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The Global Initiative for Children's Surgery (GICS)

Surgery and the First 8000 Days of Life

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EXECUTIVE SUMMARY

INTRODUCTION

While the development from child to adult spans the first 8000 days (or 21 years) of life, much of the focus in global child health has been on the first 1000 days of life (between conception and the 2nd birthday). Nonetheless, there are sensitive phases that shape development during the next 7000 days (2-21 years of age). Recent attempts to address these other critical developmental phases revolve around medical conditions, with less emphasis on surgical conditions affecting children. While the findings presented in volume 8 (Child and Adolescent Health and Development) of the Disease Control Priorities 3rd Edition (DCP3) were striking, there continues to be little mention of surgical conditions (D. Bundy and others n.d.).

Globally, about 1.7 billion children lack access to surgical care, most of whom reside in low- and middle-income countries (LMIC) where the proportion with no access reaches 92-98% (Mullapudi and others 2019). An estimated 85% of children in LMIC will develop a potentially treatable surgical condition before the age of 15 from various causes including injury, congenital malformations, and infection, contributing significantly to the burden of surgical disease (Bickler, Telfer, & Sanno-Duanda 2003). In 2019, children aged 0-14 years made up 42% of the population in low-income countries (LIC), 30% in lower-middle-income countries, 21% in upper-middle income, and 16% in high-income countries (The World Bank 2019). Despite the predominance of children in LMIC, there is a significant infrastructure gap for children's surgical care in these areas. In a survey of 37 hospitals in 10 West African countries of which 32 were tertiary hospitals, 19 facilities lacked neonatal or general intensive care units, 24 lacked apnea monitors, and 15 did not have running water (Okoye and others 2015a). Paediatric surgeon density per 100,000 children less than 15 years old in Africa was between 0 to 0.15, which is significantly lower than the American Pediatric Surgical Association recommended specialist paediatric general surgery density of 1 per 100,000 children (Krishnaswami, Nwomeh, & Ameh 2016). An estimated continent-wide deficiency of 2792 paediatric general surgeons reveals the magnitude of the workforce crisis in this region (Krishnaswami, Nwomeh, & Ameh 2016). The paediatric surgical patient is not simply a small adult but often harbours unique health problems, such as surgically correctable congenital anomalies and neonatal conditions, which may have a lasting impact on adult life and cannot be treated by a general surgeon.

Similar to low paediatric surgeon density, there is a paucity of physician anaesthesia providers (anaesthesiologist) and even fewer who are specifically trained to care for children (paediatric anaesthesiologists) (Kempthorne and others 2017). The reported number of Anaesthesiologists has been reported to be as low as 1: 2,000,000 population in parts of Africa. Children's anatomy, physiology, and children's specific surgical conditions require distinct anaesthetic skills, tissue handling skills, smaller-sized equipment and tailored infrastructure.

DEFINING THE NEXT 7000 DAYS (2-21 years of age)

The first 1000 days of life is a unique period of opportunity to establish the foundations of optimal health, growth and neurodevelopment across the lifespan. However, the next 7000 days account for ages 2-5 as well as 3 critical phases of life: middle childhood growth and consolidation phase (5-9 years), adolescent growth spurt (10-14 years) and adolescent phase of growth and consolidation (15-19 years) (D. Bundy and others n.d.; Cusick & Georgieff 2013). The first 1000 days is prioritized because poor health outcomes occur often during infancy, when the child is most frail. For example, 47% of all under-five deaths occurred in the newborn period with about one-third of those dying on the day of birth and close to three quarters dying within the first week of life in 2019 (World Health Organization 2020b). However, as interest and expenditure grow to provide better healthcare to infants, interventions in the 3 later phases are also crucial to securing the gains of investment in the first 1000 days. Furthermore, the focus in reducing mortality should broaden to improving in outcomes in those children that die from surgical conditions of all ages.

KEY MESSAGES

There is an urgent need to invest in the surgical care of children and adolescents for the following reasons:

- A large majority of the unmet burden of children's surgical diseases remains in LMIC - Close to 2 billion children and adolescents lack access to surgical care, primarily in LMIC where children 0-14 years constitute 40-50% of the population.
- Children's surgical diseases from birth to adolescence cause significant mortality and long-term suffering and disability in LMIC.

- Key limitations in surgical and anaesthesia workforce and infrastructure in LMIC hinders surgical capacity upscaling even while effective training interventions are underway through a variety of initiatives including ministries of health, professional societies and non-governmental organizations. In 2016, reported paediatric general surgeon density per 100000 children in Africa ranged between 0 and 0.15 while calculated deficits was nearly 800 paediatric general surgeons across 8 countries. Reported density of anaesthesiolgists in parts of Africa is as low as 1: 2,000,000 population. The density of paediatric anaesthesioloigsts is even lower. Children's surgery has not been given much-needed attention, as demonstrated by limited infrastructure and workforce in many regions and the absence of children's surgery in existing child health policies.
- There is a dearth of appropriate research on capacity strengthening in LMIC alongside a lack of inclusion and integration of children's surgery in child health initiatives.
- More LMIC leadership is necessary to bring these initiatives to fruition with more equitable organization and inclusion.

