SURGICAL INFECTIONS
Volume 23, Number X, 2022

DOI: 10.1089/sur.2021.187

Original Article

Clean and Confident: Impact of Sterile Instrument Processing Workshops on Knowledge and Confidence in Five Low- and Middle-Income Countries

Constance S. Harrell Shreckengost,[1,2] Nichole Starr,[1,3] Tihitena Negussie Mammo,[1,4] Natnael Gebeyehu,[1,5] Yonas Tesfaye,[6] Kinfemichael Belayneh,[5] Mansi Tara,[1] Isabela Lima,[1] Kitty Jenkin,[1] Christina Fast,[7] and Thomas G. Weiser[1,8,9]

Abstract

Background: Proper sterilization of surgical instruments is essential for safe surgery, yet re-processing methods in low-resource settings can fall short of standards. Training of Trainers (TOT) workshops in Ethiopia and El Salvador instructed participants in sterile processing concepts and prepared participants to teach others. This study examines participants' knowledge and confidence post-TOT workshop, and moreover discusses subsequent non-TOT workshops and observed sterile processing practices.

Methods: Five TOT workshops were conducted between 2018 and 2020 in Ethiopia and Central America. Participant trainers then led nine non-TOT workshops in El Salvador, Guatemala, Honduras, and Nicaragua. Interactive sessions covered instrument cleaning, packaging, disinfection, sterilization, and transportation. Participants completed pre- and post-tests, demonstrated skill competencies, and shared feedback. Perioperative sterile processing metrics were also observed in Ethiopian hospitals pre- and post-workshops.

Results: Ninety-five trainees participated in TOT workshops, whereas 169 participated in non-TOT workshops. Knowledge on a 10-point scale increased substantially after all training sessions ($+2.3 \pm 2.8$, $+2.9 \pm 1.7$, and 2.7 ± 2.5 after Ethiopian, Central American, and non-TOT workshops, respectively; all $p < 0.05$). Scores on tests of sterile processing theory also increased (Ethiopian TOT, $+68\% \pm 92\%$; Central American TOT, $+26\% \pm 20\%$; $p < 0.01$). Most respondents felt ''very confident'' about teaching (Ethiopian TOT, 72%; Central American TOT, 83%; non-TOT, 70%), whereas fewer participants felt ''very confident'' enacting change (Ethiopian TOT, 36%; Central American TOT, 58%; non-TOT, 38%). Reasons included resource scarcity and inadequate support. Nonetheless, observed instrument compliance improved after Ethiopian TOT workshops (odds ratio [OR], 1.47; 95% confidence interval [CI], 1.21–1.78; $p < 0.01$).

Conclusions: Sterile processing workshops can improve knowledge, confidence, and sterility compliance in selected low- and middle-income countries. Training of Trainers models empower participants to adapt programs locally, enhancing sterile processing knowledge in different communities. However, national guidelines, physical and administrative resources, and long-term follow-up must improve to ensure effective sterile processing.

Keywords: global surgery; sterile processing; surgical instruments; training

[1]Lifebox, London, United Kingdom, Addis Ababa, Ethiopia, New York, New York, USA.
[2]Department of Surgery, Emory University, Atlanta, Georgia, USA.
[3]Department of Surgery, University of California-San Francisco, San Francisco, California, USA.
[4]School of Medicine, [6]School of Nursing and Midwifery, Addis Ababa University, Addis Ababa, Ethiopia.
[5]St. Peter's Specialized Hospital, Addis Ababa, Ethiopia.
[7]Sterile Processing Education Charitable Trust (SPECT), Calgary, Alberta, Canada.
[8]Department of Surgery, Stanford University, Stanford, California, USA.
[9]Department of Clinical Surgery, University of Edinburgh, Edinburgh, United Kingdom.

