Original article

Safety, productivity and predicted contribution of a surgical task-sharing programme in Sierra Leone

H. A. Bolkan[1,2,3], A. van Duinen[1,2,3,4], B. Waalewijn[3,4], M. Elhassein[5], T. B. Kamara[6,8,9], G. F. Deen[7,8,9], I. Bundu[6,8,9], B. Ystgaard[2,3], J. von Schreeb[10] and A. Wibe[1,2]

[1]Institute of Cancer Research and Molecular Medicine, Norwegian University of Science and Technology (NTNU) and, [2]Department of Surgery, St Olav's Hospital, Trondheim University Hospital, Trondheim, Norway, [3]CapaCare, Trondheim, Norway and Freetown, Sierra Leone, [4]Royal Tropical Institute, Amsterdam, The Netherlands, [5]United Nations Population Fund, and Departments of [6]Surgery and [7]Medicine, Connaught Hospital, [8]Ministry of Health and Sanitation, and [9]College of Medicine and Allied Health Sciences, University of Sierra Leone, Freetown, Sierra Leone, and [10]Health System and Policy Research Group, Karolinska Institute, Stockholm, Sweden

Correspondence to: Dr H. A. Bolkan, Institute of Cancer Research and Molecular Medicine, Norwegian University of Science and Technology (NTNU), Post Box 8905, N-7491 Trondheim, Norway (e-mail: hakon.a.bolkan@ntnu.no)

Background: **Surgical task-sharing may be central to expanding the provision of surgical care in low-resource settings. The aims of this paper were to describe the set-up of a new surgical task-sharing training programme for associate clinicians and junior doctors in Sierra Leone, assess its productivity and safety, and estimate its future role in contributing to surgical volume.**

Methods: **This prospective observational study from a consortium of 16 hospitals evaluated crude in-hospital mortality over 5 years and productivity of operations performed during and after completion of a 3-year surgical training programme.**

Results: **Some 48 trainees and nine graduated surgical assistant community health officers (SACHOs) participated in 27 216 supervised operations between January 2011 and July 2016. During training, trainees attended a median of 822 operations. SACHOs performed a median of 173 operations annually. Caesarean section, hernia repair and laparotomy were the most common procedures during and after training. Crude in-hospital mortality rates after caesarean sections and laparotomies were 0·7 per cent (13 of 1915) and 4·3 per cent (7 of 164) respectively for operations performed by trainees, and 0·4 per cent (5 of 1169) and 8·0 per cent (11 of 137) for those carried out by SACHOs. Adjusted for patient sex, surgical procedure, urgency and hospital, mortality was lower for operations performed by trainees (OR 0·47, 95 per cent c.i. 0·32 to 0·71; $P < 0·001$) and SACHOs (OR 0·16, 0·07 to 0·41; $P < 0·001$) compared with those conducted by trainers and supervisors.**

Conclusion: **SACHOs rapidly and safely achieved substantial increases in surgical volume in Sierra Leone.**

Preliminary results presented to the 54th Annual Conference of the West African College of Surgeons, Kumasi, Ghana, February 2014, and the 56th Annual Conference of the West African College of Surgeons, Yaoundé, Cameroon, February 2016

Paper accepted 6 March 2017

Published online 18 May 2017 in Wiley Online Library (www.bjs.co.uk). **DOI:** 10.1002/bjs.10552

Introduction

One of the significant barriers to expansion of surgical care in low-income countries is a shortage of human resources[1]. Task-sharing is defined as a rational redistribution of tasks among healthcare workers to maximize the efforts of the existing workforce[2], and is recommended by the WHO for several tasks, including certain surgical procedures[3]. Expanding the surgical workforce in low-resource settings by task-sharing has been found to be cost- and time-effective[4–6] without corrupting surgical outcomes[7,8]. In addition, it probably improves retention of the workforce at the district level[9]. Although task-sharing in surgery is applied commonly in several East and Central African countries[10,11], it has not been adopted to the same extent in West Africa[12]. The 2015 World Health Assembly[13] resolution aiming to strengthen emergency and essential surgical care worldwide urges member states to make: '… more effective use of the health care workforce

through task-sharing … '. Although task-sharing in surgery has been widely debated and described in key publications in recent years[1,4], there are limited data on the safety of surgical task-sharing programmes and the productivity of associate clinicians as surgical providers.

Sub-Saharan West Africa has the highest unmet surgical needs in the world[4]. Before the Ebola outbreak, there were ten specialist surgical providers in government (public) hospitals[14] and 26 in private non-profit hospitals[15] in Sierra Leone. This corresponds to less than 5 per cent of the minimum threshold of 20 specialist surgeons, obstetricians and anaesthetists per 100 000 population, recently recommended by the Lancet Commission on Global Surgery[4]. To address the shortage of surgical providers, the Sierra Leonean Ministry of Health and Sanitation (MoHS) and the non-profit organization CapaCare initiated a surgical task-sharing training programme in 2011. The implementation strategy was to improve access to emergency surgical care among rural populations by enabling non-specialized medical doctors (MDs) and associate clinicians to manage surgical and obstetric emergencies safely. A surgical training programme (STP) was developed that made optimal use of the limited surgical trainers available in the country. The goal was to train 60 associate clinicians and junior MDs by 2021, such that they could deliver surgical services safely in government district hospitals and be as productive as the existing surgical workforce. Five years after initiation of this programme, the aim of the present article was to describe the set-up of the STP, assess productivity and safety, and estimate its future role in contributing to surgical volume in Sierra Leone.

Methods

Surgical training programme

The STP was planned in 2009 as Sierra Leone was recovering from a devastating civil war. This country, with 5·5 million inhabitants, at that time had only 167 MDs in clinical practice[16], poor output from the medical school and no formal postgraduate training available in surgery or obstetrics[14]. Surgical care was not prioritized in the national health agenda[17], despite an extensive surgical disease burden and mortality[18], and there was more than 90 per cent unmet surgical need[19]. In rural areas, where the majority of the population resides, 30-fold fewer operations were performed compared with urban areas[15].

The STP is located principally at district hospitals to promote post-training retention in the provinces and avoid diverting resources from any informal training of MDs in the main teaching hospitals in the capital, Freetown. The curriculum is based on the WHO Integrated Management for Emergency and Essential Surgical Care tool kit, developed by the Global Initiative for Emergency and Essential Surgical Care[20]. The training lasts 3 years and the graduates are meant to be absorbed by the MoHS and posted to district government hospitals on completion of training.

