Pediatric Surgery International (2018) 34:343–351
https://doi.org/10.1007/s00383-017-4215-z

ORIGINAL ARTICLE

Characterizing pediatric surgical capacity in the Eastern Democratic Republic of Congo: results of a pilot study

Sarah B. Cairo[1] · Luc Malemo Kalisya[2] · Richard Bigabwa[3] · David H. Rothstein[1,4]

Accepted: 14 November 2017 / Published online: 20 November 2017

Abstract

Purpose Characterize pediatric surgical capacity in the eastern Democratic Republic of Congo (DRC) to identify areas of potential improvement.

Methods The Pediatric Personnel, Infrastructure, Procedures, Equipment, and Supplies (PediPIPES) survey was used in two representative eastern DRC provinces to assess existing surgical infrastructure and capacity. We compared our results to previously published reports from other sub-Saharan African countries.

Results Fourteen hospitals in the eastern DRC and 37 in 19 sub-Saharan African (SSA) countries were compared. The average PediPIPES index for the DRC was 7.7 compared to 13.5 for SSAs. The greatest disparities existed in the areas of personnel and infrastructure. Running water was reportedly available to 57.1% of the hospitals in the DRC, and the majority of hospitals (78.6%) were dependent on generators and solar panels for electricity. Only two hospitals in the DRC (14.3%) reported a pediatric surgeon equivalent on staff, compared to 86.5% of facilities sampled in SSA reporting ≥ 1 pediatric surgeon.

Conclusions Significant barriers in personnel, infrastructure, procedures, equipment, and supplies impede the provision of adequate surgical care to children. Further work is needed to assess allocation and utilization of existing resources, and to enhance training of personnel with specific attention to pediatric surgery.

Keywords Pediatric surgery · Disparities · Global surgery · Africa · Surgical capacity · Needs assessment

Accepted for podium presentation at the American College of Surgeons Surgical Forums, Chicago, IL, Oct 2017.

✉ Sarah B. Cairo
scairo2@gmail.com

Luc Malemo Kalisya
Lucmalemo21@gmail.com

Richard Bigabwa
Richardbigabwa@gmail.com

David H. Rothstein
drothstein@kaleidahealth.org

[1] Present Address: Department of Pediatric Surgery, John R Oshei Children's Hospital, 1001 Main Street, Buffalo, NY 14202, USA

[2] HEAL Africa Hospital and College of Surgeons of East, Central and Southern Africa (COSECSA), Goma, Democratic Republic of Congo, Congo

[3] Nurse Anesthetist, Goma, Democratic Republic of Congo, Congo

[4] Department of Surgery, State University of New York at Buffalo, 3435 Main Street, Buffalo, NY 14214, USA

Introduction

Provision of surgical care in the developing world has gained significant recognition as an integral part of a functional healthcare system. Surgical disease has long been a neglected component of international development despite evidence of the cost effectiveness of providing basic surgical services [1–3]. Pediatric surgery and neonatal surgery in particular, has significant potential for cost-effective intervention. In previous studies evaluating determinants and barriers accessing surgical care, resource allocation is frequently cited as a limiting factor [4].

Over the past decade, the Democratic Republic of Congo (DRC) has been faced with some of the deadliest humanitarian crises in recent history due to a combination of political instability and civil war. The North and South Kivu provinces, located along the Eastern border of the DRC, abut Rwanda and Uganda, a factor which has contributed to political conflict over the past several decades [5]. The DRC is one of the poorest and least-developed countries in the

world, with nearly 50% of the population under 15 years of age and a 2016 Human Development Index of 0.435 ranking 176th out of 187 nations [6, 7]. Despite an official end to the conflict in 2009, poor coordination between the government and healthcare system has contributed to a nearly absent pediatric surgical infrastructure [8].

In response to the Lancet Commission on Global Surgery 2015's call to address the challenges facing provision of pediatric surgical services in low-resource settings, this study was designed to quantify and qualify pediatric surgery capacity in the eastern DRC [9].

Methods

The study protocol was reviewed by the Institutional Review Board of the University of Buffalo; the study received exemption from formal review (Study 00000365).

