUST undergraduate students rotating in these departments were recruited to participate in an IP, simulation-based curriculum consisting of department-specific simulation case scenarios identified by the faculty. We conducted a prospective, observational study to describe the effects of this IP curriculum on teamwork, CSs, and knowledge over 10 months. Research ethics board approvals were obtained for this study from the University of Calgary (Canada) and the MUST in Uganda. The study used established simulation-based research methods, including standardization of simulation scenarios across groups to minimize potential confounders.[24,25]

Study Participants and Sampling

Participants were recruited from the MUST medical and nursing schools. Third- and fifth-year medical students rotating in the clinical departments of pediatrics, internal medicine, surgery, and obstetrics were recruited to participate in the study. The nursing students enrolled to participate were in the bachelor of nursing program in their third or fourth year of study. These classes of medical (3rd- and 5th-year) and nursing (3rd- and 4th-year) students were selected because they rotate through the previously mentioned departments as part of their clinical rotations over 2 consecutive semesters (10 months). Medical and nursing students were grouped into teams of 5 participants with each team consisting of 4 medical students and 1 nursing student (ie, representative of the typical physician to nurse ratio on ward round teams in the local healthcare setting of the Mbarara Regional Referral Hospital). All students in the same departmental rotation (ie, obstetrics, surgery, internal medicine, or pediatrics) were considered a cohort. Depending on number of students per clinical rotation, 5 to 6 teams were formed per cohort. Grouping into teams was conducted through random assignment. Team members remained in the same grouping throughout the 4 clinical rotations. In situations where the number of students in a cohort could not be fitted into groups of 5, a simple random sampling was performed to obtain a cohort size divisible into equal groups of 5 persons. Nursing students were assigned to cohorts depending on their clinical rotation at the initiation of the study; however, their subsequent rotations did not mirror those of medical students who determined scenario exposures. This meant that after nursing students finished their first departmental rotation, it was not unusual for them to participate in simulation scenarios with medical student group members who were on a different departmental rotation.

Exclusion Criteria

Medical and nursing students in preclinical years and those rotating in clinical disciplines other than pediatrics, internal medicine, surgery, and obstetrics were excluded.

Study Procedures

Setting

Simulation sessions were conducted in the medical simulation center at the MUST. Simulation rooms were equipped with audiovisual recording equipment to capture video recordings of all simulations. Video recording camera views were standardized in 3 locations in the simulation laboratories to ensure the head, foot, and side view of the bed and team were captured. Duplicate videos were captured using a different video capture setup (battery powered) in the event of power failure. The videos with the best audio quality were chosen for video review (single video from a single camera per scenario). We used the Laerdal NeoNatalie (for the neonatal sepsis scenario), Laerdal MamaNatalie (for postpartum hemorrhage), and the Laerdal Resusci-Anne (for adult sepsis and postpartum bleeding) manikins in the study. The medical equipment provided was setup to reflect availability in the real clinical environment. To ensure standardization, we used study checklists for every session including manikin make and model, laboratory setup (eg, equipment availability and location), student arrival checklists, and prebrief/debrief scripts for facilitators.

Undergraduate Simulation Curriculum

One scenario was developed for each rotation: neonatal sepsis for pediatrics, postpartum hemorrhage for obstetrics, adult sepsis for internal medicine, and postoperative bleeding for surgery. See Supplemental Digital Content (SDC) 1A–D http://links.lww.com/SIH/A599 for details of each scenario and multiple-choice questions (MCQs).

A scenario of a patient with gastroenteritis was developed and implemented as an orientation scenario before scenario 1, with the primary goal of familiarizing participants to the simulation environment. Data were not collected from the orientation scenario. The scenarios were developed in partnership with key simulation educators and researchers from the KidSIM simulation program (University of Calgary), Stavanger Acute Medicine Foundation for Education and Research (SAFER), and MUST. Each scenario was developed, pilot tested, and revised for consistency by the study team. Scenarios were time limited to 20 minutes. Two of the 4 scenarios required actors that were trained[26] in the scenarios to ensure standardized responses for participants, and each had scripted histories to provide when asked (ie, postpartum hemorrhage (PPH) – mother; neonatal sepsis – mother). All other information was provided to participants by a research facilitator.

During each rotation, teams were exposed to 2 simulated scenarios, a simulation scenario at rotation start (ie, baseline), and a repeat exposure to the same scenario at the end of the rotation (ie, 1 month after baseline; Fig. 1). At the end of rotation 4, teams were exposed to a repeat scenario 4 and scenario 1 (third iteration scenario 1). We slightly modified scenario stems of these repeat scenarios, but medical content and patient progression remained unchanged as in the first iteration of the scenario. Clinical teamwork scores (CTSs) in the third iteration of scenario 1 and repeat scenario 4 were used to measure transferability of teamwork skills at 10 months. Groups that attended the entire curriculum participated in a total of 9 scenarios and debriefings over the course of 10 months. Teams were free to change team leaders; we did not track changes in team leadership during scenarios in the study period. In the event that not all team members were present for a scenario, a minimum of 3 members inclusive of a nursing student was required for scenario execution.

