Original Article

Evaluation of practice change following SAFE obstetric courses in Tanzania: a prospective cohort study

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Summary

Anaesthesia has been shown to contribute disproportionately to maternal mortality in low-resource settings. This figure exceeds 500 per 100,000 live births in Tanzania, where anaesthesia is mainly provided by non-physician anaesthetists, many of whom are working as independent practitioners in rural areas without any support or opportunity for continuous medical education. The three-day Safer Anaesthesia from Education (SAFE) course was developed to address this gap by providing in-service training in obstetric anaesthesia to improve patient safety. Two obstetric SAFE courses with refresher training were delivered to 75 non-physician anaesthetists in the Mbeya region of Tanzania between August 2019 and July 2020. To evaluate translation of knowledge into practice, we conducted direct observation of the SAFE obstetric participants at their workplace in five facilities using a binary checklist of expected behaviours, to assess the peri-operative management of patients undergoing caesarean deliveries. The observations were conducted over a 2-week period at pre, immediately post, 6-month and 12-month post-SAFE obstetric training. A total of 320 cases completed by 35 participants were observed. Significant improvements in behaviours, sustained at 12 months after training included: pre-operative assessment of patients (32% (pre-training) to 88% (12 months after training), $p < 0.001$); checking for functioning suction (73% to 85%, $p = 0.003$); using aseptic spinal technique (67% to 100%, $p < 0.001$); timely administration of prophylactic antibiotics (66% to 95%, $p < 0.001$); and checking spinal block adequacy (32% to 71%, $p < 0.001$). Our study has demonstrated positive sustained changes in the clinical practice amongst non-physician anaesthetists as a result of SAFE obstetric training. The findings can be used to guide development of a checklist specific for anaesthesia for caesarean section to improve the quality of care for patients in low-resource settings.

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Introduction

Many women worldwide die during childbirth because they do not have access to safe anaesthetic care. A recent study has shown that women undergoing caesarean delivery in sub-Saharan Africa are 50 times more likely to die than those in high-income countries [1]. The deficiency in the number of anaesthesia providers and inadequate training pose major barriers to safe obstetric anaesthetic care in these settings [2, 3].

In Tanzania, maternal mortality is high, exceeding 500 per 100,000 live births [4]. Anaesthesia is extremely under-resourced, with only 50 physician anaesthesia providers, 140 nurse anaesthetists and 40 other cadre providers, for a population of almost 54 million [5]. This makes the non-physician anaesthesia providers the backbone of the country's workforce. The training pathways for the non-physician anaesthesia providers are not standardised with high variability in duration and clinical exposure, reflecting the trend in the region [6, 7]. In many rural areas of Tanzania, the training could comprise a learn-on-the-job model or a one-year certification programme, often without any prior qualification requirement. Furthermore, once the provider becomes an independent practitioner, access to continuing medical education opportunities is almost non-existent. This may partly explain why anaesthesia has been shown to contribute disproportionately to maternal mortality in low- and middle-income countries (LMIC), with the risk increasing by almost two-fold when anaesthesia is administered by a non-physician provider [8].

The SAFE (Safer Anaesthesia from Education) Obstetric Anaesthesia (SAFE-OB) course is a three-day refresher course that was developed to fill this gap in training and provide continuing medical education to in-service anaesthesia providers in resource-constrained settings [9]. The value of short courses such as SAFE-OB and the sustainability of its impact in these settings have been scrutinised [10]. Previous studies of SAFE courses have demonstrated retention of skills and knowledge and, through qualitative methods, have reported change in practice and impact at a system level [11–15]. However, no study to date has performed Kirkpatrick Level-3 evaluations to assess the degree to which SAFE course participants apply what they have learnt to their daily job [16]. To ultimately improve the quality of obstetric anaesthesia care and patient safety, translation of knowledge into practice is the first step that needs to take place.

Using a pre-/post-interventional study design, we aimed to identify the main behavioural changes following SAFE-OB participation and to evaluate the degree and sustainability of these changes in five regional referral hospitals in the Southern Highlands zone of Tanzania.

Methods

The study was approved by Mbeya Medical Research and Ethics Committee and the institutional review boards of the University of Aberdeen and University of California, San Francisco. As this research represents an international partnership, the reflexivity statement regarding this work can be found in online Supporting Information Appendix S1.