Survey tool

The Pediatric PIPES (PediPIPES) survey tool was developed to assess pediatric surgical capacity. Adapted from the World Health Organization's Tool for Situational Analysis and the Surgeons Overseas (SOS), Personnel, Infrastructure, Procedure, Equipment, and Supplies (PIPES) tool, PediPIPES was modified to increase relevance to pediatric essential and emergency surgical care [10]. The PediPIPES tool includes 118 items used to create a weighted PediPIPES index for comparison with other institutions. The personnel score (P-score) was calculated by adding the number of personnel; the infrastructure score (I-score) was calculated by adding the number of incubators, pediatric ventilators, and operating rooms, and one point for each of 14 facility specific infrastructure items; one point was added for each procedure performed to provide a procedure score (Pr-score); an equipment score (E-score) was calculated by one point per equipment item; and the supply score (S-score) was calculated from 26 supply items at one point each. The total PediPIPES score was calculated as a sum of the P, I, Pr, E, and S-scores, divided by 118 and multiplied by 10 to create the PediPIPES index where a higher score corresponds to increased capacity for pediatric essential and emergency surgical care [11].

$$(\text{Total PediPIPES score}/118) \times 10 = \text{PediPIPES Index}.$$

The PediPIPES tool is available as an open source document on the SOS website http://www.surgeonsoverseas.org.

Data collection and analysis

There are several hundred medical facilities of varying caliber in the DRC, with more than 20 facilities in the Great Lakes Region of Africa to provide advanced hospital services. Fourteen medical facilities were identified for inclusion in pilot study. Facilities were selected who were known to provide surgical services in some capacity within two provinces in the Great Lakes Region of Africa, North Kivu and South Kivu. Fourteen healthcare facilities were assessed in the Great Lakes Region of Africa in the Democratic Republic of Congo; nine in North Kivu and five in South Kivu. Two facilities were public and represented the provincial or primary referral hospitals for their respective provinces. Five were mission facilities affiliated with Protestant or Catholic charities, five facilities semi-private, and the remaining two were designated military and police facilities (serving families of those professional communities). None of the facilities were exclusively for children. Site visits were arranged to include tour of medical facilities, interviews with facility directors, surgical staff and anesthesiology team, if applicable, and completion of the PediPIPES survey. Following completion of the analysis in the DRC, crude analysis was performed of one hospital in Kigali, the capital of Rwanda. Rwanda, in comparison with the DRC, has robust government involvement in the delivery of healthcare and a strong international presence in the capital city of Kigali. Though the delivery of pediatric surgical care in Kigali is in its infancy, analysis was included because of anecdotal reports of transferring patients with sufficient means between countries to improve access to specialized services, such as pediatric surgery.

Data collection occurred during January 2017. Descriptive statistical analyses were computed using Microsoft Excel 2010. Results of the pilot study completed in the DRC were compared to results of a PediPIPES survey distributed to 37 hospitals in ten countries in West Africa [12]. Data from West African facilities was obtained through a convenience sample of survey distributed to surgeons in the region using an email list of pediatric surgeons and general surgeons who performed pediatric surgical procedures. Interviews with participating facilities were not conducted and aggregate regional- and country-specific data were compared to data obtained in present study.

Results

PediPIPES index was calculated for each of the facilities visited and was compared by region as well as by hospital type. Historical and published controls were also used for broad comparison and point of reference. Public, provincial hospitals and the private hospital funded by a non-governmental organization (NGO) had the highest Pedi-PIPES scores at 10.8 and 11.6, respectively. Semi-public police and military facilities had the lowest scores (4.7 and 6.3, respectively), with no designated pediatric hospital beds. Total scores ranged from 4.7 to 11.6 with an average of 7.7 overall. When

compared to the facility in Rwanda and representative surveys from West African regional hospitals, the DRC pilot study revealed a lower pedi-PIPES score compared to all other countries sampled (Table 1).

Personnel

Only two facilities reported having a pediatric surgeon on staff with an average of 0.14 pediatric surgeons and 1.14 general surgeons per facility (Table 2). All facilities had at least one medical doctor and all but one facility reported having at least one medical doctor who operated on children (average nine medical doctors per facility and 4.6 medical doctors operating on children). There were no pediatric anesthesiologists and only three facilities reported having a physician anesthetist while the remainder of facilities depended on nurse anesthetists with one to six individuals per facility. Only two of the 14 facilities reported having pediatric-trained nurses. One of these facilities, however, reported specialized pediatric nursing staff as well as a recently established training program for pediatric and neonatal intensive care nurses.