A 3-minute prebriefing video was developed to cover key elements of a standardized prebriefing checklist. Participants were shown a video, which included standard elements of a simulation prebrief before each simulation session. The video

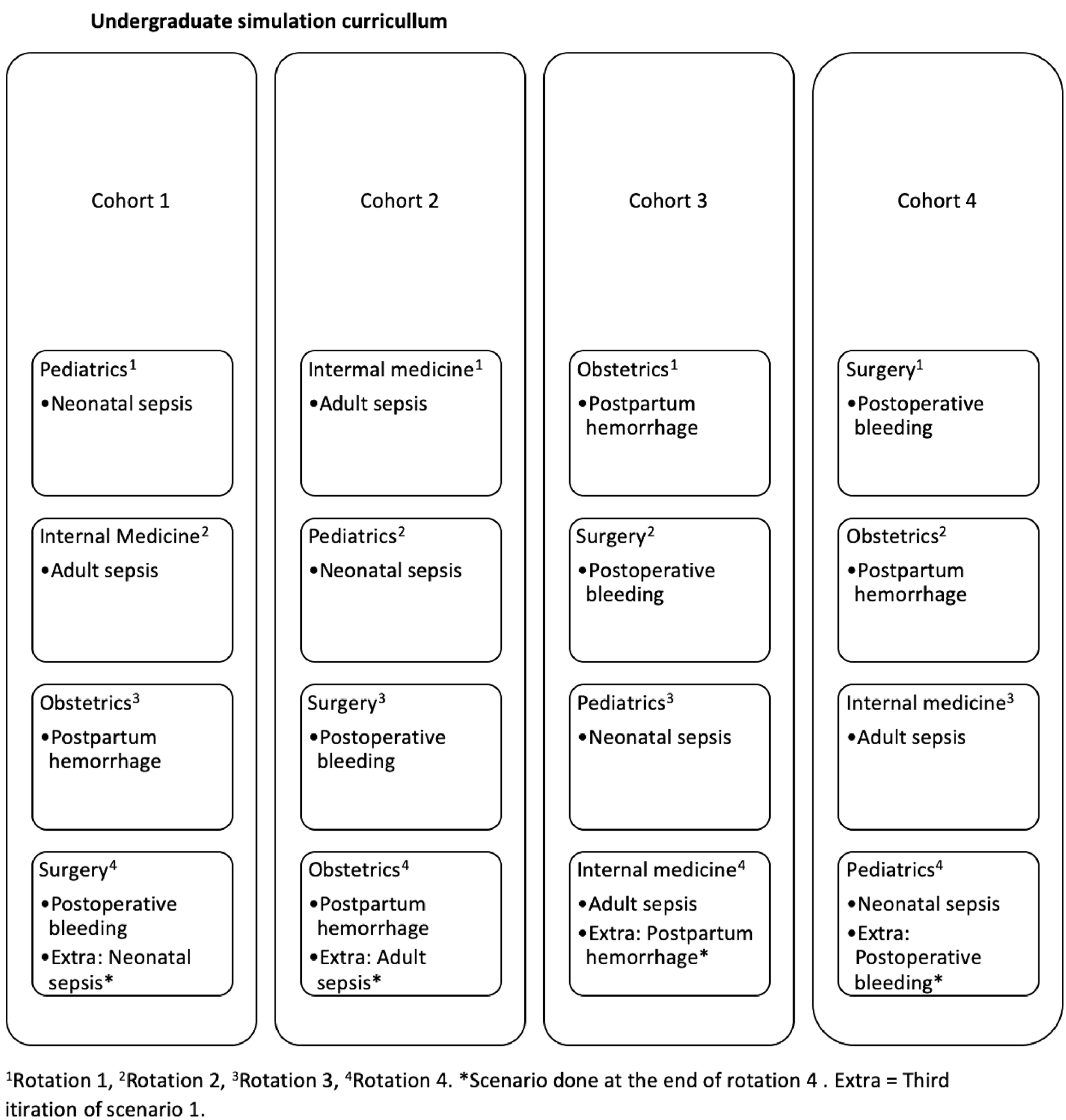

FIGURE 1. Undergraduate simulation curriculum.

was followed by an opportunity for participants to orient themselves to the environment and manikin functionality for each scenario. Manikin features and limitations were reviewed for all manikins used in all study scenarios.

A facilitated debriefing was conducted by a trained facilitator after each simulation scenario. Facilitators were trained via a standardized 2-day simulation faculty development course conducted by expert simulation faculty from the KidSIM simulation program and SAFER. A total of 8 facilitators were trained in simulation methodology and participated in the implementation of the simulation curriculum. They included 3 medical officers, 2 gynecologists, 1 pediatric resident, and 2 pediatricians. We used the Promoting Excellence and Reflective Learning in Simulation–blended method debriefing framework to facilitate debriefings.[26–28] All debriefings were scripted to include key medical and teamwork discussion points. The purpose of these debriefing scripts was to ensure that in addition to learner generated topics, all teams were exposed to key learning objectives within the 20-minute debriefing period.

Outcome Measures

Our primary outcome measure was overall teamwork performance as measured by the Clinical Teamwork Scale,[29] composed of 15 items in 5 conceptual teamwork domains of communication, situational awareness/resource management, decision making, role responsibility, and patient friendliness. A prior validation study of the CTSs, done in the context of obstetrical emergencies, demonstrated high interrater reliability and score concordance.[29] We made no changes to the CTS as aspects of teamwork measured by the CTS tool are expected performance measures in our setting. We used prerecorded videos for rater training of raters who performed video rating.