DISEASE BURDEN AVERTABLE BY CHILDREN'S SURGERY

Surgical care is vital in the treatment of many conditions including, but not limited to surgically correctable congenital anomalies, life-threatening injuries and burns, infections, and cancers. Estimates show that surgical conditions account for up to 30% of the global burden of disease, which is more than that of malaria, tuberculosis and human immunodeficiency virus (HIV) combined (Meara and others 2015). Furthermore, children's surgical disease is disproportionally higher in LMIC where children and adolescents make up about 50% of the population. Untreated child and adolescent surgical conditions have a risk of lifelong disability and an increased risk of mortality. The actual surgical need in LMIC is likely underrepresented due to the lack of access to care and high-quality data.

Congenital anomalies account for 25.3-38.8 million disability-adjusted life years (DALYs) worldwide and are ranked as the 5th leading cause of mortality in children under 5 years of age in 2019 (Institute of Health Metrics and Evaluation n.d.). It is estimated that two-thirds of the burden of disease related to congenital anomalies can be averted through surgical care (Debas and others 2015). Despite congenital anomalies being a leading cause of child mortality, in a 2020 World Health Organization report listing simple and affordable interventions that could be used to treat or prevent this group of conditions, surgical care was absent (World Health Organization 2020c). This further underscores the existing neglect of children's surgery and the continued perception that surgery is complex, expensive and not cost-effective despite a preponderance of evidence to the contrary.

In 2019, among children under five years of age, unintentional injuries accounted for 21.56 deaths per 100,000 and transport injuries 6.16 deaths per 100,000 (Institute of Health Metrics and Evaluation n.d.). Among children aged 5-14 years, unintentional injuries were responsible for 7.09 deaths per 100,000 and transport injuries 4.54 deaths per 100,000, ranking as the 2nd and 4th leading cause of death within U5 and 5-14 year age groups respectively (Institute of Health Metrics and Evaluation n.d.). In addition, about 95% of the estimated 1 million paediatric trauma deaths globally occur in LMIC, and surgical care plays a central role in reducing this burden.

The management of paediatric cancers often requires surgical intervention for diagnosis and definitive treatment. Its increasing incidence in LMIC has now made paediatric cancers a global child health priority (Gupta and others 2014). Regional variations and country-level disparities exist in cancer incidence and survival, with lower human development index countries exhibiting a 5-year survival as low as 20% (Cancer Atlas n.d.). Outcomes are poor in LMIC due to suboptimal care, scarce essential medicines and technologies, delayed diagnosis, loss to follow-up with incomplete treatment and financial burden. As a result, at least 60% of children who suffer from cancer die from their disease (*Cancer in Children* n.d.; Gupta and others 2015; Howard and others 2018).

Although poorly defined, the burden of infectious conditions (e.g., appendicitis, abscesses, bone infections, empyema, tonsillar abscesses, acute peritonitis from typhoid perforation, abdominal tuberculosis, etc.) requiring surgery in LMIC also represents a significant proportion of the burden of disease globally. This is especially frequent in Africa (Rickard and others 2020).

Despite increasing knowledge of the substantial surgical burden of disease in children, the role of surgery in improving the survival and quality of life in children is nonetheless often absent in the public health agenda, population-based strategies and interventions (Mullapudi and others 2019).

ECONOMIC EVALUATION OF CHILDREN'S SURGERY

Several aspects of children's surgery are very cost effective with significant societal economic benefits and are an ideal target for enhanced investment. A substantial number of the 43 essential surgical procedures defined by the DCP3 are children's surgical procedures (Table 1). Further definition of the economic value of paediatric surgical healthcare interventions would be a powerful advocacy tool to aid resource allocation decisions by policy makers. However, several areas of children's surgical care still lack adequate economic analysis.

Cost-Effectiveness of Children Surgical Procedures

Current evidence reveals that surgical care for congenital anomalies is a cost-effective means of reducing the burden of disease (Kim and others 2020). In Nepal, cleft lip repair added between $56,919 and $143,363 to lifetime individual income while cleft palate repair added between $152,372 and $375,412 using the value of a statistical life to calculate monetary benefit (Corlew 2010). A systematic review showed that common paediatric surgeries performed in LMIC such as inguinal hernia repair, male circumcision and cleft lip and palate repair were cost effective with cost per DALY averted of between $12.88- $78.18, $7.38-$319.39 and $18-$3462 respectively (Grimes and others 2014). Paediatric cardiac surgery in LMIC had a cost per DALY averted of $171, while surgery for congenital diaphragmatic hernia and anorectal malformations have also been shown to be cost effective (Cardarelli and others 2018; Poley and others 2008). A recent systematic review documenting the incremental cost effectiveness ratios (ICER) of paediatric surgical procedures concluded that cardiac, otolaryngology, ophthalmology, orthopaedics, urology, neurosurgery, plastic and reconstructive surgery and paediatric general surgery procedures were all found to be cost effective (sometimes defined as cost less than GDP per capita / DALY averted in LMIC) with an ICER ranging from $4-$14 per incremental DALY averted.(Saxton and others 2016)