Infrastructure

The number of hospital beds in the facilities interviewed ranged from 30 to 500 (median 111.5) compared to 20–2000 and a median of 350 at the West African hospitals evaluated by Okoye et al. [12] designated pediatric hospital beds ranged from 0 to 90 with a median of 18.5 beds. All facilities had at least one functioning operating room with an average of 2.8 operating rooms per facility. None of the facilities evaluated had pediatric specific ventilators and the number of functioning incubators ranged from zero to ten per facility (Table 3). Only 21.4% of facilities reported reliable external electricity compared to 73% of facilities in West Africa. Reported access to running water was similar between the two groups, at 57.1% in the DRC and 51.4% in West Africa. The majority of facilities (78.6%) had an incinerator, with laboratory of various capacities in all facilities and blood bank in 64.3%. Non-invasive and low-cost diagnostic studies such as ultrasound were reportedly available in all facilities compared to X-ray in 78.6% and computed tomography imaging in just three facilities (21.4%).

Table 2 Personnel at facilities assessed in Great Lakes Region of the Democratic Republic of Congo

Personnel	Total	Average per facility (min, max)
Pediatric surgeon	2	0.14 (0, 1)
General surgeon	16	1.14 (0, 2)
All medical doctors	126	9.00 (1, 40)
Medical doctors doing surgery on children	65	4.64 (0, 20)
Pediatricians	13	0.93 (0, 3)
Pediatric trained nurses	11	0.85 (0, 6)
Anesthesiologists (MD)	3	0.21 (0, 1)
Nurse anesthetists	41	2.93 (1, 6)

Procedures

There was significant variability in the procedures performed by institution ranging from 17 to 45 with a median of 27.5 procedures. Procedures evaluated were divided into six categories: anesthesia (4), respiratory (5), gastrointestinal (14), genitourinary (6), orthopedic (7), and other procedures (8). The most frequently performed procedures included wound care such as drainage of abscess, suturing, wound debridement, fracture splinting, male circumcision, basic laparotomy and bowel resection, appendectomy, and pediatric hernia repair (14 of 14 institutions). No minimally invasive procedures were performed and specialized procedures such as spina bifida operations, contracture release, repair of intestinal atresia, pull-through procedures for Hirschsprung Disease and repair of imperforate anus and

Table 1 PediPIPES aggregate and component scores by country including DRC, Rwanda, and West African Countries

	DRC (14)	Burkina Faso	Ghana	Ivory Coast	Liberia	Niger	Nigeria	Senegal	Sierra Leone
Average number beds (total)	151.9	125	2000	817	250	900	738	180	300
Average number beds (pediatric)	23.7	125	135	80	60	145	136	180	20
Average Personnel Score	10.8	135	99	118	21	40	98	23	21
Average Infrastructure Score	15.9	10	44	15	24	25	24	14	15
Average Procedures Score	30.6	37	46	38	43	45	45	42	39
Average Equipment Score	14.8	16	21	20	21	19	21	19	18
Average Supplies Score	19.4	21	22	24	25	23	26	18	18
Average Pedi-PIPES Index	7.7	18.6	19.7	18.2	11.4	12.9	18.1	9.8	9.4

Data for West African countries adapted from Okoye et al. where all countries represented have similar proportion of population under age 15

Table 3 Available infrastructure in evaluate health facilities ($n = 14$)

Infrastructure items	No. (range)
Number of operating rooms, average	2.8 (1, 6)
Number of functioning pediatric ventilators, average	0 (0, 0)
Number of newborn incubators, average	2.9 (0, 10)
Infrastructure items	**Number of facilities (%)**
Running water	8 (57.1)
External electricity	3 (21.4)
Functioning back-up generator	14 (100.0)
Incinerator	11 (78.6)
Medical records	14 (100.0)
Emergency department	12 (85.7)
Postoperative care area	13 (92.9)
Special care baby unit	6 (42.9)
Neonatal intensive care unit (NICU) or general ICU	8 (57.1)
Pretested blood available (blood bank)	9 (64.3)
Lab to test blood and urine	14 (100.0)
Functioning X-ray machine	11 (78.6)
Functioning ultrasound machine	14 (100.0)
Functioning CT scan	3 (21.4)

abdominal wall defects were reported in less than 50% of participating facilities (Table 4).

Equipment and supplies

Total equipment scores ranged from 8 to 20 with a median score of 16 (maximum 22); total supplies score ranged from 15 to 25 with a median score of 19 (maximum 26). None of the facilities evaluated had laparoscopic supplies or neonatal T-pieces (Table 5). Very few facilities reported adequate eye protection, syringe pumps, pediatric endoscopic equipment, or apnea monitors. The majority of facilities reported adapting adult anesthesia equipment including oxygen mask and tubing, stethoscope, blood pressure measuring equipment, thermometers, and weighing scales for use in pediatrics. Less than 50% of facilities reported having nasogastric tubes, thoracic drains, and urinary catheters appropriately sized for pediatric patients. Basic supplies such as gowns and drapes for the operating room were reported as available at 92.9–100% of facilities though most (13 out of 14 facilities) reported re-usable materials with marginal sterilization capabilities through washing and occasionally boiling of materials. Dressing supplies, needles, disposable syringes, intravenous cannulas and intravenous infusion sets (adapted from adult equipment) were sufficient at the majority of institutions.

