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The Impact of Natural Disaster on Pediatric Surgical Delivery: A Review of Haiti Six Months Before and After the 2010 Earthquake

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Abstract: Little is known about pediatric surgical disease in resource-poor countries. This study documents the surgical care of children in central Haiti and demonstrates the influence of the 2010 earthquake on pediatric surgical delivery. **Methods.** We conducted a retrospective review of operations performed at Partners in Health/Zanmi Lasante hospitals in central Haiti. **Results.** Of 2,057 operations performed prior to the earthquake, 423 were pediatric (20.6%). Congenital anomalies were the most common operative indication (159/423 operations; 33.5%). Pediatric surgical volume increased significantly after the earthquake, with

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670 operations performed (23.0% post-earthquake *v.* 20.6% pre-earthquake, $p=.03$). Trauma and burns became the most common surgical diagnoses after the disaster, and operations for non-traumatic conditions decreased significantly ($p<.01$). **Conclusion.** Congenital anomalies represent a significant proportion of baseline surgical need in Haiti. A natural disaster can change the nature of pediatric surgical practice by significantly increasing demand for operative trauma care for months afterward.

Key words: Pediatrics, surgery, resource-poor settings, burden of surgical disease, natural disaster.

Pediatric populations are often disproportionately large in developing countries. In Haiti, for example, roughly 37% of the population is under 15 years of age, compared with roughly 20% in the United States and 18% in the United Kingdom.¹ Little is known about the scale or scope of surgically treatable conditions affecting children in resource-poor areas. Without care, children with otherwise surgically-treatable diseases face a life of unnecessary morbidity and truly represent the neglected stepchildren, as it were, of public health efforts in low and middle income countries (LMICs).² Global health efforts in LMICs should address these surgical needs of children.

Efforts in Africa are beginning to define the pediatric burden of surgical disease,^{3,4} but formalized networks for global pediatric surgery have yet to be developed.⁵ Even less is known about the pediatric surgical care delivered in Haiti. Because of the January 2010 earthquake, Haiti presents a unique opportunity not only to examine baseline pediatric surgical care, but also to evaluate the influence of a natural disaster on pediatric care in a resource-poor setting.

Surgical resources throughout Haiti were lacking even before the earthquake, which added a significant disease burden to an already stressed health care infrastructure.⁶ Partners in Health (PIH) and its Haitian sister organization Zanmi Lasante (ZL) operate hospitals throughout the Central Plateau and Artibonite region. For over 25 years, they have provided essential medical and surgical services for the nation's most needy.⁷ Our own recent report illustrated the ability of this pre-existing health care network to respond to the acute spike in demand for surgical services in the immediate aftermath of the earthquake,⁶ when much of the health care infrastructure was destroyed. Hospitals and health centers that remained intact following the disaster were stressed and stretched beyond capacity.

Subjective experience in providing surgical care to the underserved in Haiti both before and after the January 2010 earthquake suggested a substantial need for the surgical care of children in the region. With this study, our purpose is to provide objective evidence of both the baseline surgical care provided to children in central Haiti and to demonstrate the influence of the earthquake on pediatric surgical demand and provision. We hypothesized that that pediatric operations constituted a substantial component of surgical care prior to the earthquake and that post-earthquake operations were largely related to traumatic injury.

Methods

Following approval by the institutional review boards and ethics committees of both Children's Hospital Boston and Partners in Health/Zanmi Lasante (PIH/ZL), we conducted a retrospective review of pediatric surgical volume at five PIH/ZL hospitals throughout the Central and Artibonite districts of Haiti: Cange, St. Marc, Petite Riviere, Hinche, and Belladere. We culled operative logs and included all major operations (procedures occurring in an operating room with local, regional, spinal, or general anesthesia) from July 2009 to July 2010 on all consecutive patients 18 years of age and younger. We collected data on age, gender, hometown, primary and secondary diagnoses, operation, operative time, surgeon, anesthesia type, and transfusion requirement. Primary and secondary surgical diagnoses were categorized based on previous studies (congenital anomalies, genitourinary, obstetrics and gynecology, gastrointestinal, neoplasms, infection, otolaryngology, trauma and burns, and miscellaneous).³ To determine baseline pediatric surgical volume, we analyzed pre-earthquake data from July 1, 2009 to January 11, 2010. We next compared pre- and post-earthquake (January 12, 2010 to July 1, 2010) pediatric surgical care. For trend analyses, we categorized both pre- and post-earthquake time periods into month-long blocks.