Trainers and training sites were identified by visiting and assessing the surgical activity and infrastructure of all provincial hospitals with 24-h availability of MDs performing surgery[19]. The most surgically active were invited to take part as partner hospitals and a memorandum of understanding granted trainees supervised access to all surgical and obstetric care (*Appendix S1*, supporting information). Initially, all partner hospitals were run by private non-profit organizations, based on limited capacity and personnel in government district hospitals. Several government hospitals subsequently became partners (*Fig. 1*).

All associate clinicians (known as community health officers (CHOs) in Sierra Leone) and junior MDs who meet the minimum entry criteria are eligible for the STP. CHOs have 3-year basic medical diploma training to be in charge of community health centres[21], but many also work as medical operatives in hospitals. CHOs must complete 2 years of postgraduate clinical practice before applying for the STP. MDs can apply directly after internship. Applicants are interviewed by CapaCare and the MoHS; a more rigorous full-day assessment was added in 2014. Positive discrimination favours women and applicants from highly underserved districts among equally qualified candidates. Trainee salaries are paid by the MoHS or CapaCare. There are no tuition fees, but a 4-year postgraduate binding agreement with the MoHS has been introduced to promote retention in public service. Two trainees began in January 2011 and, since then, between four and seven have been admitted biannually.

Fig. 2 outlines the training content and time frame. For 6 months, trainees undergo an introductory course at the central teaching facility, Masanga Hospital in Tonkolili district[22]. The theoretical training has evolved and matured over the past 5 years, and now comprises six intensive modules lasting 2–4 weeks (*Appendix S2*, supporting information). These modules are taught by teams of one to three international trainers, who are all specialists in surgery, obstetrics, anaesthesia, orthopaedics and radiology, in addition to midwives, and anaesthesia and operating theatre nurses. Local specialist surgeons provide theoretical and practical training during shorter courses (2–3 days). Training encompasses predefined or problem-based lectures, e-learning, grand rounds,

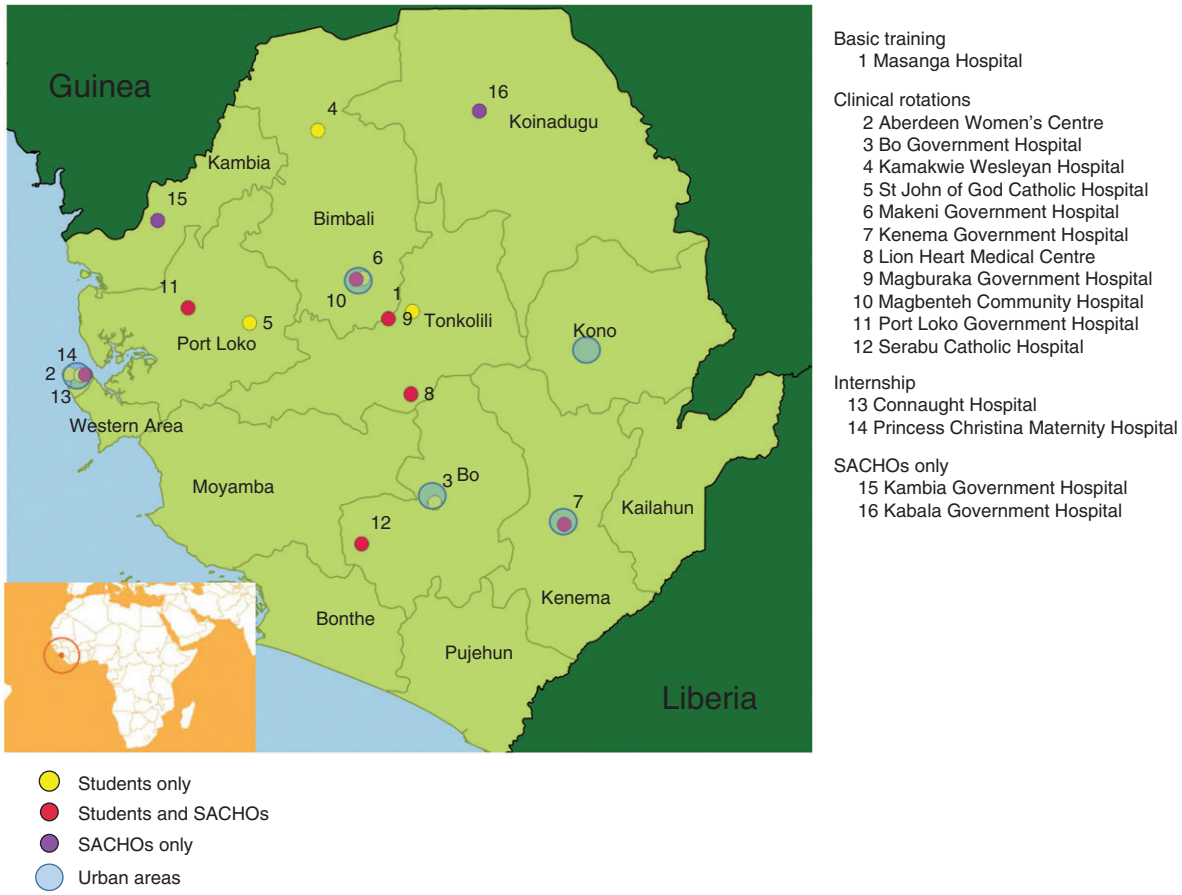

Fig. 1 Hospitals as of July 2016 taking part in the surgical training programme or that have employed surgical assistant community health officers (SACHOs)

case presentations, journal clubs, mortality and morbidity reviews, bedside clinical teaching, outpatient clinics, radiology conferences, basic ultrasound training, surgical audits, surgical skills laboratories, veterinary laboratories for emergency and trauma procedures, and hands-on operative training to master context-adapted and resource-poor surgery.

After successful completion of the introductory course, trainees undergo three 6-month clinical rotations in partner hospitals, engaging in all aspects of care of the surgical patient. Trainees are assigned to a local supervisor, a MD or specialist in surgery and/or obstetrics. At specific intervals (*Appendix S2*, supporting information), they are called back to Masanga Hospital for refresher training. A monitoring and evaluation officer, and national and international training coordinators supervise trainees and trainers at all training sites.

Trainee progression is gauged by informal guidance, formal written evaluations, biannual review of surgical logbooks, and written and oral examinations. Local specialist surgeons and obstetricians, all faculty at the College of Medicine and Allied Health Sciences of the University of Sierra Leone, assess the results of the final written and oral examinations after 2 years. A successful outcome grants a diploma in Emergency Surgery, Obstetrics and Gynaecology. The MDs are then posted to a government hospital. CHOs complete a 1-year internship in the main tertiary surgical and maternity training hospitals in Freetown, which, if completed satisfactorily, leads to appointment as a surgical assistant community health officer (SACHO) at a government district hospital. All operations performed by trainees and SACHOs require the supervision of a MD.

