Surgery xxx (2020) 1–8

Contents lists available at ScienceDirect

Surgery

journal homepage: www.elsevier.com/locate/surg

Burden of emergency pediatric surgical procedures on surgical capacity in Uganda: a new metric for health system performance

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ARTICLE INFO

Article history:
Accepted 4 December 2019
Available online xxx

ABSTRACT

Background: The significant burden of emergency operations in low- and middle-income countries can overwhelm surgical capacity leading to a backlog of elective surgical cases. The purpose of this investigation was to determine the burden of emergency procedures on pediatric surgical capacity in Uganda and to determine health metrics that capture surgical backlog and effective coverage of children's surgical disease in low- and middle-income countries.

Methods: We reviewed 2 independent and prospectively collected databases on pediatric surgical admissions at Mulago National Referral Hospital and Mbarara Regional Referral Hospital in Uganda. Pediatric surgical patients admitted at either hospital between October 2015 to June 2017 were included. Our primary outcome was the distribution of surgical acuity and associated mortality.

Results: A combined total of 1,930 patients were treated at the two hospitals, and 1,110 surgical procedures were performed. There were 571 emergency cases (51.6%), 108 urgent cases (9.7%), and 429 elective cases (38.6%). Overall mortality correlated with surgical acuity. Emergency intestinal diversions for colorectal congenital malformations (anorectal malformations and Hirschsprung's disease) to elective definitive repair was 3:1. Additionally, 30% of inguinal hernias were incarcerated or strangulated at time of repair.

Conclusion: Emergency and urgent operations utilize the majority of operative resources for pediatric surgery groups in low- and middle-income countries, leading to a backlog of complex congenital procedures. We propose the ratio of emergency diversion to elective repair of colorectal congenital malformations and the ratio of emergency to elective repair of inguinal hernias as effective health metrics to track this backlog. Surgical capacity for pediatric conditions should be increased in Uganda to prevent a backlog of elective cases.

Introduction

Recent studies have demonstrated the substantial unmet need in surgery and anesthesia care, particularly in low- and middle-income countries (LMICs).[1,2] The passage of resolution A68/15 on Strengthening Emergency And Essential Surgical Anesthesia Care as a Component of Universal Health Coverage by the World Health Assembly in 2015 further highlighted the importance of global surgery within global health programs.[3] Attention has turned to quantifying the unmet burden of surgical disease in specific subpopulations, including identifying critical gaps in surgical infrastructure and surgical and anesthesia workforce to better inform operative resource allocation.[4]

Children's surgery has been especially marginalized in global health and child health programs in LMICs leading to significant limitations in surgical capacity.[5,6] Recent estimates suggest that 1.7

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https://doi.org/10.1016/j.surg.2019.12.002
0039-6060/

billion children do not have access to safe surgical care around the world.[7] In East Africa, independent cross-sectional surveys in Rwanda and Uganda found that 6.3% and 7.4% of children, respectively, had current untreated surgical disease.[8,9] In a review of pediatric surgery admissions in Kijabe, Kenya, investigators noted that surgical correction for congenital anomalies were delayed by up to 6 years from optimal surgical timing.[10]

There are numerous challenges to increasing children's surgical capacity in Uganda.[11] There are currently 4 pediatric surgeons and 3 pediatric anesthesiologists working in 2 centers in the country: Mulago National Referral Hospital in Kampala and Mbarara Regional Referral Hospital in Mbarara. Each institution has 1 dedicated pediatric operating room. These are the only 2 centers in Uganda with dedicated pediatric surgery teams and operating rooms, which serve a country of 20 million children.[12] According to recent international guidelines for children's surgery,[13] these are the only 2 centers in the country capable of safely performing complex pediatric procedures, including congenital repairs and oncology procedures. Previous evidence from sub-Saharan Africa demonstrated that emergency pathology results in the majority of admissions in children's surgical wards.[14,15] Given the significant limitations on children's surgical capacity within Uganda, we hypothesized that the burden of emergency procedures at Mulago and Mbarara may create a backlog of complex, pediatric elective cases, including congenital anomaly repairs. Furthermore, we set out to determine if this data supports the development of health metrics that would capture the pediatric surgical capacity backlog and the effective coverage of children's surgical disease in resource limited settings.

Methods

We evaluated 2 prospective clinical databases of children treated by the pediatric surgery teams at Mulago National Referral Hospital and Mbarara Regional Referral Hospital from October 2015 to June 2017. Both hospitals are tertiary care facilities and represent the major referral hospitals of the country. All children younger than 12 years old who were admitted to the children's surgical ward or treated in consultation by the pediatric surgery team at either hospital were included in analysis. Children were excluded from analysis if there were insufficient clinical or operative details in the database regarding their admission.