Surgical site infections are among the most common avoidable health care–associated infections and come with substantial cost and morbidity [1,2]. Low- and middle-income countries (LMIC) are disproportionately affected by such infections [3,4]. Peri-operative practices including appropriate patient preparation, antibiotic use, and hand hygiene can reduce infection risk [3,5]. One fundamental peri-operative practice is proper sterilization of surgical instruments. When sterile processing techniques fall short of standards, risk of surgical site infection increases [6]. Instruments may become contaminated during operations or at any stage of the sterile processing cycle [7], and failures of sterilization and harmful device re-use practices are a major cause of healthcare-associated infections [6].

Although lapses in sterile processing occur worldwide, reprocessing procedures in LMIC are more likely to fall short of international standards [8]. The World Health Organization (WHO), Pan American Health Organization, and Jhpiego Corporation are among several organizations that have released manuals for sterile processing departments in LMIC [6,9]. However, access to sterile processing training remains scarce.

This study explores the effects of sterile processing workshops implemented in Ethiopia and Central America by Lifebox, an international non-profit organization dedicated to safer surgery and anesthesia. Working in collaboration with the non-profit Sterile Processing Education Charitable Trust (SPECT) and building on SPECT's experiences Tanzania [10], Benin [11], Ethiopia [12], and Cambodia [13], Lifebox led five sterile processing workshops using a Training of Trainers (TOT) model. This study examines the data obtained from these TOT workshops and from subsequent non-TOT workshops held across Central America.

Methods

Training of Trainers Safer Surgical Instruments workshops

Lifebox and SPECT implemented a quality improvement initiative using a workshop named Safer Surgical Instruments in Ethiopia, El Salvador, Honduras, Guatemala, and Nicaragua between 2018 and 2020. This workshop used a TOT framework. Experts affiliated with Lifebox and SPECT taught sterile processing concepts and skills in addition to training participants to teach others. Healthcare workers already responsible for reprocessing surgical instruments were targeted for participation.

The TOT course was developed in alignment with the WHO *Decontamination and Reprocessing of Medical Devices for Healthcare Facilities* manual [6]. The course contained both lecture and interactive sessions on the following topics: foundations of the sterile process, current standards; proper care of surgical instruments; and methods for addressing teaching others. For evaluation, participants provided anonymous feedback on post-workshop surveys and completed multiple-choice tests of sterile processing theory. These tests were designed to evaluate the workshop's impact on knowledge; they were not designed to provide technical sterile processing certification. Thus, no threshold was defined for passing the tests.

In Ethiopia, materials were in English, whereas in El Salvador, materials were in Spanish. Each workshop took place over two to three days and was offered alongside workshops on Surgical Safety Checklist Implementation. Given that these workshops were part of a quality improvement initiative, no Institutional Review Board approval was sought.

Five TOT workshops were led by Lifebox between 2018 and 2020 (Table 1), with four in Ethiopia and one in El Salvador. The El Salvador TOT workshop was organized in partnership with Operation Smile and the Asociación de Médicos Anestesiólogos de El Salvador (AMAES) and was attended by participants from hospitals based in El Salvador, Guatemala, Honduras, and Nicaragua.

Sterile processing indicator evaluation

In Central America, the Safer Surgical Instruments workshops were implemented as stand-alone programs, whereas in Ethiopia the workshops were given as an integral part of another quality improvement program from Lifebox called

Table 1. Workshop Dates and Locations

Type	*City*	*Country*	*Dates*	*Number of participants*
TOT	Addis Ababa	Ethiopia	November 29–30, 2018	24
	San Salvador	El Salvador	February 14–16, 2019	13
	Gondar	Ethiopia	June 19–20, 2019	26
	Addis Ababa	Ethiopia	August 6–8, 2019	13
	Addis Ababa	Ethiopia	March 10–11, 2020	19
Trainee-led non-TOT	Managua	Nicaragua	October 28–30, 2019	15
	Guatemala City	Guatemala	October 11, 2019	20
	San Miguel	El Salvador	October 8–9, 2019	61
	Santa Ana	El Salvador	October 15–16, 2019	(aggregate total)[a]
	San Salvador	El Salvador	October 28–29, 2019	
	San Vicente	El Salvador	October 22–23, 2019	
	Antigua	Guatemala	November 23, 2019	26
	Siguatepeque	Honduras	November 7–9, 2019	27
	Zacapa	Guatemala	December 5, 2019	20

TOT = Training of Trainers.