Data collection

A prospective observational registry began with the initiation of the STP. Data were obtained from trainees' and SACHOs' surgical logbooks. Twenty items related to patient demographics, operation, surgical provider,

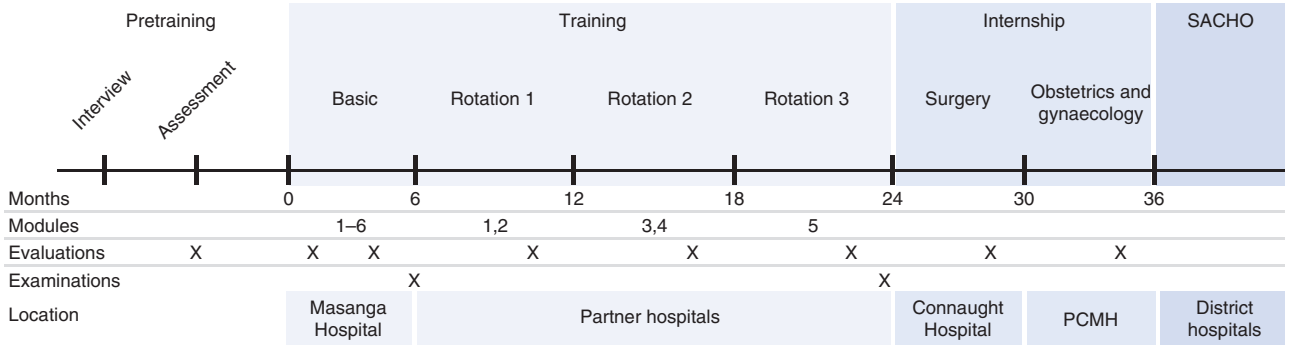

Fig. 2 Content and time frame for the surgical training programme. SACHO, surgical assistant community health officer; PCMH, Princess Christina Maternity Hospital

Table 1 Key performance indicators of the surgical training programme until July 2016

	2010	2011	2012	2013	2014	2015	2016*	Total
Trainees								
Applicants	1	11	45	36	24	39	14	170
New trainees enrolled	0	5	9	11	6	12	5	48
MDs graduated	–	–	–	1	0	0	0	1
CHOs graduated	–	–	–	0	4	5	3	12
Dropout	–	0	2	1	5	2	1	11
Trainer resources								
Modules taught	1	6	7	13	6	7	7	47
International trainers	3	10	13	20	12	11	9	78†
Partner hospitals	0	2	7	11	12	15	16	16
Operations attended/performed								
Trainees	–	849	3321	6865	4765	5010	3462	24 272 (89·2)
SACHOs	–	–	–	–	260	1575	1109	2944 (10·8)

Values in parentheses are percentages. *January to July. †A total of 44 international trainees made 78 training visits. MD, medical doctor; CHO, community health officer; SACHO, surgical assistant community health officer.

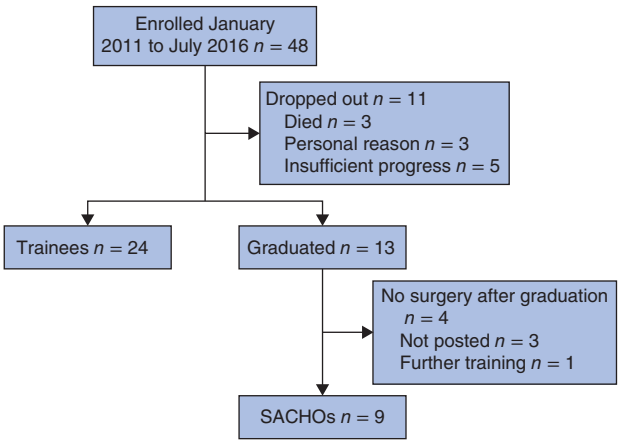

Fig. 3 Status of trainees and surgical assistant community health officers (SACHOs) by July 2016

hospital and outcomes were recorded for all operations between January 2011 and July 2016 (*Appendix S3*, supporting information).

Table 2 Annual volume of surgical procedures

	Annual no. of surgical procedures	
	During training (13 graduated)	After training (9 SACHOs)
Caesarean section	83 (67–94)	96 (62–108)
Hernia repair	72 (64–85)	41 (35–68)
Laparotomy	22 (18–30)	9 (8–10)
Appendicectomy	8 (7–11)	7 (5–18)
Dilatation and curettage	9 (6–13)	9 (1–16)
Hysterectomy	8 (5–10)	3 (2–8)
Other	84 (76–96)	46 (23–57)
Overall	274 (237–322)	204 (128–266)

Values are median (i.q.r.). SACHO, surgical assistant community health officer.

Logbook recording of roles during an operation builds upon the supervision definitions approved by the Joint Committee on Surgical Training (JCST) in the UK and Ireland[23]. Observed is a procedure observed by an unscrubbed trainee. Assisted is where a trainer performs the key components of a procedure. Directly supervised

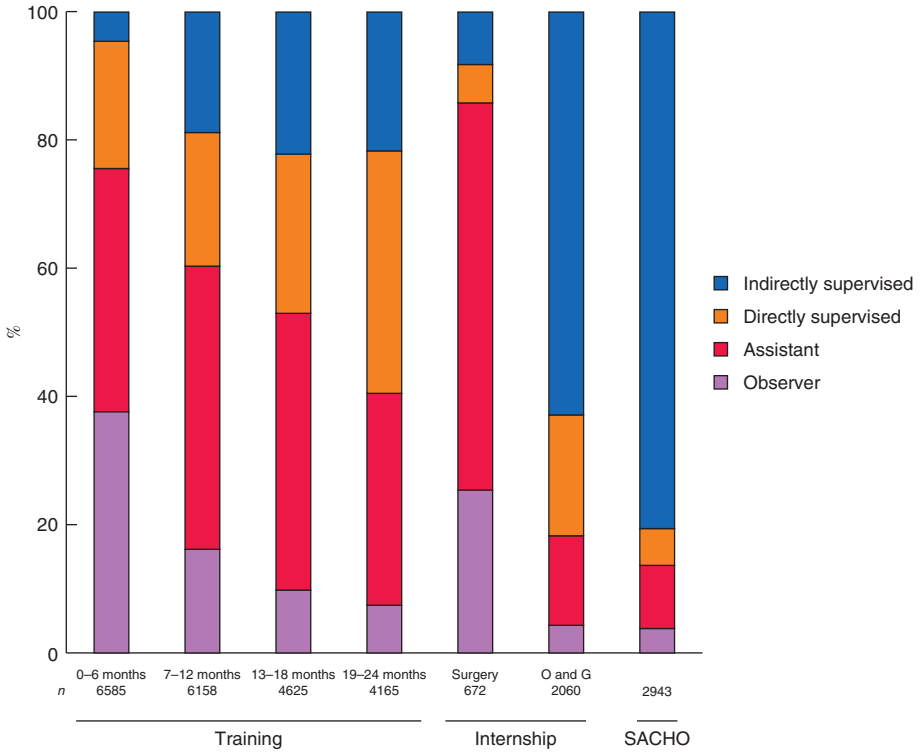

Fig. 4 Role during surgical procedures by 6-month intervals during training (training + internship) and after graduation (surgical assistant community health officer, SACHO). O and G, obstetrics and gynaecology