Secondary outcomes included CSs as measured by a scenario-specific skills checklist. Each checklist had a different number of items; the adult sepsis checklist had 23 items, the neonatal sepsis checklist had 27 items, postoperative bleeding checklist had 22 items, and the PPH checklist had 19 items (See SDC 2A–D http://links.lww.com/SIH/A600 for details of all scenario-specific checklists). Specialty-specific knowledge was measured by multiple-choice tests. Skills checklists were developed and/or derived from various sources, including the following: the Bleeding after Birth training program (ie, PPH scenario),[30] World Health Organization Guidelines (ie, sepsis scenarios and postoperative bleeding scenario),[31] and expert opinion (ie, for all scenarios). When possible, preexisting checklists were reviewed, modified based on expert opinion, and pilot tested with nonstudy participants for individual scenarios before being used in the study.

Knowledge was measured using an MCQ test (10 questions per test) specific to each scenario. Multiple-choice questions for neonatal sepsis scenario were from Essential Care for Every Baby[32] and Essential Care for Small Babies[33] training programs of the American Academy of Pediatrics. Postpartum hemorrhage MCQs were from the Bleeding after Birth training program of the Helping Mothers Survive program.[30] Multiple-choice questions for adult sepsis and postoperative bleeding were selected from MCQ databases for the departments of internal medicine and surgery of the MUST, World Health Organization guidelines, and modified based on expert opinion. Participant total knowledge score (KS) could range from 0 to 10.

Timing of Measurements

Teamwork (CTSs) were assessed retrospectively by video review using CTS-trained raters, with scores captured at baseline and at the end of rotation 4 at 10 months for 2 different scenarios (Fig. 2). Clinical skills were assessed at baseline and at the end of rotation 4 (10 months) in real time using trained CS checklist raters for each scenario (Fig. 2). Knowledge scores were measured using rotation-specific MCQs at baseline, at 1 month, and end of rotation 4 (10 months; Fig. 2). All MCQs were administered before scenario exposure. At the end of rotation 4, scenario 1 MCQs were offered to each participant in addition to the department specific MCQs before the third iteration of scenario 1.

Rater Training

Two local MUST faculty served as CTS raters. The CTS rater training was accomplished over 2 days using a CTS rater indicator guide and conducted in the same manner as CS checklist training. Study videos were randomly assigned to the 2 trained CTS raters, with the initial eight videos being reviewed in duplicate to ensure good interrater reliability (κ statistic >0.8). All videos were relabeled to ensure that collection time stamps were removed. Videos were randomly assigned to raters. All video rating was performed at the end of the study.

Six faculty from the MUST simulation center (pediatricians, obstetrician, and medical officers) were trained 1 week before study launch as CS checklist raters. Rater training involved review of the CS checklists, followed by practice rating of all 4 scenarios on prerecorded, nonstudy videos, and discussion among raters to achieve consensus after each video. Raters were trained over 2 days. At the end of the training, raters achieved an interrater agreement of κ equal to or greater than 0.79 for all 4 scenarios. During the study, CS checklist raters rotated through all 4 scenarios equally; because of the nature of the rating (ie, conducted in real time), raters were not blinded to the assessment time point. The initial 10% of scenarios received duplicate ratings to ensure good interrater reliability (κ statistic >0.8). The remainder of the scenarios were reviewed by 1 rater only. Initial rater training and 10% duplicate scenario ratings were conducted before rating for baseline and 10-month assessments were completed.

Sample Size

We used a convenience sample in which all medical and nursing students in the clinical years (defined previously) were invited to voluntarily participate in the study.

Data Analysis

We used χ^2 tests to compare the baseline characteristics of the students (Table 1) from the different rotation groups. We compared baseline and 1-month KSs with a paired t test to determine whether there was a significant difference. We tested the data for normal distribution using the Shapiro-Wilk test. Our data were normally distributed and were suitable for a t test. We also used paired t test to compare month 1 and month 10 KSs to measure knowledge retention. To compare CS checklist scores, we used nonparametric Wilcoxon rank sum test and examined the hypothesis that scores at baseline and