[a]Data from El Salvador non-TOT workshops were supplied to Lifebox in aggregate form by local teams and are not included in calculation of quantitative results.

Clean Cut [14]. This program emphasizes compliance with six evidence-based peri-operative infection standards with the goal of reducing surgical site infections [14]. In addition to surgical instrument sterility, these standards including hand hygiene, antibiotic prophylaxis, reusable linen sterility, gauze counting, and use of the Surgical Safety Checklist. Data are collected for a month prior to any Clean Cut implementation and continuously throughout the six-month program. Targeted education for each standard is performed during the six months in accordance with individual hospital needs. Detailed methods for this program have been described previously [14].

The subset of the Clean Cut data collected pertaining to sterile instrument processing were available from seven of the 10 Ethiopian hospitals in which the Safer Surgical Instruments workshops were implemented. Specific metrics collected were the presence of a sterility indicator inside instrument trays; color change of the sterility indicator if present; dryness of the instrument tray; and replacement of the instrument tray if needed. These variables were further coded into an overall instrument compliance variable. Compliance required the presence of a sterility indicator that has changed color in a dry tray or replacement of the tray if the indicator is absent, if the indicator has not changed color, or if the tray is wet.

Non-TOT Safer Surgical Instruments Workshops

El Salvador TOT workshop participants from El Salvador, Guatemala, Honduras, and Nicaragua organized and implemented their own Safer Surgical Instruments workshops (Table 1). These were led without direct Lifebox or SPECT oversight but with the same Spanish-language materials used by Lifebox and SPECT instructors in the TOT workshops. Workshops were shortened to one to two days, with the precise format of the workshops adapted by local teams to meet their needs.

Analytic methods

Survey responses as well as pre-workshop and post-workshop test results were compiled from their paper format into spreadsheets for analysis. To assess between-country differences in TOT workshop outcomes, the data from the four Ethiopian TOT workshops were aggregated and compared with data from the single TOT workshop in El Salvador. Data compared included pre- and post-workshop test scores, participants' personal assessment of pre- and post-workshop knowledge rated on a 10-point scale, and participants' Likert-scale ratings of confidence, comfort, and likelihood of teaching sterile processing information to others and enacting change at their home institutions. Pre- and post-test scores were calculated as a percentage of 22 questions, and the raw difference and percent improvement were calculated. Paired Student t-tests and Mann-Whitney U tests were used to compare pre-workshop to post-workshop test scores and perceived knowledge; unpaired Student t-tests and Wilcoxon rank sum tests were used to compare these factors between regions. Fisher exact tests were used to compare categorical variables between regions whereas McNemar tests were used to compare paired categorical variables within regions.

Data from non-TOT workshops were provided voluntarily to Lifebox for analysis. Original survey responses were provided to Lifebox after the Nicaraguan, Honduran, and Guatemalan non-TOT workshops, but not after the non-TOT El Salvadorian workshops. Thus, survey data for the non-TOT workshops in Nicaragua, Honduras, and Guatemala were combined, but non-TOT El Salvador survey data were excluded. Wilcoxon rank sum tests were used to compare perceived knowledge on a ten-point scale between the Central American TOT and non-TOT workshops, whereas Fisher exact and McNemar tests were used to compare categorical variables between Central American TOT and non-TOT workshops. Pre- and post-test scores were available as an aggregated percent change in overall score from El Salvadorian and Guatemalan non-TOT sites, and no statistical analysis was performed to compare test scores between TOT and non-TOT sites.

For the data regarding intra-operative sterility metrics, pre-workshop observations from across all hospitals were combined, as were post-workshop observations from across all hospitals. Overall pre- and post-workshop compliance frequencies were calculated. Chi-square and Fisher exact tests were performed to compare pre- and post-workshop compliance frequency. All statistical calculations were computed in Microsoft Excel Version 16.49 (Microsoft, Redmond, WA) and RStudio Version 1.1.456 (RStudio, Boston, MA).