(JCST category S-TS) is when the trainee performs key components of the procedure with the trainer scrubbed. Indirectly supervised (JCST category S-TU and P) is when the trainee completes the procedure from start to finish and the trainer is unscrubbed. Paper logbooks were signed and validated by trainers after each procedure and uploaded monthly (Microsoft® Excel format; Microsoft, Redmond, Washington USA) to a cloud server for review.

Crude in-hospital mortality, the most commonly used definition of perioperative risk in low-resource settings[24], was used as a pragmatic marker of safety. Mortality rates following trainees' and SACHOs' indirectly supervised operations were compared with previously documented mortality from Sierra Leone[25,26]. In addition, mortality associated with the operations performed under indirect supervision was compared with that of operations conducted by the trainers and supervisors (observed). Progression towards surgical maturity was evaluated based on how trainees' roles during operations developed throughout training. Annual volume of operations performed (indirectly supervised) by the SACHOs was employed as a measure of productivity and to calculate potential future contributions to surgical volume. Productivity was compared against previously documented surgical productivity in Sierra Leone[15,19].

Results are reported in accordance with guidelines for implementation and operational research[27]. All hospitals that took part in the training agreed to share the surgical data (*Table S1*, supporting information). Trainees and SACHOs supplied written informed consent to share non-identifiable logbook data. The Sierra Leone Ethics and Scientific Review Committee granted ethical approval.

Statistical analysis

Differences in volumes of surgery between trainees and SACHOs and in-hospital mortality risk were tested using the Pearson χ^2 test. Age of patients was compared between groups by means of a *t* test. Factors associated with in-hospital mortality were determined by univariable and multivariable logistic regression analysis. The multivariable analysis was adjusted for trainee role, patient sex, urgency of surgery, operation and hospital type. Odds ratios (ORs) are reported with 95 per cent confidence intervals. All tests were two-tailed and statistical significance

Table 3 Operative data during training and after graduation

	During training† ($n = 24\,272$)	After graduation‡ ($n = 2944$)	*P*§
Role of trainee or SACHO			< 0·001
Observer	4515 (18·6)	114 (3·9)	
Assistant	9311 (38·4)	290 (9·9)	
Directly supervised	5724 (23·6)	170 (5·8)	
Indirectly supervised	4715 (19·4)	2369 (80·5)	
Missing	7 (0·0)	1 (0·0)	
Age of patient (years)*	32·6(16·5)	30·3(14·0)	< 0·001¶
Sex			< 0·001
M	10 244 (42·2)	853 (29·0)	
F	14 016 (57·7)	2090 (71·0)	
Missing	12 (0·1)	1 (0·0)	
Urgency			< 0·001
Planned	13 031 (53·7)	905 (30·7)	
Emergency	11 222 (46·2)	2037 (69·2)	
Missing	19 (0·1)	2 (0·1)	
Surgical procedure			< 0·001
Caesarean section	6438 (26·5)	1290 (43·8)	
Hernia repair	6471 (26·7)	610 (20·7)	
Laparotomy	2142 (8·8)	232 (7·9)	
Appendicectomy	834 (3·4)	134 (4·6)	
Dilatation and curettage	866 (3·6)	100 (3·4)	
Hysterectomy	667 (2·7)	67 (2·3)	
Other	6854 (28·2)	511 (17·4)	
Hospital			< 0·001
Government	6577 (27·1)	1709 (58·1)	
Private non-profit	17 643 (72·7)	1235 (41·9)	
Missing	52 (0·2)	0 (0)	

Values in parentheses are percentages unless indicated otherwise; *values are mean(s.d.). †Forty-eight trainees; ‡nine surgical assistant community health officers (SACHOs). §Pearson χ^2 test, except ¶two-sample *t* test.

was set at $P < 0·050$. Missing data were excluded from the analyses.

Results

Forty-eight trainees, two junior MDs and 46 CHOs, enrolled in the STP between January 2011 and July 2016 (*Table 1*). Three died (Ebola 2, motor accident 1) and three left for personal reasons (chronic sickness 1, emigration 1, lack of motivation 1). Five were removed from the programme because of insufficient progress, mostly during the initial 6 months (*Fig. 3*). Forty-four international trainers conducted 78 training visits to Sierra Leone, delivering 47 training modules. Twelve CHOs and one MD graduated, of whom eight are currently posted as SACHOs in district hospitals and one in a referral hospital. Four graduates have not yet recorded any operations (1 MD continued postgraduate surgical training in Ghana, 3 graduates were posted after July 2016).

Productivity

Forty-eight trainees and nine SACHOs logged 27 216 operative training and service delivery episodes during the study period, 24 272 as trainees and 2944 as SACHOs. Those who completed the programme (13 graduates) took part in a median of 274 (237–322) surgical procedures annually, a median total of 822 per trainee during the 3 years of training (*Table 2*). The nine posted SACHOs took part in a median of 204 surgical procedures annually, and 173 (i.q.r. 109–226) were supervised indirectly. Caesarean section, hernia repair and laparotomy were the most frequent operations both during training and after graduation. Except for the surgical internship, the proportion of procedures performed by the trainees increased the further they were into the training (*Fig. 4*). Some 80·5 per cent of operations recorded by the SACHOs were indirectly supervised (2369 of 2944). Caesarean sections accounted for 43·8 per cent of the SACHO operations (1290 of 2944).

Compared with the trainees, the SACHOs participated in more operations in government hospitals (27·1 *versus* 58·1 per cent; $P < 0·001$) and more emergency operations (46·2 *versus* 69·2 per cent; $P < 0·001$), operated on younger patients ($P < 0·001$) and were more likely to operate on female patients (57·7 *versus* 71·0 per cent; $P < 0·001$) (*Table 3*).