Discussion

The 2015 Lancet Commission of Global Surgery brought attention to the effect the deficits in access to surgical care and the profound health, and economic impact safe, affordable surgical and anesthesia care can have on a nation [9, 13, 14]. While several surgical conditions were identified as measures of a nation's health, pediatric surgery was specifically excluded. Many factors appear to influence the high mortality of pediatric patients with the majority of neonatal mortality in LMICs attributed to perinatal infections, birth asphyxia, and poor nutrition [15, 16]. Most recent studies, however, draw attention to the large burden and disproportionately high mortality of surgical diseases such as congenital anomalies [17–19]. Despite a recent report of a high prevalence of surgical disease affecting pediatric patients in the eastern DRC and the barriers to care, there are no published data quantifying the capacity available to address pediatric surgical need [5]. Based on our assessment of pediatric surgical capacity in eastern DRC using the PediPIPES survey, we found that pediatric surgical care in the region is limited by shortage of pediatric-trained personnel, inadequate medical infrastructure, limited capacity to perform highly specialized operations, limited supply of pediatric-specific equipment.

There are multiple tools in existence for assessing the disease burden and corresponding capacity for care in a nation with limited evaluation of the physical, psychological, and financial impact of pediatric illness on a family and society [13]. With greater than 50% of the population in the DRC and other LMICs under 15 years of age, the need for quality pediatric surgical and trauma care cannot be understated. Capacity assessment tools developed under the guidelines of the World Health Organization Tool for Situational Analysis to Assess Emergency and Essential Surgical Care (WHO TSA) include, but are not limited to, Pedi-PIPES, the Children's Surgical Center Designations with Scope of Practice (CSCDSP) and the Checklist for Children's Trauma Room (CCTR) [20–22]. The Pedi-PIPES tool was utilized for easy administration, to allow simple data analysis, to permit comparison between facilities, and to document changes in the pediatric surgical capacity over time. Based on our assessment of pediatric surgical capacity in eastern DRC using the PediPIPES survey, we found that pediatric surgical care in the region is limited by shortage of pediatric-trained personnel, inadequate medical infrastructure, limited capacity to perform highly specialized operations, limited supply of pediatric-specific equipment.

An area of particular interest in this study and in the realm of global surgery capacity assessments lies in the qualified workforce or personnel. In the DRC, for instance, there are approximately 0.2–0.4 pediatric surgeons per 1 million

Table 4 Procedures performed by facilities ($n = 14$)

Anesthesia, *n* (%)	Respiratory, *n* (%)	Gastrointestinal, *n* (%)	Genitourinary, *n* (%)	Orthopedic, *n* (%)	Other procedures, *n* (%)
Ketamine, 14 (100.0)	Chest tube insertion, 7 (50.0)	Appendectomy, 14 (100.0)	Male circumcision, 14 (100.0)	Fracture splinting, 14 (100.0)	Resuscitation, 13 (92.9)
General, 13 (92.9)	Tracheostomy, 4 (28.6)	Bowel resection and anastomosis, 14 (100.0)	Pediatric hernia repair, 14 (100.0)	Casting of fractures, 13 (92.9)	Suturing, 14 (100.0)
Regional, 8 (57.1)	Thoracotomy, 7 (50.0)	Closure of intestinal stomas, 7 (50.0)	Orchidopexy, 13 (92.9)	Pediatric amputation, 10 (71.4)	Wound debridement, 14 (100.0)
Spinal, 11 (78.6)	Repair of esophageal atresia, 3 (21.4)	Creation of intestinal stoma, 13 (92.9)	Repair of testicular torsion (78.6)	Traction for closed fracture, 13 (92.9)	Incision and drainage of abscess, 14 (100.0)
	Removal of airway and esophageal foreign bodies, 5 (35.7)	Pyloromyotomy (open), 8 (57.1)	Repair of imperforate hymen, 11 (78.6)	Treatment of open fracture, 8 (57.1)	Burn management, 13 (92.9)
		Intestinal atresia repair, 5 (35.7)	Ovarian cystectomy, 12 (85.7)	Non-operative treatment of clubfoot, 11 (78.6)	Contracture release, 4 (28.6)
		Repair of imperforate anus, 5 (35.7)			Skin grafting, 11 (78.6)
		Pediatric abdominal wall defect repair, 6 (42.9)		Osteomyelitis management, 11 (78.6)	Spina bifida, 3 (21.4)
		Rectal biopsy, 4 (28.6)			
		Insertion of g-tube, 6 (42.9)			
		Ladd procedure, 4 (28.6)			
		Laparotomy, 14 (100.0)			
		Pull-through procedure for Hirschsprung Disease, 4 (28.6)			
		Resection of solid abdominal mass, 10 (71.4)			