The SAFE-OB course participants came from facilities throughout the Southern Highlands zone, from which five facilities were selected as observation sites. Facility selection considerations included ensuring geographic variation within the region, sufficient volume of caesarean sections (>15 per week), referral level facilities and not an urban teaching hospital. The five facilities were Mbeya Zonal, Mbeya Regional, Iringa Regional, Njombe Regional and Sumbawanga Regional Referral Hospitals. Participants were eligible if they were anaesthetic providers at one of the included hospitals. Written consent was obtained from participants by research assistants after written and verbal information regarding the study was provided. No patient identifiable data was recorded and consent from patients was deemed unnecessary by the institutional review boards. The World Federation of Societies of Anaesthesiologists (WFSA) Anaesthesia Facility Assessment Tool was utilised to conduct facility level assessments before commencement of the first (pre-SAFE-OB) observation period, to establish whether there were significant differences in resource availability that might impact on the behaviour of anaesthesia providers [17]. The observation checklist was developed based on SAFE course content, established best practice guidelines for caesarean section anaesthetic care and previous studies looking at self-reported behavioural change [15, 18, 19]. The checklist included observations and documentation of: patient pre-operative assessment; pre-operative preparation; team communication; conduct of spinal anaesthesia; behaviours specific to anaesthesia management of pregnant patients and caesarean delivery; and occurrence of adverse events and their management. Observable behaviours were included from the time of pre-operative assessment through to the patient reaching their immediate postoperative destination (online Supporting Information Appendix S2). Five study observers were either physician anaesthetists or registrars with training and clinical experience in anaesthesia for caesarean section. None of the observers worked at the facilities included in this study. A detailed observation instruction manual was distributed to observers, and a training session provided where observers and a co-investigator observed a caesarean section, compared checklist scoring and discussed discrepancies of any elements. This was repeated in five cases over a two-day period until observers were found to score elements similarly. Developed in 2011 by the WFSA and the Association of Anaesthetists, the SAFE-OB course is a three-day course for anaesthesia providers focused on the fundamentals of obstetric anaesthesia. To date, 6435 providers have been trained on 216 SAFE-OB courses in 47 countries (WFSA, personal communication). Non-physician anaesthesia providers in the Southern Highlands zone of Tanzania were invited to attend one of two SAFE-OB courses followed by a 1.5-day refresher course at three months. The refresher course included skills practice and focused discussions on change management and overcoming barriers to change and was offered at three locations in geographical proximity to participants' place of work.

Data collection occurred between September 2019 and September 2020. Once attendance at the course was confirmed and the sites selected, pre-intervention observations were taken. Study observers visited each hospital for a two-week data collection period during all phases of the study. The study observer would wait for caesarean sections and proceed with the checklist of observations. Observations were conducted 24 h per day and repeated immediately after completion of SAFE-OB (generally within 2 weeks of the course) and at 6 and 12 months.

Observations began when participants interacted with the patient. A printed observation package was used to record participant actions in real time. Study data were collected and managed using REDCap electronic data capture tools hosted at the University of California, San Francisco [20, 21]. Study observers were instructed not to intervene unless they deemed their assistance was required to provide lifesaving care to the patient or neonate. These occurrences were noted separately and excluded from the main analysis.

A typical approach to sample size calculation is to include an estimate of possible effect size. Given the wide variety of behaviours observed, and that an in-situ study of operating theatre behavioural change had not occurred, an a priori estimate of effect size was not possible. Therefore, for this initial study, we aimed to observe as many cases as possible. Descriptive statistics were calculated for all variables. To evaluate the effect of SAFE-OB over time, comparisons were made between pre- and post-intervention behaviour frequency. Cases were pooled based on exposure to SAFE-OB to increase the sample of cases. Results were reviewed visually and in tabular form to identify candidate behaviours that were most likely to show a difference. Chi-squared tests were used to identify differences in pre-SAFE-OB and immediately post-SAFE-OB values for candidate behaviours, with Fisher's exact test used where appropriate. Behaviours with statistically significant differences were selected for regression. A mixed effects logistic regression was used to examine the change in behaviour frequency at the different observation phases, controlling for participant and hospital. Analysis revealed that the sample was indeed too small to measure the magnitude of behavioural change with meaningful precision; the odds ratios are nonetheless reported here as a measure of directional change across phases, rather than magnitude. Analyses were performed in Stata 15 (StataCorp LP, College Station, TX, USA) and Python 3.9.12 with Pandas library 1.5.2 [22].