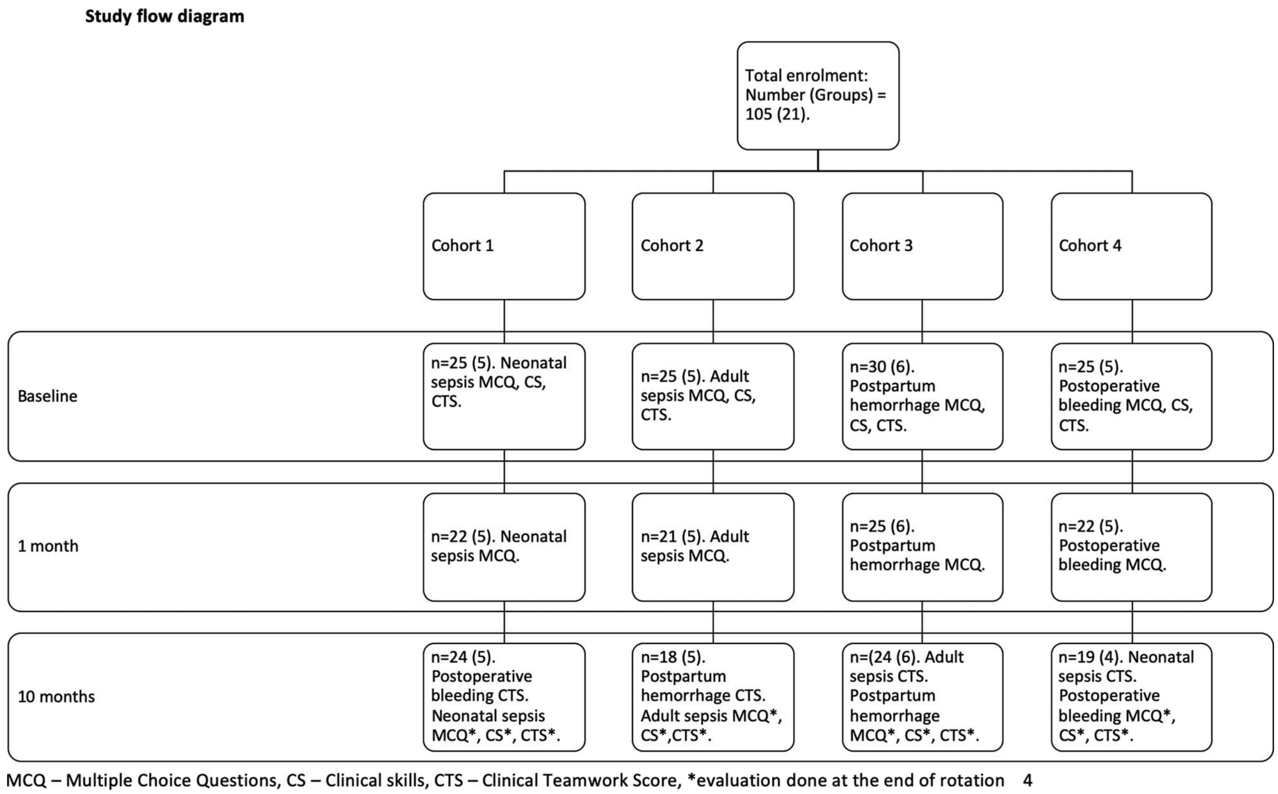

FIGURE 2. Study flow diagram.

at 10 months were significantly different. We had a small number of up to 5 to 6 groups per scenario, and therefore, we applied nonparametric statistics to the data. We used a paired *t* test to compare the CTSs before simulation exposure and 10 months in the same scenario (scenario 1) and different scenario settings (scenario 4) to baseline.

TABLE 1. Participant Characteristics

	Pediatrics (n = 25), n (%),	Internal Medicine (n = 25), n (%)	Surgery (n = 25), n (%)	Obstetrics (n = 25), n (%)
Course				
Nursing	5 (20)	5 (20)	5 (20)	6 (20)
Medicine	20 (80)	20 (80)	20 (80)	24 (80)
Sex				
Male	16 (64)	13 (52)	14 (56)	15 (50)
Female	9 (36)	12 (48)	11 (44)	15 (50)
HBB before				
None	18 (72)	20 (80)	24 (96)	25 (83.3)
Some	7 (28)	5 (20)	1 (4)	5 (16.7)
ECEB before				
None	21 (84)	23 (92)	24 (96)	28 (93.3)
Some	4 (16)	2 (8)	1 (4)	2 (6.7)
ECSB before				
None	22 (88)	23 (92)	25 (100)	29 (96.7)
Some	3 (12)	2 (8)	0 (0)	1 (3.3)
HMSBAB				
None before	20 (80)	20 (80)	23 (92)	19 (63.3)
Some	5 (20)	5 (20)	2 (8)	11 (36.7)
CEMONC				
None before	22 (88)	23 (92)	24 (96)	28 (93.3)
Some	3 (12)	2 (8)	1 (4)	2 (6.7)
BEMONC				
None before	21 (84)	22 (88)	25 (100)	20 (100)
Some	4 (16)	3 (12)	0 (0)	0 (0)

BEMONC, basic emergency maternal obstetric and newborn care; CEMONC, comprehensive emergency maternal and newborn care; ECEB, Essential Care for Every Baby; ECSB, Essential Care for Small Babies; HBB, Helping Babies Breathe; HMS BAB, Helping Mothers Survive Bleeding after Birth.

RESULTS

Demographics and Other Baseline Characteristics

In total, 84 medical and 21 nursing students were enrolled in the study. These were 25 students per rotation of pediatrics, internal medicine, and surgery and 30 students from obstetrics (n = 105 participants, n = 21 groups). No students switched to unanticipated rotations during the course of the study. Participant characteristics for each rotation are shown in Table 1. There was no significant difference in participant characteristics across all 4 cohorts apart from prior exposure to Basic Emergency Maternal Obstetric and Newborn Care (BEMONC) training. Cohort 1 students were more likely to have prior exposure to BEMONC at baseline compared with students in other cohorts ($P = 0.036$). However, the total number of students who reported attendance of BEMONC training at baseline was low (6/105). The number of participants and groups that completed assessments was variable at the different time points (Fig. 2) for various reasons, including competing classes, other school-related commitments, personal commitments, or inconvenient timing of assessment.

Teamwork Skills

Clinical teamwork scores improved from a mean of 55.9% [standard deviation (SD) = 14.4] at baseline to 88.6% (SD = 8.5) at 10 months ($P < 0.01$) when groups were tested with the same clinical scenario. When groups were exposed to a different clinical scenario at 10 months, CTSs were also significantly improved [77.8% (SD = 20.1)] compared with baseline ($P = 0.01$; Fig. 3).