Surgical Platform

First-level hospitals in LMIC are particularly cost-effective as a surgical delivery platform, with costs of $10-$220 per DALY averted for all surgical care delivered (Gosselin, Maldonado, & Elder 2010; Gosselin & Heitto 2008; McCord & Chowdhury 2003). Hence, there is a need to ensure availability that these facilities are capable of safely providing a wide array of basic emergency skills. The Optimal Resources for Children's Surgical Care (OReCS) document from the Global Initiative for Children's Surgery provides a comprehensive guide on best practices for human resource, infrastructure and procedures that would allow for provision of children's surgical care at various hospital levels (Table 2) (D. Grabski and others 2019).

Table 1: Essential children surgery procedures by hospital level, derived from Optimal Resources for Children's Surgical Care (D. Grabski and others 2019)

Surgical Condition	Health Center	First-level hospital	Referral hospital		
			Second-level hospital	Third-level hospital	National children's hospital
Trauma/ Injuries	Resuscitation: BLS Injuries: Wound care for simple lacerations, Fractures: closed non-displaced Burns: first degree	Resuscitation: ALS, ATLS Injuries: Thoracostomy Trauma Laparotomy Trauma-amputation Fractures: Closed reduction, Open I&D with external fixator placement Burns: first, 2nd degree < 10% TBSA, excluding face, hands, perineum Simple escharotomy	Resuscitation: All, NICU, PICU Injuries: Trauma Thoracotomy Renal/Urethral trauma Vascular shunt Fasciotomy Craniotomy Fractures: Complex nonunion & malunion, Pinning for slipped capital femoral epiphysis Burns: first, 2nd degree < 10% TBSA excluding face,	Resuscitation: All, NICU, PICU Injuries: Complex Neuro-trauma Complex neurovascular extremity injuries including limb spearing operations Fractures: All including Cranial fractures Burns: >10% TBSA Burns including face, hands, perineum	All

			hands, perineum		
Congenital anomalies	Screening: Abdominal hernias, Urogenital abnormalities, Hip dysplasia & limb deformities, Congenital heart defects, Neural tube defects, Craniofacial anomalies	Inguinal hernia/ hydrocele repair, Relief of urinary obstruction: catheterization & suprapubic cystostomy, Club foot: non-operative manipulation, Treatment of PDA dependent disease with IV prostaglandin E2	Neonatal intestinal obstruction, Meatal stenosis, Orchidopexy for testicular torsion & palpable undescended testes, Closed reduction and Pavlik harness for hip dysplasia, Club foot operative treatment, Hydrocephalus	Gastroschisis & Omphalocele Anoplasty and Pull through for ARM/Hirschsprung, Hypospadias/epispadias, Development dysplasia of Hip, Clubfoot, PDA, Coarctations, TOF, Spina bifida, myelomeningocele, meningocele, dysmorphic syndromes, craniofacial abnormalities, syndactyly	All

Infections	I&D of superficial abscess	Thoracostomy for empyema Laparotomy for Appendectomy,	Leprosy, Tonsillectomy I&D of neck abscess	Advanced osteomyelitis, tenosynovitis, sepsis and septic shock, I&D	All

		typhoid complications, I&D of superficial, pyomyositis, perianal, anorectal abscess, Septic arthritis, Osteomyelitis, Extraction, drainage of abscess, caries		of retropharyngeal abscess, treatment for intracranial infections (hydrocephalus, subdural empyema)	
Tumors	Screening for all abdominal tumors	Biopsy of palpable or U/S visualized mass Excision of benign tumors/cysts	Biopsy of all tumors, Excision of benign tumors/cysts Diagnosis of malignant tumors	Abdominal and urologic malignant tumors Malignant tumors of extremities Head and neck tumors Simple intracranial tumors	All
Others	Male circumcision using plastibell, Rectal prolapse reduction Foreign body removal from ears, nose, mouth	Central venous line Laparotomy for Intestinal obstruction	Functional and obstructive urinary pathology (pelvic-ureteral obstruction) Arthrotomy synovectomy Shunt Tap & Trans-fontanelle Ventricle Tap	Muscular dystrophy, limb reconstruction ureteral duplication anomalies, vesico-ureteral reflux Free Tissue Transfer, Local Flaps, Amniotic band release tympanoplasty, Ossiculoplasty,	All

Abbreviations-ALS- Advanced Life Support; ATLS- Advanced Trauma Life Support; BLS- Basic Life Support; ARM- Anorectal Malformation; I&D- Incision and Drainage; NICU- Neonatal Intensive Care Unit; PICU-Paediatric Intensive Care Unit; PDA- Patent Ductus Arteriosus, TBSA- Total Body Surface Area; TOF-Tetralogy of Fallot; U/S- Ultrasound

Table 2: Surgical procedures for children by facility level, classified by subspecialty