Table 4 Logistic regression analysis to identify factors associated with in-hospital mortality during training (48 trainees, 24 272 surgical training episodes)

				Univariable analysis		Multivariable analysis	
	Alive	Died*	Missing	Odds ratio†	*P*	Odds ratio†	*P*
Student role							
Observer	4397	116 (2·6)	2	1·00 (reference)		1·00 (reference)	
Assistant	9075	225 (2·4)	11	0·94 (0·75, 1·18)	0·592	0·99 (0·78, 1·25)	0·915
Directly supervised	5633	89 (1·6)	2	0·60 (0·45, 0·79)	< 0·001	0·74 (0·55, 0·99)	0·045
Indirectly supervised	4678	36 (0·8)	1	0·29 (0·20, 0·42)	< 0·001	0·47 (0·32, 0·71)	< 0·001
Missing	7	0	0				
Sex							
M	9974	262 (2·6)	8	1·00 (reference)		1·00 (reference)	
F	13 804	204 (1·5)	8	0·56 (0·47, 0·68)	< 0·001	0·43 (0·35, 0·54)	< 0·001
Missing	12	0	0				
Urgency							
Planned	12 907	120 (0·9)	4	1·00 (reference)		1·00 (reference)	
Emergency	10 865	345 (3·1)	12	3·42 (2·77, 4·21)	< 0·001	4·05 (3·18, 5·15)	< 0·001
Missing	18	1	0				
Surgical procedure							
Caesarean section	6383	54 (0·8)	1	1·00 (reference)		1·00 (reference)	
Hernia repair	6435	33 (0·5)	3	0·61 (0·39, 0·94)	0·024	0·68 (0·41, 1·13)	0·135
Laparotomy	1937	199 (9·3)	6	12·14 (8·95, 16·48)	< 0·001	7·14 (5·06, 10·08)	< 0·001
Appendicectomy	826	8 (1·0)	0	1·14 (0·54, 2·41)	0·722	0·93 (0·44, 2·00)	0·861
Dilatation and curettage	860	6 (0·7)	0	0·82 (0·35, 1·92)	0·655	0·97 (0·41, 2·23)	0·917
Hysterectomy	654	13 (1·9)	0	2·34 (1·28, 4·33)	0·006	3·62 (1·93, 6·79)	< 0·001
Other	6695	153 (2·2)	6	2·70 (1·98, 3·69)	< 0·001	2·78 (1·96, 3·95)	< 0·001
Hospital							
Government	6510	67 (1·0)	0	1·00 (reference)		1·00 (reference)	
Private non-profit	17 228	399 (2·3)	16	2·25 (1·73, 2·92)	< 0·001	1·54 (1·16, 2·03)	0·003
Missing	52	0	0				

Values in parentheses are *percentages and †95 per cent confidence intervals.

Safety

The crude in-hospital mortality rate for all operations recorded as involving trainees was 1·9 per cent (466 of 24 256); it was 2·6 per cent (116 of 4513) for observed operations and 0·8 per cent (36 of 4714) for indirectly supervised operations (*Table 4*). Mortality following observed caesarean sections was 1·2 per cent (8 of 688) and 0·7 per cent (13 of 1915) for indirectly supervised procedures. The mortality rate was 7·5 per cent (53 of 703) after observed and 4·3 per cent (7 of 164) for indirectly supervised laparotomies. The risk of a fatal outcome after adjustment for patient sex, surgical procedure, urgency and hospital type was significantly lower for operations the trainees performed under indirect supervision *versus* observed operations (OR 0·47, 95 per cent c.i. 0·32 to 0·71; $P < 0·001$). A comparison of case mix between the observed and indirectly supervised surgical procedures for trainees and SACHOs is provided in *Table S1* (supporting information).

The SACHOs recorded an overall mortality rate of 1·7 per cent (51 of 2944), 9·6 per cent (11 of 114) for observed operations and 0·8 per cent (20 of 2369) per cent for indirectly supervised procedures (*Table 5*). Adjusted analysis of operations conducted by the SACHOs under indirect supervision showed a significantly lower risk of a fatal outcome compared with operations the SACHOs observed (OR 0·16, 95 per cent c.i. 0·07 to 0·41; $P < 0·001$). Postoperative mortality for procedures carried out by SACHOs with indirect supervision was 0·4 per cent (5 of 1169) for caesarean sections and 8·0 per cent (11 of 137) for laparotomies.

Future contributions to surgical volume

If the productivity of the SACHOs remains at a median of 173 (i.q.r. 109–226) operations a year, 60 SACHOs will perform 10 404 (6528–13 566) operations annually in Sierra Leone in 2021. If 44 per cent of the operations

Table 5 Logistic regression analysis to identify factors associated with in-hospital mortality after graduation (9 surgical assistant community health officers, 2944 operations)

			Univariable analysis		Multivariable analysis	
	Alive	Died*	Odds ratio†	*P*	Odds ratio†	*P*
Student role						
Observer	103	11 (9·6)	1·00 (reference)		1·00 (reference)	
Assistant	273	17 (5·9)	0·58 (0·26, 1·29)	0·182	0·65 (0·26, 1·65)	0·364
Directly supervised	167	3 (1·8)	0·17 (0·05, 0·62)	< 0·001	0·12 (0·02, 0·50)	0·004
Indirectly supervised	2349	20 (0·8)	0·11 (0·06, 0·20)	< 0·001	0·16 (0·07, 0·41)	< 0·001
Missing	1	0				
Sex						
M	819	34 (4·0)	1·00 (reference)		1·00 (reference)	
F	2073	17 (0·8)	0·20 (0·11, 0·36)	< 0·001	0·19 (0·09, 0·39)	< 0·001
Missing	1	0				
Urgency						
Planned	899	6 (0·7)	1·00 (reference)		1·00 (reference)	
Emergency	1992	45 (2·2)	3·38 (1·44, 7·96)	0·005	3·95 (1·48, 10·59)	0·006
Missing	2	0				
Surgical procedure						
Caesarean section	1284	6 (0·5)	1·00 (reference)		1·00 (reference)	
Hernia repair	607	3 (0·5)	1·06 (0·26, 4·24)	0·937	0·50 (0·10, 2·62)	0·412
Laparotomy	202	30 (12·9)	31·78 (13·06, 77·32)	< 0·001	10·51 (3·77, 29·26)	< 0·001
Appendicectomy	134	0 (0)	–	–	–	–
Dilatation and curettage	100	0 (0)	–	–	–	–
Hysterectomy	67	0 (0)	–	–	–	–
Other	499	12 (2·3)	5·14 (1·92, 13·78)	< 0·001	1·49 (0·44, 4·94)	0·513
Hospital						
Government	1694	15 (0·9)	1·00 (reference)		1·00 (reference)	
Private non-profit	1199	36 (2·9)	3·39 (1·85, 6·22)	< 0·001	1·50 (0·72, 3·11)	0·277
Missing	0	0				

Values in parentheses are *percentages and †95 per cent confidence intervals.

continue to be caesarean sections, they will carry out 4578 (2872–5969) sections annually.