TABLE 2. Clinical Skills Group Mean Test Scores Across 4 Content Areas at Baseline and 10 Months

Content Area	Baseline, %, SD (No. Groups)	10 Months, %, SD (No. Groups)	Wilcoxon Rank Sum Test *P*
Neonatal sepsis	65.9, 6.1 (n = 5)	79.3, 12.5 (n = 5)	0.11
Postpartum hemorrhage	81.5, 9.8 (n = 6)	81.5, 4.4 (n = 6)	1.0
Postoperative bleeding	71.8, 3.8 (n = 5)	74.1, 10.1 (n = 4)	0.90
Adult sepsis	70.4, 4.7 (n = 5)	81.7, 9.6 (n = 4)	0.14

Clinical Skills

Mean CS checklist scores showed no significant improvement from baseline to 10 months across content areas (neonatal sepsis, $P = 0.11$; postpartum hemorrhage, $P = 1.0$; postoperative bleeding, $P = 0.9$; adult sepsis, $P = 0.14$). See Table 2 for details.

Knowledge

There was a significant increase in mean MCQ scores from baseline to 1 month for neonatal sepsis ($P = 0.006$), adult sepsis ($P = 0.024$), postoperative bleeding ($P = 0.035$), and postpartum hemorrhage ($P < 0.001$). There was no significant change in mean MCQ scores between 1 month and 10 months (neonatal sepsis, $P = 0.18$; adult sepsis, $P = 0.81$; postoperative bleeding, $P = 0.13$; postpartum hemorrhage, $P = 0.53$), demonstrating evidence of knowledge retention across content areas (Table 3).

DISCUSSION

We have demonstrated that the implementation of an IP simulation curriculum for undergraduate students is feasible in a

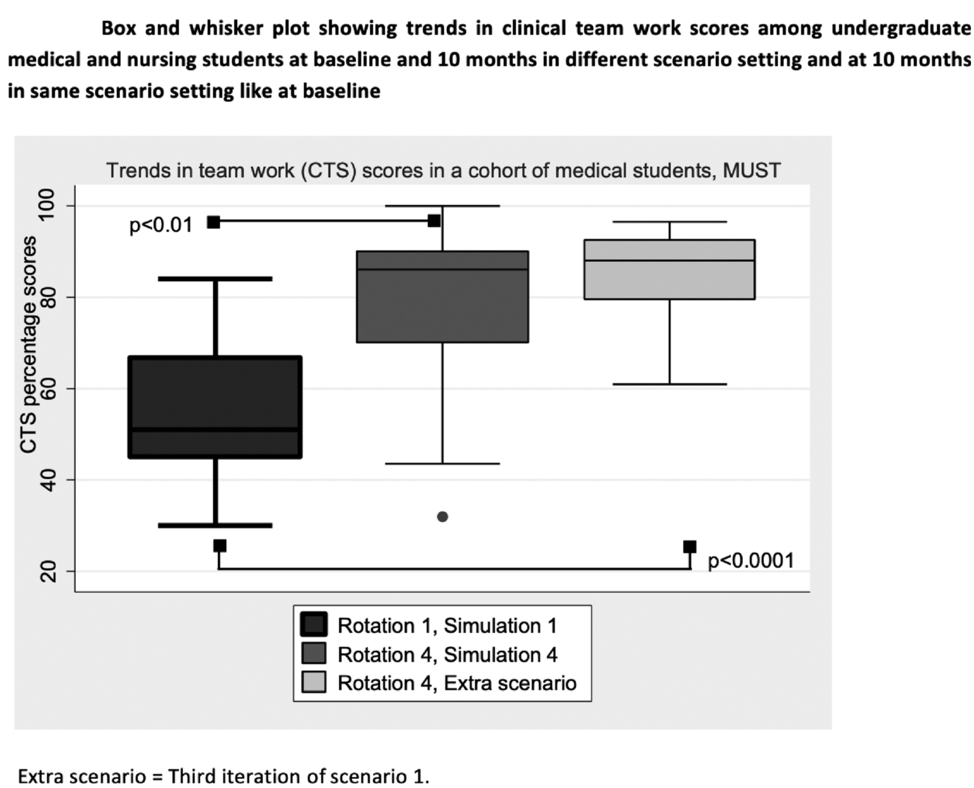

FIGURE 3. Box and whisker plot showing trends in clinical team work scores among undergraduate medical and nursing students at baseline and 10 months in different scenario setting and at 10 months in same scenario setting like at baseline.