Specialty	Health Center	First-level hospital	Referral hospital		
			Second-level hospital	Third-level hospital	National children's hospital
Anesthesia	Local anesthesia	General anesthesia without invasive monitoring or post- operative ventilation; Children < 3 months old and ASA > 3 referred to higher level facility	General anesthesia for most Major surgeries; all ages	General anesthesia for all subspecialty surgical procedures; all ages and co-morbidities	General anesthesia for subspecialty surgical procedures, all ages and co-morbidities
Cardiac Surgery	Cardiovascular examination for congenital heart defects, ECG	Medical treatment (PE2) of PDA-dependent diseases, Basic Echocardiography	Same as First-level hospital	Surgical closure of PDA, Surgical correction of simple coarctation (non-neonatal)	All cardiac surgery procedures including Catheterization for ASD and pulmonary valve stenosis, Palliative treatment of TOF
Critical Care	Recognition of illness severity, Treatment of pneumonia, dehydration	Airway management, Resuscitation and stabilization, Venous Cut-down, Treatment of sepsis, Pneumonia, Meningitis	Acute paediatric emergencies, Treatment of ARDS, Septic Shock, Coma	All NICU and PICU procedures, Treatment of traumatic brain injury, Meningoencephalitis, Cardiac failure	All NICU and PICU procedures, All co- morbid conditions
General Surgery	I&D of superficial abscess,	Trauma and Emergency laparotomy,	Trauma Thoracotomy, ARM &	All General Surgery procedures including repair of	All General Surgery procedures

	Simple and minor lacerations	Emergency colostomy, Hernia repair Trauma amputation, Thoracostomy, Anoplasty (cut-back)	Hirschsprung Disease	gastroschisis and omphalocele, intra-abdominal malignancy	
Neurosurgery	Diagnosis and Triage of Neurotrauma	Exploratory Burr Holes, Trans-fontanelle Ventricular Tap	Trauma Craniotomy	ICP monitor, Intracranial infection, Hydrocephalus, Myelomeningocele, Neuroendoscopy	Vascular Malformations, Complex cranial tumors, Congenital Spinal Deformities, Cranial Malformations, Epilepsy

Ophthalmology	Antibiotic eye drops, Irrigation of eye after chemical injury	Foreign Body, Corneal Scratch, Hyphema	Lid Lacerations, Corneal laceration, Cataract operation (> 10 years old)	Cataract surgery (all ages), squint surgery, primary closure of trauma, Simple ptosis surgery	Glaucoma and corneal procedures, Retinopathy of premature procedures, Oculoplastic procedures
Oral Maxillofacial Surgery	Simple lacerations, Antibiotics	Dental extraction	Repair of cleft lip/palate Fabrication of feeding plates, pre-surgical naso-alveolar molding,	Facial reconstruction, Distraction osteogenesis, Osteosynthesis	All Oral Maxillofacial Procedures
Orthopedic Surgery	Splinting for simple fractures	Wound care for open fractures,	Closed Reduction for Hip	Definitive management of osteomyelitis/septi	Excision/Reconstruction of bony tumors, Correction of brachial

		Drainage for orthopedic infections (Osteomyelitis), Ponseti technique for club foot	Dysplasia, Pinning slipped capital femoral epiphysis, Fasciotomy, Syndactyly release	c arthritis, All vascular injuries, spina bifida, muscular dystrophy	plexus injury, Tendon transfers, multiple congenital deformities
Otolaryngology	Otoscopy, Rhinoscopy, Removal of foreign body from ear, nose	Drain superficial head and neck abscess, Tonsillitis treatment, Swallowed foreign body, Torticollis	Excision of benign neck mass, tonsillectomy	Parapharyngeal & retropharyngeal abscess, Tympanoplasty, Ossiculoplasty, tympano-mastoidectomy, Bone anchored hearing aids	Laryngotracheal reconstruction, Slide tracheoplasty, Complex head and neck mass excision
Plastic Surgery	Simple Laceration Repair, Management of first degree burns	Management of 2nd degree burns, Escharotomy, Stabilization of Vascular Trauma and Wound Sepsis	Complex laceration repair, Vascular shunt to preserve inflow in trauma, Revision amputation,	Soft tissue coverage (grafts, local flaps, free tissue transfer), repair of cleft lip/palate, management of craniofacial & congenital hand anomalies	Complex reconstruction after tumor excision, Management of complex cranial vault and hand anomalies
Urology	Urinary Tract Infection, Local wound care after circumcision	Circumcision, Paraphimosis, Orchiopexy, preputial-plasty, Urethral catheterization	Cystostomy, Vesicostomy, Orchiopexy, Imperforate hymen	Hypospadias and epispadias treatment, Urethral valve resection, complex repair of bladder exstrophy, nephrostomy, genitoplasty, Urolithiasis management	Mitrofanoff intervention for spina bifida, Kidney Transplant

Abbreviations- ARDS- Acute Respiratory Distress Syndrome; ARM- Anorectal Malformation; ASA- American Society of Anesthesiologist physical status classification; I&D- Incision and Drainage; ICP- Intracranial pressure; NICU- Neonatal Intensive Care Unit; PE2- Prostaglandin E2, PICU- Paediatric Intensive Care Unit; TOF- Tetralogy of Fallot

Cost of Universal Access to Children's Surgery

In DCP3, the cost required to scale up delivery of the components of essential surgery at first level hospitals was estimated, but such estimates are not presently available for children's surgery (Debas and others 2015).