The database was initiated in Mulago Hospital by the pediatric surgery team in 2012 and refined in 2015.[16] In discussion with the pediatric surgery team at Mbarara, the database was then adapted to this site. The databases are nearly identical at each site, though data collection and storage remain independent. Both databases include information on demographic and clinical data for each patient treated by the pediatric surgery team and includes age, sex, travel distance, referral status, admission diagnosis, final diagnosis, surgical intervention, procedure details, length of hospital stay, operative complications, and in-hospital mortality. Based on a patient's presenting diagnosis and surgery, we stratified each procedure as emergency (surgery necessary within 24 hours, such as colostomy for high anorectal malformation, trauma, infection), urgent (surgery necessary within 1–2 weeks, such as oncologic procedures based on timing for neoadjuvant therapy or biopsy), or elective (surgery can be safely completed >1 month, such as elective hernia repairs) (a list of diagnosis/procedures in each category are provided in Appendix 1). The primary outcome was the distribution of surgical acuity at both hospitals. The secondary outcome was in-hospital mortality divided by surgical acuity. A descriptive subgroup analysis was conducted by the main procedures represented in both emergency and elective acuity levels including anorectal malformation (ARM) procedures, Hirschsprung's procedures, and inguinal hernias to determine the feasibility of developing specific health metrics to determine the backlog of complex elective cases.

For normally distributed data, mean and standard deviation was reported. For non-parametric data, median and interquartile range (IQR) was reported. The Student's t test, the Wilcoxon rank sum test, and Fisher exact test were used as appropriate. All hypothesis tests were considered 2-sided and a P value of .05 was considered significant for all analyses. Data collection was performed using Microsoft Access 2016 (Redmond, WA) and data analysis was performed using SAS version 9.4 (SAS Institute, Cary, NC). The study was approved by the Institutional Review Board at Mulago Hospital in Kampala, Uganda (Protocol # MREC: 464) and at Yale University School of Medicine (Protocol # 1605017844).

Results

There were 1,930 children treated at both hospitals over the study period. Mulago treated 1,377 children, and Mbarara treated 553 children. Patient characteristics are presented in Table I. The median age at both sites was 1.24 years (IQR 0.24, 4.0), with a slightly younger population presenting to Mulago, 1.0 years (IQR 0.16, 3.48) vs 1.49 years (IQR 0.39, 4.82), $P = .0008$). Of the patients across both hospitals, 33.8% were female. Patients presented from 76 political districts across the country (69 to Mulago and 27 to Mbarara, $P < .0001$) (Fig 1). The median distance traveled by patients to Mulago was 19 kilometers (IQR 9, 100). Mbarara did not routinely collect distance to hospital data. Mulago and Mbarara had different referral patterns. A percentage of children (35.6%) presented to Mulago as a referral from another hospital, while 7.2% of children presented to Mbarara as a referral ($P < .0001$).

Procedure distribution and mortality by surgical acuity

Six hundred and twenty-seven procedures were completed at Mulago (45.6% of admissions), and 483 procedures were completed at Mbarara (87.3% of admissions) ($P < .0001$) (Table II). The classification of surgical acuity across both sites included 571 emergency procedures (51.6%), 108 urgent procedures (9.7%), and 429 elective procedures (38.6%). The overall mortality across both sites was 7.3% for all surgical acuity levels (Table III). Overall mortality increased from elective to emergency procedures. Overall mortality for elective procedures was 0.9%, for urgent procedures it was 5.6%, and for emergency procedures it was 12.4%.

The most common emergency operation at both sites was a laparotomy for intussusception (19.7%). This includes 32 operations which included intestinal diversion, of which 11 were reversed over the study period (34.3%). Emergency intestinal diversions for anorectal malformations was 15.9% of emergency cases, while diversion for Hirschsprung's disease (HD) was 5.4% of emergency cases. Incarcerated or strangulated hernias represented 8.0% of the total cases. There were a significant number of blunt abdominal trauma ($n = 51$) and additional trauma admissions ($n = 17$) across both sites, which led to 14 operations. There were 26 incision and drainages for abscesses, 15 appendicitis cases, and 9 ileal perforations from typhoid disease.