TABLE 3. Mean KSs at Baseline, 1-Month, and 10-Month Follow-up

Measurement	n*	Baseline (SD)	1 Month (SD) (Skills Acquisition)	P	10 Months (SD) (Skills Retention)	P†
Neonatal sepsis	20	8.0 (1.33)	8.95 (0.88)	0.006	8.65 (1.18)	0.18
Adult sepsis	19	5.21 (1.22)	6.42 (1.95)	0.024	6.52 (1.13)	0.81
Postoperative bleeding	18	6.33 (0.76)	6.83 (0.85)	0.035	6.33 (1.14)	0.13
Postpartum hemorrhage	22	7.95 (0.89)	8.91 (0.87)	<0.001	9.04 (0.89)	0.53

*Number of students who completed all 3 assessments.
†Compares 10- to 1-month scores.

low-resource setting. Interprofessional exposure of undergraduate students in Africa is rare, although it represents a great opportunity for professional development.[34] Simulation-based medical education is gradually growing in Africa with most initiatives focused on skills development.[34–36] Our study provides insights into the feasibility of implementing an IP undergraduate simulation curriculum for medical and nursing students and its associated learning outcomes. This IP simulation curriculum seems to be associated with acquisition and retention of teamwork skills that are transferable to a different clinical context. Clinical skills showed no significant improvement at 10 months compared with baseline; however, knowledge of rotation-specific content was acquired and retained for all 4 content areas.

Although the Mbarara University had no prior experience using healthcare simulation as an educational modality, this study demonstrates the feasibility of implementing such a curriculum in a resource-limited setting. In addition to simulation faculty development, we attribute the success of this curriculum implementation to a number of factors: (1) stakeholder engagement, (2) grant funding for purchase of simulation equipment and supplies and for the hire of additional faculty dedicated to simulation, and (3) institutional investment in simulation infrastructure. The Mbarara University leadership dedicated a 700 square meter space, funded the remodeling of this space into a simulation center, and hired a simulation laboratory coordinator using its own resources. Students, teaching faculty, and university administrators were engaged in planning and simulation perception studies that helped in understanding anticipated simulation implementation challenges and opportunities specific to our setting that were vital in curriculum design and implementation. The 4 additional faculty hired specifically for simulation played a critical role in building simulation capacity among teaching faculty as a sustainability measure. Sustainability can be further enhanced if faculty and students have dedicated time allocated to medical simulation. In this way, both students and faculty will be supported to embrace healthcare simulation for teaching and learning. We encourage other programs in low-resource settings to consider dedicated time allocation for simulation in teaching schedules as an early strategy for implementation of their simulation curricula.

Simulation-based education provides a safe, low-risk environment for healthcare trainees and providers to practice effective teamwork. With simulated medical crisis, teams are able to rehearse critical teamwork skills such as communication, situational awareness, resource management, decision making, and role responsibility.[29,37–39] Prior systematic reviews of the simulation education literature describe simulation-based education as an effective means of enhancing teamwork among undergraduates, postgraduates, and practicing healthcare professionals.[17,20–24] Our study builds on this literature by providing evidence to support an association between simulation-based training and improved teamwork skills for undergraduate students in a low-resource setting. Students in our curriculum were exposed to nine different simulated clinical scenarios over 10 months, with teamwork concepts integrated into the debriefing conversation of each of those scenarios. By weaving in several key elements of instructional design associated with enhanced learning outcomes,[17,40,41] repetitive practice, feedback/debriefing, and clinical variation, we were able to demonstrate an association between simulation and long-term retention and transferability of teamwork skills to different clinical contexts.

We believe that several variables contributed to transferability of teamwork skills across contexts in our study. With the design of our study, participants were in the same groups throughout the year, thus providing them opportunity to refine their performance as a team over the year. The opportunity to apply teamwork principles in different contexts, coupled with facilitator feedback during debriefing, likely helped reinforce positive behaviors. Lastly, regular spacing of training opportunities likely prevented significant skill decay between simulation sessions. Future studies evaluating this curriculum design in other low-resource settings are required to demonstrate generalizability of the intervention across programs and learner groups.

With our curriculum design, we observed knowledge acquisition and retention in most content areas. Prior work has shown simulation-based education to be highly effective at improving knowledge acquisition across various different specialties and content areas.[17,20,21,40] In our study, we observed similar results, with participants demonstrating good knowledge acquisition for different content area after clinical simulation and debriefing within a 1-month period. While knowledge acquisition is desirable, the application of knowledge in the form of clinical management and skills is ultimately more important. Despite the improvement in knowledge acquisition observed in our study, we exercise caution in completely attributing this effect to the intervention due to the lack of a control group in this study.

Reflecting on the instructional design of the simulation-based curriculum provides insight into why our results were variable depending on the outcome analyzed and sheds light on how future curricula can be modified to achieve enhanced outcomes. In contrast to teamwork skills and knowledge, we did not demonstrate significant improvement in CSs among our cohort of students when participants exposed to a scenario at baseline were exposed to a repeat 10 months later. Prior studies demonstrated that spaced practice (ie, opportunities for training distributed over time) of CSs is more effective than massed practice (ie, training all at once),[16,17,40] for improving learning outcomes. Our participants were exposed to CS sets specific to a rotation (eg, internal medicine) only during that block (ie, 2 simulation scenarios in 1 block), with little structured opportunity to practice those specific skills over the remaining 9 months of the curriculum. The lack of CSs improvement at

10 months is not surprising given the massed practice design of the curriculum as it relates to specific CSs. On the other hand, teamwork skills might have shown significant improvement at 10 months compared with baseline because these skills were debriefed at every single simulation scenario irrespective of department of rotation in a low-dose, high-frequency fashion. Future modification of the curriculum should include opportunity for repetitive practice of simulation scenarios spaced out over the year.