CHALLENGES OF IMPROVING ACCESS TO CHILDREN'S SURGERY

Workforce

The paediatric general surgical workforce in LMIC suffers from a severe shortage. In 2016, calculated national deficits in LMIC were between 6 and 780 paediatric surgeons depending on individual country population, while the United States had an excess of 640 paediatric general surgeons for the same age group (Krishnaswami, Nwomeh, & Ameh 2016). Paediatric neurosurgeon density in LIC of Africa is about 1 per 30 million children with more than 75% of patients traveling more than 2 hours to access emergency neurosurgical care (Dewan and others 2018). One general surgeon and <1 paediatric general surgeon serves a million people in Africa, with paediatric surgical services especially lacking for children under 6 years of age in LMIC (Madhuri, Stewart, & Lakhoo 2019; Toobaie and others 2019). Anaesthesia for children is equally challenging in LMIC. In Kenya, a cohort of paediatric surgical patients had a mortality rate that was at least 100 times higher than their HIC counterparts. Moreover, patients who fall under the American Society of Anaestheisa (ASA) class III or higher had increased odds of mortality. (Newton and others 2020). The density of physician and non-physician anaesthesia providers in these settings is very low. Moreover, they often have variable training and scant support with limited opportunity for continuing education, resulting in a deficit in knowledge, skill and equipment to manage paediatric patients (Hodges and others 2007; Kempthorne and others 2017; Tuyishime, Powell, & Evans 2021). Inadequate nursing levels remain prevalent in LMIC and are linked to increased mortality and prolonged hospitalisation (Haegdorens and others 2019)). Therefore, strengthening paediatric nursing is recommended for the reduction of under-five mortality (McKerrow and others 2014). Nurses often receive inadequate training and are too overworked to provide quality care to cover large populations (Day and others 2014). Recent work has shown that greater than 500,000 under 5 childhood deaths, 60% in the neonatal age group, could be averted through scaling up the surgical workforce in LMIC (Truche and others 2021).

Infrastructure

The dire children's surgery infrastructure gap in LMIC' mandates capital investments and wider equipment availability and maintenance at all levels of the health system. Without purposeful allocation of appropriate resources to children's surgical capacity building, economic growth in an LMIC does not translate into any significant improvement in delivering essential and emergency surgical care to children (Okoye and others 2015b). In Uganda, the implementation of a dedicated paediatric operating room had an ICER of $37.25 per DALY averted or $3,321 per life saved, compared to no existing operating room (Yap and others 2021). Furthermore, this cost-effectiveness analysis has been replicated in Nigeria, where two additional operating rooms were installed, yielding an ICER of $82 per DALY averted from the charity or installation perspective, and $137 per DALY averted from the healthcare system perspective (E. Ameh 2021). This model's ICER suggests that the construction and maintenance of a dedicated paediatric operating room in sub-Saharan Africa is very cost effective in the setting of a pre-existing hospital space and workforce.

APPROACHES TO IMPROVE ACCESS

Deliberate efforts to scale up access to children's surgical care is urgently needed in the limited-resource settings of LMIC. Several countries have created or are in the process of creating National Surgical, Obstetrics and Anesthesia Plans (NSOAPs). Inclusion of children's surgery in these plans will allow for a systematic, centralized, and sustainable approach to improving access to children's surgical care (Federal Ministry of Health 2019; Global Initiative for Children's Surgery and others 2021). GICS used a modified Surgical Assessment Tool to create the OReCS, a template of a paediatric oriented NSOAP which can serve as a foundation for a roadmap to include children's surgery in national upscaling plans (Global Initiative for Children's Surgery and others 2021). Outlined in the OReCS, the resources recommended for different levels of children's surgical care are designed to support basic, intermediate and complex/advanced surgical care for children in low-resource settings, providing a guide for minimum standards for those planning surgical services for children in LMIC even in the absence of a national surgical plan. Nevertheless, funding to expand children's surgical care remains a major challenge, and government funding alone has been substantially insufficient. Expansion of health insurance, innovative taxation mechanisms and collaboration with local and international non-governmental developmental partners could help improve funding for children's surgery (Ullrich and others 2022). A recent study showed up to 17 times higher odds of incurring catastrophic health expenditure in LMIC than HIC for children's surgery. In addition, the global health community has over the last several years been having more in-depth dialogues on the importance of equitable relationships between HIC and LMIC partners in the framework of "decolonizing global health", especially in ensuring that LMIC voices are heard and that LMIC capacity can be strengthened. This dimension must also be integrated with all ongoing initiatives (Hedt-Gauthier and others 2019; Scheiner and others 2020).