Oncology cases predominated the urgent surgical acuity level with sacrococcygeal teratoma (27.8%), intra-abdominal mass not otherwise specified (18.5%), and Wilms tumor (16.7%) the most common solid organ malignancies across both sites. Elective herniorrhaphy was the most common elective procedure at both sites with inguinal hernia repairs (24.4%) as the most common. Posterior sagittal anorectoplasty (PSARP) (6.8%) was the next most common

Table I
Presenting patient characteristics at Mulago Hospital and Mbarara Hospital

Patient characteristic or clinical parameter	Mulago Hospital	Mbarara Hospital	Total	Significance
Age (y)*	1.0 (0.16, 3.48)	1.49 (0.39, 4.82)	1.24 (0.24, 4.0)	$P = .0008$
Sex (female)	244 (35.7%)	144 (31.2%)	368 (33.8%)	$P = .122$
Distance traveled (km)*	19 (9, 100)	–	–	–
Districts	69	27	76	$P < .0001$
Mode of referral†				$P < .0001$
Outpatient clinic	679	131	810	
Emergency room	179	258	437	
Referred from another hospital	490	40	530	

* Results are in median values with interquartile range in parenthesis.
† Missing data for mode of referral = 114 patients across both hospitals.

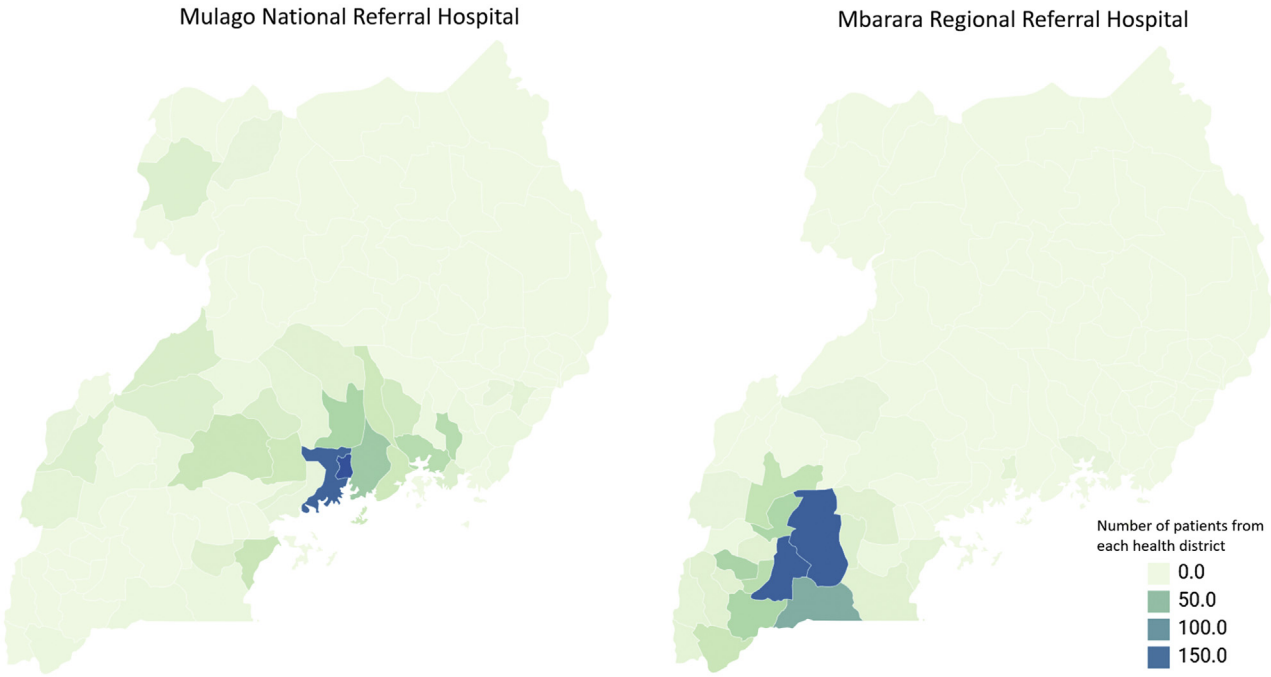

Fig 1. Heatmap of political districts in Uganda. Density is the number of patients from each district referred to either Mulago National Referral Hospital or Mbarara Regional Referral Hospital.

elective procedure at both sites followed by orchiopexy for undescended testis (7.7%).

Anorectal malformations and Hirschsprung's disease

Diversion for ARM with colostomy was the second most common emergency procedure, while PSARP and ostomy reversal was the second most common elective procedure performed at both hospitals. There were 112 emergency procedures and 57 elective procedures (28 ostomy reversals and 29 PSARP). At Mulago, the database includes children that were admitted to the pediatric surgery ward for an operation regardless of whether an operation occurred. Over the study period, 39 patients were admitted to the hospital for either a PSARP or ostomy reversal for ARM but were discharged without getting a procedure. In total, Mulago performed 40 PSARPs or ostomy reversals for ARM over the study period, meaning 50% of patients were admitted for an elective procedure but were discharged without receiving definitive repair or colostomy closure due to their case being indefinitely delayed by emergency procedures. HD was similarly represented in both emergency categories for colostomy diversion and elective procedures for pull-through operations. Across both hospitals over the study period, there were 31 total diversions for HD and 6 total pull-throughs.