Laparoscopic surgeries and non-operative reduction of intussusception excluded; not performed at any participating institution

population ages 0–17 years representing a chronic shortage of qualified pediatric surgeons in Africa [23]. In many parts of Africa, general surgeons and medical providers attend to the surgical needs of children [24, 25]. In this study, only three facilities were identified with pediatric surgeons while the majority described generalists and occasional general surgeons functioning as the designated pediatric surgeons. In an attempt to enhance the specialist surgeon workforce, the College of Surgeons of East, Central, and Southern Africa (COSECSA) was developed [26]. The pediatric surgical curriculum, which now includes rotations in pediatric surgery, general surgery, neurosurgery, orthopedics, urology, plastic surgery, maxillofacial surgery, anatomic pathology, pediatric intensive care, and nursery, has increased the quantity and quality of pediatric surgical providers in many LMICs in Africa [27]. Only one provider in the eastern DRC is presently engaged in the COSECSA training program, further emphasizing the need for workforce capacity building with a minimum of standardized education for non-specialized surgical providers. In contrast, as of 2016, there are 20 pediatric surgeons per 1 million children with only 19% of the population under age 15 in the United States [6, 28].

No designated pediatric anesthesiologists were identified in the course of this study, a finding that is similar to other studies addressing pediatric surgical capacity and training models in LMICs [29]. Anesthesia for pediatric surgery patients is often limited and provided almost uniformly by non-physicians with variable training [29–31]. Anecdotal experiences demonstrate the significant impact that lack of pediatric anesthesia has on the outcome of surgical procedures and the complexity of procedures performed. Without pediatric specialists for perioperative care, critical patients, and especially infants and neonates are dependent on proper post-operative and resuscitative therapy. As seen in this study, however, there were very few centers with pediatric nurses or trained neonatologists. Combined with the shortage of pediatric surgeons, the absence of consistent provision of anesthesia contributes significantly to delays in care

Table 5 Equipment and supplies in surveyed facilities ($n = 14$)

Equipment and supplies	No. (%)
Compressed oxygen cylinder	9 (64.3)
Oxygen concentrator	14 (100.0)
Pediatric resuscitation bag and valve mask	11 (78.6)
Oropharyngeal airway	9 (64.3)
Endotracheal tubes	13 (92.9)
Anesthesia machine	12 (85.7)
Pulse oximeter (at least one)	12 (85.7)
Oxygen mask and tubing	8 (57.1)
Stethoscope (adult or pediatric)	13 (92.9)
Pediatric blood pressure monitoring equipment	7 (50.0)
Thermometer	14 (100.0)
Weighing scale (infant specific or adaptable mechanism)	12 (85.7)
Pediatric-specific abdominal surgical instruments	4 (28.6)
Kidney dish, stainless steel	13 (92.9)
Functional sterilizer (autoclave)	10 (71.4)
Functional suction pump (manual or electric)	13 (92.9)
Electrocautery machine	11 (78.6)
Apnea monitor/apnea alarm detector	3 (21.4)
Syringe pumps	2 (14.3)
Endoscopy (any of esophagoscope, bronchoscope, or cystoscope)	4 (28.6)
Operating room lights	13 (92.9)
Sterile and examination gloves	13 (92.9)
12 F or smaller pediatric nasogastric tube	6 (42.9)
Pediatric or adaptable IV fluid infusion sets	10 (71.4)
Pediatric or adaptable blood infusion sets	10 (71.4)
IV cannulas, syringes, disposable needles, tourniquets/equivalent	14 (100.0)
Bandages sterile	12 (85.7)
Adhesive tape	11 (78.6)
Suture	12 (85.7)
Pediatric urinary catheters (including 6 F)	4 (28.6)
Sharps disposal container	14 (100.0)
Scalpel blades	14 (100.0)
Face masks	13 (92.9)
Eye protection (goggles, safety glasses)	2 (14.3)
Apron	13 (92.9)
Boots (theater shoes)	10 (71.4)
Gowns for surgeon/scrub nurse	13 (92.9)
Drapes (for operation)	14 (100.0)
Chest tubes including 12 F or smaller	4 (28.6)
Pediatric or adaptable tracheostomy tubes	4 (28.6)

Laparoscopic supplies and neonatal T-piece excluded, not available at any facilities

and high mortality amongst pediatric surgical patients [32, 33].