SUMMARY: SURGERY AS A CORE COMPONENT OF UNIVERSAL HEALTH COVERAGE

The large unmet burden of paediatric surgical conditions affecting an estimated 1.7 billion children is shouldered predominantly by LMIC, and about 85% of children within the region developing a potentially treatable condition before the age of 15 years (Bickler, Telfer, & Sanno-Duanda 2003; Mullapudi and others 2019). If left unaddressed, surgical conditions in children result in tremendous preventable mortality, lifelong disability and economic losses. Many surgical conditions in children can be treated in a cost-effective manner. There has been increasing interest and involvement from the global community to scale up access to surgical care, but children's surgery has not been a primary area of emphasis. Without addressing surgical conditions, universal health coverage and the child-health related targets of the sustainable development goals (SDGs) cannot be achieved in LMIC. Some of these SDGs include SDG 1 reduction of poverty; SDG 3.2 – reduction of preventable newborn and under 5 years of age mortality; SDG 3.4 – reduction by one third premature deaths from NCDs; SDG 3.6 – reduction by one half deaths and injuries from road traffic crashes; SDG 4 quality education; SDG 5 gender equality; SDG 8 economic growth; SDG 10 reduced inequalities; SDG 13 climate change; and SDG 17 partnerships Urgent action must be taken now to ensure the full capacity of children's surgical care can benefit families and communities in LMIC. The next sections of this document summarize several key areas of children's surgery with recent evidence, current activities, and priority future directions.

BURDEN OF CHILDREN'S SURGICAL CONDITIONS IN LMIC

TRAUMA AND INJURIES

Background

In 2016, 4,883,194 people died from unintentional injuries worldwide based on global health estimates by the World Health Organization, which is five times the HIV and tuberculosis deaths (World Health Organization 2016). Of those, about 20% or 1 million deaths and 50 million disabilities were in children aged from 0 to 18 years. Trauma is the most common cause of paediatric deaths and is a leading cause of disability among children worldwide. Ninety five percent of the 5.8 million annual trauma deaths occur in low-and-middle-income countries (LMIC) where children make up a greater percentage of the population (Chandran, Hyder, & Peek-Asa 2010; Debas and others 2015; He and others 2014; Kiragu and others 2018; Peden & World Health Organization 2008). 830,000 of the nearly 1 million annual trauma deaths in children are caused by unintentional injuries (Peden & World Health Organization 2008). In fact, trauma is the most common reason for a paediatric hospital admission (Foster and others 2017). The 5 most common causes of unintentional injuries in children are road traffic crashes, falls, burns, drowning and poisoning (Peden & World Health Organization 2008). An alarming number of children are also injured or killed in war-zones, disasters and from child abuse (Carlson and others 2016; He and others 2014). Older children, adolescents and young adults are most affected. There is currently a global shift towards prioritization of child and adolescent health resulting in special attention towards examining and addressing non-fatal illness and disability including injury related disability.

The Burden

In 2019, injuries were responsible for 9.6% of all deaths in children and adolescents less than 20years old (Institute of Health Metrics and Evaluation n.d.). Factors responsible for a significantly high burden of unintentional childhood injury in LMIC include: inherent curiosity and absence of risk aversion in children, a universal lack of safe play areas, and child labor often occurring in dangerous conditions (Bartlett 2002; He and others 2014).

A national household survey of 2176 children in Uganda found that lifetime prevalence of untreated surgical conditions was 14%, with trauma as the predominant surgical condition at 48.4%, followed by wounds due to injury 19.7%, acquired deformities 16.2% and burns 12.5% (Butler and others 2016). In a multicenter prospective cohort study across 11 countries, 8 of which were LMIC, the most common mechanisms for paediatric trauma were road traffic crashes, falls and interpersonal violence (Bradshaw and others 2018). In a multisite LMIC study on unintentional injuries in children aged 12 years and below, falls accounted for about 50% of the cases while RTIs and burns accounted for 16.3% and 8.8% respectively (He and others 2014).

Due to its impact on child morbidity and mortality figures, childhood injury prevention and treatment is key in the overall improvement of children's health. However, provision of trauma care varies widely across the world and is often inadequate. In Ghana, hospital assessments revealed marked deficiencies in trauma training and essential emergency equipment including airway supplies, chest tubes, blood pressure cuffs, blood draw supplies, and portable x-rays (Ankomah and others 2015).