Discussion

During training, the volume of surgical training episodes was high and there seemed to be progression towards surgical maturity, with exposure corresponding to procedures performed after graduation. Both trainees and SACHOs experienced lower in-hospital mortality for operations they conducted under indirect supervision than in the observed operations carried out by their trainers and supervisors. The programme has been able to train in private non-profit hospitals and transfer graduates to government district hospitals. The current productivity of the SACHOs indicates that task-shared surgical providers can perform a considerable volume of emergency surgery at district government hospitals in the near future.

The primary strength of this study is the large prospectively registered number of operative training episodes that were included. The major challenges were related to the Ebola outbreak, which not only caused the tragic deaths of two students, but also placed all those involved under such risk that the programme was forced to shut down for nearly a year during the peak of Ebola transmission[28]. Unstable access to trainers and rapid changes in healthcare priorities among the partner hospitals during and after the Ebola outbreak were also challenging.

The major limitations of the study are that participants themselves recorded the operations and their outcomes, with a potential for reporting bias. Negative outcomes may be reported less than positive ones, possibly contributing to a general underestimation of mortality. Validation of logbook entries by local trainers and supervisors, however, should counteract this. The same operation may have multiple attendants of this programme, as a trainee might observe while a SACHO carries out the operation under indirect supervision. Assessing the safety of surgery based on crude postoperative in-hospital mortality has its limitations, partly because crude mortality depends on many non-surgical factors and partly because the in-hospital mortality rate is often low. Morbidity outcomes, especially those more related to the surgical procedure, would better

expose quality of practice offered by the surgical provider, but such data were not available for this study.

Safety of surgery is of utmost importance in any training programme, no matter what resources are available[29]. The postoperative mortality of indirectly supervised caesarean sections carried out by trainees (0·7 per cent) and SACHOs (0·4 per cent) was no higher than the rate reported previously from Sierra Leone (1·2 per cent, 4 of 338)[25], or by a systematic review[30] (median 1·4 per cent) including 19 publications from western Sub-Saharan Africa. In addition, the postoperative mortality of indirectly supervised laparotomies performed by trainees (4·3 per cent) and SACHOs (8·0 per cent) was no greater than previously reported mortality in Sierra Leone (10·1 per cent, 18 of 178)[26] or a recently established 30-day mortality rate (8·7 per cent, 114 of 1316) from a multicountry low-Human Development Index setting[31].

Although the analyses were adjusted for sex, urgency, surgical procedure and hospital type, the observed operations as reference for mortality were still prone to selection bias as there was no adjustment for co-morbidity and severity of the surgical condition. Poorer outcomes for patients operated on by trainers compared with trainees are also found in high-income settings[32], and difference in case mix has been suggested as an explanation for this. The procedures conducted by the trainers and supervisors in the present study may have been more complex than those undertaken by trainees and SACHOs, limiting the comparability of performance between the groups. Safety in surgery has much to do with selection of who is to operate on whom, when and where. High-risk patients should be handled by the most competent providers. Comparing mortality between the supervision groups gives an indication on how operative risks are distributed, and is therefore a relevant measure of safety of the programme and the introduction of a new cadre. Procedures on high-risk patients seem to be used less often for training purposes, the more experienced supervisors seem to resume responsibility for the more challenging operations, and the SACHOs refer or call for assistance when needed.

SACHOs were almost twice as productive as surgical providers in government hospitals in 2012[15]. The high proportion of operations conducted with only indirect supervision indicates that task-sharing is accepted by the existing surgical providers in district government hospitals. As all (except 1) of the SACHOs work in district hospitals, and more than two-thirds of the patients operated on are women, it seems that the programme is able to target the most vulnerable part of the population – females of reproductive age living in the provinces. The 10 404 operations this programme is projected to complete annually by 2021 corresponds to an increase of 110 per cent compared with the 9500 operations performed in all government hospitals in 2012[19]. Assuming annual population growth continues at 1·9 per cent[33] for the second part of this decade and other surgical providers maintain levels of surgical activity found in 2012[19], the country will perform 435 operations per 100 000 inhabitants in 2021, still far below the universal target of 5000 annual operations the Lancet Commission on Global Surgery[4] recently suggested. An additional 4162 caesarean sections represent an increase of 160 per cent from the 2012 level of activity in government hospitals[19].

This programme could not have been established without the willingness of a broad range of diverse private non-profit hospitals to align under one common training scheme. There have been surgical training initiatives in Sierra Leone before the STP[34–38], but no systematic use of private non-profit hospitals, where the majority of the surgery in the country is performed[19]. As others have also suggested[39], the capacity and expertise among international institutions offering surgical services in low-income countries should be better utilized for capacity building and training.

Another important strategy has been the use of short-term international volunteers to supplement the insufficient volume of available local tutors. Short-term surgical missions might not be sustainable[40]; however, in the Sierra Leonean context, the extreme shortage of skilled surgical providers has necessitated importing a wide range of specialists with dedicated time for intensive teaching and training. As seen with repeated short-course training of laparoscopic skills in Mongolia[41], deployment undertaken in a systematic way over many years can be fruitful. The combination of engagement of tutor capacity in the private non-profit sector and the structured and long-term commitment of international volunteers on short-term visits could also be replicated in other highly underserved settings[42].

Introduction of surgical task-sharing must include regulation, mentoring and supervision of clinical activity, remuneration of professional development and acceptance of the new cadre[43]. If neglected, there is a considerable risk of drainage towards urban areas, the private non-profit sector or even non-clinical positions, if better rewarded[44]. Lack of remuneration and poor carrier pathways might be reasons for difficulties in attracting junior MDs to the STP. To date there is no legal protection for SACHOs in Sierra Leone, and there is no regulating body formally overseeing the medical practices of the CHO cadre. This makes clinical governance challenging, with both patient and healthcare practitioner safety poorly attended to. Currently, this is

resolved at the hospital level where individual MDs assume informal responsibility and supervisory duties for the work performed by SACHOs. High turnover of MDs in government district hospitals makes this system fragile and in need of continued surveillance. Hospital visits by CapaCare medical staff and trainers, together with an annual surgical meeting, offer some mentoring to the SACHOs; however, this needs further development and the involvement of senior Sierra Leonean specialists.

