Published in final edited form as:

J Pediatr Surg. 2016 April ; 51(4): 659–669. doi:10.1016/j.jpedsurg.2015.08.063.

Surgery for children in low-income countries affected by humanitarian emergencies from 2008 to 2014: The Médecins Sans Frontières Operations Centre Brussels experience^{☆,☆☆,★,★★}

Katherine T. Flynn-O'Brien^{a,b,*}, Miguel Trelles^c, Lynette Dominguez^c, Ghulam Hiadar Hassani^{d,e}, Clemence Akemani^{d,f}, Aamer Naseer^{c,g}, Innocent Bagura Ntawukiruwabo^{d,h}, Adam L. Kushner^{i,j,k}, David H. Rothstein^{l,m}, and Barclay T. Stewart^{a,n,o}

^aDepartment of Surgery, University of Washington, Seattle, WA, USA

^bHarborview Injury Prevention and Research Center, Seattle, WA, USA

^cSurgery, Anesthesia, Gynecology, and Emergency Medicine Unit, Médecins Sans Frontières, Brussels, Belgium

^dMédecins sans Frontières-Operational Centre Brussels, Surgical Unit, Brussels, Belgium

^eBoost General Hospital, Médecins sans Frontières, Lashkar-Gah, Afghanistan

^fGeneral Referral Hospital, Médecins sans Frontières, Lubutu, Democratic Republic of the Congo

^gDargai DHQ Hospital, Dargai, Pakistan

^hGeneral Referral Hospital, Médecins sans Frontières, Masisi, Democratic Republic of the Congo

ⁱSurgeons OverSeas (SOS), New York, NY, USA

^jDepartment of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

^kDepartment of Surgery, Columbia University, New York, NY, USA

^lDepartment of Surgery, Women & Children's Hospital of Buffalo, NY, USA

^mDepartment of Surgery, University at Buffalo, SUNY, Buffalo, NY, USA

ⁿSchool of Medical Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[☆]Conflict of interest: Outside of the authors' relationship with Médecins Sans Frontières there are no conflicts of interest.

^{☆☆}Submission declaration: This work has not been published previously and is not under consideration for publication elsewhere. It has been approved by all authors.

[★]Role of the funding source: This study was funded by Médecins Sans Frontières (MSF); however MSF as an organization did not have a role in study design, data analysis, data interpretation, manuscript preparation, or in the decision to submit the article for publication.

^{★★}Author contributions: KTF, MT, LD, GHH, CA, AN, IBN and BTS were responsible for study design and implementation at study sites. MT, LD, GHH, CA, AN, and IBN were responsible for data collection and/or supervision at each site or headquarters. KTF, MT, LD, ALK, DHR, and BTS performed data analysis and interpretation. KTF, ALK, DHR, and BTS drafted the manuscript. All authors contributed significantly to subsequent drafts and putting the findings into context.

^{*}Corresponding author at: University of Washington, Department of Surgery, 1959 NE Pacific St., Suite BB-487, P.O. Box 356410, Seattle, WA 98195-6410. Tel.: +1 206 543 3680. flynnobr@uw.edu (K.T. Flynn-O'Brien).

^oDepartment of Surgery, Komfo Anokye Teaching Hospital, Kumasi, Ghana

Abstract

Purpose—Pediatric surgical care is deficient in developing countries disrupted by crisis. We aimed to describe pediatric surgical care at Médecins Sans Frontières-Brussels (MSF-OCB) projects to inform resource allocation and define the pediatric-specific skillset necessary for humanitarian surgical teams.

Methods—Procedures performed by MSF-OCB from July 2008 to December 2014 were reviewed. Project characteristics, patient demographics and clinical data were described. Multivariable logistic regression was performed to determine predictors of perioperative death.

Results—Of 109,828 procedures, 26,284 were performed for 24,576 children (22% of all procedures). The most common pediatric operative indication was trauma (13,984; 57%). Nine percent of all surgical indications were due to violence (e.g., land mines, firearms, gender-based violence, etc.). The majority of procedures (19,582; 75%) were general surgical, followed by orthopedic (4350; 17%), and obstetric/gynecologic/urologic (2135; 8%). Perioperative death was low (42; 0.17%); independent predictors of death included age <1 year, use of general anesthesia with a definitive airway, and operation during conflict.

Conclusion—Surgical care for children comprised nearly a quarter of all procedures performed by MSF-OCB between 2008 and 2014. Attention to trauma surgery and infant perioperative care is particularly needed. These findings are important when resourcing projects and training surgical staff for humanitarian missions.

Keywords

Pediatric; Global surgery; Developing country; Humanitarian; Crisis; Natural disaster

Unmet surgical need is a major public health problem globally, particularly in low- and middle-income countries (LMICs) [1–3]. However, the proportion of that burden that falls on children is poorly characterized [5–7].

A number of barriers to surgical care prevent children from receiving treatment in LMICs, including critical resource deficiencies, insufficient pediatric-specific supplies, and a lack of national government and international aid support [8–15]. As a result, unmet surgical needs in children, even for common conditions (e.g., burns, hernias, appendicitis), result in a large number of preventable deaths and even greater disability [5,13,16–18]. Highly specialized operations requiring particular equipment, knowledge and skill are performed even less frequently; an estimated 12.4 million DALYs in LMICs are incurred by three congenital anomalies alone (cleft lip and palate, congenital heart anomalies, and neural tube defects) [19]. When the already fragile healthcare systems of many LMICs are further strained by political unrest, conflict, natural disasters, or epidemics, they are uniformly unable to meet the demands for essential or specialized services, such as pediatric surgery [20,21].

Médecins Sans Frontières (MSF; Doctors Without Borders) is a multinational non-governmental organization that has provided humanitarian assistance to more than 100 million patients since its inception in 1971 [22]. MSF is divided into five operational centers,

each capable of providing surgical care [20]. One of these operational centers is MSF Operations Centre Brussels (MSF-OCB). MSF-OCB is committed to providing quality surgical care to the most vulnerable populations during crisis, including children [23]. Requisite for providing quality care is a thorough understanding of the operative epidemiology at MSF-OCB projects. However, pediatric-specific operative epidemiology and skills required by humanitarian surgical teams have not been well described.

To address this gap, we aimed to describe surgical care for children (i.e. patients <18 years) at projects operated by MSF-OCB from 2008 to 2014 [24]. Through detailed analysis of operative volume and indications, patient and procedural details, and predictors of perioperative mortality in the pediatric surgical population in a large cohort of humanitarian-based surgical projects, the data might guide planning for humanitarian surgical assistance, allow more precise resource allocation, define the pediatric-specific skillset necessary for surgeons embarking on humanitarian missions and provide an evidence base for advocating for the protection of this vulnerable population during crisis.

1. Materials and methods

1.1. Data collection

All procedures performed in an operating theater managed by MSF-OCB from July 2008 through December 2014 were recorded using a standardized Patient Surgical Record (PSR). The PSR was developed by MSF for operational research needs. Therefore, patient identifiers for longitudinal evaluation and specific clinical data, such as imaging, laboratory values and long-term outcomes were not recorded. The PSR variables included age, gender, American Society of Anesthesia (ASA) physical status score, type of anesthesia utilized, operative indication, procedure(s) performed, procedure order and urgency, perioperative death (i.e. death from initiation of anesthesia care to discharge from the recovery ward) and project site. The PSR was transcribed monthly into a database (Excel; Microsoft, Redmond, WA, USA) and transmitted to MSF-OCB headquarters in Brussels, Belgium. At headquarters, the Surgical, Anesthesia, Gynecology and Emergency Medicine (SAGE) Unit reviewed all data for completeness and accuracy. Discrepancies, missing data or questions were immediately corrected after reconciliation with program personnel.

1.2. Definitions

The reason for MSF-OCB assistance for each project was characterized as maternity, natural disaster, conflict, or hospital support. Projects primarily dedicated to the care of women during childbirth and in the peri-partum setting were considered maternity. Non-maternity projects that did not care for those injured as a result of widespread conflict or after natural disaster were considered to be hospital support.

Children were defined as all individuals under the age of 18 years. Age groups were defined using the Centers for Disease Control and Prevention epidemiologic health-related age groupings (i.e. <1 year, 1–4 years, 5–9 years, 10–14 years and 15–24 years) [25]. The 15–24 year old age group was truncated at 18 years of age. Types of anesthesia included general anesthesia with an airway (i.e. endotracheal intubation, laryngeal mask airway), general

anesthesia without an airway (i.e. ketamine-based anesthesia), regional or local anesthesia (e.g. spinal, epidural, peripheral nerve blocks, local infiltration), and 'combined or other.' Procedures were defined as emergent, urgent, or elective; and were classified as first operation, planned return operation, or unplanned return operation.