Chi-squared tests were used to determine differences between categorical variables and t-tests were used to detect differences in pre- and post-earthquake frequencies for continuous variables. The alpha threshold for significance was set at $p \leq 0.05$. All statistical tests were performed using IBM SPSS, v19.1 (Chicago, IL).

Results

Baseline pediatric surgical care. Of 2,057 operations performed in the pre-earthquake time period, 423 (20.6%) were for pediatric patients. Most of the patients were male and the highest volume was conducted at Cange (Table 1). Children were treated for a variety of surgical diagnoses prior to the earthquake (Table 2). The most common diagnostic group was congenital anomalies (33.5%), including hernia (21.1%), cryptorchidism (5.1%), and hydrocele (3.8%). Genitourinary and obstetric and gynecologic conditions comprised a large proportion of surgical care as well (14.3% and 13.5%, respectively). Traumatic injuries constituted just 3.1% of all operations during this time period. Specifically, surgical treatment for fracture/dislocation and burns were relatively rare (2.1% and 0.4%, respectively).

Influence of the earthquake on pediatric surgery. The demographic makeup of the pediatric surgical population was not significantly different between pre- and post-earthquake groups (Table 1). Overall, PIH/ZL hospitals provided more operations for children after the earthquake than before ($n=670$ v. 423 cases, respectively), and surgery for children constituted a significantly larger percentage of total operations after the earthquake ($p=.03$).

Table 3 provides univariate analyses comparing pre- and post-earthquake volume by diagnosis. Subgroup analyses were performed for the most common diagnoses related to trauma and burns and congenital anomalies. Operations for nearly all non-trauma diagnoses decreased after the earthquake. Congenital, obstetric and gynecologic,

Table 1.
PATIENT DEMOGRAPHIC CHARACTERISTICS

	Pre-Earthquake			Post-Earthquake			OR	95% CI	p-value
	Pediatric	All	%	Pediatric	All	%			
Female gender	155	1181	13.1%	238	1587	15.0%	0.98	0.94,1.03	.48
Mean Age (SD)	9.7 (5.5)	32.5 (18.0)	N/A	9.9 (5.4)	30.5 (17.1)	N/A	N/A	N/A	.36
	Pediatric	All	% Pediatric	Pediatric	All	% Pediatric	OR	95% CI	p-value
Clinical Site									
Cange	194	867	22.4%	385	1294	29.8%	1.43	1.17,1.74	.01
St Marc	84	418	20.1%	139	686	20.3%	1.10	0.81,1.49	.59
Belladere	45	232	19.4%	10	161	6.2%	0.28	0.14,0.57	.01
Hinche	94	469	20.0%	111	594	18.7%	0.98	0.72,1.33	.94
Petite Riviere	6	71	8.5%	25	176	14.2%	1.39	0.54,3.58	.65
Total	423	2057	20.6	670	2911	23.0	1.17	1.02,1.34	.03

Chi-square tests were used to determine significant differences as proportions of the whole. T-tests were used to determine significant differences in mean age between pre- and post-earthquake groups.

OR = Odds Ratio

CI = Confidence Interval

Table 2.

**MOST COMMON PEDIATRIC SURGICAL DIAGNOSES
(PRIMARY AND SECONDARY) IN CENTRAL HAITI,
PRE-EARTHQUAKE (JULY 2009–JANUARY 11TH, 2010)**