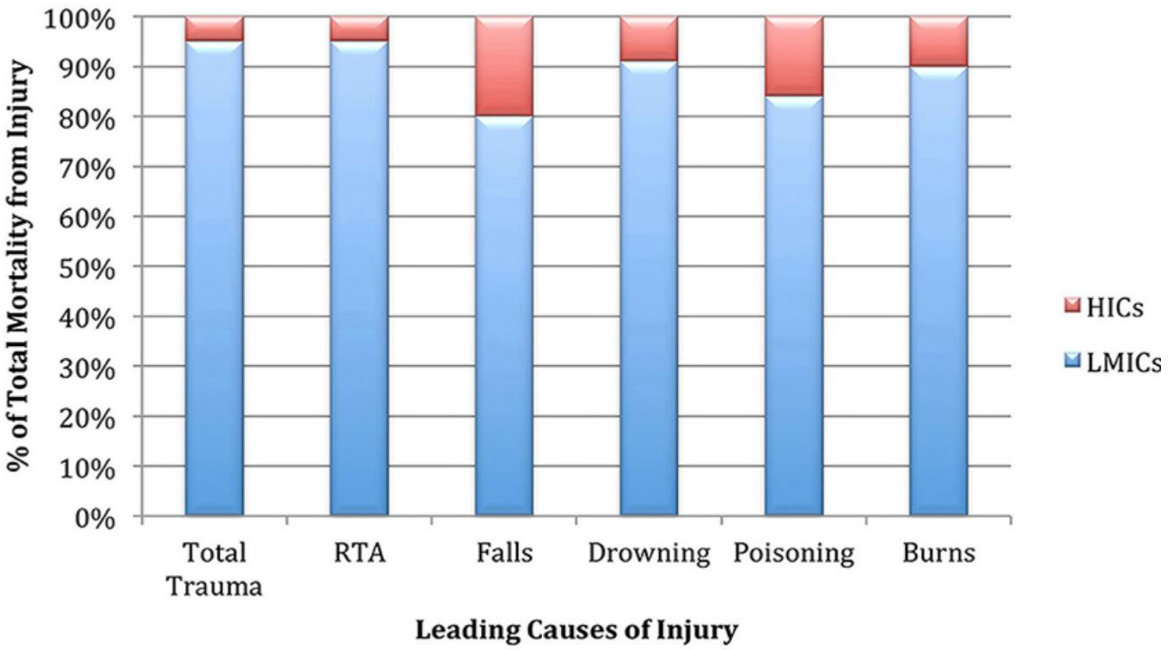


Figure 1: Global leading causes of injury. Source: Kiragu AW, Dunlop SJ, Mwarumba N, et al. Paediatric trauma care in low resource settings: Challenges, opportunities, and solutions. Front Pediatr. 2018;6:155. doi:10.3389/fped.2018.00155

Figure 2: Graph demonstrating the distribution of age at injury in low- and middle-income countries (LMIC) and high-income countries (HIC).

Road Traffic Crashes

Though underreported, road traffic crashes are currently the leading cause of death for children and young adults aged 5-29 years, with the numbers steadily increasing to 1.35 million deaths in 2016 (World Health Organization 2018). Mortality rate is about 27.5 per 100,000 population in LMIC, three times higher than that of HIC at 8.3 per 100,000 population (World Health Organization 2018). RTAs have surpassed falls as a leading cause of death and injury in children, killing 186,300 children less than 18 years of age annually, with boys twice as likely to be killed as girls (Emejulu & Shokunbi 2010; Li, Alonge, & Hyder 2016). Over 35% of global child deaths from RTAs occur in Sub-Saharan Africa (Li, Alonge, & Hyder 2016). In an observational study of children's hospital in South Africa, nearly 50% of 4,690 children less than 14 years old presenting with road traffic crash injuries were between 5 and 9 years of age, with the most common mechanisms of injury being vehicular pedestrian crashes (about 75% of cases) and unrestrained passengers crash injuries (Isaac, Van Niekerk, & Van As 2015). About 58% had minor injuries and 40% required inpatient treatment. Pedestrian accidents in children occur not only during the trip between home and school, but also out in the streets. A multi-institutional study in Brazil showed that 81.3% of child pedestrian accidents occurred on the streets off the home-school path, and 27% of the children were out of school (Abib and others 2017). In LMIC, road traffic safety measures are especially limited and contribute to the high burden of RTA. Children are particularly vulnerable as pedestrians in poorly planned traffic environments where pedestrian walkways are often absent. In addition, they are often not appropriately restrained as passengers (Abantanga 2002; World Health Organization 2018). The risk is further increased by the sweeping urbanization taking place in LMIC (Abdur-Rahman, van As, & Rode 2012). As a result of these deficiencies, the SDG 3.6 to halve the number of global deaths and injuries from road traffic crashes by 2020 was far from realized by the end of the target year. Improving road safety with wider installation of speed bumps at high injury incidence locations, seat belt use, helmet laws, enhanced vehicle safety, pedestrian walkways, enforcement of speed limits and sober driving, should be part of a national healthcare plan aimed at reducing the burden of trauma (Banstola & Mytton 2017; Li, Alonge, & Hyder 2016).