MSF classification groups and sub-groups for indication and procedure type have been detailed elsewhere [20]. Briefly, indication for operation was grouped into one of three mutually exclusive categories: trauma, non-trauma, and obstetric/gynecologic (Ob/Gyn). Trauma indications included injuries associated with conflict (e.g., those resulting from mines, bombs, gun shots, assault, gender-based violence, torture), and injuries not directly associated with conflict (e.g., those from road traffic collisions, falls, burns). Non-trauma indications included abscess, typhoid perforations, intestinal obstruction, appendicitis, tumor, and others. Ob/Gyn indications included maternal fetal conditions, referred to in this manuscript as maternal/fetal to avoid confusion between indication for operation and procedure description.

Procedures were grouped into six mutually exclusive categories: minor surgery, wound surgery, visceral surgery, orthopedics, obstetrics/gynecology/urology (Ob/Gyn/Uro), and specialized surgery. Minor surgery, wound surgery, and visceral surgery were considered "general surgical" procedures. Procedure categories have also been detailed previously [20]. Examples of minor surgery included simple wound treatment, abscess drainage, circumcision and drain placement. Wound surgery included extensive debridement, digital amputation, burn dressings, and foreign body removal. Visceral surgery included operations such as appendectomy, exploratory laparotomy and repair of solid or hollow viscus injury. Orthopedic surgery included treatment of fractures, amputations, joint surgery, and repair of tendon or nerve injury. Ob/Gyn/Uro surgery included cesarean sections, genital fistula procedures, tubal ligation, and interventions for renal and external genital pathology. Specialized surgery included procedures typically completed under the auspices of ophthalmology, neurosurgery, maxillofacial surgery and others [20].

1.3. Data analysis

Total and age-specific counts and/or relative proportions were presented for patient characteristics, indication for operation and operative details. Further analysis of surgery for infants (i.e., children <1 year old) and surgeries for trauma was presented to highlight important aspects of caring for these vulnerable populations in austere settings and during conflict or after disaster. Chi² test for independence (with degrees of freedom equal to $k_R - 1$ row categories times $k_C - 1$ column categories) was used to evaluate differences between categorical variables. One- and two-sample tests of proportions with two-sided p-value set at 0.05 were completed for comparison of binomial proportions. Bivariate logistic regression was performed to evaluate predictors of perioperative death. A multivariable logistic model was built based on bivariate statistical significance at the $p = 0.05$ level and an *a priori* hypothesis of the following clinically relevant confounders: age, sex, ASA score, and indication for operation (trauma, non-trauma, maternal/fetal). All analyses were completed with Stata v12 (College Station, TX, USA).

To compare the relative proportion of procedures performed between age groups, ranks are provided. Ranks were shaded to more easily appreciate the change in rank between age groups. For all rank lists, dark gray is the most common procedure performed. Procedures performed less commonly were shaded progressively lighter shades of gray. White represents the least common procedure performed.

1.4. Ethics approval

Retrospective description of de-identified, routinely collected data satisfied MSF Ethical Review Board exemption criteria. Johns Hopkins Bloomberg School of Public Health Institutional Review Board approved secondary analyses.

2. Results

2.1. Characteristics of MSF-OCB projects and pediatric patients

Between 2008 and 2014, MSF-OCB provided surgical assistance at 45 projects in 19 countries (Fig. 1). In total, 109,828 operations were performed during the study period; 24,576 were for children (22%). Twenty-one projects were conflict missions (47% of projects). Among conflict projects, nearly one-third of the operations performed were for children (13,969; 29%). Twelve projects provided hospital support (27%), six provided assistance after natural disaster (13%), and six were maternity missions (13%); these projects performed 21%, 19% and 8% of operations for children, respectively.

Two-thirds of children were male (15,327; 62%) and the mean age was 8.9 years (SD 5.2; Table 1). When stratified by age group, demographic and operative characteristics varied significantly ($p < 0.001$ for sex, ASA category, anesthesia type, surgical indication, operative urgency, and perioperative death). Notably, among 15–17 year olds, girls made up a greater proportion of surgeries than boys (55% vs. 45%, $p < 0.001$). In this age group, maternal/fetal conditions accounted for one-third of operative indications ($n = 1723$; 34% of operations for 15–17 year olds).

2.2. Indications

Trauma was the most common indication for surgery outside of infancy. Trauma operations were nearly twice as common compared to non-trauma operations in children over five (5–9 years, 65% vs. 35%; 10–14 years, 65% vs. 33%; 15–17 years 41% vs. 25%; $p < 0.001$), while only slightly more common in children 1–4 years of age (57% vs. 42%; $p < 0.001$). Seventy-one percent of operations for infants were for non-trauma indications. In infants, skin and soft tissue infection accounted for almost half of all operative indications ($n = 504$; 46%). Other common causes included intestinal obstruction, hernia, and circumcision, which together accounted for 17% of operative indications among infants. Congenital anomaly was the indication for 6% of operations for infants (64 of 1096 operations) and only 1% of operations for children 1–4 years of age (63 of 5337 operations).

2.3. Procedures

There were 26,284 procedures performed for the 24,576 children during the study period (Table 2). Of these, 5539 (21%) were minor (e.g. simple wound closure, incision and

drainage, circumcision). Extensive wound debridement and procedures for burn care were also common (16% and 11% of procedures, respectively). The majority of procedures were general surgical (19,582; 75%); however, 17% were orthopedic, 8% were Ob/Gyn/Urologic, and 1% were more specialized. The most salient difference between procedures by age group was the greater relative proportion of burn care procedures in younger children (19% <1 year, 23% 1–4 years, 12% 5–9 years, 5% 10–14 years, and 3% 15–17 years; $p < 0.001$; Table 2; expanded list provided in Appendix A).

2.4. Trauma care

Since trauma was the most common indication for surgery (13,984 operations; 57%), this was further explored. Predictably, trauma accounted for the majority of operations for children at projects providing assistance after natural disaster or during conflict (79% and 66% of all operations, respectively). However, 38% of operations at hospital support projects and 3% of operations at maternity projects were for trauma. The proportion of operations for trauma increased among all project-types during the study period (27% to 73% of all operations performed in 2008 and 2014, respectively; $p < 0.001$) (Fig. 2; detailed list of procedural indications by project-type provided in Appendix B). The increase was driven by unintentional injuries (21% of all pediatric operations in 2008 to 63% in 2014; $p < 0.001$) more than conflict injuries (6% in 2008 to 10% in 2014; $p < 0.001$), despite the change in relative proportion reaching statistical significance in both categories.

Injury mechanism varied by age group (Table 4). Most trauma operations were for mechanisms not directly related to conflict (11,664/13,984 trauma operations; 83%). Road traffic collisions accounted for 22%, burns 24%, and other injuries including falls 37%. Violence and conflict-related mechanisms accounted for 17% of trauma operations (gunshot wounds 8%; bomb blasts 5%; stab wounds 2%; and others 1%). Violence contributed to a greater proportion of trauma operations with each increase in age group category: 7% of infants, 8% of children 1–4 years, 10% 5–9 years, 22% 10–14 years, and 31% 15–17 years ($p < 0.001$ for trend). The most frequently performed procedures after injury included the management of complex wounds (e.g., extensive debridement, burn care, skin/muscle graft; 6764 procedures; 44% of all trauma procedures), fractures (3319; 21%), and minor wounds (e.g., minor debridement, simple wound closure; 3549; 23%).

2.5. Perioperative death

There were 42 pediatric perioperative deaths during the study period (i.e. death from start of anesthesia care to discharge from the recovery room; perioperative death rate 0.17%; detailed demographic and procedural details provided in Appendix C). Perioperative death was significantly higher in infants (0.82%; 9/1096 infants) compared to all other age groups (1–4 years, 0.11%; 5–9 years, 0.12%; 10–14 years, 0.16%; 15–17 years, 0.16%; $p < 0.001$; Table 1). In bivariate analysis comparing children who died compared to children who survived, age, urgency of operation, ASA score, type of anesthesia, and reason for humanitarian assistance were important predictors of perioperative death (Table 3). Gender and indication for operation (i.e., trauma, non-trauma, maternal/fetal) were not associated with death. The final multivariable logistic model, which controlled for age, sex, urgency of operation, ASA, type of anesthesia, indication for operation and reason for humanitarian

assistance, showed high discrimination (c-statistic 0.9343) and modest goodness of fit (McFadden's pseudo- $R^2 = 0.36$). Age less than one year, ASA score 3, emergency operation, general anesthesia with an airway, and conflict project were independently associated with death (Table 3). No perioperative deaths occurred during elective operations or at maternity projects. Each of the nine infants who died was treated during conflict, however only three were related to trauma (i.e., two gunshot wounds, one severe burn). Three additional infant deaths were from congenital disease (e.g. giant omphalocele, gastroschisis, undefined), two from intussusception, and one from peritonitis of unknown etiology.