There was variable participation in simulation sessions among undergraduate students during the course of the study. This was primarily related to the fact that simulation was being introduced at the Mbarara University and had not been integrated as a mandatory part of training. Without an established organizational culture supporting simulation, participants primarily attended research sessions in their spare time. Despite this challenge, we were able to maintain a consistent 1-month spacing between rotation simulations and recruit most students to participate in the curriculum. We anticipate that simulation curricula, once scheduled as part of routine teaching curriculum, will result in increased student participation and dedicated faculty teaching time to using simulation methodology.

Limitations

Our study had several limitations. We conducted an observational study with no control group. Although we seem to have demonstrated acquisition and retention of teamwork skills and knowledge, these results were potentially confounded by other intervening factors (ie, other longitudinal learning opportunities), and, as such, should be viewed in the context of a study with no true control group. This study design does not allow us to definitely determine whether differences in scenario performance between groups were solely due to the educational experience or influenced by other variables (eg, intervening clinical experiences, differences in participant knowledge). In addition, there was the potential for selection bias as participants who attended at 10 months may have been more motivated or higher performers.

We set a maximum debriefing time of 20 minutes but did not set a minimum debriefing duration. This may have contributed to shorter (and potentially less effective) debriefings in some situations; conversely, setting a maximum may have prevented lengthier discussion that may have contributed to more significant improvements in knowledge and skills. Our sample size was limited by the number of students available for participation at MUST; this was particularly important for team-based outcomes (ie, teamwork and CSs). Our CS raters were not blinded to scenario time points, which may have influenced their ratings. We acknowledge that the CS checklists were modified from other checklists and were not independently tested for validity. Despite the relatively small sample, we were still able to show significant improvements in teamwork skills. Future work could explore the implementation of this curriculum across multiple sites in Africa to demonstrate generalizability.

CONCLUSIONS

Our study demonstrated that an IP, simulation-based undergraduate curriculum is feasible to implement in low-resource settings and may positively influence acquisition of teamwork skills and knowledge. A randomized controlled trial is required to determine the true attributable effect of simulation training on teamwork, KS, and CS.

ACKNOWLEDGMENTS

The authors thank the following individuals, who had important contribution and whose support was instrumental to the success of our research team: Didem Erman, University of Calgary; Jerome Kabakyenga, Mbarara University; Samuel Maling, Mbarara University; Doreen Mlahagwa, Simulation for Life program Mbarara University, and the undergraduate clinical year medical and nursing students of the Mbarara University 2016–2017 academic year.

REFERENCES

1. Rule ARL, Maina E, Cheruiyot D, et al. Using quality improvement to decrease birth asphyxia rates after 'Helping Babies Breathe' training in Kenya. *Acta Paediatr* 2017;106:1666–1673.
2. Msemo G, Massawe A, Mmbando D, et al. Newborn mortality and fresh stillbirth rates in Tanzania after helping babies breathe training. *Pediatrics* 2013;131:e353–e360.
3. Moucheraud C, Owen H, Singh N, et al, Countdown Case Study Collaboration Group. Countdown to 2015 country case studies: what have we learned about processes and progress towards MDGs 4 and 5? *BMC Public Health* 2016;16(Suppl 2):794.
4. Arabi AME, Ibrahim SA, Manar AR, et al. Perinatal outcomes following helping babies breathe training and regular peer-peer skills practice among village midwives in Sudan. *Arch Dis Child* 2018;103:24–27.
5. Uganda Bureau of Statistics (UBOS) and ICF. *Uganda Demographic and Health Survey 2016*. Kampala, Uganda and Rockville, Maryland: UBOS and ICF; 2018:307–308.
6. Liu L, Oza S, Hogan D, et al. Global, regional, and national causes of under-5 mortality in 2000–15: an updated systematic analysis with implications for the Sustainable Development Goals. *Lancet* 2016;388:3027–3035.
7. Keats EC, Ngugi A, Macharia W, et al. Progress and priorities for reproductive, maternal, newborn, and child health in Kenya: a countdown to 2015 country case study. *Lancet Glob Health* 2017;5:e782–e795.
8. Ersdal HL, Singhal N, Msemo G, et al, participants in the Utstein consensus process: How to implement successful Helping Babies Survive and Helping Mothers Survive programs. Successful implementation of helping babies survive and helping mothers survive programs-an utstein formula for newborn and maternal survival. *PLoS One* 2017;12:e0178073.
9. Bhutta ZA, Das JK, Bahl R, et al, Lancet Newborn Interventions Review Group; Lancet Every Newborn Study Group. Can available interventions end preventable deaths in mothers, newborn babies, and stillbirths, and at what cost? *Lancet* 2014;384:347–370.
10. Arlington L, Kairuki AK, Isangula KG, et al. Implementation of "helping babies breathe": a 3-year experience in Tanzania. *Pediatrics* 2017;139: e20162132.
11. Bang A, Patel A, Bellad R, et al. Helping Babies Breathe (HBB) training: what happens to knowledge and skills over time? *BMC Pregnancy Childbirth* 2016;16:364.
12. Cordova E, Al-Rousan T, Castillo-Angeles M, et al. Effect of low-cost interventions on the retention of knowledge and skills following Helping Babies Breathe training. *Int J Gynecol Obstet* 2018;142:248–254.
13. Sutton RM, Niles D, Meaney PA, et al. Low-dose, high-frequency CPR training improves skill retention of in-hospital pediatric providers. *Pediatrics* 2011;128:e145–e151.
14. Kumar P, Yamada NK, Fuerch JH, et al. The Neonatal Resuscitation Program: current recommendations and a look at the future. *Indian J Pediatr* 2014;81:473–480.
15. Lin Y, Cheng A, Grant VJ, et al. Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers - a randomized controlled trial. *Resuscitation* 2018;130:6–12.