Spanish free-text survey responses were translated by bilingual staff prior to transcribing. Responses to the question: ''What challenges do you expect when you try to make changes at your facility?'' were analyzed and informally coded.

Results

Training of Trainers Safer Surgical Instruments workshops

A total of 82 people participated in the four Ethiopian TOT workshops, whereas 13 people participated in the single El Salvador TOT workshop. Participants across locations consisted of people with similar roles and levels of training, namely, nurses and technicians already working in the sterile processing departments at their hospitals.

Results of pre- and post-workshop didactic tests in TOT workshops

Percent correct scores on multiple-choice tests improved after both the Ethiopian ($72\% \pm 19\%$ vs. $48\% \pm 14\%$; $p < 0.001$) and El Salvadorian ($77\% \pm 10\%$ vs. $64\% \pm 10\%$; $p = 0.013$) TOT (Table 2). Although Ethiopian participants had lower pre-workshop scores relative to El Salvadorian participants ($48\% \pm 14\%$ vs. $64\% \pm 10\%$; $p < 0.001$), post-workshop scores did not significantly differ between the two countries ($72\% \pm 19\%$ in Ethiopia vs. $77\% \pm 10\%$ in El Salvador; $p = 0.520$).

Survey results from TOT workshops

Perceived knowledge after TOT workshops was substantially higher than pre-workshop perceived knowledge in both Ethiopia (pre: 6.7 ± 2.6 vs. post: 9.0 ± 1.5; $p < 0.001$) and El Salvador (pre: 6.4 ± 1.8 vs. post: 9.3 ± 0.7; $p = 0.004$; Table 3). All participants at the El Salvador workshop rated the workshop helpfulness as 10 on a 10-point scale. Although participants at the Ethiopian workshops rated workshop helpfulness substantially lower than those from El

Table 2. Pre- and Post-Workshop Didactic Tests from TOT Workshops in Ethiopia and El Salvador

	All TOT n = 95	*Ethiopia n = 82*	*El Salvador n = 13*	*Inter-country p*[a]
Pre-test score	50% ± 15%	48% ± 14%	64% ± 10%	<0.001[a]
Missing	8	8	0	
Post-test score	72% ± 18%	72% ± 19%	77% ± 10%	0.520[a]
Missing	7	7	0	
Score improvement	22% ± 16%	24% ± 16%	13% ± 12	0.009[a]
Missing	12	12	0	
Pre- versus post-workshop p value[b]	<.001[b]	< 0.001[b]	0.013[b]	

Data are shown as the mean score calculated as percentage correct of 22 questions ± standard deviation.
TOT = Training of Trainers.
[a]Tests of significance between Ethiopian and El Salvador groups as calculated by Student t-tests.
[b]Tests of significance between pre-workshop and post-workshop groups as calculated by paired Student t-tests.

Salvadorian workshop participants (p = 0.005), ratings remained high at greater than nine on the 10-point scale (9.1 ± 1.6).

Participants also rated post-workshop confidence teaching and confidence in their ability to enact change as not at all, somewhat, or very. The percentages of participants that were very confident teaching (72% vs. 83%; p = 0.494) and very confident in their ability to enact change (36% vs. 58%; p = 0.198) were similar after both Ethiopia and El Salvador TOT workshops. In Ethiopia, substantially fewer participants were very confident about enacting change than were very confident teaching (36% vs. 72%; p < 0.001). This difference in confidence in change versus confidence teaching was not significant in El Salvador (58% vs. 83%; p = 0.248).

Participants identified challenges implementing improvements at their home facilities in free-text response format. Responses were categorized into four categories: resistant attitudes/negativity; lack of knowledge; lack of resources; and lack of administrative or physician support. Of the 33 Ethiopian surveys reviewed, 14 (42%) identified resources as a major barrier; 11 (33%) identified resistance to change; 5 (15%) identified lack of knowledge; and 3 (9%) identified lack of administrative or physician support. Of the 11 El Salvadorian surveys reviewed, 2 (18%) identified resources as a major barrier; 7 (64%) identified resistance to change; 2 (18%) identified lack of knowledge. None identified lack of administrative or physician support.