3. Discussion

This study aimed to describe surgical care for children at MSF-OCB projects from 2008 to 2014, with a focus on age-specific procedure distributions and trauma surgery. Surgery for children during humanitarian crises was very common, particularly during conflict. Traumatic injuries were most common across all project-types, but non-trauma and maternal/fetal pathology were also prevalent. The most common procedures require a variety of operative skills, from debridements and bowel resections to cesareans and fracture fixation. Additionally, this study demonstrated that infants, as well as children undergoing general anesthesia with an airway, had greater odds of death than other children undergoing surgery. These findings are useful for humanitarian surgical assistance programs planning to strategically allocate resources and clinicians embarking on humanitarian missions. This study also contributes to the evidence base that supports the need to advocate for the protection of children during war.

Several descriptions of the operative epidemiology of children treated by humanitarian projects have been published [16,26–32]. However, most of these refer to specialty- and/or country-specific projects in cardiac surgery, neurosurgery, otolaryngology, and ophthalmology during non-disaster, non-conflict time periods [16,26–32]. Recently, descriptions of surgical care in post-earthquake Haiti and during Operation Iraqi Freedom and Operation Enduring Freedom have also been published [32,33,36]. However, large, multi-country descriptions of pediatric surgical care from humanitarian surgical assistance projects during crisis have not been published. Continuing Promise, a surgical assistance project of the United States Navy, deployed to seven peace-time countries in Central and South America, and treated 340 children between April and July 2009 [31]. The most frequently performed procedures were inguinal and umbilical hernias (23% and 14%, respectively), followed by circumcision (9%), mass excision (8%), and hydrocele/varicocele/orchiopexy (5%) [31]. Surgical sub-specialists performed 36% of cases [31].

In disaster settings, orthopedic injuries and wounds account for a greater proportion of pediatric surgical cases than before a disaster. For example, the Israeli Defence Force Medical Corps dispatched a field hospital after the 2010 Haiti earthquake. The team treated 318 pediatric patients in 10 days; 57 (21%) required surgery, most commonly performing wound debridement (20%), external fixation (16%) and amputation (14%) [37]. The United States Naval Ship Comfort treated 237 pediatric surgical patients in Haiti after the earthquake; orthopedic procedures represented 71% of the cases [38]. Partners in Health/

Zanmi Lasante-run hospitals in Haiti reported on procedures before and after the earthquake. About 21% of operations completed between July 2009 and July 2010 were for children [33]. In pre-earthquake Haiti, congenital anomalies accounted for 34% of procedures, hernia 21%, and genitourinary and obstetric causes 14% each, while trauma and burns accounted for only 3% of pediatric operations [33]. In post-earthquake Haiti, trauma and burns accounted for 39% of pediatric operations [33]. These reports demonstrate that the scope of humanitarian surgical care during and after crisis differs significantly from that in usual LMIC settings. Our study moved beyond single-country descriptions, and explored in detail the breadth and depth of surgical procedures performed on children at a variety of project-types in countries around the world, all with different crises and struggles, making our findings more generalizable and informative for the physician and trainee interested in humanitarian work and global surgery as well as for foundation-based resources allocation.

MSF-OCB projects do not focus on pediatric surgery specifically. Many of the procedures that may fall under a pediatric surgeon's purview in a high-income country are completed by a general surgeon or a medical officer in LMICs and during humanitarian crisis. Therefore, outside of emergency procedures for congenital anomalies (e.g. neonatal intestinal obstruction), surgeon availability may drive the relative proportions of operative indications performed in our study population. If more pediatric surgeons participated in MSF projects, more congenital anomalies could be addressed, considerate of perioperative capacity. Ultimately, pediatric surgical care capacity building is required to reduce unmet surgical care needs in children [34]. This includes medical and nursing education, capital investment in infrastructure (e.g. essential surgical care equipment and supplies, incubators, pediatric-sized nondrug consumables), creation and maintenance of a reliable supply chain, and dependable financing mechanisms. In the meantime, dedicated pediatric surgical assistance programs are required to augment current demand in LMICs by providing patient care and on-the-job training to local staff. [35]

A few particular findings in our study warrant additional comment: in particular, MSF-OCB projects cared for a significant number of burn injuries, particularly in younger ages. Children in LMICs are at high-risk of burn injury for a number of reasons; particularly, proximity to open cooking fires. Additionally, safe infrastructure and behavior that typically protect children from injury are often disrupted during conflict or after natural disaster [39]. These data corroborate findings from a recent review on burns in LMICs, wherein burn injury was more common among infants and toddlers from birth to 4 years of age, and then tapered off during adolescence [38]. Pediatric burn care demands significant resources from surgical projects compared to other conditions given the need for serial procedures (e.g., extensive debridements), large dressing changes under anesthesia, intensive care and long hospitalizations [40]. Therefore, anticipating this burden and ensuring that the knowledge, skills and resources necessary to adequately care for pediatric injury and burns are available to humanitarian surgical projects are important.

Salient in our findings, about one in every ten children who underwent surgery at MSF-OCB projects was a victim of land mines, bombs, firearms, assault, stabbings, gender-based violence or torture. Humanitarian surgical teams are in a unique position to identify a pattern of intolerable acts affecting children given their exposure to these injuries and understanding

of the contextual complexities. Subsequently, surgical teams have an opportunity to advocate for the protection of children and other vulnerable populations during conflict. Examples of successful healthcare-led recognition and systematic documentation of such acts that built an evidence-base for advocacy that, in turn, led to significant steps toward civilian protection include the Mine Ban Treaty, Convention on Cluster Munitions and the conference of the Ethiopian Society of Obstetricians and Gynecologists and Synergie des Femmes pour les Victimes des Violences Sexuelles [41–43]. These agreements or meetings provided a platform for the creation of international legislation, amendments to the rules of war and the establishment of specific injury management guidelines.

Congenital operations are beyond the intended scope of MSF-OCB projects. However, the existing literature supports a role for surgical assistance programs to reduce this burden when not operating during crisis and when specialist care is available [4,19,33,44]. Higashi and colleagues described a significant burden of disease from common congenital anomalies in LMICs (e.g., cleft lip and palate, intestinal atresia, neural tube defects) [19], wherein 57% of the 21.6 million DALYs incurred by congenital anomalies may potentially be addressed by access to surgical care [19]. Gupta et al. found that 7% of all unmet surgical need in Nepal was due to congenital anomalies [45]. Groen et al. estimated that need to be 3% in Sierra Leone [46]. MSF-OCB refrains from performing surgery for congenital anomalies when possible for two reasons: first, there is an extraordinary demand for emergency procedures (e.g., injury, acute abdomen); and second, there is a lack of humanitarian staff with the experience or training necessary to care for complex anomalies (e.g., cleft lip, imperforate anus). However, humanitarian surgical assistance programs that do not operate during crisis may consider addressing the congenital disease burden and building pediatric surgical capacity as part of their directive.

The perioperative death rate was low in MSF-OCB projects. However, perioperative death among infants was significantly higher compared to older age groups. Independent risk factors for perioperative death were identified: ASA score 3, emergency operation, general anesthesia with an airway, and conflict project. Most of these risk factors were not modifiable at the hospital-level. However, particular care should be taken when deciding to operate on an infant or determining that a child requires an airway. The perioperative capacity of many hospitals and humanitarian projects in LMICs is extremely limited [15]. As a result, teams often work with few physical resources and rely on task-sharing [47,48]. While the outcomes of projects that rely on task-sharing are similar to projects with a well-trained anesthetist [48], complex cases (e.g., surgery for infants, management of children in extremis) require greater resources, training and experience. Taking these into consideration when resourcing projects and training task-sharers is important.

Though this study represents the largest description of surgeries for children during humanitarian crises to date, the data must be interpreted cautiously. The operational data used for this study do not include certain variables that would be helpful for more accurately estimating resource needs for future humanitarian projects (e.g., prehospital deaths, those that did not seek care but had a surgical condition, children with conditions too complex than resources could manage or in too great a number to be treated, specific-item consumption (e.g. gauze use for burn care, plaster use for fractures)). Procedural details and

specifics related to operative indication(s) were limited to the coding structure of the PSR [20]. Similarly, detailed clinical data that could better guide quality improvement programs were not collected (e.g., time to theatre after diagnosis, post-operative pain assessments and longer-term outcome variables, such as in-hospital death or discharge disability scores). The importance of incorporating these variables into routine data collection by surgical projects cannot be overstated. However, doing so with limited number of staff and in projects that typically operate above capacity is complex and potentially detrimental to the quality or efficiency of care in the short run. Lastly, the perioperative death rate reported in this study was unexpectedly low and does not include the mortality related to surgical disease in the pediatric population more broadly. This was likely the result of two factors: i) many children died before reaching the hospital or were not operated on because they would have required care beyond the capabilities of the facility at that time; and ii) the indicator does not incorporate deaths after discharge from the recovery room. The death rate of children during crisis is certainly higher than what is reported here. Despite these limitations, these results allow reasonable conclusions to be drawn with regard to the large burden of pediatric surgical disease in LMICs during crisis and the need to incorporate pediatric-specific considerations into the planning, monitoring and evaluation processes of humanitarian surgical assistance programs. Further, by describing pediatric operative epidemiology across countries, projects and time, our findings are more generalizable than hospital- or country-specific descriptions previously published.