The average age of patients that presented for initial diversion for either ARM or HD was 5 days (IQR 2, 177 days). Thirty-three of 234 patients (14.1%) who presented with a primary diagnosis of ARM or HD had multiple surgeries. Of this subgroup, the average time from initial ostomy diversion to definitive repair was 246.5 days (IQR 127, 308 days), while the time from definitive repair to colostomy closure was 165 days (IQR 138, 209.5 days). Overall, 38 of 122 ostomies created for ARM or HD (31.1%) were reversed over the study period.

Inguinal hernia repair

Inguinal hernia repairs were the most common elective procedure at both hospitals ($n = 104$). Emergency operations for incarcerated or strangulated inguinal hernias was the third most common emergency procedure across both hospitals ($n = 46$). The percentage of incarcerated or strangulated hernia repairs was

Table II
Select operations by surgical acuity at Mulago Hospital and Mbarara Hospital

Surgical acuity	Pathology/procedure	Mulago Hospital	Mbarara Hospital	Total (percentage)
Emergency				
	Intussusception	76 (22.4%)	37 (21.2%)	113 (19.7%)
	Diverting colostomy for anorectal malformation	71 (20.9%)	20 (11.5%)	91 (15.9%)
	Incarcerated/strangulated inguinal hernia	40 (11.8%)	6 (3.4%)	46 (8.0%)
	Incarcerated umbilical hernia	11 (3.2%)	6 (3.4%)	17 (2.9%)
	Pyloric stenosis	23 (6.8%)	10 (5.7%)	33 (5.8%)
	Diverting colostomy for Hirschsprung's disease	24 (7.1%)	7 (4.0%)	31 (5.4%)
	Incision and drainage (abscess)	9 (2.7%)	17 (9.8%)	26 (4.5%)
	Duodenal obstruction	23 (6.8%)	2 (1.1%)	25 (4.4%)
	Appendicitis	13 (3.8%)	2 (1.1%)	15 (2.6%)
	Operative trauma (blunt and penetrating)	9 (2.7%)	5 (2.9%)	14 (2.4)
	Small bowel obstruction (NOS)	5 (1.5%)	5 (2.9%)	10 (1.7%)
	Typhoid ileal perforation	6 (2.7%)	3 (1.7%)	9 (1.5%)
	Total*	339	174	573
Urgent				
	Sacrococcygeal teratoma	19 (33.3%)	11 (21.6%)	30 (27.8%)
	Intra-abdominal mass (NOS)	16 (28.1%)	4 (7.8%)	20 (18.5%)
	Wilms tumor	7 (12.3%)	11 (21.6%)	18 (16.7%)
	Biliary atresia	5 (8.8%)	1 (2.0%)	6 (5.6%)
	Teratomas (NOS)	0 (0%)	3 (5.8%)	3 (2.8%)
	Total	57	51	108
Elective				
	Herniorrhaphy			
	Inguinal	37 (21.6%)	67 (26.2%)	104 (24.4%)
	Umbilical	18 (10.5%)	30 (11.7%)	48 (11.2%)
	Hydrocele	12 (7.0%)	12 (4.7%)	24 (5.6%)
	Anorectal malformation			
	PSARP	23 (13.4%)	6 (8.9%)	29 (6.8%)
	Ostomy reversal	17 (9.9%)	11 (4.3%)	28 (6.7%)
	Undescended testis	11 (6.4%)	22 (8.6%)	33 (7.7%)
	Hypospadias	14 (8.2%)	16 (6.3%)	30 (7.0%)
	Cleft lip/palate	0 (0%)	19 (7.4%)	19 (4.4%)
	Hirschsprung's disease			
	Pull-through	5 (2.9%)	1 (0.4%)	6 (1.4%)
	Ostomy reversal	5 (2.9%)	5 (1.9%)	10 (2.3%)
	Intussusception (ostomy reversal)	9 (5.3%)	2 (0.8%)	11 (2.6%)
	Cystic hygroma/lymphatic malformation	0 (0%)	9 (3.5%)	9 (2.1%)
	Total	171	256	429

NOS, not otherwise specified.
* Excludes gastroschisis and omphalocele, which are largely treated nonoperatively.