Results

The maternal mortality ratio of the facilities ranged from 248 to 502 per 100,000 patients and the neonatal mortality rate ranged from 22 to 84 per 1000 live births. These were comparable with reported national rates of a maternal mortality ratio of 524 (World Bank data 2018) and neonatal mortality rate of 21 (World Bank data 2017). In the year the study commenced, these facilities reported a mean (SD) of 4170 (1642) births. The caesarean section rate across all facilities was 46% (9598/20,850 deliveries) with 74–97% of these conducted under spinal anaesthesia. Each study site had between one and five functioning operating theatres. Facilities were similar in terms of infrastructure (e.g. availability of water, electricity, oxygen and blood, and information management) and equipment and medication (except for propofol and some alternative uterotonics and vasopressors; see online Supporting Information Appendix S3). Only one facility had physician anaesthetic providers, who were excluded from the study due to involvement as study co-ordinators. No site had either physician or non-physician anaesthetists in training. Before the study, the World Health Organisation (WHO) Surgical Safety Checklist was used ``*rarely*´´ at two facilities, and ``*sometimes*´´, ``*often*´´ and ``*always*´´ in each of the remaining three facilities.

A total of 320 cases completed by 35 participants were observed by five study observers. The distribution of the number of anaesthetics per participant, per phase and at each referral regional hospital can be found in online Supporting Information Appendix S4. Nurse anaesthetists performed 89% (n = 284) of cases and 71% (n = 227) were

Table 1 Characteristics of cases observed per phase of study. Values are number (proportion).

	Pre-SAFE-OB n = 100	Immediately post-SAFE-OB n = 89	6-months post-SAFE-OB n = 89	12-months post-SAFE-OB n = 43	All n = 320
Hospital					
Iringa Regional	16 (16%)	7 (8%)	9 (10%)	6 (14%)	38 (12%)
Mbeya Regional	30 (30%)	20 (22%)	10 (11%)	10 (23%)	70 (22%)
Njombe Regional	4 (4%)	11 (12%)	10 (11%)	8 (19%)	33 (10%)
Sumbawanga Regional	18 (18%)	12 (13%)	1 (1%)	3 (6%)	34 (10%)
Mbeya Zonal	32 (32%)	39 (44%)	59 (66%)	16 (37%)	146 (46%)
Cadre					
Assistant nurse anaesthetist	15 (15%)	14 (16%)	1 (1%)	0	30 (9%)
Nurse anaesthetist	84 (84%)	75 (84%)	82 (93%)	43 (100%)	284 (89%)
Other (specify)	0	0	5 (6%)	0	5 (2%)
Case urgency					
Elective	25 (25%)	28 (31%)	23 (26%)	16 (37%)	92 (28%)
Emergency	73 (74%)	61 (69%)	66 (74%)	27 (63%)	227 (71%)
Indication					
Breech presentation	0	4 (4%)	3 (3%)	5 (11%)	12 (3%)
Eclampsia	0	1 (1%)	0	0	1 (0%)
Fetal distress	11 (11%)	5 (5%)	21 (23%)	8 (18%)	45 (14%)
Multiple pregnancy	1 (1%)	5 (5%)	4 (4%)	0	10 (3%)
Obstructed labour	22 (22%)	16 (17%)	13 (14%)	6 (13%)	57 (17%)
Other	16 (16%)	16 (17%)	14 (15%)	5 (11%)	51 (15%)
Placental abruption	1 (1%)	0	0	0	1 (0%)
Severe pre-eclampsia	0	4 (4%)	1 (1%)	0	5 (1%)
Previous scars	51 (51%)	46 (51%)	47 (52%)	23 (53%)	167 (52%)

emergency/urgent, with the most common indication being a labouring patient in the presence of a previous uterine scar (52%, n = 167) (Table 1). Patient ASA physical status was not recorded in 62% (n = 199) of the cases. With regards to the types of providers in the operating theatre, the anaesthesia provider was present 100% of the time; interns 69–76%, medical officers (non-speciality trained) 29–65%; obstetric residents 13–31%; obstetric consultants 11–17%; midwives 92–97%; nurses 90–97%; and scrub nurses 74–80% of the time during the caesarean sections. Eight cases were excluded where the observer intervened in case management (pre-SAFE-OB n = 3, post-SAFE-OB n = 3, 6-months post-SAFE-OB n = 2). These included two cases of high spinal; a failed intubation; an obstetric haemorrhage; a case of severe refractory hypotension; one case at the request of the anaesthesia provider; and two cases where the observer had to intervene in neonatal resuscitation and thus was unable to continue observations.