3.1. Conclusions

Nearly a quarter of surgical procedures performed at MSF-OCB projects were for children, with injury being the most common pediatric operative indication. The case mix was diverse and required a broad skill-set. Among the many findings that require consideration in current and future humanitarian surgical projects are the greater odds of death among infants and children who required an airway as well as the considerable unmet surgical need for congenital anomalies. This study identified several ways in which the humanitarian surgical community can potentially reduce the death and disability of children living in LMICs during crisis: better allocate resources to hospitals and humanitarian surgical assistance projects appropriately, with particular consideration of pediatric-sized supplies; improve the recognition of high-risk children and training for non-pediatric surgeons and anesthetists caring for this age group; and advocate for the role of surgery in public health, for the prevention of injuries among children affected by the breakdown of safe society, and for the protection of vulnerable populations during conflict. By responding to these challenges, the death and disability of children living in LMICs affected by crisis might be reduced and a safer, healthier and more productive generation promoted.

Acknowledgments

We thank the dedicated national and international staff that provided the expertise and care for these patients. In addition, we thank all of those involved in data collection and management for their contribution to those who will require humanitarian surgical care in the future.

Appendix

Appendix A

All pediatric surgical procedures completed by Médecins Sans Frontières Operations Centre Brussels projects from 2008 to 2014, rank ordered by overall population proportion and stratified by age group and presented with rank order, frequency, and relative proportion for each procedure type; n = 26,284.

	Total		<1 year		1–4 years		5–9 years		10–14 years		15–17 years	
	N	%	Rank; N	%	Rank; N	%	Rank; N	%	Rank; N	%	Rank; N	%
Simple wound ^b	1; 5539	(21.1)	1; 408	(36.6)	1; 1424	(25.5)	1; 1470	(21.1)	2; 1466	(20.3)	3; 771	(14.2)
Extensive debridement ^c	2; 4271	(16.3)	4; 98	(8.8)	3; 647	(11.6)	2; 1127	(16.2)	1; 1559	(21.6)	2; 840	(15.5)
Burn care, dressing changes	3; 2794	(10.6)	2; 208	(18.7)	2; 1297	(23.3)	3; 844	(12.1)	6; 321	(4.5)	10; 124	(2.3)
Drain insertion ^d	4; 2266	(8.6)	3; 157	(14.1)	4; 496	(8.9)	5; 622	(8.9)	4; 656	(9.1)	5; 335	(6.2)
Fracture reduction, traction	5; 1895	(7.2)	10; 9	(0.8)	6; 246	(4.4)	4; 713	(10.3)	3; 686	(9.5)	6; 241	(4.5)
Cesarean delivery	6; 1492	(5.7)	–	–	–	–	31 ^a ; 1	(0.01)	17; 70	(1.0)	1; 1421	(26.2)
Bowel resection or other GI surgery	7; 1416	(5.4)	6; 54	(4.9)	10; 110	(2.0)	8; 276	(4.0)	5; 628	(8.7)	4; 348	(6.4)
Hernia, hydrocele, hemorrhoids ^e	8; 1400	(5.3)	5; 62	(5.6)	5; 477	(8.6)	6; 435	(6.3)	8; 265	(3.7)	9; 161	(3.0)
Open reduction internal fixation	9; 969	(3.7)	–	–	8; 126	(2.3)	7; 350	(5.0)	7; 306	(4.2)	7; 187	(3.5)
Exploratory laparotomy	10; 621	(2.4)	7; 39	(3.5)	12; 75	(1.4)	10; 142	(2.0)	9; 192	(2.7)	8; 173	(3.2)
External fixation	11; 478	(1.8)	–	–	17; 38	(0.7)	9; 163	(2.3)	11; 177	(2.5)	12; 100	(1.9)
Skin/muscle graft or flap	12; 432	(1.6)	11 ^a ; 7	(0.6)	13; 56	(1.0)	11 ^a ; 114	(1.6)	10; 181	(2.5)	15; 74	(1.4)
Other general surgical procedures	13; 361	(1.4)	8; 30	(2.7)	11; 83	(1.5)	16; 73	(1.1)	13; 96	(1.3)	13; 79	(1.5)
Foreign body removal	14; 358	(1.4)	11 ^a ; 7	(0.6)	9; 125	(2.2)	13; 99	(1.4)	16; 79	(1.1)	17; 48	(0.9)
Hardware removal	15; 304	(1.2)	–	–	16; 40	(0.7)	11 ^a ; 114	(1.6)	12; 101	(1.4)	16; 49	(0.9)
Other orthopedic procedures	16; 265	(1.0)	16 ^a ; 1	(0.1)	14; 49	(0.9)	14; 88	(1.3)	14; 92	(1.3)	20; 35	(0.7)
Urologic procedures	17; 261	(1.0)	14; 4	(0.4)	7; 133	(2.4)	15; 76	(1.1)	20; 38	(0.5)	24; 10	(0.2)
Limp amputation	18; 250	(1.0)	9; 10	(0.9)	15; 47	(0.8)	17; 65	(0.9)	15; 83	(1.2)	19; 45	(0.8)
Osteomyelitis curettage	19; 153	(0.6)	–	–	21; 14	(0.3)	18; 54	(0.8)	18; 64	(0.9)	23; 21	(0.4)
Other obstetrical/gynecologic proc.	20; 143	(0.5)	15 ^a ; 3	(0.3)	18 ^a ; 17	(0.3)	20; 20	(0.3)	21; 25	(0.4)	14; 78	(1.4)
Solid viscus procedures	21; 125	(0.5)	13 ^a ; 5	(0.5)	18 ^a ; 17	(0.3)	19; 40	(0.6)	19; 39	(0.5)	21 ^a ; 24	(0.4)
Dilation and curettage	22; 118	(0.5)	–	–	–	–	31 ^a ; 1	(0.0)	27 ^a ; 5	(0.1)	11; 112	(2.1)
Obstetric fistula	23; 55	(0.2)	–	–	–	–	–	–	24 ^a ; 8	(0.1)	18; 47	(0.9)
Plastic procedures	24; 42	(0.2)	15 ^a ; 3	(0.3)	18 ^a ; 17	(0.3)	21 ^a ; 11	(0.2)	26 ^a ; 6	(0.1)	27 ^a ; 5	(0.1)
Neurosurgical procedures	25; 40	(0.2)	13 ^a ; 5	(0.5)	25; 5	(0.1)	24; 10	(0.1)	22; 12	(0.2)	25; 8	(0.2)
Hysterectomy, pelvic tumor removal	26; 34	(0.1)	–	–	27 ^a ; 3	(0.1)	28 ^a ; 3	(0.0)	27 ^a ; 5	(0.1)	22; 23	(0.4)
Ophthalmology procedures	27; 32	(0.1)	16 ^a ; 1	(0.3)	22 ^a ; 8	(0.1)	21 ^a ; 11	(0.2)	25 ^a ; 7	(0.1)	27 ^a ; 5	(0.1)
Ectopic pregnancy	28 ^a ; 30	(0.1)	–	–	–	–	31 ^a ; 1	(0.0)	27 ^a ; 5	(0.1)	21 ^a ; 24	(0.4)
Otolaryngology procedures	28 ^a ; 30	(0.1)	–	–	22 ^a ; 8	(0.1)	21 ^a ; 11	(0.2)	25 ^a ; 7	(0.1)	28 ^a ; 4	(0.1)
Vascular procedures	30 ^a ; 21	(0.1)	15 ^a ; 3	–	28; 2	(0.1)	25; 9	(0.1)	23; 10	(0.1)	28 ^a ; 4	(0.1)
Thoracotomy	30 ^a ; 21	(0.1)	–	–	27 ^a ; 3	(0.1)	26 ^a ; 4	(0.0)	25 ^a ; 7	(0.1)	26; 6	(0.0)
Other specialist procedures	32; 22	(0.1)	–	(0.3)	24; 6	(0.0)	30; 2	(0.1)	26 ^a ; 6	(0.1)	29 ^a ; 2	(0.0)
Joint surgery	33; 19	(0.1)	–	–	26; 4	(0.1)	28 ^a ; 3	(0.0)	24 ^a ; 8	(0.1)	28 ^a ; 4	(0.1)
Nerve procedures	34; 11	(0.0)	–	–	–	–	31 ^a ; 1	(0.0)	27 ^a ; 5	(0.1)	27 ^a ; 5	(0.1)
Oral and maxillofacial procedures	35; 10	(0.0)	–	–	27 ^a ; 3	(0.1)	26 ^a ; 4	(0.1)	29; 1	(0.0)	29 ^a ; 2	(0.0)

	Total		<1 year		1–4 years		5–9 years		10–14 years		15–17 years	
	N	%	Rank; N	%	Rank; N	%	Rank; N	%	Rank; N	%	Rank; N	%
Bone graft	36; 6	(0.0)	–	–	–	–	31 ^a ; 1	(0.0)	28; 3	(0.0)	29 ^a ; 2	(0.0)
Total	26,284	(100)	1114	(100)	5576	(100)	6958	(100)	5975	(100)	6661	(100)

^aIndicates tie.