Evaluation of sterile processing indicators in Ethiopia

A total of 2,861 operations were observed prior to the workshops, and a total of 534 operations were observed after the workshops (Table 4). The presence of a sterility indicator in sterile instrument trays was observed more

Table 3. Evaluation Surveys after TOT Workshops in Ethiopia and El Salvador

	All TOT n = 95	*Ethiopia n = 82*	*El Salvador n = 13*	*Inter-country p*[a]
Perceived knowledge pre-workshop[b]	6.7 ± 2.5	6.7 ± 2.6	6.4 ± 1.8	0.713[a]
Missing	34	33	1	
Perceived knowledge post-workshop[b]	9.0 ± 1.4	9.0 ± 1.5	9.3 ± 0.7	0.614[a]
Missing	34	33	1	
Perceived knowledge difference[b]	2.4 ± 2.6	2.3 ± 2.8	2.9 ± 1.7	0.379[a]
Missing	34	33	1	
Pre versus post-workshop knowledge p value[c]	< 0.001[c]	< 0.001[c]	0.004[c]	
Helpfulness of training[b]	9.3 ± 1.5	9.1 ± 1.6	10 ± 0	0.005[a]
Missing	24	23	1	
Very comfortable teaching[d]	35 (60%)	26 (57%)	9 (75%)	0.329[a]
Missing	37	36	1	
Very likely to teach[d]	25 (46%)	17 (40%)	8 (67%)	0.188[a]
Missing	41	40	1	
Very confident teaching[d]	48 (74%)	38 (72%)	10 (83%)	0.494[a]
Missing	30	29	1	
Very confident in change[d]	25 (40%)	18 (36%)	7 (58%)	0.198[a]
Missing	33	32	1	
Confidence teaching versus confidence in change[e]	< 0.001[e]	< 0.001[e]	0.248[e]	

TOT = Training of Trainers.
[a]Tests of significance between Ethiopian and El Salvador groups as calculated by Student t-test, Wilcoxon rank sum, χ^2, or Fisher exact tests.
[b]Data are shown as the mean value or difference of values of a 10-point scale ± standard deviation.
[c]Tests of significance between pre-workshop and post-workshop results as calculated by paired Wilcoxon rank sum tests.
[d]Respondents were asked to rank confidence, comfort, and likelihood as very, somewhat, or not at all. Data are shown as the number of respondents answering very (percent).
[e]Tests of significance comparing the frequency of participants very confident in teaching versus very confident in change using McNemar tests.

Table 4. Sterile Processing Indicators before and after TOT Workshops in Ethiopia

	Pre-workshop N = 2,861	*Post-workshop N = 534*	*Pre- versus post- p*[a]
Sterility indicator present	1,235 (44%)	299 (56%)	<0.001[a]
Missing	36	2	
Sterility indicator color change[b]	1,212 (98%)	263 (99%)	1[a]
Missing	3	32	
Dry tray	2,756 (97%)	493 (94%)	<0.001[a]
Missing	33	9	
Tray replaced if needed[c]	32 of 856 (4%)	18 of 83 (21%)	<0.001[a]
Missing	785	176	
Instrument compliance	1,195 (43%)	253 (52%)	<0.001[a]
Missing	56	49	

TOT = Training of Trainers.
[a]Tests of significance between pre-workshop and post-workshop groups as calculated by χ^2 or Fisher exact test.
[b]Percentage shown is calculated from the total number of sterility indicators present.
[c]Percentage shown is calculated from total number of trays identified as needing replacement (absent sterility indicator, no color change, or wet tray).

frequently after the workshops (56% post-workshop vs. 44% pre-workshop; $p < 0.001$), although the frequency of sterility indicator color change did not change (99% post-workshop vs. 98% pre-workshop; $p = 1$). Although trays were more frequently found wet after the workshop (94% dry trays post-workshop vs. 96% dry trays pre-workshop; $p < 0.001$), such trays were appropriately reprocessed more frequently (21% post-workshop vs. 4% pre-workshop; $p < 0.001$). Post-workshop overall instrument compliance (52%) was improved relative to pre-workshop compliance (43%) in both t-test ($p < 0.001$) and in univariable logistic regression (odds ratio [OR], 1.47; 95% confidence interval [CI], 1.21–1.78; $p < 0.001$). The Cohen D effect size of this outcome was 0.62, indicating a moderate effect [15].