Further research on the outcomes of operations offered within task-sharing initiatives is required, with recording of postoperative morbidity events related to the surgical procedure, as this will better reveal the quality of operative skills. The long-term implications of introducing task-sharing, referral patterns, optimal mixes of surgical health cadres, and how barriers to access surgical care are affected, all need further investigation.

Overall, this study has indicated that the training of associate clinicians within a structure where government and private non-profit district hospitals are brought under one training umbrella, in combination with systematic deployment of international volunteer specialists on short-term rotations, is feasible and safe. The model provides high exposure to surgical training episodes and makes efficient use of limited local trainers. Currently, the programme is on track to deliver 60 additional surgical providers by 2021, all bestowed with the ability to be more productive than the existing surgical workforce without compromising the safety of surgical services offered. The potential gains are considerable, and it appears to reach the most vulnerable part of the population – women living in the provinces. Crucial for maintaining quality of care and retention in surgical service delivery in the provinces is to offer structured mentoring, adequate remuneration, and to strengthen clinical governance by developing more robust systems for regulation and supervision of surgical activities.

Acknowledgements

The authors acknowledge support in terms of planning of both the study and the training programme, surgical training provided and teaching the trainees to collect data. They thank the Sierra Leonean-based international coordinators of the training programme, D. van Leerdam and M. Grootjans; Dutch tropical doctors on long-term contracts at the main teaching location, Masanga Hospital: F. van Raaij, J. Westendorp, C. Bijen, M. Oostvogels and J. van Kesteren; the founders of the Masanga Hospital Rehabilitation Project for housing the STP, P. B. Jørgensen and S. Haas, who also acted as trainers; CapaCare's accountant, A. van Duinen, for administrative support regarding finances related to the study; and all the dedicated volunteer international trainers, in particular L. M. Hunt who also critically reviewed the manuscript. The programme and the study would never have been initiated without the support of D. A. Bash-Taqi (former Director of Hospitals and Laboratory Services of the MoHS), A. Conteh, Chief CHO (MoHS) and Chief Obstetrician, and A. P. Koroma, at Princess Christina Maternity Hospital, Freetown.

The Norwegian University of Science and Technology funded all parts of the study. The funding source had no role in any aspect of the study.

Disclosure: The authors declare no conflict of interest.

References

1 Bergström S, McPake B, Pereira C, Dovlo D. Workforce innovations to expand the capacity for surgical services. In *Disease Control Priorities, Third Edition (Volume 1): Essential Surgery*, Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME, Mock CN (eds). World Bank Publications: Washington, 2015; 307–316.

2 WHO. *Task Shifting: Rational Redistribution of Tasks among Health Workforce Teams: Global Recommendations and Guidelines*. http://www.who.int/healthsystems/TTR-TaskShifting.pdf?ua=1 [accessed 5 December 2016].

3 WHO. *Optimizing Health Worker Roles to Improve Access to Key Maternal and Newborn Health Interventions Through Task Shifting*. http://www.who.int/reproductivehealth/publications/maternal_perinatal_health/978924504843/en/index.html [accessed 5 December 2016].

4 Meara JG, Leather AJ, Hagander L, Alkire BC, Alonso N, Ameh EA *et al*. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet* 2015; **386**: 569–624.

5 Kruk ME, Pereira C, Vaz F, Bergström S, Galea S. Economic evaluation of surgically trained assistant medical officers in performing major obstetric surgery in Mozambique. *BJOG* 2007; **114**: 1253–1260.

6 Hoyler M, Hagander L, Gillies R, Riviello R, Chu K, Bergström S *et al*. Surgical care by non-surgeons in low-income and middle-income countries: a systematic review. *Lancet* 2015; **385**(Suppl 2): S42.

7 Beard JH, Oresanya LB, Akoko L, Mwanga A, Mkony CA, Dicker RA. Surgical task-shifting in a low-resource setting: outcomes after major surgery performed by nonphysician clinicians in Tanzania. *World J Surg* 2014; **38**: 1398–1404.

8 Wilson A, Lissauer D, Thangaratinam S, Khan KS, MacArthur C, Coomarasamy A. A comparison of clinical officers with medical doctors on outcomes of caesarean section in the developing world: meta-analysis of controlled studies. *BMJ* 2011; **342**: d2600.

9 Pereira C, Cumbi A, Malalane R, Vaz F, McCord C, Bacci A *et al*. Meeting the need for emergency obstetric care in Mozambique: work performance and histories of medical