^bIncludes abscess drainage, circumcision.

^cIncludes fasciotomy, digital amputation.

^dIncludes chest tube, puncture or drainage of cavity.

^eIncludes obstruction, stones, tubal, etc.

Appendix B

All surgical indications for procedures completed on children by Médecins Sans Frontières Operations Centre Brussels projects from 2008 to 2014, with frequency and relative proportion presented among each project-type, n = 24,576.

	Total		Disaster		Maternity		Support		Conflict	
Trauma	13,984	(56.9)	2508	(78.6)	42	(3.0)	2256	(37.7)	9178	(65.7)
Mines	119	(0.5)	0	(0.0)	0	(0.0)	11	(0.2)	108	(0.8)
Gunshot wounds	1187	(4.8)	76	(2.4)	0	(0.0)	213	(3.6)	898	(6.4)
Bombs	552	(2.3)	1	(0.0)	0	(0.0)	83	(1.4)	468	(3.4)
Stab wounds	329	(1.3)	78	(2.4)	0	(0.0)	84	(1.4)	167	(1.2)
Assault	62	(0.3)	1	(0.0)	0	(0.0)	9	(0.2)	52	(0.4)
Rape	18	(0.1)	0	(0.0)	6	(0.4)	3	(0.1)	9	(0.1)
Torture	53	(0.2)	5	(0.2)	0	(0.0)	2	(0.0)	46	(0.3)
Traffic ^a	3016	(12.3)	626	(19.6)	1	(0.1)	294	(4.9)	2095	(15.0)
Burns ^b	3409	(13.9)	132	(4.1)	17	(1.2)	832	(13.9)	2428	(17.4)
Other injuries ^c	5239	(21.3)	1589	(49.8)	18	(1.3)	725	(12.1)	2907	(20.8)
Non-trauma	8751	(35.6)	593	(18.6)	540	(37.8)	3449	(57.6)	4169	(29.9)
Abscess	4471	(18.2)	410	(12.9)	157	(11.0)	1341	(22.4)	2563	(18.4)
Tropical disease	204	(0.8)	23	(0.7)	64	(4.5)	18	(0.3)	99	(0.7)
Vasculopathy	84	(0.3)	4	(0.1)	7	(0.5)	30	(0.5)	43	(0.3)
Benign tumors, cysts	234	(1.0)	10	(0.3)	7	(0.5)	123	(2.1)	94	(0.7)
Malignant tumors	28	(0.1)	3	(0.1)	1	(0.1)	6	(0.1)	18	(0.1)
Tumor, other/unknown	102	(0.4)	0	(0.0)	3	(0.2)	63	(1.1)	36	(0.3)
Iatrogenic ^d	69	(0.3)	4	(0.1)	1	(0.1)	11	(0.2)	53	(0.4)
Congenital anomaly	200	(0.8)	7	(0.2)	21	(1.5)	74	(1.2)	98	(0.7)
Other, obstruction, etc.	3341	(13.6)	132	(4.1)	278	(19.5)	1778	(29.7)	1153	(8.3)
Hemorrhage (non-trauma)	18	(0.1)	0	(0.0)	1	(0.1)	5	(0.1)	12	(0.1)
Maternal/fetal	1841	(7.5)	90	(2.8)	847	(59.3)	282	(4.7)	622	(4.5)
Maternal/fetal	1568	(6.4)	87	(2.7)	719	(50.3)	220	(3.7)	542	(3.9)
Post-partum hemorrhage	119	(0.5)	2	(0.1)	62	(4.3)	13	(0.2)	42	(0.3)
Post-partum complications ^e	154	(0.6)	1	(0.0)	66	(4.6)	49	(0.8)	38	(0.3)

^aIncludes driver or passenger of a motorized vehicle, pedestrians, or cyclists.

^bIncludes fire, scald, and chemical burns.

^cIncludes foreign objects, natural catastrophes, work and domestic accidents, etc.

^dIncludes traditional and clandestine medicine.

^eIncludes endometriosis, vesico-vaginal fistula, uterine perforation, etc.

Appendix C

Demographic and procedural details for all peri-operative deaths in children captured in the PSR for Médecins Sans Frontières Operations Centre Brussels projects from 2008 to 2014, n = 42.

Project location	Mission-type	Age	Sex	Year	Urgency	ASA	Order	Anesthesia	Indication	Indication details	Notes
Gogrial, South Sudan	Conflict	1d	M	2012	Emergency	3	1	GA w/ airway	Non-trauma	Congenital	Giant omphalocele
Masisi, Democratic Republic of Congo	Conflict	1d	F	2010	Emergency	3	1	GA w/ airway	Non-trauma	Congenital	Gastroschisis
Lashkar-Gah, Afghanistan	Conflict	2d	M	2012	Emergency	1	1	GA w/ airway	Trauma	Gunshot wound	
Masisi, Democratic Republic of Congo	Conflict	30d	M	2009	Emergency	1	1	GA w/o airway	Trauma	Gunshot wound	Lumbar gunshot wound
Gogrial, South Sudan	Conflict	30d	F	2011	Emergency	2	1	GA w/ airway	Non-trauma	Congenital	
Masisi, Democratic Republic of Congo	Conflict	3 m	F	2008	Emergency	4	1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	Intussusception
Gogrial, South Sudan	Conflict	4 m	M	2013	Emergency	3	1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	Intussusception
Masisi, Democratic Republic of Congo	Conflict	6 m	F	2011	Urgent	3	2	GA w/o airway	Trauma	Burns	Third degree burns
Masisi, Democratic Republic of Congo	Conflict	6 m	M	2011	Urgent	1	2	GA w/ airway	Non-trauma	Abscess	Peritonitis
Masisi, Democratic Republic of Congo	Conflict	1y	M	2008	Emergency	5	1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	
Kunduz, Afghanistan	Conflict	1y	M	2013	Emergency	4	1	GA w/ airway	Trauma	Traffic	
Bangassou, Central African Republic	Conflict	2y	F	2014	Urgent	1	2	GA w/o airway	Non-trauma	Abscess	
Gogrial, South Sudan	Conflict	2y	M	2011	Emergency	3	1	GA w/o airway	Trauma	Gunshot wound	Left arm amputation
Kunduz, Afghanistan	Conflict	3y	F	2013	Emergency	4	1	GA w/ airway	Trauma	GSW	
Lubutu, Democratic Republic of Congo	Support	4y	F	2009	Emergency	5	1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	
Kunduz, Afghanistan	Conflict	5y	M	2013	Emergency	3	2	GA w/o airway	Trauma	Other injuries	
Kunduz, Afghanistan	Conflict	5y	M	2011	Emergency	4	1	GA w/ airway	Trauma	Traffic	
Kunduz, Afghanistan	Conflict	5y	M	2014	Emergency	5	2	Combined, Other	Trauma	Other injuries	
Lashkar-Gah, Afghanistan	Conflict	6y	F	2011	Emergency	4	1	GA w/ airway	Trauma	Traffic	
Lashkar-Gah, Afghanistan	Conflict	7y	M	2012	Emergency	5	1	GA w/ airway	Non-trauma	Hemorrhage not trauma	
CitŽ-Soleil, Haiti	Disaster	8y	F	2010	Emergency		1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	
Kunduz, Afghanistan	Conflict	8y	M	2013	Emergency	3	1	GA w/ airway	Trauma	Other injuries	
Tabarre, Haiti	Disaster	9y	M	2013	Emergency	2	1	GA w/ airway	Trauma	Other injuries	
Mon, India	Support	11y	M	2012	Emergency	4	1	GA w/ airway	Trauma	Traffic	Hypovolemic shock
Masisi, Democratic Republic of Congo	Conflict	11y	F	2009	Emergency	1	1	GA w/ airway	Non-trauma	Vasculopathy	Intussusception
Masisi, Democratic Republic of Congo	Conflict	11y	M	2010	Emergency	5	1	GA w/ airway	Trauma	Traffic	Splenic rupture
Masisi, Democratic Republic of Congo	Conflict	12y	F	2014	Emergency	3	1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	Volvulus, necrotic bowel
Kunduz, Afghanistan	Conflict	12y	M	2014	Urgent	1	2	GA w/ airway	Trauma	Traffic	
Kunduz, Afghanistan	Conflict	12y	M	2012	Emergency	1	1	GA w/ airway	Trauma	Other injuries	
Lubutu, Democratic Republic of Congo	Support	13y	F	2009	Emergency	2	1	GA w/o airway	Non-trauma	Unknown type of tumor	Respiratory distress
Kunduz, Afghanistan	Conflict	13y	M	2013	Emergency	1	1	Combined, Other	Trauma	Traffic	
Masisi, Democratic Republic of Congo	Conflict	13y	M	2008	Emergency	3	1	GA w/o airway	Non-trauma	Tropical disease	
Dargai, Pakistan	Support	15y	M	2010	Emergency	3	1	GA w/ airway	Trauma	GSW	
Dargai, Pakistan	Support	15y	F	2011	Emergency	1	1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	
Lubutu, Democratic Republic of Congo	Support	15y	F	2008	Emergency	2	1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	