Non-TOT Safer Surgical Instruments workshops

A total of 169 people participated in the nine Central American non-TOT workshops across El Salvador, Guatemala, Honduras, and Nicaragua (Table 1). Reports submitted to Lifebox by the local staff indicated that the participants consisted primarily of nurses and technicians already working in the sterile processing departments at their hospitals.

Results of pre- and post-workshops didactic tests in non-TOT workshops

Percentage improvement between pre-workshop and post-workshop scores on multiple choice tests of sterile processing theory was reported in aggregate. Guatemalans reported 45.6% improvement whereas El Salvadorians reported 25.7% improvement. This compares with a 21.3% improvement among participants in the Central American TOT workshop. Neither raw nor aggregate scores were reported from the Honduran or Nicaraguan non-TOT workshops.

Survey results from non-TOT workshops

El Salvador non-TOT workshop survey responses were not available and thus excluded from analysis, bringing the total number of survey responses analyzed to 108 (Table 5). At the Central American non-TOT workshops, post-workshop perceived knowledge (9.2 ± 1.2) was higher than pre-workshop perceived knowledge (6.5 ± 2.2; $p < 0.001$). Non-TOT participants' perceived knowledge did not differ from that of Central American TOT participants (pre-workshop comparison, $p = 0.700$; post-workshop, $p = 0.935$).

The percentages of participants who were very confident teaching (70% vs. 83%; $p = 0.504$) and very confident in their ability to enact change (38% vs. 58%; $p = 0.217$) were similar when comparing non-TOT and TOT workshops. However, the percentage of participants that were very confident in their ability to enact change was significantly lower than the percentage of participants who were very confident teaching after the non-TOT workshop (38% vs. 70%; $p < 0.001$).

Responses regarding challenges implementing change were categorized into the same four categories as before. Of the 96 non-TOT survey responses reviewed, 10 (10%) identified resources as a major barrier; 58 (60%) identified resistance to change; nine (9%) identified lack of knowledge; and 14 (15%) identified lack of administrative or physician support. The remaining five responses not categorized in these codes did not indicate any challenges.

Discussion

The Safer Surgical Instruments TOT workshops led by Lifebox and SPECT in Ethiopia and Central America between 2018 and 2020 effectively imparted knowledge and improved confidence to teach sterile processing concepts. In Central America, where TOT workshop participants subsequently led their own workshops, participants in these non-TOT workshops similarly improved knowledge. In Ethiopia, sterile processing practices observed peri-operatively improved after workshop participation. Collectively, these data indicate that sterile processing workshops have potential to improve knowledge, confidence, and behaviors in diverse LMIC.

A central tenet of TOT workshops is to teach not only didactic concepts, but also to empower participants to teach to others. Participants in the Central American TOT workshop worked with professional medical organizations based in El Salvador, Guatemala, Honduras, and Nicaragua to mount non-TOT workshops. These workshops, led by regional instructors, demonstrate the success of the TOT model. Workshops were well-attended and effective in imparting knowledge.