Informed consent was obtained > 90% of the time in all observation phases. Communication about the surgical indication between the surgeon and anaesthetist increased from 68% to 86% ($p = 0.006$) immediately post-SAFE-OB and continued to increase. The other elements of the WHO checklist all significantly increased from baseline when compared with immediately post-SAFE-OB (sign-in 12% to 52% ($p < 0.001$), time-out 12% to 51% ($p < 0.001$) and sign-out 3% to 20% ($p < 0.001$)) and remained above baseline values through the remaining phases (Tables 2 and 3, Fig. 1). In both unadjusted and adjusted analyses, these trends remained significant through all phases (Table 3). Five of eight main categories of pre-operative preparation behaviours significantly improved from baseline when compared with immediately post-SAFE-OB (Fig. 1, Table 2). These included: pre-operative assessment of patients; checking for functioning anaesthetic machine; functioning suction; airway equipment; and neonatal resuscitation equipment. The former two behaviours were sustained through all phases in unadjusted analysis, while pre-operative anaesthesia assessment and checking for functioning suction were sustained through all phases in adjusted analyses (Table 3). Five of the 13 behaviours in this section improved significantly from baseline to immediately

Table 2 Clinical behaviours and adverse events observed during caesarean deliveries. Values are number (proportion).

	Pre-SAFE-OB n = 100	Immediately post-SAFE-OB n = 89	6-months post-SAFE-OB n = 89	12-months post-SAFE-OB n = 43	All n = 320	x^2
Communication and WHO checklist						
Consent	93 (93%)	89 (100%)	89 (100%)	43 (100%)	314 (98%)	0.03
Indication	68 (68%)	75 (86%)	88 (99%)	43 (100%)	274 (86%)	0.006
Sign-in	12 (12%)	46 (52%)	51 (57%)	28 (65%)	137 (43%)	<0.001
Time-out	12 (12%)	45 (51%)	47 (53%)	19 (44%)	123 (38%)	<0.001
Sign-out	3 (3%)	18 (20%)	26 (30%)	13 (30%)	60 (19%)	<0.001
Pre-operative preparation						
Pre-operative anaesthetic assessment	32 (32%)	45 (51%)	61 (69%)	38 (88%)	176 (55%)	0.01
Checks recent Hb level	42 (42%)	35 (40%)	37 (44%)	31 (74%)	145 (46%)	0.67
Anaesthetic machine checked	44 (44%)	55 (62%)	79 (91%)	40 (93%)	218 (68%)	0.014
Checks availability of GA drugs	64 (64%)	57 (64%)	72 (81%)	43 (100%)	236 (74%)	0.995
Airway equipment checked	86 (86%)	88 (99%)	81 (91%)	40 (93%)	295 (92%)	0.001
Suction present and working	73 (73%)	82 (92%)	80 (90%)	37 (86%)	272 (85%)	<0.001
Vasopressor present	100 (100%)	89 (100%)	85 (96%)	43 (100%)	317 (99%)	-
Confirms neonatal equipment available	92 (92%)	88 (99%)	88 (99%)	42 (100%)	310 (97%)	0.037
Obtains i.v. access	99 (100%)	88 (100%)	89 (100%)	42 (100%)	318 (100%)	-
Attaches running fluids	99 (100%)	87 (100%)	89 (100%)	41 (100%)	316 (100%)	-
Spinal management						
Wears hat	95 (100%)	84 (100%)	87 (98%)	41 (100%)	307 (99%)	-
Wears mask	95 (100%)	84 (100%)	86 (97%)	40 (98%)	305 (99%)	-
Wears sterile gloves	95 (100%)	84 (100%)	89 (100%)	41 (100%)	309 (100%)	-
Uses cleaning solution	92 (98%)	83 (100%)	89 (100%)	41 (100%)	305 (99%)	0.499
Maintains sterile field	63 (67%)	73 (87%)	84 (94%)	41 (100%)	261 (85%)	0.002
Applies tilt or wedge after spinal	41 (43%)	57 (69%)	76 (86%)	33 (80%)	207 (67%)	<0.001
Monitors vital signs after spinal	93 (98%)	84 (100%)	89 (100%)	40 (98%)	306 (99%)	0.499
Measures block height	30 (32%)	55 (65%)	63 (71%)	29 (71%)	177 (57%)	<0.001
Administers vasopressor when appropriate	43 (49%)	37 (67%)	27 (71%)	14 (70%)	121 (60%)	0.037
Administers/confirms i.v. antibiotics	63 (66%)	74 (88%)	81 (93%)	38 (95%)	256 (84%)	<0.001
Administers oxytocin	93 (98%)	84 (100%)	89 (100%)	39 (95%)	305 (99%)	0.499
Oxytocin administered at the correct time	51 (54%)	48 (58%)	52 (60%)	26 (63%)	177 (58%)	0.632
Remains present in the theatre	74 (80%)	66 (80%)	66 (76%)	36 (90%)	242 (80%)	0.88
Adverse events						
Failed spinal (inadequate block)	19 (19%)	9 (10%)	2 (2%)	2 (5%)	32 (10%)	0.086
Loss of consciousness	1 (1%)	1 (1%)	0	0	2 (1%)	1.0
Prolonged hypoxia	5 (5%)	1 (1%)	0	0	6 (2%)	0.216
Persistent hypotension	52 (52%)	44 (49%)	24 (27%)	16 (37%)	136 (42%)	0.725
Major haemorrhage	2 (2%)	0	0	0	2 (1%)	0.499