While a number of facilities reported caring for patients with complex congenital diseases such as intestinal atresia and tracheoesophageal fistula, limitations in equipment and infrastructure are concerning. The tool utilized is limited in its ability to evaluate surgical outcome and mortality, thus undercutting the definition of "capacity". In the assessment of surgical capabilities, the Lancet Commission identified three Bellwether procedures to be used as a proxy for surgical systems that have the ability to provide a broad range of procedures [13]. Several studies have attempted to define a Bellwether procedure for pediatric surgery with recommendations including gastroschisis, intestinal atresia, and anorectal malformations [34–36]. Though only treated at a few facilities evaluated here, the discrepancy between procedures

performed and available infrastructure and equipment call attention to differential treatment practices in the absence of parenteral nutrition and pediatric ventilators. Educational programs and community outreach are essential to identify available and cultural acceptable practice patterns in an effort to address the complex, multifaceted needs for provision of surgical services that go beyond a checklist.

In addition to shortages of qualified providers affecting provision of surgical care, this pilot study identified significant deficits in infrastructure in two provinces of the eastern DRC. The average score for facilities in the DRC for infrastructure, 15.9, was only slightly lower than the median for all countries included at 16.5 despite ranging from 8 to 25. The areas of greatest variability included number of functioning newborn incubators, consistent availability of external electricity and running water, and access to computed tomography for diagnostic purposes. Many of the limitations in infrastructure were related to lack of government engagement and poor monitoring of charity and mission aid [27]. At the facilities evaluated in this study, for instance, there were a total of five operating rooms built through support by foreign aid agencies. Unfortunately, due to the lack of nurses and physicians, the operating rooms could not be used and instead served as an example of inappropriate resource allocation and poor coordination of aid [37]. With growing interest by surgical trainees in global health, many partnerships have emerged in an attempt to build capacity, support education, research, and service in surgery though the need for measured and coordinated development is imperative [38, 39].

Models exist for short-term surgical missions in LMICs where limited, and often low priority, equipment and supplies are delivered. Most of the facilities evaluated reported sufficient access to basic surgical supplies but a significant deficit in pediatric-specific equipment such as surgical instruments, anesthesia machines, and apnea monitors. Many facilities reported adapting adult supplies for pediatric patients when possible. For specific supplies such as urinary catheters and nasogastric tubes, pediatric-specific supplies often required purchase by patient families though availability within the city and province was marginal, at best, and often dependent on donations from visiting aide teams.

Limitations

One of the major limitations in this study is in the capacity assessment tool utilized. While the Pedi-PIPES tool was specifically adapted for the assessment of surgical capacity in LMICs, adaptations were required to apply the tool to the sites in the DRC limiting the generalizability and comparability to historical sites. In comparison with the study performed in West Africa, this study was strengthened by having standard interview techniques and explanations of components. While this enhanced control compared to survey distribution to surgeons across sub-Saharan Africa, it may have also introduced some bias or response modification introduced by the presence of the American research team [12]. The differences in distribution of survey and interview also significantly limit the comparability of these data to those identified in historical controls with a presumed tendency towards over estimation of capacity on survey compared to interview. Additionally, there is limited literature to explain why certain items are included in the Pedi-PIPES tool such as a kidney dish which does not seem to pertain specifically to pediatric surgical capacity.

As a pilot study, this study is limited by the small sample size of hospitals surveyed and districts of DRC included compared to the total number of hospitals in the region. North and South Kivu were selected for pilot study based on existing relationships with healthcare personnel to facilitate interviews, ease of access, and increased concentration of higher level (i.e., secondary or tertiary versus community level) hospitals. Further studies will assess capacity for pediatric surgical care in all provinces of the DRC, including the capital city in the western part of the country. Prior to the present study, it was believed that a single pediatric surgeon was practicing in the capital, Kinshasa, located more than 2800 km from Goma in North Kivu, where this study was conducted [5]. This discrepancy may represent increased presence of surgical providers or, more likely, differential definitions of pediatric surgeons [40–42].

While French is the official language of the DRC, four additional national languages are considered to be primary languages. The interviews were conducted predominantly in French though some providers involved in the study spoke conversational English as well [43]. While surveys report that as many as 59% of Congolese refugees have no oral English skills and many individuals speak native languages without reading or writing schools, knowledge and use of French language are nearly ubiquitous in the population of higher education [6]. Additionally, the study was conducted as a snapshot of hospitals acknowledging that significant variability exists in the availability of different supplies at different times and potential for depreciation of infrastructure based on the fluctuating political and foreign-aid climate.