Diagnosis	N=423	% of all pediatric diagnoses	Mean Age in years (SD)
Congenital Anomalies	159	33.5	7.4 (4.8)
Hernia	100	21.1	7.8 (4.6)
Cryptorchidism	24	5.1	7.9 (3.4)
Hydrocele	18	3.8	9.3 (5.2)
Imperforate Anus	9	1.9	0.8 (0.6)
Hirschsprungs	3	0.6	2.3 (1.2)
Varicocele	1	0.2	17 (—)
Miscellaneous	4	0.8	3.8 (3.6)
Genitourinary	68	14.3	8.4 (4.2)
Phimosis/Paraphimosis	37	7.8	8.6 (4.6)
Long prepuce	21	4.4	8.4 (3.9)
Urinary obstruction	1	0.2	12.0 (—)
Miscellaneous	9	1.9	6.8 (2.6)
Obstetrics and Gynecology	64	13.5	17.1 (1.2)
Other labor related	30	6.3	17.4 (0.8)
CPD	27	5.7	16.6 (1.4)
Eclampsia/Preeclampsia	7	1.5	17.8 (.45)
Gastrointestinal	33	7.0	7.1 (4.6)
Peritonitis	9	1.9	11.2 (3.3)
Colostomy	9	1.9	5.8 (4.6)
Appendicitis	3	0.6	8.0 (1.4)
Intussusception	1	0.2	8.0 (—)
Bowel obstruction	2	0.4	7.5 (0.7)
Pyloric stenosis	1	0.2	0.8 (—)
Miscellaneous	8	1.7	4.2 (4.0)
Neoplasms	31	6.5	12.3 (4.7)
Infections	22	4.6	6.1 (5.3)
Abscess	18	3.8	5.4 (5.3)
Osteomyelitis	1	0.2	13.0 (—)
Miscellaneous	3	0.6	8.0 (5.3)
Otolaryngology	22	4.6	7.2 (4.0)
Tonsillitis	19	4.0	6.4 (3.2)
Thyroid	1	0.2	16.0 (—)
Miscellaneous	2	0.4	14.0 (—)
Trauma and Burns	15	3.1	10.9 (4.8)
Fracture/Dislocation	10	2.1	12.3 (4.0)
Burns	2	0.4	10.5 (9.2)
Amputation	2	0.4	9.0 (1.4)
Miscellaneous	3	0.6	6.7 (2.9)
Miscellaneous	60	12.7	11.7 (4.4)

Numbers may not sum due to missing values and/or multiple diagnoses. Ages calculated based on primary diagnoses.

genitourinary, and otolaryngologic related operations all decreased significantly in both absolute volume and percentage of total volume ($p < .01$ for each). Conversely, procedures related to trauma and burns and miscellaneous surgical procedures, including wound debridement, increased in absolute volume and percentage of total volume ($p < .01$ for each). For example, there were nine (2.1%) operations for fracture/dislocation prior to the earthquake compared with 195 (29.1%) after ($p < .01$), and all but two amputations were performed after the disaster ($p < .01$). By comparison, operations for trauma among the adult population in this region constituted 3.4% of the surgical volume pre-earthquake (53/1550 operations) and 16.7% post-earthquake (353/2111 operations).

The temporal trends for pediatric surgical procedures for trauma and burns are depicted in Figure 1. Following the disaster, trauma and burn-related surgical volume increased substantially above monthly pre-earthquake averages (dashed line), and it remained elevated throughout the six-month post-earthquake period.

Table 3.

INFLUENCE OF THE EARTHQUAKE ON MAJOR PEDIATRIC SURGICAL DIAGNOSES (N = 1093)

Diagnosis (% of all Pediatric Cases)	Pre- Earthquake	Post- Earthquake	OR	95%CI	p-value
Total Pediatric Surgical Cases	423 (100.0)	670 (100.0)	N/A	N/A	N/A
Trauma and Burns	14 (3.3)	259 (38.8)	18.36	(10.5,32.0)	.01
Fracture/Dislocation	9 (2.1)	195 (29.1)	18.88	(9.58,37.3)	.01
Amputation	2 (0.5)	23 (3.4)	7.48	(1.76,31.9)	.01
Burns	2 (0.5)	9 (1.3)	2.87	(0.62,13.3)	.16
Congenital Anomalies	140 (33.4)	80 (12.0)	0.27	(0.20,0.37)	.01
Hernia	93 (22.0)	43 (6.4)	0.24	(0.17,0.36)	.01
Cryptorchidism	15 (3.5)	6 (0.8)	0.25	(0.10,0.64)	.01
Hydrocele	17 (4.0)	10 (1.4)	0.36	(0.16,0.80)	.02
Obstetrics and Gynecology	55 (13.1)	43 (6.4)	0.46	(0.30,0.69)	.01
Genitourinary	52 (12.4)	21 (3.1)	0.23	(0.14,0.39)	.01
Gastrointestinal	30 (7.2)	35 (5.2)	0.72	(0.43,1.19)	.24
Neoplasms	30 (7.2)	33 (4.9)	0.68	(0.41,1.12)	.14
Infections	22 (5.3)	32 (4.8)	0.91	(0.52,1.59)	.76
Otolaryngology	21 (5.0)	13 (1.9)	0.38	(0.19,0.76)	.01
Miscellaneous	55 (13.1)	151 (22.6)	1.9	(1.38,2.71)	.01

Numbers may not sum due to missing values. Frequencies based on primary diagnosis only.