Table III
Clinical outcomes at Mulago Hospital and Mbarara Hospital

Patient characteristic or clinical parameter	Mulago Hospital	Mbarara Hospital	Total	Significance
Total treated patients	1,377	553	1,930	–
Total operative rate*	627 (45.6%)	483 (87.3%)	1,110 (57.5%)	$P < .0001$
Postoperative LOS (d)*,†	2 (1, 5)	3 (1, 6)	3 (1, 5)	$P = .0007$
Operative disposition				
Recovery and discharge*	540 (86.1%)	440 (91.1%)	980 (88.3%)	$P = .01$
Transferred*	11 (1.8%)	3 (0.6%)	14 (2.4%)	$P = .09$
Disposition NOS	11 (1.8%)	24 (4.9%)	35 (3.1%)	–
Postoperative mortality				
Overall*	65 (10.4%)	16 (3.3%)	81 (7.3%)	$P < .0001$
Emergency	59 (14.8%)	12 (6.9%)	71 (12.4%)	
Urgent	4 (7.0%)	2 (3.9%)	6 (5.6%)	
Elective	2 (1.2%)	2 (0.8%)	4 (0.9%)	

LOS, length of stay; *NOS*, not otherwise specified.
* Significance was determined by either the χ^2 test or the Wilcoxon rank sum test as appropriate.
† Results are median values with interquartile range in parenthesis.

46/150 (30.7%) across both hospitals. The median age of children who underwent an emergency operation was 1.3 years (IQR 0.6, 3.0 years), while the age of children undergoing elective repair was 2.5 years (IQR 1.2, 5.0 years) ($P = .035$). At Mulago hospital, where again data was collected on all patients admitted to the surgery service regardless of whether they had surgery, 48 of 125 patients (38.4%) admitted with an inguinal hernia were discharged without having a procedure, again due to emergency procedures delaying the elective procedure. The postoperative mortality rate for different acuity levels of inguinal hernia presentation was not statistically different; 1 patient died during an emergency procedure (2.63%), and 1 patient died during an elective procedure (0.92%) ($P = .709$).

Discussion

In this report we demonstrate that emergency procedures utilize 50% of the pediatric surgical capacity across the 2 major referral hospitals in Uganda. Furthermore, we demonstrated significant differences in the number of emergency to elective procedures in several key pediatric surgery diseases. The ratio of emergency diversions for ARM to elective PSARP or ostomy reversal was 2:1, while the ratio of emergency diversion for HD to pull-through procedures was 4:1. Furthermore, the proportion of colorectal congenital cases that were delayed due to emergency procedures was ~50%. As Mulago and Mbarara are the only 2 hospitals with dedicated pediatric surgery teams in Uganda, the discrepancy between emergency diversions to complex colorectal congenital repairs has significant implications on the surgical capacity of pediatric surgery within the country. Lastly, we demonstrate that 30% of inguinal hernias across both hospitals were incarcerated or strangulated at time of presentation, and 40% of all inguinal hernia admissions at Mulago were delayed.

Other studies from sub-Saharan African demonstrated similar findings regarding the burden of emergency procedures on pediatric surgery teams. In a prospective database of clinical admissions to the pediatric surgery ward in Gambia, Bickler et al found that 46.9% of admission were for injuries including burns and 14.5% were for infections requiring surgery.[14] In a retrospective study of pediatric surgical admissions in Nigeria, investigators similarly noted that the most common diagnoses at admission were trauma (36.7%), congenital anomalies (27.9%), and surgical infections (22.6%).[15] The burden of emergency pathology is not limited to hospital admissions. In a recent household study in Uganda, 7.4% of children were found to have an unmet surgical condition; 48.4% were trauma related and 12.5% were related to burns, along with 19.7% untreated wounds.[8] Though these admission and household survey investigations demonstrate the clinical burden of emergency surgical pathology in children living in LMICs, the present investigation is the first to demonstrate the impact of surgical acuity on the operative volume of a pediatric surgery team in Uganda.

At each hospital in this study, there is currently 1 dedicated pediatric operating room and limited pediatric anesthesia capability. Under most circumstances, only 1 pediatric operation can occur at a time, and emergency procedures necessarily delay elective cases. This infrastructure limitation further limits optimization of the current limited pediatric surgery workforce at each respective hospital. Qualitatively, emergency cases routinely delay urgent and elective procedures throughout the week. As a recent example, the surgical team at Mulago had 2 elective splenectomies, 2 Wilms tumor resections, and a PSARP on the operative schedule from Monday through Wednesday. However, 3 patients came in over the weekend with emergency operative pathology including 1 pyloric stenosis, 1 diversion for ARM, and 1 intussusception. In addition, a patient was admitted with gastroschisis and another patient with an esophageal atresia with a tracheoesophageal fistula. The resulting emergency procedures utilized the operative capacity of the pediatric surgery and anesthesia team over the first 2 days of the week delaying the elective and urgent cases. Like many other LMIC contexts, loss to follow-up is a critical issue in Uganda, and these bumped cases often turn into indefinite delays. Of the 48 children who were admitted to Mulago for an elective inguinal hernia repair and were discharged before getting surgery, only 1 patient (2.1%) returned within the study period for surgical repair.