WHO, World Health Organization; GA, general anaesthesia; i.v., intravenous.

post-SAFE-OB. These included: maintenance of sterile field while administering spinal (67% to 87%, p = 0.002); administration of antibiotics within 1 h of incision (66% to 88%, p < 0.001); measurement of height of spinal blockade (32% to 65%, p < 0.001); application of left lateral tilt (43% to 69%, p < 0.001); and administration of vasopressor to treat spinal hypotension (49% to 67%, p = 0.037) (Fig. 1). This was largely true across all phases in adjusted and unadjusted analyses, with the notable exception that appropriate vasopressor administration was not consistent

Table 3 Odds ratio of behavioural change at immediately, 6-months and 12-months post-training compared with pre-SAFE-OB observations.

	Immediately post-SAFE-OB		6-months post-SAFE-OB		12-months post-SAFE-OB	
	OR (95%CI)	p value	OR (95%CI)	p value	OR (95%CI)	p value
Unadjusted analysis						
Communication and WHO checklist						
Consent	1.0	-	1.0	-	1.0	-
Indication	2.76 (1.31–5.81)	0.008	38.82 (5.16–291.89)	<0.001	1.0	-
Sign-in	7.84 (3.77–16.32)	<0.001	9.84 (4.72–20.53)	<0.001	13.69 (5.73–32.68)	<0.001
Time-out	7.5 (3.61–15.6)	<0.001	8.41 (4.03–17.52)	<0.001	5.81 (2.48–13.61)	<0.001
Sign-out	8.2 (2.33–28.9)	0.001	13.56 (3.94–46.71)	<0.001	14.01 (3.74–52.47)	<0.001
Pre-operative preparation						
Pre-operative anaesthetic assessment	2.17 (1.2–3.92)	0.01	4.63 (2.51–8.55)	<0.001	16.15 (5.81–44.91)	<0.001
Anaesthetic machine checked	2.06 (1.15–3.68)	0.015	12.57 (5.49–28.75)	<0.001	16.97 (4.92–58.52)	<0.001
Airway equipment checked	14.33 (1.84–111.33)	0.011	1.65 (0.66–4.14)	0.287	2.17 (0.59–7.98)	0.243
Suction present and working	4.33 (1.78–10.54)	0.001	3.29 (1.45–7.45)	0.004	2.28 (0.87–6.01)	0.095
Confirms neonatal equipment available	7.65 (0.94–62.44)	0.057	7.65 (0.94–62.44)	0.057	1.0	-
Spinal variables						
Maintains sterile field	3.27 (1.52–7.02)	0.002	8.27 (3.04–22.46)	<0.001	1.0	-
Applies tilt or wedge after spinal	2.89 (1.56–5.35)	<0.001	8.34 (4.01–17.34)	<0.001	5.43 (2.27–13.0)	<0.001
Measures block height	4.11 (2.2–7.67)	<0.001	5.25 (2.8–9.85)	<0.001	5.24 (2.35–11.65)	<0.001
Administers vasopressor when appropriate	2.1 (1.04–4.25)	0.038	2.51 (1.11–5.69)	0.027	2.39 (0.84–6.79)	0.103
Administers/ confirms i.v. antibiotics	3.76 (1.71–8.25)	<0.001	6.86 (2.7–17.41)	<0.001	9.65 (2.19–42.57)	0.003
Adjusted analysis						
Communication adjusted						
Consent	1.0	-	1.0	-	1.0	-
Indication	3.74 (1.22–11.43)	0.021	101.68 (8.32–1242.96)	<0.001	1.0	-
Sign-in	15.79 (4.53–55.08)	<0.001	11.8 (3.16–43.99)	<0.001	55.1 (12.54–242.08)	<0.001
Time-out	13.38 (3.81–46.92)	<0.001	6.78 (1.77–25.93)	0.005	25.17 (5.69–111.33)	<0.001
Sign-out	27.75 (4.07–189.07)	<0.001	47.23 (6.32–353.12)	<0.001	226.16 (23.78–2151.05)	<0.001
Pre-operative adjusted checks						
Pre-operative anaesthetic assessment	4.1 (1.64–10.26)	0.003	11.04 (4.07–30.01)	<0.001	111.54 (25.8–482.17)	<0.001
Anaesthetic machine checked	1.87 (0.81–4.32)	0.144	26.99 (6.5–112.01)	<0.001	202.61 (23.38–1755.89)	<0.001
Airway equipment checked	14.35 (1.83–112.65)	0.011	1.58 (0.58–4.27)	0.37	2.01 (0.53–7.61)	0.305