Table 5. Evaluation Surveys after Both TOT and Non-TOT Workshops in Central America

	All Central America n = 121	*TOT n = 13*	*Non-TOT n = 108*	*TOT versus non-TOT p*[a]
Perceived knowledge pre-workshop[b]	6.5 ± 2.1	6.4 ± 1.8	6.5 ± 2.2	0.700[a]
Missing	1	1	0	
Perceived knowledge post-workshop[b]	9.2 ± 1.1	9.3 ± 0.7	9.2 ± 1.2	0.935[a]
Missing	2	1	1	
Perceived knowledge difference[b]	2.7 ± 2.4	2.9 ± 1.7	2.7 ± 2.5	0.682[a]
Missing	2	1	1	
Pre- versus post-knowledge p value[c]	< 0 .001[c]	0.004[c]	< 0.001[c]	
Helpfulness of training[d]	9.8 ± 0.5	10 ± 0	9.8 ± 0.5	0.095[a]
Missing	2	1	1	
Very comfortable teaching[d]	68 (59%)	9 (75%)	59 (57%)	0.354[a]
Missing	6	1	5	
Very likely to teach[d]	44 (38%)	8 (67%)	36 (35%)	0.056[a]
Missing	6	1	5	
Very confident teaching[d]	82 (71%)	10 (83%)	72 (70%)	0.504[a]
Missing	6	1	5	
Very confident in change[d]	46 (40%)	7 (58%)	39 (38%)	0.217[a]
Missing	6	1	5	
Confidence teaching versus confidence in change[e]	<0.001[e]	0.248[e]	<0.001[e]	

[a]Tests of significance between Ethiopian and El Salvador groups as calculated by Student t-test, Wilcoxon rank sum, χ^2, or Fisher exact tests.
[b]Data are shown as the mean value or difference of values of a 10-point scale ± standard deviation.
[c]Tests of significance between pre-workshop and post-workshop results as calculated by paired Wilcoxon rank sum tests.
[d]Respondents were asked to rank confidence, comfort, and likelihood as very, somewhat, or not at all. Data are shown as the number of respondents answering very (percent).
[e]Tests of significance comparing the frequency of participants very confident in teaching versus very confident in change using McNemar tests.

Perceived knowledge improvement was consistent with improvements in multiple-choice test score after both the Ethiopian and Central American TOT workshops, with post-test scores in both locations averaging above 70%. The present data are consistent with improvements following prior sterile processing programs led by SPECT in Benin (improvement from 57% to 71%) [11] and Ethiopia (48% to 69%) [12]. Moreover, reprocessing practices in both Benin [11] and Ethiopia [12] also improved. Notably, the workshops in the present study were designed to enhance knowledge and skills but were not designed for sterile instrument processing certification. Thus, these data signal workshop impact on sterile processing knowledge retention, but further study will be needed to associate the scores with ability.

The TOT workshops also instilled participants with confidence and comfort teaching sterile processing. Interestingly, participants in non-TOT workshops also reported high levels of confidence teaching, though this was not an express aim of these workshops. Confidence to teach about sterile processing has also been reported by participants in other non-TOT workshops, such as those led by SPECT in Cambodia [13]. This demonstrates the power of TOT workshops, as participants continue knowledge sharing and teaching beyond a single workshop.

Unfortunately, participants' confidence in their ability to teach did not necessarily translate into confidence in the ability to enact change. Only 36% of Ethiopian TOT participants reported feeling very confident implementing change, significantly fewer than the 72% who reported high confidence in their teaching ability. This difference was not found among Central American TOT participants, as evidenced by their implementation of non-TOT workshops. However, these non-TOT participants were like their Ethiopian TOT counterparts in their pessimism regarding change, with only 38% expressing high confidence enacting change.

Barriers to change cited by Ethiopian TOT and Central American non-TOT participants included negative attitudes towards change, lack of knowledge, lack of resources, and lack of administrative and physician support. Such challenges are unsurprising and have been described consistently in evaluations of various quality improvement efforts in LMIC [8,16]. Although Central American TOT participants similarly cited negativity, lack of knowledge, and lack of resources, they did not cite lack of administrative and physician support. The relatively greater confidence in their ability to enact change on the part of the Central American TOT participants may reflect this difference in perceived support. Subsequent Lifebox workshops will endeavor to engage administrative personnel in the workshops, instead of just the staff actively involved in sterile processing day to day. The necessity of cooperation among administrative, operative, and sterile processing staff is not unique to low- and middle-income settings but is fundamental to the safety of operations anywhere [17]. Future workshops may benefit from adding a focus on teamwork among these different stakeholders.