Conclusion

This study identified significant barriers in personnel, infrastructure, procedures, equipment, and supplies that impede the provision of adequate surgical care to children. Compared to similar assessments of historical controls in West Africa, the barriers to accessing adequate care in the eastern

DRC appeared to be more extensive. In-person facility visits, and combination qualitative and quantitative surveys can yield rich data to help characterize surgical needs and opportunities for improvement in pediatric surgical infrastructure The results of this study, ongoing evaluations of surgical capacity in the DRC, and geospatial analysis of the population compared to available healthcare facilities will be used to support centralization of specialty care and improved resource allocation. Additionally, a mechanism to enhance training of personnel with specific attention to pediatric surgery and triage through community providers is under development to further support these efforts.

Compliance with ethical standards

Conflict of interest The authors have no potential conflicts of interest, including financial interests and relationships or affiliations relevant to the subject of this manuscript and research.

References

1. Gosselin R, Ozgediz D, Poenaru D (2013) A square peg in a round hole? Challenges with DALY-based burden of disease calculations in surgery and a call for alternative metrics. World J Surg 37(11):2507–2511
2. McCord C, Chowdhury Q (2003) A cost effective small hospital in Bangladesh: what it can mean for emergency obstetric care. Int J Gynaecol Obstet 81(1):83–92
3. Ozgediz D, Riviello R (2008) The "other" neglected diseases in global public health: surgical conditions in sub-Saharan Africa. PLoS Med 5(6):e121
4. Forrester JD, Forrester JA, Kamara TB et al (2016) Self-reported determinants of access to surgical care in 3 developing countries. JAMA Surg 151(3):257–263
5. Malemo Kalisya L, Nyavandu K, Machumu B, Kwiratuwe S, Rej PH (2015) Patterns of congenital malformations and barriers to care in Eastern Democratic Republic of Congo. PLoS One 10:e0132362
6. Congolese Refugee Health Profile (2016) https://www.cdc.gov/immigrantrefugeehealth/pdf/congolese-health-profile.pdf. Accessed 2017
7. International Human Development Indicators (2016) The Democratic Republic of Congo. http://hdr.undp.org/en/countries/profiles/COD. Accessed 2017
8. Ahuka OL, Toko RM, Omanga FU, Tshimpanga BJ (2006) Congenital malformations in the North-Eastern Democratic Republic of Congo during civil war. East Afr Med J 83(2):95–99
9. Meara JG, Greenberg SL (2015) Global surgery as an equal partner in health: no longer the neglected stepchild. Lancet Glob Health 3(Suppl 2):S1–S2
10. Fuller AT, Butler EK, Tran TM et al (2015) Surgeons overseas assessment of surgical need (SOSAS) Uganda: update for household survey. World J Surg 39(12):2900–2907
11. Groen R, Kamara T, Dixon-Cole R, Kwon S, Kingham T, Kushner A (2012) A tool and index to assess surgical capacity in low income countries: an initial implementation in Sierra Leone. SpringerLink. World J Surg 36:1970
12. Okoye M, Ameh E, Kushner A, Nwomeh B (2015) A pilot survey of pediatric surgical capacity in West Africa. SpringerLink. World J Surg 39:669–676
13. Meara JG, Leather AJ, Hagander L et al (2016) Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. Int J Obstet Anesth 25:75–78
14. Chao TE, Sharma K, Mandigo M et al (2014) Cost-effectiveness of surgery and its policy implications for global health: a systematic review and analysis. Lancet Glob Health 2(6):e334–e345
15. Bickler S, Weiser T, Kassebaum N et al (2015) The international bank for reconstruction and development, the world bank. In: Bank TIBfRaDTW (eds) Essential surgery: disease control priorities, vol 1, 3rd edn, chap 2. Washington, DC
16. Ozgediz D, Poenaru D (2012) The burden of pediatric surgical conditions in low and middle income countries: a call to action. J Pediatr Surg 47(12):2305–2311
17. Badrinath R, Kakembo N, Kisa P, Langer M, Ozgediz D, Sekabira J (2014) Outcomes and unmet need for neonatal surgery in a resource-limited environment: estimates of global health disparities from Kampala, Uganda. J Pediatr Surg 49(12):1825–1830
18. Black RE, Cousens S, Johnson HL et al (2010) Global, regional, and national causes of child mortality in 2008: a systematic analysis. Lancet 375(9730):1969–1987
19. Rosano A, Botto LD, Botting B, Mastroiacovo P (2000) Infant mortality and congenital anomalies from 1950 to 1994: an international perspective. J Epidemiol Community Health 54(9):660–666
20. Morse T, Haller J, B O (1976) Checklist for a children's trauma room. J Trauma 16(10):763–765
21. Kushner AL, Cherian MN, Noel L, Spiegel DA, Groth S, Etienne C (2010) Addressing the millennium development goals from a surgical perspective: essential surgery and anesthesia in 8 low- and middle-income countries. Arch Surg 145(2):154–159
22. Oldham KT (2014) Task force for children's surgical care: optimal resources for children's surgical care in the United States. J Am Coll Surg 218(3):480–487e
23. O'Neill JA, Gautam S, Geiger JD et al (2000) A longitudinal analysis of the pediatric surgeon workforce. Ann Surg 232(3):442–453
24. Bickler SW, Kyambi J, Rode H (2001) Pediatric surgery in sub-Saharan Africa. Pediatr Surg Int 17(5–6):442–447
25. Millar AJ, Rode H, Davies MR, Cywes S (1993) Paediatric surgery in the RSA—practice and training. S Afr Med J 83(2):85–88
26. O'Flynn D, O'Flynn E, Deneke A, Yohannan P, da Costa A, O'Boyle C, Byrne E (2017) Training surgeons as medical educators in Africa. J Surg Educ 74(3):539–542
27. Amado V, Martins DB, Karan A, Johnson B, Shekherdimian S, Miller LT, Taela A, DeUgarte DA (2017) Global general pediatric surgery partnership: the UCLA–Mozambique experience. J Pediatr Surg **(e-pub ahead of print)**
28. UN: global child deaths down by almost half since 1990. 2017. http://www.worldbank.org/en/news/press-release/2013/09/13/un-
29. Zoumenou E, Gbenou S, Assouto P et al (2010) Pediatric anesthesia in developing countries: experience in the two main university hospitals of Benin in West Africa. Paediatr Anaesth 20(8):741–747
30. Bang'na Maman O, Kabore A, Zoumenou E et al. (2009) Anesthesia for children in Sub-Saharan Africa—a description of settings, common presenting conditions, techniques and outcomes. Pediatr Anaesth 19:7–11
31. Amponsah G (2010) Challenges of anaesthesia in the management of the surgical neonates in Africa. Afr J Paediatr Surg 7(3):134–139
32. Ameh EA, Chirdan LB (2001) Paediatric surgery in the rural setting: prospect and feasibility. West Afr J Med 20(1):52–55
33. Ilori I, Ituen A, Eyo C (2013) Factors associated with mortality in neonatal surgical emergencies in a developing ter tiary hospital in Nigeria. Open J Pediatr 3:231–235
34. Ford K, Poenaru D, Moulot O et al (2016) Gastroschisis: Bellwether for neonatal surgery capacity in low resource settings? J Pediatr Surg 51(8):1262–1267