(continued)

Table 3 (*continued*)

	Immediately post-SAFE-OB		6-months post-SAFE-OB		12-months post-SAFE-OB	
	OR (95%CI)	p value	OR (95%CI)	p value	OR (95%CI)	p value
Suction present and working	9.94 (2.87–34.41)	<0.001	8.06 (2.49–26.05)	<0.001	7.92 (2.03–31.0)	0.003
Confirms neonatal equipment available	22.64 (0.67–759.47)	0.082	7.06 (0.43–115.6)	0.17	1.0	0.993
Spinal adjusted variables						
Maintains sterile field	2.87 (1.02–8.03)	0.045	9.22 (2.38–35.81)	0.001	1.0	-
Applies tilt or wedge after spinal	2.33 (0.99–5.45)	0.052	8.8 (3.14–24.65)	<0.001	10.52 (3.04–36.41)	<0.001
Measures block height	8.52 (3.31–21.91)	<0.001	10.79 (4.17–27.97)	<0.001	14.78 (4.57–47.77)	<0.001
Administers vasopressor when appropriate	2.49 (0.95–6.49)	0.062	3.14 (1.01–9.78)	0.049	6.16 (1.37–27.76)	0.018
Administers/ confirms i.v. antibiotics	5.79 (1.86–18.06)	0.002	15.24 (4.14–56.16)	<0.001	33.2 (4.63–238.24)	<0.001

WHO, World Health Organisation; i.v., intravenous.

throughout (Tables 2 and 3). Persistent hypotension, defined as systolic blood pressure < 80 mmHg or > 20% below baseline for > 10 min, occurred in 42% of all the cases observed throughout the whole study. The rate of inadequate neuraxial anaesthesia showed a decreasing trend from 19% at baseline to 10% immediately post-SAFE-OB, 4% at 6 months and 5% at 12 months. However, this was not statistically significant which may be due to the low sample size (Table 2). Intravenous ketamine supplementation was used in 78% of all failed spinal cases while the remaining 22% were converted to general anaesthesia. High proportions (84–99%) of patients were recovered in the corridor of the operating theatre complex and 52–85% of postoperative patients were unattended in all the phases of study.

Discussion

The three-day SAFE-OB course has been shown to lead to improved, and retained, skills and knowledge, as well as reported practice changes and impact at a system level. This study performed a Kirkpatrick Level 3 evaluation, utilising direct observations in the workplace to assess the degree to which SAFE-OB participants apply what they have learnt to their practice. Through observations of a cohort of non-physician anaesthesia providers practising in Tanzania, we report sustained improvements across all three observed domains of clinical practice during anaesthesia for caesarean section: communication; pre-operative preparation; and intra-operative management. To our knowledge, this is the first study to evaluate Level 3 by direct observation of behaviours and to demonstrate translation of knowledge into the workplace in low-resource settings following implementation of an anaesthesia short course.