Despite barriers cited, the evidence from in-hospital observations in Ethiopia indicates that the workshops are associated with improvements in sterile processing procedures. Sterility indicators were present in 12% more instrument trays after the workshops, 17% more problematic trays were replaced, and overall instrument compliance improved (OR,

1.47; 95% CI, 1.21–1.78; $p < 0.001$). Although post-workshop overall compliance remained at 52%, clearly far from perfect, the change in compliance is associated with an effect size of 0.62, which indicates a moderate effect [15]. Although the present study was not designed to evaluate whether this change in compliance is associated with improved patient outcomes, similar imperfect compliance has been linked to reductions in surgical site infections [14].

Given that these data were collected from the subset of hospitals also engaged in another quality improvement program called Clean Cut [14], improvement in instrument compliance cannot be solely attributed to the sterile processing workshops. However, our calculations of the ''pre-'' and ''post-'' instrument compliance measures were based on the dates of the Safer Instruments workshops specific to each hospital, irrespective of the stage of Clean Cut implementation or whether the hospital was engaged in Clean Cut at all. Thus, the data presented here can be considered indicative of the incremental effect of a single workshop on sterile instrument compliance. Moreover, the data presented here are consistent with observed improvements in after SPECT sterile processing workshops elsewhere in Tanzania [10], Ethiopia [12], and Cambodia [13].

The data presented have other limitations in addition to the overlap with another quality improvement program. The Central American TOT workshop was smaller than the Ethiopian TOT workshops, with an exclusive participant group drawn from across four countries, making comparison between the two regions difficult. Although the Central American TOT workshop was successful in encouraging participants to lead sterile processing workshops locally, Lifebox partners in Central America were unable to collect intra-operative observations to evaluate for behavioral changes. Future efforts will need to incorporate this type of data collection. In addition, long-term changes in either sterile processing knowledge or behavior cannot be extrapolated. Lifebox had planned to follow up their sterile processing workshops with additional surveys and focus groups in 2020, but these plans were prevented by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) pandemic.

In conclusion, the Safer Surgical Instruments workshops from Lifebox demonstrated potential to improve sterile processing knowledge in five low- and middle-income countries. The workshops led in Ethiopia were also associated with substantial improvements in sterile processing procedures. Although peri-operative observations were not available in Central America, the workshops there demonstrated a different type of success. Building on the TOT model used, workshop participants coordinated their own workshops with similar improvements in knowledge. Although national guidelines, physical and administrative resources, and long-term follow-up must improve to assure effective sterile processing, the Safer Surgical Instruments workshops show promise addressing this oft neglected component of safe surgery.

Acknowledgments

We would like to acknowledge Fernanda Morales for contributions to the San Salvador workshop and Nebiyou Tigabu for contributions to workshops in Addis Ababa.

Funding Information

Funding for Central America workshops came from the IZUMI Foundation for the grant entitled Improving Surgical and Anesthesia Safety in Central America (El Salvador, Guatemala, Honduras, Nicaragua).

Author Disclosure Statement

Dr. Harrell Shreckengost is a Lifebox Associate Fellow. Dr. Starr is the Lifebox Senior Fellow. Dr. Negussie Mammo is the Lifebox Global Clinical Director. Dr. Gebeyehu is a Lifebox Fellow. Mr. Tesfaye has no financial interests or conflicts to disclose. Mr. Belayneh has no financial interests or conflicts to disclose. Ms. Tara is the Lifebox South Asia Program Manager. Ms. Lima is the Lifebox Central America Program Coordinator. Ms. Jenkin is the Lifebox Head of Communications. Ms. Fast is the SPECT Founder and Executive Director. Dr. Weiser is the Lifebox Consulting Medical Officer. Other than these roles, all authors declare no further financial interests or conflicts to disclose.

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Address correspondence to:
Dr. Constance S. Harrell Shreckengost
Department of Surgery
Emory University
1364 Clifton Road, NE, Suite B206
Atlanta, GA 30322
USA

E-mail: csharrell@gmail.com