16. Cheng A, Nadkarni V, Mancini M, et al. Resuscitation education science: educational strategies to improve outcomes from cardiac arrest: a scientific statement from the American Heart Association. *Circulation* 2018;138: e82–e122.

17. Cook DA, Hatala R, Brydges R, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. *JAMA* 2011;306:978–988.

18. Cook DA, Brydges R, Zendejas B, et al. Mastery learning for health professionals using technology-enhanced simulation: a systematic review and meta-analysis. *Acad Med* 2013;88:1178–1186.

19. Cook DA, Brydges R, Hamstra SJ, et al. Comparative effectiveness of technology-enhanced simulation versus other instructional methods: a systematic review and meta-analysis. *Simul Healthc* 2012;7:308–320.

20. Cheng A, Lang TR, Starr SR, et al. Technology-enhanced simulation and pediatric education: a meta-analysis. *Pediatrics* 2014;133:e1313–e1323.

21. Ilgen JS, Sherbino J, Cook DA. Technology-enhanced simulation in emergency medicine: a systematic review and meta-analysis. *Acad Emerg Med* 2013;20:117–127.

22. Boet S, Bould MD, Fung L, et al. Transfer of learning and patient outcome in simulated crisis resource management: a systematic review. *Can J Anaesth* 2014;61:571–582.

23. Gordon M, Darbyshire D, Baker P. Non-technical skills training to enhance patient safety: a systematic review. *Med Educ* 2012;46:1042–1054.

24. Hughes AM, Gregory ME, Joseph DL, et al. Saving lives: a meta-analysis of team training in healthcare. *J Appl Psychol* 2016;101:1266–1304.

25. Cheng A, Kessler D, Mackinnon R, et al. Reporting guidelines for health care simulation research: extensions to the CONSORT and STROBE statements. *BMJ Simul Technol Enhanced Learn* 2016;2:51–60.

26. Adler MD, Overly FL, Nadkarni VM, et al, International Network for Simulation-Based Pediatric Innovation, Research and Education (INSPIRE) CPR Investigators. An approach to confederate training within the context of simulation-based research. *Simul Healthc* 2016;11:357–362.

27. Eppich W, Cheng A. Promoting excellence and reflective learning in simulation (PEARLS): development and rationale for a blended approach to health care simulation debriefing. *Simul Healthc* 2015;10:106–115.

28. Bajaj K, Meguerdichian M, Thoma B, et al. The PEARLS Healthcare Debriefing Tool. *Acad Med* 2018;93:336.

29. Guise JM, Deering SH, Kanki BG, et al. Validation of a tool to measure and promote clinical teamwork. *Simul Healthc* 2008;3:217–223.

30. Evans CL, Johnson P, Bazant E, et al. Competency-based training "Helping Mothers Survive: Bleeding after Birth" for providers from central and remote facilities in three countries. *Int J Gynaecol Obstet* 2014;126:286–290.

31. Rhodes A, Evans LE, Alhazzani W, et al. Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016. *Crit Care Med* 2017;45:486–552.

32. Bose C, Singhal N, Berkelhermer S, et al. *Essential Care for Every Baby Facilitator Flip Chart*. 1st ed. Itasca, IL: American Academy of Pediatrics; 2014:31b.

33. Singhal N, Berkelharmer S, Barber G, et al. *Essential Care for Small Babies Flip Chart*. 1st ed. Itasca, IL: American Academy of Pediatrics; 2015:24.

34. Walker L, Cross M, Barnett T. Mapping the interprofessional education landscape for students on rural clinical placements: an integrative literature review. *Rural Remote Health* 2018;18.

35. Rosman SL, Nyirasafari R, Bwiza HM, et al. Rapid cycle deliberate practice vs. traditional simulation in a resource-limited setting. *BMC Med Educ* 2019;19:314.

36. Pattinson RC, Bergh AM, Ameh C, et al. Reducing maternal deaths by skills-and-drills training in managing obstetric emergencies: a before-and-after observational study. *S Afr Med J* 2019;109: 241–245.

37. Gilfoyle E, Koot DA, Annear JC, et al, Teams4Kids Investigators and the Canadian Critical Care Trials Group. Improved clinical performance and teamwork of pediatric interprofessional resuscitation teams with a simulation-based educational intervention. *Pediatr Crit Care Med* 2017;18:e62–e69.

38. Sigalet E, Donnon T, Cheng A, et al. Development of a team performance scale to assess undergraduate health professionals. *Acad Med* 2013;88:989–996.

39. Cheng A, Donoghue A, Gilfoyle E, Eppich W. Simulation-based crisis resource management training for pediatric critical care medicine: a review for instructors. *Pediatr Crit Care Med* 2012;13:197–203.

40. Cook DA, Hamstra SJ, Brydges R, et al. Comparative effectiveness of instructional design features in simulation-based education: systematic review and meta-analysis. *Med Teach* 2013;35:e867–e898.

41. Motola I, Devine LA, Chung HS, et al. Simulation in healthcare education: a best evidence practical guide. AMEE Guide No. 82. *Med Teach* 2013;35(10):e1511–e1530.