The Kirkpatrick model is an established and recognised method of evaluating training programmes. In 2015, the original model was revised to emphasise the importance of the relationship of training on participants' work [23]. The four levels outlined in the model are: reaction; learning; behaviour; and results. Results evaluation focuses on evaluating outcomes, which in the context of the SAFE-OB course, relates to improved safety of anaesthesia, reduction in critical incidents and ultimately, maternal mortality. In our study, > 70% of cases were emergency and 52% of these were a labouring patient with a previous uterine scar. This highlights the variations in antenatal case planning in low-resource settings compared with higher income countries, where many of these cases would have been scheduled as elective cases. The operating theatre team composition may also be unique to this setting, predominantly comprising junior obstetric staff, medical officers, non-physician anaesthetists and nurses. All these factors can have a potential impact on patient care and outcome, making results evaluation highly complex and challenging.

Our results highlight the changes in clinical behaviours that are aligned with evidence-based medicine and best practice guidelines in obstetric anaesthesia. Our study participants showed improvement in administration of

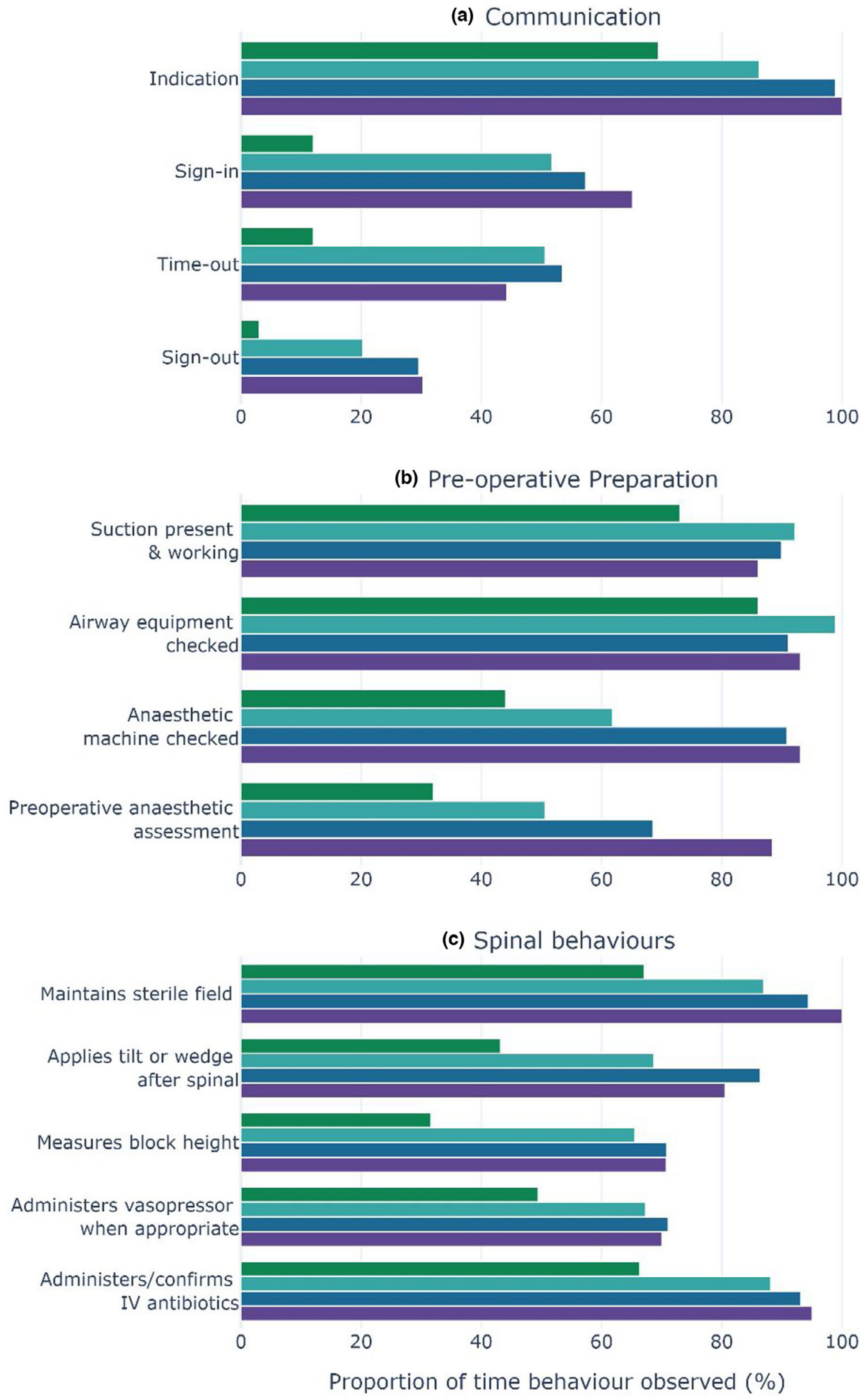

Figure 1 Behaviours with significant improvement immediately post-SAFE-OB training when compared with baseline for (a) communication, (b) pre-operative preparation and (c) spinal behaviours. Data are expressed as a proportion of the total number of cases observed, at the different phases of the study. Dark green, pre-SAFE-OB; turquoise, immediately post-SAFE-OB; blue, 6 months post-SAFE-OB; purple, 12 months post-SAFE-OB.

prophylactic antibiotics and maintaining a sterile technique during spinal procedure, both of which have been recommended by the WHO and shown to reduce serious infectious complications [24, 25]. There was also improvement in measurement of spinal block height pre-incision, which likely contributed to a reduction in the rate of intra-operative neuraxial failure from 18% at baseline to 10% immediately post-SAFE-OB to 2–4% at 6 and 12 months [26, 27] and increased utilisation of vasopressor to prevent spinal hypotension, which is in keeping with best-practice guidelines [28]. We observed an increase in the uptake of the WHO Surgical Safety Checklist, a tool which has been shown to reduce postoperative complications by up to 25% and mortality after surgery by 0.5–5% [29, 30].

Studies have shown that low-dose, high-frequency models for in-service training can lead to improved process of care, health outcomes and cost-effectiveness in low-resource settings [31–33]. We incorporated a 1.5-day follow-up refresher component which was conducted near participants' workplaces, to focus on skill practice and discussions on change management and overcoming barriers to change. The incorporation of this component may have impacted on sustained behaviour change.