Project location	Mission-type	Age	Sex	Year	Urgency	ASA	Order	Anesthesia	Indication	Indication details	Notes
Lashkar-Gah, Afghanistan	Conflict	16y	F	2012	Emergency	3	1	GA w/ airway	OB	Maternal fetal	
Batangafo, Central African Republic	Conflict	16y	F	2009	Emergency	4	1	GA w/o airway	OB	Maternal fetal	Still birth
Dargai, Pakistan	Support	16y	M	2009	Urgent	1	2	Local, Regional, Spinal	Trauma	Traffic	
Masisi, Democratic Republic of Congo	Conflict	16y	F	2010	Emergency	5	1	GA w/ airway	Non-trauma	Obstruction, stones, hernia, etc.	Poly-trauma
Guri-El, Somalia	Conflict	17y	M	2010	Emergency	5	U	GA w/o airway	Trauma	Gunshot wound	
Bangolo, Ivory Coast	Conflict	17y	F	2008	Emergency	3	1	GA w/ airway	OB	Maternal fetal	Retained products of conception
Tabarre, Haiti	Disaster	17y	M	2012	Emergency	3	1	GA w/ airway	Trauma	Traffic	

OB, obstetric/gynecologic; U, unplanned.

References

- Farmer PE, Kim JY. Surgery and global health: a view from beyond the OR. *World J Surg.* 2008; 32:533–6. [PubMed: 18311574]
- Ozgediz D, Jamison D, Cherian M, et al. The burden of surgical conditions and access to surgical care in low- and middle-income countries. *Bull World Health Organ.* 2008; 86:646–7. [PubMed: 18797625]
- Weiser TG, Regenbogen SE, Thompson KD, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet.* 2008; 372:139–44. [PubMed: 18582931]
- Mock CN, Donkor P, Gawande A, et al. Essential surgery: key messages from Disease Control Priorities, 3rd edition. *Lancet.* 2015; 385(9983):2209–12. [PubMed: 25662414]
- Ozgediz D, Poenaru D. The burden of pediatric surgical conditions in low and middle income countries: a call to action. *J Pediatr Surg.* 2012; 47:2305–11. [PubMed: 23217895]
- Bickler S, Ozgediz D, Gosselin R, et al. Key concepts for estimating the burden of surgical conditions and the unmet need for surgical care. *World J Surg.* 2010; 34:374–80. [PubMed: 19862570]
- Bickler SW, Rode H. Surgical services for children in developing countries. *Bull World Health Organ.* 2002; 80:829–35. [PubMed: 12471405]
- Ameh EA, Adejuyigbe O, Nmadu PT. Pediatric surgery in Nigeria. *J Pediatr Surg.* 2006; 41:542–6. [PubMed: 16516632]
- Okoye MT, Ameh EA, Kushner AL, et al. A pilot survey of pediatric surgical capacity in West Africa. *World J Surg.* 2014; 39:669–76.
- Elhalaby EA, Uba FA, Borgstein ES, et al. Training and practice of pediatric surgery in Africa: past, present, and future. *Semin Pediatr Surg.* 2012; 21:103–10. [PubMed: 22475115]
- Chirdan LB, Ameh EA, Abantanga FA, et al. Challenges of training and delivery of pediatric surgical services in Africa. *J Pediatr Surg.* 2010; 45:610–8. [PubMed: 20223329]
- Bickler SW, Kyambi J, Rode H. Pediatric surgery in sub-Saharan Africa. *Pediatr Surg Int.* 2001; 17:442–7. [PubMed: 11527185]
- Kushner AL, Groen RS, Kamara TB, et al. Assessment of pediatric surgery capacity at government hospitals in Sierra Leone. *World J Surg.* 2012; 36:2554–8. [PubMed: 22851151]
- Ademuyiwa AO, Bode CO, Adesanya OA, et al. Non-trauma related paediatric abdominal surgical emergencies in Lagos, Nigeria: epidemiology and indicators of survival. *Niger Med J.* 2012; 53:76–9. [PubMed: 23271850]
- Ankomah J, Stewart BT, Oppong-Nketia V, et al. Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana. *J Pediatr Surg.* 2015 Nov; 50(11):1922–7. [PubMed: 25841284]
- Calisti A, Belay K, Mazzoni G, et al. Promoting major pediatric surgical care in a low-income country: a 4-year experience in Eritrea. *World J Surg.* 2011; 35:760–6. [PubMed: 21327599]

17. Kushner AL, Kallon C, Kamara TB. Free health care in Sierra Leone: the effect on pediatric surgery. *J Pediatr Surg.* 2012; 47:628–9.
18. Gupta S, Mahmood U, Gurung S, et al. Burns in Nepal: a population based national assessment. *Burns.* 2014; 41(5):1126–32. [PubMed: 25523087]
19. Higashi H, Barendregt JJ, Kassebaum NJ, et al. The burden of selected congenital anomalies amenable to surgery in low and middle-income regions: cleft lip and palate, congenital heart anomalies and neural tube defects. *Arch Dis Child.* 2014; 100(3):233–8. [PubMed: 25260520]
20. Wong EG, Trelles M, Dominguez L, et al. Surgical skills needed for humanitarian missions in resource-limited settings: common operative procedures performed at Medecins Sans Frontieres facilities. *Surgery.* 2014; 156:642–9. [PubMed: 24661767]
21. Chu K, Rosseel P, Trelles M, et al. Surgeons without borders: a brief history of surgery at Medecins Sans Frontieres. *World J Surg.* 2010; 34:411–4. [PubMed: 19672649]
22. Activity report 2011. London: Medecins Sans Frontieres; 2011.
23. International activity report 2012. London: Medecins Sans Frontieres; 2012.
24. OCB medical activity report 2013. Belgium: Medecins Sans Frontieres; 2013.
25. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. [Accessed April 2, 2015] Web-based Injury Statistics Query and Reporting System (WISQARS) [online]. 2013. Available from URL: <http://www.cdc.gov/injury/wisqars/>
26. Marom T, Dagan D, Weiser G, et al. Pediatric otolaryngology in a field hospital in the Philippines. *Int J Pediatr Otorhinolaryngol.* 2014; 78:807–11. [PubMed: 24656226]
27. Davis MC, Than KD, Garton HJ. Cost effectiveness of a short-term pediatric neurosurgical brigade to Guatemala. *World Neurosurg.* 2014; 82:974–9. [PubMed: 25150203]
28. Nguyen N, Jacobs JP, Dearani JA, et al. Survey of nongovernmental organizations providing pediatric cardiovascular care in low- and middle-income countries. *World J Pediatr Congenit Heart Surg.* 2014; 5:248–55. [PubMed: 24668973]
29. Rogers DJ, Collins C, Carroll R, et al. Operation airway: the first sustainable, multidisciplinary, pediatric airway surgical mission. *Ann Otol Rhinol Laryngol.* 2014; 123:726–33. [PubMed: 24835243]
30. Unite for Site. [Accessed March 10, 2015] Global delivery programs at a glance. Available at URL: <http://www.uniteforsight.org/whatwe-do/global-health-delivery>
31. Walk RM, Glaser J, Marmon LM, et al. Continuing promise 2009—assessment of a recent pediatric surgical humanitarian mission. *J Pediatr Surg.* 2012; 47:652–7. [PubMed: 22498377]
32. Klimo P Jr, Ragel BT, Scott WH Jr, et al. Pediatric neurosurgery during Operation Enduring Freedom. *J Neurosurg Pediatr.* 2010; 6:107–14.
33. Hughes CD, Nash KA, Alkire BC, et al. The impact of natural disaster on pediatric surgical delivery: a review of Haiti six months before and after the 2010 earthquake. *J Health Care Poor Underserved.* 2012; 23:523–33. [PubMed: 22643604]
34. Patel PB, Hoyler M, Maine R, et al. An opportunity for diagnostic development in global surgery: cleft lip and palate care in resource limited settings. *Plast Surg Int.* 2012; 1–12. 892437.
35. Magee W, Raimondi H, Beers M, et al. Effectiveness of international surgical program model to build local sustainability. *Plast Surg Int.* 2012; 1:6–185725.
36. McIntyre T, Hughes CD, Pauyo T, et al. Emergency surgical care delivery in post-earthquake Haiti: Partners in Health and Zanmi Lasante experience. *World J Surg.* 2011; 35:745–50. [PubMed: 21249359]
37. Farfel A, Assa A, Amir I, et al. Haiti earthquake 2010: a field hospital pediatric perspective. *Eur J Pediatr.* 2011; 170:519–25. [PubMed: 21340487]
38. Walk RM, Donahue TF, Sharpe RP, et al. Three phases of disaster relief in Haiti—pediatric surgical care on board the United States Naval Ship Comfort. *J Pediatr Surg.* 2011; 46:1978–84. [PubMed: 22008338]
39. Donaldson RI, Hung YW, Shanovich P, et al. Injury burden during an insurgency: the untold trauma of infrastructure breakdown in Baghdad, Iraq. *J Trauma.* 2010; 69:1379–85. [PubMed: 21150518]