The burden of emergency operations on the surgical capacity of Mulago and Mbarara are evident by the significant discrepancy between the number of emergency diversions for ARM and HD and the limited number of definitive repairs. While previous reports have suggested the accumulating backlog of congenital anomalies, this study is the first to report the ratio of urgent/emergency fecal diversion for colorectal procedures to definitive repair.[5] There were 91 diversions for ARM at both Mulago and Mbarara but only 29 PSARPs. Meaning over the study period, roughly 60 children were diverted and awaiting definitive repair. At Mulago alone, 39 children were admitted for either a PSARP or ostomy reversal following an ARM repair and were discharged without ever receiving an operation. There were 40 PSARPs or ostomy reversals for ARM at Mulago over the study period. As many children received elective operations for ARM as were admitted for the procedure and discharged without receiving the operation. The same trend was seen in HD, where 31 emergency diversions where done over the study period and only 7 total pull-through procedures. This occurred due to emergency cases “bumping” elective cases. As previously stated, Mulago and Mbarara were the only hospitals routinely doing complex congenital repairs within the country, meaning it is highly unlikely these children would be able to get definitive repairs at another hospital. In this particular case, there is significant morbidity for children living with ostomies in Uganda.[17] There are no ostomy bags, little to no services for ostomy care, and children and mothers may be ostracized from their family and community.

Another indication of the backlog of elective cases is the high ratio of incarcerated to non-incarcerated (elective) inguinal hernia repairs in Uganda. The overall emergency inguinal hernia repair presentation rate was 30% across both hospitals. At Mulago, more children presented with an incarcerated or strangulated hernia ($n = 40$) then a non-incarcerated elective procedure ($n = 37$). Stated another way, 50% of children at the national referral hospital do not get their inguinal hernias repaired unless they become incarcerated and the procedure becomes an emergency. Data from high income studies suggest that ~5% to 10% of inguinal hernia repairs in children are incarcerated at time of repair.[18-20] In a large longitudinal study of nearly 80,000 children, investigators found the incarceration rate to be 4.19%.[19] Seo et al demonstrated an incarceration rate of 5.8% in a series of ~3,500 children.[20] There are higher rates of incarceration in younger children; in a study of ~1,000 children <2 years old, investigators found that the overall incarceration rate was 11.8%,[18] giving a rough range of 5% to 10% for children. Very little data exists on the incarceration rate of inguinal hernias in children living in East Africa, though for reference, in adult male populations in Ghana, incarceration rates are ~25%.[21]

There is a growing need to develop practical and relevant metrics to evaluate and monitor system performance in global pediatric surgery.[22] One of the current issues is developing a metric that captures the surgical backlog and effective coverage of children’s surgical disease.[23] We propose 2 new health metrics for evaluating surgical backlog of children’s surgery in resource limiting settings, which were highlighted in this study: (1) the ratio of emergency colostomy diversions to definitive repairs (PSARPs) in anorectal malformations and (2) the percentage of inguinal hernias that are incarcerated at the time of repair. These 2 health metrics can be independently understood within the 3-delay model of healthcare.[24,25]

The percentage of pediatric inguinal hernias that are incarcerated at the time of repair at a regional or national referral hospital may reflect any of the 3 delays in the model: (1) a patient deciding to seek care, (2) a patient reaching the appropriate level of care (which would be satisfied at either a regional or national referral hospital with pediatric trained surgeons), or (3) a patient receiving appropriate care once they access the healthcare system. Tracking the ratio of incarcerated hernias to elective repairs at a national hospital would be an appropriate composite measure of pediatric surgical access within the healthcare system. Furthermore,

previous studies have demonstrated that pediatric inguinal hernia repairs in Uganda are both safe and cost effective.[26] They are also common procedures in children that reflect both elective and emergency procedures.