35. Chirdan LB, Uba AF, Pam SD (2004) Intestinal atresia: management problems in a developing country. Pediatr Surg Int 20(11–12):834–837
36. Ezomike UO, Ekenze SO, Amah CC (2014) Outcomes of surgical management of intestinal atresias. Niger J Clin Pract 17(4):479–483
37. Forestier C, Cox AT, Horne S (2016) Coordination and relationships between organisations during the civil–military international response against Ebola in Sierra Leone: an observational discussion. J R Army Med Corps 162(3):156–162
38. Taro T, Yao C, Ly S et al (2016) The global surgery partnership: an innovative partnership for education, research, and service. Acad Med 91(1):75–78
39. Yao CA, Taro TB, Wipfli HL et al (2016) The Tsao fellowship in global health: a model for international fellowships in a surgery residency. J Craniofac Surg 27(2):282–285
40. Chirdan LB, Ameh EA, Abantanga FA, Sidler D, Elhalaby EA (2010) Challenges of training and delivery of pediatric surgical services in Africa. J Pediatr Surg 45(3):610–618
41. Elhalaby EA, Uba FA, Borgstein ES, Rode H (2012) Training and practice of pediatric surgery in Africa: past, present, and future. Semin Pediatr Surg 21(2):103–110
42. Krishnaswami S, Nwomeh BC, Ameh EA (2016) The pediatric surgery workforce in low- and middle-income countries: problems and priorities. Semin Pediatr Surg 25(1):32–42
43. Central Intelligence Agency. The World Factbook (2017) Democratic Republic of Congo. Accessed 2017