doctors and assistant medical officers trained for surgery. *BJOG* 2007; **114**: 1530–1533.
10 Mkandawire N, Ngulube C, Lavy C. Orthopaedic clinical officer program in Malawi: a model for providing orthopaedic care. *Clin Orthop Relat Res* 2008; **466**: 2385–2391.
11 Chilopora G, Pereira C, Kamwendo F, Chimbiri A, Malunga E, Bergström S. Postoperative outcome of caesarean sections and other major emergency obstetric surgery by clinical officers and medical officers in Malawi. *Hum Resour Health* 2007; **5**: 17.
12 Mullan F, Frehywot S. Non-physician clinicians in 47 sub-Saharan African countries. *Lancet* 2007; **370**: 2158–2163.
13 WHO. *World Health Assembly Resolution A68/31: Strengthening Emergency and Essential Surgical Care and Anaesthesia as a Component of Universal Health Coverage*. http://apps.who.int/gb/ebwha/pdf_files/WHA68/A68_31-en.pdf [accessed 5 December 2016].
14 Vaughan E, Sesay F, Chima A, Mehes M, Lee B, Dordunoo D *et al.* An assessment of surgical and anesthesia staff at 10 government hospitals in Sierra Leone. *JAMA Surg* 2015; **150**: 237–244.
15 Bolkan HA, Hagander L, von Schreeb J, Bash-Taqi D, Kamara TB, Salvesen Ø *et al.* The surgical workforce and surgical provider productivity in Sierra Leone: a countrywide inventory. *World J Surg* 2016; **40**: 1344–1351.
16 Ministry of Health and Sanitation. *National Health Sector Strategic Plan 2010– 2015*; 2009. http://www.internationalhealthpartnership.net/fileadmin/uploads/ihp/Documents/Country_Pages/Sierra_Leone/NationalHealthSectorStrategicPlan_2010-15.pdf [accessed 5 December 2016].
17 Dare AJ, Lee KC, Bleicher J, Elobu AE, Kamara TB, Liko O *et al.* Prioritizing surgical care on national health agendas: a qualitative case study of Papua New Guinea, Uganda, and Sierra Leone. *PLoS Med* 2016; **13**: e1002023.
18 Groen RS, Samai M, Stewart KA, Cassidy LD, Kamara TB, Yambasu SE *et al.* Untreated surgical conditions in Sierra Leone: a cluster randomised, cross-sectional, countrywide survey. *Lancet* 2012; **380**: 1082–1087.
19 Bolkan HA, Von Schreeb J, Samai MM, Bash-Taqi DA, Kamara TB, Salvesen O *et al.* Met and unmet needs for surgery in Sierra Leone: a comprehensive, retrospective, countrywide survey from all health care facilities performing operations in 2012. *Surgery* 2015; **157**: 992–1001.
20 WHO. *Integrated Management for Emergency and Essential Surgical Care (IMEESC) Tool Kit*. http://www.who.int/surgery/publications/imeesc/en/ [accessed 5 December 2016].
21 Transformative Education for Health Professionals. *Sierra Leone's Community Health Officers*. http://whoeducationguidelines.org/content/sierra-leone's-community-health-officers [accessed 17 January 2017].
22 *Masanga Hospital*. https://en.wikipedia.org/wiki/Masanga_Hospital [accessed 5 December 2016].
23 *Supervision Code Help Guide – eLogbook*. https://www.elogbook.org/rcsed/messageboard/displayfile.aspx?attachmentId=539 [accessed 5 December 2016].
24 Ng-Kamstra JS, Greenberg SL, Kotagal M, Palmqvist CL, Lai FY, Bollam R *et al.* Use and definitions of perioperative mortality rates in low-income and middle-income countries: a systematic review. *Lancet* 2015; **385**: S29.
25 Chu K, Maine R, Trelles M. Cesarean section surgical site infections in sub-Saharan Africa: a multi-country study from Medecins Sans Frontieres. *World J Surg* 2015; **39**: 350–355.
26 McConkey SJ. Case series of acute abdominal surgery in rural Sierra Leone. *World J Surg* 2002; **26**: 509–513.
27 Hales S, Lesher-Trevino A, Ford N, Maher D, Ramsay A, Tran N. Reporting guidelines for implementation and operational research. *Bull World Health Organ* 2016; **94**: 58–64.
28 Milland M, Bolkan HA. Enhancing access to emergency obstetric care through surgical task shifting in Sierra Leone: confrontation with Ebola during recovery from civil war. *Acta Obstet Gynecol Scand* 2015; **94**: 5–7.
29 van der Leeuw RM, Lombarts KM, Arah OA, Heineman MJ. A systematic review of the effects of residency training on patient outcomes. *BMC Med* 2012; **10**: 65.
30 Uribe-Leitz T, Jaramillo J, Maurer L, Fu R, Esquivel MM, Gawande AA *et al*. Variability in mortality following caesarean delivery, appendectomy, and groin hernia repair in low-income and middle-income countries: a systematic review and analysis of published data. *Lancet Glob Health* 2016; **4**: e165–e174.
31 GlobalSurg Collaborative. Mortality of emergency abdominal surgery in high-, middle- and low-income countries. *Br J Surg* 2016; **103**: 971–988.
32 Kelly M, Bhangu A, Singh P, Fitzgerald JE, Tekkis PP. Systematic review and meta-analysis of trainee- *versus* expert surgeon-performed colorectal resection. *Br J Surg* 2014; **101**: 750–759.
33 UN Data. *World Statistics Pocketbook – Sierra Leone*. http://data.un.org/CountryProfile.aspx?crName=sierra%20leone [accessed 17 January 2017].
34 Mante SD, Gueye SM. Capacity building for the modified filarial hydrocelectomy technique in West Africa. *Acta Trop* 2011; **120**(Suppl 1): S76–S80.
35 Leow JJ, Groen RS, Kamara TB, Dumbuya SS, Kingham TP, Daoh KS *et al.* Teaching emergency and essential surgical care in Sierra Leone: a model for low income countries. *J Surg Educ* 2011; **68**: 393–396.
36 Bräuer MD, Antón J, George PM, Kuntner L, Wacker J. Handling postpartum haemorrhage – obstetrics between tradition and modernity in post-war Sierra Leone. *Trop Doct* 2015; **45**: 105–113.
37 Sivarajah V, Tuckey E, Shanmugan M, Watkins R. Surgical training during a voluntary medical-surgical camp in Sierra Leone. *Br J Surg* 2013; **100**: 156–157.
38 Kushner AL, Kamara TB, Groen RS, Fadlu-Deen BD, Doah KS, Kingham TP. Improving access to surgery in a

developing country: experience from a surgical collaboration in Sierra Leone. *J Surg Educ* 2010; **67**: 270–273.
39 Ng-Kamstra JS, Riesel JN, Arya S, Weston B, Kreutzer T, Meara JG *et al*. Surgical non-governmental organizations: global surgery's unknown nonprofit sector. *World J Surg* 2016; **40**: 1823–1841.
40 Nthumba PM. 'Blitz surgery': redefining surgical needs, training, and practice in sub-Saharan Africa. *World J Surg* 2010; **34**: 433–437.
41 Vargas G, Price RR, Sergelen O, Lkhagvabayar B, Batcholuun P, Enkhamagalan T. A successful model for laparoscopic training in Mongolia. *Int Surg* 2012; **97**: 363–371.
42 Grimes CE, Maraka J, Kingsnorth AN, Darko R, Samkange CA, Lane RH. Guidelines for surgeons on establishing projects in low-income countries. *World J Surg* 2013; **37**: 1203–1207.
43 Bergström S. Training non-physician mid-level providers of care (associate clinicians) to perform caesarean sections in low-income countries. *Best Pract Res Clin Obstet Gynaecol* 2015; **29**: 1092–1101.
44 Munga MA, Kilima SP, Mutalemwa PP, Kisoka WJ, Malecela MN. Experiences, opportunities and challenges of implementing task shifting in underserved remote settings: the case of Kongwa district, central Tanzania. *BMC Int Health Hum Rights* 2012; **12**: 27.

Supporting information

Additional supporting information may be found in the online version of this article:

Appendix S1 Template memorandum of understanding between CapaCare and partner hospital (Word document)

Appendix S2 Post-Graduate Surgical Training Curriculum – extracts from the student guide (Word document)

Appendix S3 Logbooks and evaluation schemes (Word document)

Table S1 Operative data for observed and indirectly supervised surgical procedures during training and after graduation (Word document)

Editor's comments

This paper is interesting and informative, and fits nicely in the current global research priorities of understanding individual countries' surgical systems and improving access to surgical care. *BJS* is an international journal with a global reach and supports well executed and comprehensive studies like this one. The authors managed to address important topics in their contribution including surgical workforce and sustainability within the framework of a training programme. They address issues that are relevant to other healthcare systems, also from more developed countries.

B. P. L. Wijnhoven
Editor, BJS