In contrast, the ratio of emergency colostomy diversions to definitive repairs (PSARPs) for anorectal malformations specifically represents that last delay in the model— receiving appropriate care once the healthcare system is accessed. A child presenting to the regional referral hospital for an ARM has already sought care and reached the appropriate level of care. If the pediatric surgery team has the capacity only to do an emergency diversion but not the longer definitive repair, this represents a specific limitation on pediatric surgery capacity at the hospital. As the incidence of congenital malformations like ARM are generally consistent over a 6-month timeframe, tracking the ratio of emergency diversions to definitive repairs may reflect changes in pediatric surgical capacity within the health system.

In addition, by tracking the incarceration rate and ratio of emergency diversion to definitive repairs in ARM in diverse LMIC settings, appropriate ratios of these health metrics may be empirically calculated and benchmarked. Once established, these health metrics could assist in tracking outcomes after the implementation of health policies aimed at addressing pediatric surgery capacity limitations.

Postoperative mortality, tracked with the acuity of surgical procedures at both hospitals, is consistent with other reported literature.[27] There were differences in mortality between the hospitals at all procedural acuity levels. For emergency procedures, Mulago had a 14.8% postoperative mortality rate, while Mbarara had a 6.9% postoperative mortality. This information is difficult to interpret as surgical risk stratification, to control for other factors besides surgical acuity, is not possible with our prospective database.[28,29] We hope to pilot further variables to capture this risk stratification although a set of such variables for children in resource-limited settings has not been established.[30–32] Mulago is receiving significantly more referrals from other hospitals (490 vs 40), and the children are younger (1.0 year old vs 1.5 years old), which likely reflects Mulago's role as a national referral hospital.

The significant backlog of elective cases demonstrated in this investigation has significant consequences for the Ugandan health system. The national referral hospital, more so than the main regional referral hospital, appears to be inundated with emergency procedures that delay complex elective cases, which can only be carried out at these hospitals. The findings of this study support increasing the operative resources for children's surgery at Mulago National Hospital. This includes increased dedicated operating rooms so that emergency procedures do not delay elective procedures. Current work by the non-profit organization, KidsOR, is expanding pediatric-specific operating rooms in Uganda and is an important working solution to the elective backlog highlighted in this study.[33] Alternative models, as have been developed for elective reconstruction in plastics, orthopedics, neurosurgery, and ophthalmology in Uganda, are freestanding niche hospitals that do not treat emergencies.[34–36] Pediatric surgery and anesthesia fellowship training in-country are also needed to boost perioperative care capacity. To address this, the pediatric surgery fellowship at Mulago National Referral Hospital was recently expanded to include Mbarara Regional Referral Hospital, increasing the number of pediatric surgery fellows trained in Uganda each year.[37] According to recent international guidelines for optimal resource distribution for children's surgery, district and other regional referral hospitals with general surgeons can perform less complex elective and emergency procedures including inguinal hernia repairs and diversion for intussusception. This may also reduce the burden of emergency cases on the regional and national referral hospitals allowing these hospitals to perform more complex congenital and oncology cases.[13,38] A pediatric surgery training program for rural general surgeons has been developed recently in Uganda for this purpose.[37] The introduction of new procedural capability may also assist in addressing the burden of emergency procedures. The introduction of saline enemas to reduce intussusception in children was effective in an Ethiopian hospital.[39]

This study has several limitations. It is a retrospective review of 2 clinical and operative databases. However, given that Mulago and Mbarara Hospitals are the national and regional referral hospitals as well as the only centers routinely providing specialized pediatric surgery services in the country, we believe the information remains informative. Important emergency disease categories, most notably "burns" will be under-represented in our database as these patients are directly admitted to and cared for by the plastic surgery team at each respective hospital. One of the limitations of the database includes a lack of clinical details, which limits our ability to risk stratify patients allowing a more in-depth analysis of perioperative mortality as well as a comprehensive list of postsurgical morbidity. We were also unable to evaluate how limitations in other pediatric subspecialties, including anesthesia, pathology, and radiology, affect the burden of emergency pediatric procedures on the healthcare system.

In conclusion, the burden of emergency procedures on the limited surgical capacity for children's surgery in Uganda have significant effects on the healthcare system. The high rates of emergency procedures being performed at the national referral hospital and major regional referral hospital in Western Uganda demonstrate that increased surgical resources are necessary to allow for both emergency procedures while not limiting the number of complex elective procedures. Validation of more specific metrics such as rates of incarcerated to elective hernia repair and temporary diversion to definitive repair of colorectal procedures may also provide greater information about surgical backlogs and associated morbidity in similar settings.

Funding/Support

This research study did not receive any specific grants or other funding source that supported this investigation.

Conflict of interest/Disclosure

All authors associated with this work have no financial or other potential conflicts of interest to report.