40. Forjuoh SN. Burns in low- and middle-income countries: a review of available literature on descriptive epidemiology, risk factors, treatment, and prevention. *Burns*. 2006; 32:529–37. [PubMed: 16777340]
41. United Nations. [Accessed March 15, 2015] Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction. 1997. Available at <http://www.refworld.org/docid/3ae6b3ad0.html>
42. Addis Ababa Fistula Hospital, EngenderHealth/The ACQUIRE Project, Ethiopian Society of Obstetricians and Gynecologists, et al.. Traumatic gynecologic fistula: a consequence of sexual violence in conflict settings. New York: EngenderHealth/The ACQUIRE Project; 2006.
43. Diplomatic conference for the adoption of a convention on cluster munitions. Dublin: International Committee of the Red Cross; 2008.
44. Del Rossi C, Fontechiari S, Casolari E, et al. Treatment of congenital anomalies in a missionary hospital in Bangladesh: results of 17 paediatric surgical missions. *Acta Biomed*. 2008; 79:260–3. [PubMed: 19260390]
45. Gupta S, Shrestha S, Ranjit A, et al. Conditions, preventable deaths, procedures and validation of a countrywide survey of surgical care in Nepal. *Br J Surg*. 2015; 102:700–7. [PubMed: 25809125]
46. Groen RS, Samai M, Stewart KA, et al. Untreated surgical conditions in Sierra Leone: a cluster randomised, cross-sectional, countrywide survey. *Lancet*. 2012; 380:1082–7. [PubMed: 22898076]
47. Eliah E, Lewallen S, Kalua K, et al. Task shifting for cataract surgery in eastern Africa: productivity and attrition of non-physician cataract surgeons in Kenya, Malawi and Tanzania. *Hum Resour Health*. 2014; 12(Suppl. 1):S4, 1–7. [PubMed: 25859627]
48. Chu KM, Ford NP, Trelles M. Providing surgical care in Somalia: a model of task shifting. *Confl Health*. 2012; 5:12, 1–5.

Countries where MSF-OCB provided surgical assistance: Afghanistan (AFG), Burundi (BDI), Central African Republic (CAF), Ivory Coast (CIV), Democratic Republic of Congo (COD), Haiti (HTI), India (IND), Kenya (KEN), Mali (MLI), Mauritania (MRT), Niger (NER), Pakistan (PAK), Philippines (PHL), Sudan (SDN), Sierra Leone (SLE), Somalia (SOM), South Sudan (SSD), Syria (SYR), and Chad (TCD). MSF assistance does not necessarily indicate surgical assistance. MSF-OCB assistance indicates only countries with surgical assistance (i.e. other countries received MSF-OCB assistance that was not surgical).

Fig. 1.

Countries where Médecins Sans Frontières (MSF) and MSF Operations Centre Brussels provided surgical assistance to children from 2008 through 2014. Countries where MSF-OCB provided surgical assistance: Afghanistan (AFG), Burundi (BDI), Central African Republic (CAF), Ivory Coast (CIV), Democratic Republic of Congo (COD), Haiti (HTI), India (IND), Kenya (KEN), Mali (MLI), Mauritania (MRT), Niger (NER), Pakistan (PAK), Philippines (PHL), Sudan (SDN), Sierra Leone (SLE), Somalia (SOM), South Sudan (SSD), Syria (SYR), and Chad (TCD). MSF assistance does not necessarily indicate surgical assistance. MSF-OCB assistance indicates only countries with surgical assistance (i.e. other countries received MSF-OCB assistance that was not surgical).

Fig. 2.
Number of pediatric operations completed per year by indication through Médecins Sans Frontières-Operations Centre Brussels (MSF-OCB) between 2008 and 2014.

Table 1

Demographic and operative characteristics of children who underwent surgery at Médecins Sans Frontières Operations Centre Brussels projects from 2008 to 2014, stratified by age group^a; n = 24,576.

	Total		<1 year		1–4 years		5–9 years		10–14 years		15–17 years	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Age, years (mean (SD), range)	8.9(5.2)	(0, 17)	0.4(0.3)	(0, 0.9)	2.6(1.0)	(1, 4)	6.9(1.4)	(5, 9)	11.9(1.4)	(10, 14)	16.1(0.8)	(15, 17)
Male	15,327	(62.3)	659	(60.1)	3430	(64.3)	4306	(66.8)	4641	(70.3)	2291	(45.0)
ASA class												
1, healthy patient	17,815	(74.7)	704	(65.1)	4044	(78.0)	4916	(78.0)	4771.00	(75.1)	3382.00	(69.2)
2, mild systemic disease	4976	(20.9)	259	(24.0)	1028	(17.9)	1129	(17.9)	1280.00	(20.2)	1280.00	(26.2)
3, severe systemic disease	901	(3.8)	96	(8.9)	140	(2.7)	220	(3.5)	260	(4.1)	185	(3.8)
4, constant threat to life	143	(0.6)	20	(1.9)	18	(0.3)	32	(0.5)	37	(0.6)	36	(0.7)
5, moribund	17	(0.1)	2	(0.2)	5	(0.1)	3	(0.0)	2	(0.0)	5	(0.1)
Anesthesia												
General with airway	2955	(12.0)	99	(9.0)	400	(7.5)	737	(11.4)	1086.00	(16.4)	633	(12.4)
General without airway	17,388	(70.8)	861	(78.6)	4545	(85.2)	5196	(80.6)	4516.00	(68.4)	2270.00	(44.6)
Regional or local	3645	(14.8)	72	(6.6)	279	(5.2)	428	(6.6)	853	(12.9)	2013.00	(39.6)
Combined or other	587	(2.4)	64	(5.8)	113	(2.1)	89	(1.4)	150	(2.3)	171	(3.4)
Surgical indication category												
Trauma	13,984	(56.9)	316	(28.8)	3068	(57.5)	4189	(64.9)	4316.00	(65.3)	2095.00	(41.2)
Non-trauma	8751	(35.6)	779	(71.1)	2263	(42.4)	2253	(34.9)	2186.00	(33.1)	1270.00	(25.0)
Maternal/Fetal	1841	(7.5)	1	(0.1)	6	(0.1)	8	(0.1)	103	(1.6)	1723.00	(33.9)
Urgency of operation												
Emergent	8356	(34.0)	303	(27.6)	1335	(25.0)	1770	(27.4)	2139.00	(32.4)	2809.00	(55.2)
Urgent	12,639	(51.4)	628	(57.3)	2919	(54.7)	3643	(56.5)	3678.00	(55.7)	1771.00	(34.8)
Elective	3581	(14.6)	165	(15.1)	1083	(20.3)	1037	(16.1)	788	(11.9)	508	(10.0)
Operation order												
First operation	16,265	(66.2)	715	(65.2)	3521	(66.0)	4031	(62.5)	4110.00	(62.2)	3888.00	(76.4)
Planned return	8198	(33.3)	378	(34.5)	1798	(33.7)	2386	(37.0)	2468.00	(37.4)	1168.00	(23.0)
Unplanned return	113	(0.5)	3	(0.3)	18	(0.3)	33	(0.5)	27	(0.4)	32	(0.6)
Death	42	(0.2)	9	(0.8)	6	(0.1)	8	(0.1)	9	(0.2)	10	(0.2)

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

SD, standard deviation; ASA, American Society of Anesthesiologists physical status score.
a All categories were statistically significantly different across age groups (Chi² test for independence; p < 0.001 for all).

Table 2

Top 95% procedures completed by Médecins Sans Frontières Operations Centre Brussels project for children from 2008 to 2014, stratified by age-group and presented with rank order,^a frequency, and relative proportion for each procedure type; n = 26,284.