OR = Odds Ratio

CI = Confidence Interval

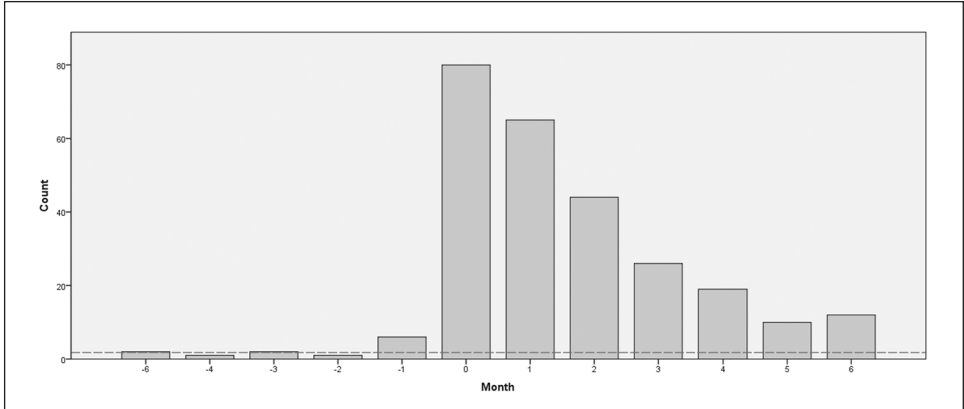


Figure 1. Trends in trauma-related pediatric surgical care by month, July 2009–July 2010.

Figures represent volume of cases. Time point 0 represents a month-long interval beginning with the earthquake on January 12, 2010. The dashed referent line is defined as the pre-earthquake monthly average across all sites.

Discussion

We found a broad array of pediatric surgical disease and surgical practice in central Haiti prior to the earthquake. Following the earthquake, we noted significant changes in the scope and volume of pediatric surgical care. This study illustrates how a natural disaster is associated with the demand for, and provision of, pediatric surgical services in resource-poor settings.

The baseline epidemiologic data for pediatric surgical conditions in Haiti prior to January 2010 demonstrates the need for dedicated pediatric surgical services among this uniquely vulnerable population. Pediatric surgical volume represented a substantial portion (21–24%) of all surgical cases at PIH/ZL hospitals, and each facility provided essential pediatric surgical care. Prior to the earthquake, for example, over one third of all pediatric operations were conducted for children with congenital anomalies. Surgery can provide effective treatment for these disease conditions that, if left untreated, would otherwise likely lead to a lifetime of morbidity, social stigmatization, and economic detriment.⁸

Although previous assessments in Africa have identified pediatric trauma as a leading cause of morbidity,^{3,9–11} we found traumatic injury to be an uncommon diagnosis leading to an operation prior to the earthquake. There are several potential explanations for our findings. Haiti lacks a network of high-speed roadways, which may decrease the potential for high-speed motor vehicle trauma. Alternatively, the lack of adequately maintained roadways may adversely affect access to timely surgical care. Additionally, due to a lack of orthopedic hardware, trained orthopedic surgeons, and intraoperative imaging capabilities at some of the PIH/ZL hospitals, many long-bone fractures are routinely treated non-operatively with traction and pinning rather than an operative reduction and fixation. Therefore, these injuries would be underrepresented in the

operative logs. It is also likely that some pediatric trauma patients were treated at other facilities or died of their injury.

Infection was also an uncommon diagnosis in our study. In contrast, other surveys of pediatric surgical conditions in developing countries have demonstrated a significant burden of infection-related surgical disease, including osteomyelitis, pyomyositis, and abscess.^{3,12} Even after the earthquake, infection-related operations comprised few of the surgical cases in our cohort (5%). Perhaps largely because the region surrounding the PIH/ZL hospitals was not significantly affected by the earthquake, living conditions may have been better than in Port-au-Prince. High infectious disease rates in tent villages and settlement camps in the capital post-earthquake contributed significantly to that population's surgical morbidity,^{13,14} but this was not seen among our study population. Additionally, many infection-related procedures in our population, such as wound debridements, may have been conducted outside of the operating room and thus would not have been captured by the operative log records.

The overall volume of pediatric surgery changed significantly after the earthquake. With the exception of one site, all PIH/ZL hospitals experienced an increase in surgical demand. Cange likely increased its surgical volume more than the other hospitals because of its reputation as the longest-running of the PIH/ZL hospitals and because it was the primary site for international surgical volunteers.