Appendix Table 1: Pediatric Surgical Conditions Collected in Database

CODE	CONDITION	Surgical Acuity
1	High anorectal malformation	Colostomy – 1; PSARP- 3
2	Vestibular anus	Colostomy – 1; PSARP- 3
3	Other low anorectal malformations	Colostomy – 1; PSARP- 3
4	Hirschsprung's Disease	Colostomy – 1; PSARP- 3
5	Intussusception	1
6	Sacrococcygeal teratoma	2
7	Other teratomas	2
8	Wilms tumor	2
9	Biliary atresia	2
10	Gastroschisis	1
11	Omphalocele	1
12	Burkitt's lymphoma	2
13	Other lymphomas	2
14	Umbilical hernia	Incarcerated/strangulated- 1; Elective repair- 3

(*continued*)

CODE	CONDITION	Surgical Acuity
15	Inguinal hernia	Incarcerated/strangulated- 1; Elective repair- 3
16	Hydrocele	3
17	Blunt abdominal trauma	1
18	Splenic rupture	1
19	Other forms of trauma	1
20	Necrotizing fasciitis	1
21	Abscess/cellulitis	1
22	Rectal prolapse	3
23	Pyloric stenosis	1
24	Hemangioma	3
25	Constipation/fecal impaction	3
26	Esophageal atresia with TOF	1
27	Duodenal obstruction	1
28	Jejunal atresia	1
29	Ileal atresia	1
30	Colonic atresia	1
31	Cloaca	Colostomy- 1; Complex elective repair- 3
32	Cystic hygroma/ lymphatic malformation	3
33	Appendicitis	1
34	GERD	3
35	Primary peritonitis	1
36	Typhoid ileal perforation	1
37	Ovarian tumors	2
38	Cloacal exstrophy	1
39	Post circumcision hemorrhage or sepsis	1
40	Prune belly syndrome	3
41	Thyroglossal duct cyst	Infected- 1; Elective- 3
42	Mesenteric cysts	2
43	Undescended testicle	3
44	Rhabdomyosarcoma	2
45	Choledochal cyst	3
46	Conjoint twins	1
00	Other non-coded conditions	1, 2 or 3

Surgical Acuity- 1- emergent, 2- urgent, 3- elective

(*continued*)

Code	Type of Surgery	Surgical Acuity
21	Laparotomy	1- emergent; 2- urgent; 3- elective
22	Laparotomy and reduction	1
23	Laparotomy, resection and stoma	1
24	Laparotomy, resection and anastomosis	1
25	Laparotomy, drainage and lavage	1
26	Laparotomy and splenectomy	1
27	Laparotomy and excision	1- emergent; 2- urgent; 3- elective
28	Laparotomy reduction and anastomosis	1
29	Duodenoduodenostomy	1
30	Duodenal web excision	1
31	Excision of SCT	2
32	Gastrojejunostomy	1- emergent; 2- urgent; 3- elective
33	Gastrocystostomy	1- emergent; 2- urgent; 3- elective
34	Orchiopexy	3
35	Appendectomy	1
36	Plication of rectal prolapse	3
37	Redo circumcision	1- emergent; 3- elective
38	Redo PSARP	1- emergent; 3- elective
39	Nephrectomy	2
40	Pyloromyotomy	1
41	Umbilical/epigastric hernia repair	Incarcerated/ strangulated- 1; Elective repair- 3
42	Excision of splenic cyst	2
43	Kasai procedure	2
44	Omphalocele repair	1
45	Gastroschisis repair	1
46	Rectal polyp excision	3
47	Esophageal atresia and TOF repair	1
48	Emergency separation of twins	1
49	Posterior sagittal anorecto-vagino-urethroplasty	3
50	Lavage and tension sutures	1

Surgical Acuity- 1- emergent, 2- urgent, 3- elective

Appendix Table 2: Surgical Codes Collected in Database

Code	Type of Surgery	Surgical Acuity
1	Colostomy creation	1
2	Ileostomy creation	1
3	Stoma refashioning	1 or 3
4	Colostomy closure	3
5	Ileostomy closure	3
6	Hydrocelectomy	3
7	Herniotomy	Incarcerated/ strangulated- 1; Elective repair- 3
8	Herniotomy and resection and anastomosis	1
9	Swenson Procedure	3
10	Soave Procedure	3
11	Duhamel Procedure	3
12	Pull through and closure of stoma	3
13	Rectal biopsy	2
14	Excision/ tru-cut biopsy	2- presumed malignant; 3- presumed elective
15	Colostomy and rectal biopsy	1
16	PSARP	3
17	PSARP and SCT excision	2
18	Anoplasty	3
19	EUA and dilatation	3
20	Incision and Drainage, skin graft, and debridement	1

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