	Total			<1 year			1–4 years			5–9 years			10–14 years			15–17 years		
	Rank	N	(%)	r	n	(%)	r	n	(%)	r	n	(%)	r	n	(%)	r	n	(%)
Simple wound ^b	1	5,539	(21)	1	408	(36.6)	1	1,424	(25.5)	1	1,470	(21.1)	2	1,466	(20.3)	3	771	(14.2)
Extensive debridement ^c	2	4,271	(16)	4	98	(8.8)	3	647	(11.6)	2	1,127	(16.2)	1	1,559	(21.6)	2	840	(15.5)
Bum care, dressing changes	3	2,794	(11)	2	208	(18.7)	2	1,297	(23.3)	3	844	(12.1)	6	321	(4.5)	10	124	(2.3)
Drain insertion ^d	4	2,266	(9)	3	157	(14.1)	4	496	(8.9)	5	622	(8.9)	4	656	(9.1)	5	335	(6.2)
Fracture reduction, traction	5	1,895	(7)	10	9	(0.8)	6	246	(4.4)	4	713	(10.3)	3	686	(9.5)	6	241	(4.5)
Cesarean delivery	6	1,492	(6)	–	–	–	–	–	–	16	1	(0.0)	16	70	(1.0)	1	1,421	(26.2)
GI surgery	7	1,416	(5)	6	54	(4.9)	10	110	(2.0)	8	276	(4.0)	5	628	(8.7)	4	348	(6.4)
Hernia, hydrocele	8	1,400	(5)	5	62	(5.6)	5	477	(8.6)	6	435	(6.3)	8	265	(3.7)	9	161	(3.0)
ORIF	9	969	(4)	–	–	–	8	126	(2.3)	7	350	(5.0)	7	306	(4.2)	7	187	(3.5)
Exploratory laparotomy	10	621	(2)	7	39	(3.5)	12	75	(1.4)	10	142	(2.0)	9	192	(2.7)	8	173	(3.2)
External fixation	11	478	(2)	–	–	–	17	38	(0.7)	9	163	(2.3)	11	177	(2.5)	11	100	(1.9)
Skin/muscle graft, flap	12	432	(2)	11	7	(0.6)	13	56	(1.0)	11	114	(1.6)	10	181	(2.5)	13	74	(1.4)
Other general surgical	13	361	(1)	8	30	(2.7)	11	83	(1.5)	15	73	(1.1)	13	96	(1.3)	12	79	(1.5)
Foreign body removal	14	358	(1)	11	7	(0.6)	9	125	(2.2)	13	99	(1.4)	15	79	(1.1)	15	48	(0.9)
Hardware removal	15	304	(1)	–	–	–	16	40	(0.7)	11	114	(1.6)	12	101	(1.4)	14	49	(0.9)
Other orthopedic	16	265	(1)	16	1	(0.1)	14	49	(0.9)	14	88	(1.3)	14	92	(1.3)	16	35	(0.7)

GI: gastrointestinal; ORIF: open reduction, internal fixation; r: rank.

^aRanks were shaded to more easily appreciate the change in rank between age groups. Some ranks are equivalent. Dark gray is the most common procedure performed. Procedures performed less commonly are progressively lighter shades of gray. White represents the least common procedure performed.

^bIncludes abscess drainage, circumcision.

^cIncludes fasciotomy, digital amputation.

^dIncludes chest tube, puncture or drainage of cavity.

Table 3

Unadjusted and adjusted odds of death by demographic and operative characteristics among children who underwent operation at Médecins Sans Frontières Operations Centre Brussels projects from 2008 to 2014.

	Died		Unadjusted			Adjusted ^a		
	n	(%)	OR	95% CI	p-value	OR	95% CI	p-value
Sex								
Female	18	(0.2)	Referent			Referent		
Male	24	(0.2)	0.8	(0.4, 1.5)	0.485	0.6	(0.3, 1.3)	0.204
Age								
15–17 years	10	(0.2)	Referent			Referent		
10–14 years	9	(0.2)	0.7	(.3, 1.7)	0.425	0.7	(0.3, 2.0)	0.536
5–9 years	8	(0.1)	0.6	(.2, 1.6)	0.331	0.6	(0.2, 1.8)	0.335
1–4 years	6	(0.1)	0.6	(.2, 1.6)	0.279	0.7	(0.2, 2.2)	0.496
<1 year	9	(0.8)	4.2	(1.7, 10.4)	0.002	3.8	(1.2, 12.1)	0.025
ASA class								
1, healthy patient	10	(0.1)	Referent			Referent		
2, mild systemic disease	4	(0.1)	1.4	(0.4, 4.6)	0.544	0.9	(0.3, 3.0)	0.908
3, severe systemic disease	13	(1.4)	26.1	(11.4, 59.6)	0.000	6.8	(2.7, 17.2)	0.000
4, constant threat to life	7	(4.9)	91.7	(34.4, 244)	0.000	15.3	(5.1, 45.9)	0.000
5, moribund	7	(41.2)	1247	(396, 3930)	0.000	199	(54.7, 724)	0.000
Anesthesia								
General with airway	30	(1.0)	Referent			Referent		
General without airway	9	(0.1)	0.1	(0.0, 0.1)	0.000	0.1	(0.1, 0.3)	0.000
Regional or local	1	(0.0)	0.0	(0.0, 0.2)	0.000	0.1	(0.0, 0.6)	0.017
Combined (including other)	2	(0.3)	0.3	(0.1, 1.4)	0.133	0.5	(0.1, 2.6)	0.398
Surgical indication category								
Trauma	21	(0.2)	Referent			Referent		
Non-trauma	18	(0.2)	1.4	(0.7, 2.6)	0.327	0.7	(0.3, 1.5)	0.317
Maternal/fetal	3	(0.2)	1.1	(0.3, 3.6)	0.895	0.7	(0.1, 3.8)	0.723
Urgency of operation^b								
Urgent	5	(0.0)	Referent			Referent		

	Died n	OR	95% CI	p-value	Adjusted ^a		
					OR	95% CI	p-value
Emergency	37	(0.4)	(4.4, 28.6)	0.000	5.9	(1.8, 19.3)	0.004
Project-type^c							
Support	7	(0.1)	Referent		Referent		
Disaster	3	(0.1)	(0.2, 3.1)	0.752	0.9	(0.2, 4.4)	0.848
Conflict	32	(0.2)	(0.0, 0.0)	0.107	3.0	(1.2, 7.5)	0.018
Operation order							
First operation	34	(0.2)	Referent		Referent		
Planned return	7	(0.1)	(0.2, 0.9)	0.031	1.7	(0.6, 4.9)	0.321
Unplanned return	1	(0.9)	(0.6, 31.4)	0.155	2.4	(0.3, 21.4)	0.458

OR: odds ratio; CI: confidence interval; ASA: American Society of Anesthesiologists physical status score.

^aOR was adjusted for age, ASA class, type of anesthesia, urgency of operation, project type, and order of operation.

^bNo deaths occurred in children who underwent elective surgery.

^cNo deaths occurred in children who underwent surgery at maternity-designated projects.

Table 4

Rank^a, frequency and relative proportion of injury-related procedural indications, stratified by age group, treated by Médecins Sans Frontières Operations Centre Brussels projects from 2008 to 2014; n = 13,984.

Total			<1 year			1–4 years			5–9 years			10–14 years			15–17 years		
Rank	N	(%)	Rank	N	(%)	Rank	N	(%)	Rank	N	(%)	Rank	N	(%)	Rank	N	(%)
Other ^b	5,239	(38)	2	62	(20)	2	931	(30)	1	1,786	(43)	1	1,795	(42)	1	665	(38)
Burn	3,409	(24)	1	224	(71)	1	1,591	(52)	2	1,005	(24)	4	432	(10)	4	157	(24)
Traffic	3,016	(22)	4	9	(2.9)	3	307	(10)	3	974	(23)	2	1,150	(27)	2	576	(22)
GSW	1,187	(8.5)	3	13	(4.1)	4	105	(3.4)	4	145	(3.5)	3	456	(11)	3	468	(8.5)
Bomb	552	(4.0)	6	2	(0.6)	5	70	(2.3)	5	143	(3.4)	5	255	(5.9)	6	102	(4.0)
Stab	329	(2.4)	5	4	(1.3)	6	39	(1.3)	6	61	(1.5)	6	115	(2.7)	5	110	(2.4)
Mine	119	(0.9)	–	–	–	7	10	(0.3)	7	33	(0.8)	7	59	(1.4)	7	17	(0.9)
Assault	62	(0.4)	–	–	–	8	6	(0.2)	8	19	(0.5)	8	26	(0.6)	8	11	(0.4)
Torture	53	(0.4)	7	1	(0.3)	8	6	(0.2)	9	17	(0.4)	9	20	(0.5)	9	9	(0.4)
GBV	18	(0.1)	7	1	(0.3)	10	3	(0.1)	10	6	(0.1)	10	8	(0.1)	10	0	(0.1)

GSW: gunshot wound; GBV: gender based violence.

^aRanks were shaded to more easily appreciate the change in rank between age groups. Some ranks were ties. Dark gray is the most common procedure performed. Procedures performed less commonly are progressively lighter shades of gray. White represents the least common procedure performed.

^bOther includes falls, foreign body impalement, domestic injuries, and game/sport injuries.