As well as behaviours that did change, it is important to consider those which did not, so we can identify gaps in training or barriers to practice change. Despite notable improvements in use of the WHO Surgical Safety Checklist, overall use remained low. This is not unexpected as successful implementation requires multidisciplinary operating theatre team training and a longitudinal effort to overcome local contextual barriers [34, 35]. Despite improved administration of vasopressors to treat hypotension, the rate of persistent hypotension remained high throughout all phases of the study. This may be related to limited resources (e.g. availability of additional vasopressors) or may relate to lack of learners' understanding of its implication. Our study also shows severe deficiency in the infrastructure, personnel and monitoring equipment for post-anaesthesia care at all study sites, reflecting a neglected area within the healthcare system in these settings. Postoperative death is now being recognised as a leading cause of death globally, with half occurring in LMICs, highlighting the need for urgent initiatives to address this problem [36, 37].

Due to a relatively small sample size, the width of the confidence intervals makes it difficult to interpret the magnitude of change. Despite this, this study does demonstrate consistent directional changes in behaviour as a consequence of the SAFE-OB training. Whilst efforts were made to observe and analyse any adverse events or critical incidents which occurred, their infrequent occurrence, limited observation period and the need for the observer to intervene and assist, made their numbers too small to analyse. This is also the case for obstetric general anaesthesia, with most of these cases managed with ketamine and an unsecured airway. The possibility of altered behaviours in response to awareness of being observed, for example the Hawthorne effect, may have contributed. Whilst efforts were made to utilise observers from external facilities who were not known to the participants, their presence may have led to altered actions. The impact on patient outcome was not evaluated. As discussed earlier, this is difficult as morbidity and mortality solely attributed to anaesthesia is rare and is often impacted by multiple factors.

Through direct observation of clinical behaviours, our study has built on previous findings and highlighted the value of short courses such as SAFE-OB for in-service practitioners in low-resource settings. Whilst it is recognised that the expansion of the anaesthesia workforce in LMICs is a necessity, this needs to be done in conjunction with quality training of both pre- and in-service providers in order to decrease maternal mortality. Our findings also suggest future potential initiatives including development of an educational or behavioural checklist specific for anaesthesia for caesarean section and improvement in postoperative care in low-resource settings.

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Supporting Information

Additional supporting information may be found online via the journal website.

Appendix S1. Structured reflexivity statement.

Appendix S2. Structured observation checklist.

Appendix S3. Facility assessments of infrastructure, equipment and anaesthetic drugs of the five study sites.

Appendix S4. Number of caesarean sections observed per participant, per phase of study at each referral regional hospital.