In addition to an increased number of children requiring surgery, the earthquake also altered the case mix. Trauma and burns became the most common indication for surgery, and congenital anomalies were a less common reason for an operation after the earthquake. This surge in trauma was likely a direct result of the disaster itself; similar results have been demonstrated among pediatric populations in field hospital reports from other disaster settings.^{9,10,11} Furthermore, a large group of Haitians fled the capital city in the aftermath of the earthquake, and it is possible that part of the surge in PIH/ZL trauma volume in the weeks following the disaster reflects this migration.¹⁵ Knowledge of the presence of international volunteers at PIH/ZL hospitals could also have contributed to a surge in demand for trauma surgery, even for conditions unrelated to the earthquake.

As scarce resources and personnel shifted to address acute surgical needs, the operative rates for non-traumatic causes fell among the pediatric population. Over the ensuing six months, trauma volume remained above pre-earthquake averages and non-trauma volume, including surgery for congenital anomalies, remained below average. Children with non-traumatic surgical needs were thus potentially not receiving care, and were either suffering, dying from their conditions, or experiencing a delay in surgical treatment after the earthquake. This shift represents the significant strain that natural disasters can exert in regions with limited surgical resources at baseline. Without a functional surgical delivery system in place, hospitals may not be able to meet the baseline demands of the population for an extended period of time,¹⁶ even with a significant supply of international volunteers. So, our findings reinforce the idea that a functionally sustainable surgical delivery system is essential to public health in resource-poor settings.

This analysis demonstrates that surgical care for children is a substantial and unique component of public health. Surgical diseases affecting the young are categorically

different than those affecting adults, and additional resources should be targeted to address those needs for both individual and societal benefit. Investment in and development of surgical services for children in resource-poor settings can have significant health and economic benefits to individuals, families, and nations.^{17,18}

Our analysis also provides insight into the way that disasters affect the surgical care of pediatric populations. Children constituted a large proportion of the injured following the Haiti earthquake: resources should be developed to accommodate the specific trauma needs of this population. In addition to the acute demand for trauma surgery, children continue to require surgical care for non-traumatic diagnoses, and international aid networks should be coordinated to address these needs. Similarly, post-operative rehabilitation services for children, especially after traumatic injury, represent an essential area of development. As this example in Haiti illustrates, natural disasters are particularly damaging to regions with limited resources. In light of the data and with the understanding that disasters will occur in the future, disaster preparedness plans must reflect the unique needs of children in resource-poor settings.¹⁹

The present study has a number of limitations. Operative data were collected *via* a retrospective review of each hospital's operative log. Although record-keeping was not uniformly complete across all sites, logs largely were well kept, and they provided a standard data metric that allowed our data to be comparable. The logs represent only procedures performed in the operating theatre. Additionally, our review includes only services rendered, or *met need*, at the point of care, and do not reflect the unmet burden of surgical disease in the region. Furthermore, we only captured six months before and six months after the earthquake. Our study time period may have been too short to account fully for potential seasonal variations either in surgical demand or in levels of international volunteers present in Haiti. Finally, PIH/ZL operate facilities in central Haiti, and we have no operative data from Port-au-Prince or other regions that were closer to the initial disaster. It is possible that the earthquake influenced surgical demand differently in these regions.¹³

This study provides regionally specific evidence for the significant burden of surgically treatable conditions among the pediatric population in central Haiti and how a natural disaster impacts surgical delivery. Future studies in global pediatric surgery should begin with a more comprehensive evaluation of the scope of the burden of pediatric surgical disease, including investigations of unmet need. Additionally, disaster preparedness plans specific to the needs of children should be studied and implemented in resource-poor settings. Large numbers of both children and adults require surgery following a disaster, and limited resources often must stretch to meet the differing needs of these populations. Local health care infrastructures, whether domestically or internationally staffed, should develop plans to accommodate not only the surgical needs specific to children, but also the mental, psychological, and familial demands.

From a public health perspective, broader maternal and child health campaigns could help to address surgery's role in pediatric care. The United Nation's Millennium Development Goals 4 and 5 are targeted to improve maternal and child health, and these are intimately related to surgical care. Rather than surgery, obstetrics, and pediatric care competing, we should continue to join forces to address these common problems that unite our individual efforts. Horizontal, multidisciplinary measures

including improvements in perinatal nutrition and education, obstetric care, and surgery can pair prevention and treatment to provide mutually reinforcing improvements for pediatric public health.

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