Burns

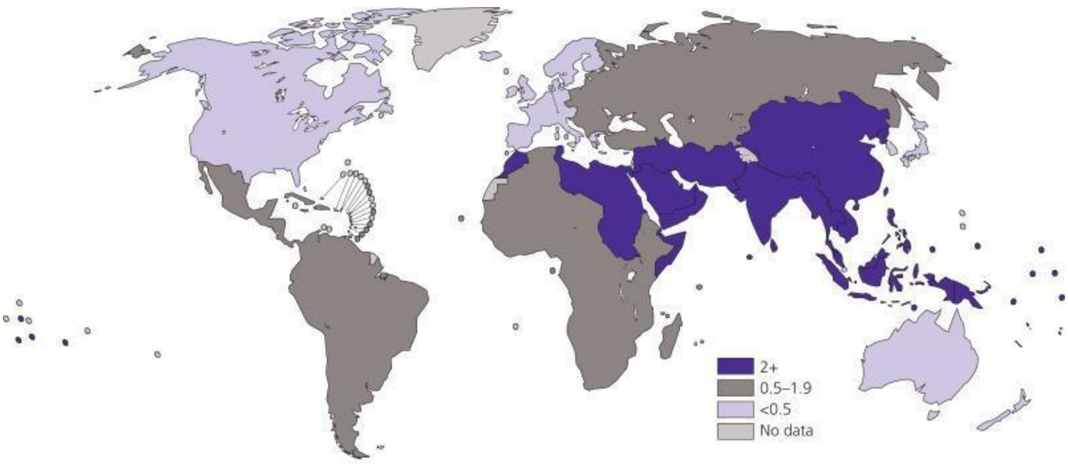
Globally, over 30,000 new burn cases occur daily, and an estimated 11 million people suffer burn injuries annually leading to over 265,000 deaths (Argenta & Demos 2017; Gali, Madziga, & Naaya 2004; World Health Organization n.d.-a). As with other traumatic injuries, the vast majority (up to 96%) of burn injuries and deaths occur in LMIC (World Health Organization n.d.-a). Children below the age of 15 years old are at increased risk of burns in LMIC, where up to 80% of all burns occur in children less than 10 years old and 1 in 5 cases is fatal (Nthumba 2016). Burns leave long-lasting damage, as 18% of the 173,000 Bangladeshi children who are moderately or severely burned each year are left with a permanent disability. Many are left with lifelong disfigurement, poverty and societal isolation (Stokes & Johnson 2017; World Health Organization n.d.-a).

Paediatric burns are more likely to be fatal or result in permanent disability, with the underdeveloped healthcare infrastructure of LMIC contributing to poor outcomes (Wesson and others 2013). One regional referral center in Tanzania found that almost half of burn victims arrived >72 hours after injury (Ringo & Chilonga 2014). In South Africa, most hospitalized burned children came from informal settlements (Parbhoo, Louw, & Grimmer-Somers 2010). Burn wound care is particularly challenging when low resource areas do not have access to clean water or opioid analgesia for pain control (Jeng, Gibran, & Peck 2014; Kiragu and others 2018). In HIC burn centers, 50% children survive burns up to 90% of total body surface area (TBSA), while in LMIC, mortality as high as 50% is reported for burns less than 40% of TBSA and up to 100% mortality for burns >40% TBSA (Kasten, Makley, & Kagan 2011; Tyson and others 2013). If LMIC center outcomes matched those in the best performing HIC burn centers, over 34,000 additional lives could be saved worldwide. Burn centers employ protocolized resuscitation, topical antibiotics, skin grafting and have a mean daily cost per 1% total burn surface per patient as low as $2.65 (B. Atiyeh, Masellis, & Conte 2009; Gallaher and others 2015). In addition, burn centers are more likely to employ contracture avoidance techniques like splinting and physiotherapy to prevent further morbidity (Kiragu and others 2018). Poor outcomes in burn patients in LMIC are most often related to delayed presentation, lack of trained personnel and a paucity of burn centers (Tyson and others 2013). Additionally, the majority of childhood burns occur in the home, and public health interventions that target prevention such as changing fuel type, moving cooking fire location, and safe fuel storage have resulted in a reduction of burns (B. S. Atiyeh, Costagliola, & Hayek 2009; World Health Organization 2011).

Falls

Falls are a leading cause of paediatric emergencies and hospitalizations and are the second leading cause of unintentional injury-related death after RTAs.(de Ramirez and others 2012). Annually, more than 37 million fall-related injuries are severe enough to require medical attention, of which 400,000 are fatal with more than 80% of fall related fatalities occurring in LMIC (World Health Organization 2021). In 2004, nearly 47,000 children and adolescents under the age of 20 years died from falls worldwide (World Health Organization n.d.-b). While HIC had average mortality rates of between 0.2 and 1.0 per 100,000 children aged less than 20 years, LMIC in the same region had mortality rates up to 3 times higher (World Health Organization n.d.-b).

Children living in countries with poor infrastructure and unsafe housing conditions are especially at risk for fall injuries (He and others 2014). Males have a higher risk of falling worldwide, while infants in LMIC suffer significantly higher rates of fall-related injuries (Debas and others 2015). Efforts to prevent falls include window guards, building regulations, safe housing, access to safe playgrounds, and better supervision of children (He and others 2014; Kiragu and others 2018).



Africa	Americas		South-East Asia	Europe		Eastern Mediterranean		Western Pacific	
LMIC	HIC	LMIC	LMIC	HIC	LMIC	HIC	LMIC	HIC	LMIC
1.5	0.2	0.7	2.7	0.3	1.0	2.2	2.9	0.4	2.2

Figure 3: Fatal fall-related injury rates per 100 000 children by WHO region and country income level, 2004. HIC = High-income countries; LMIC = low-income and middle-income countries. Source: WHO (2008), Global Burden of Disease: 2004 update.

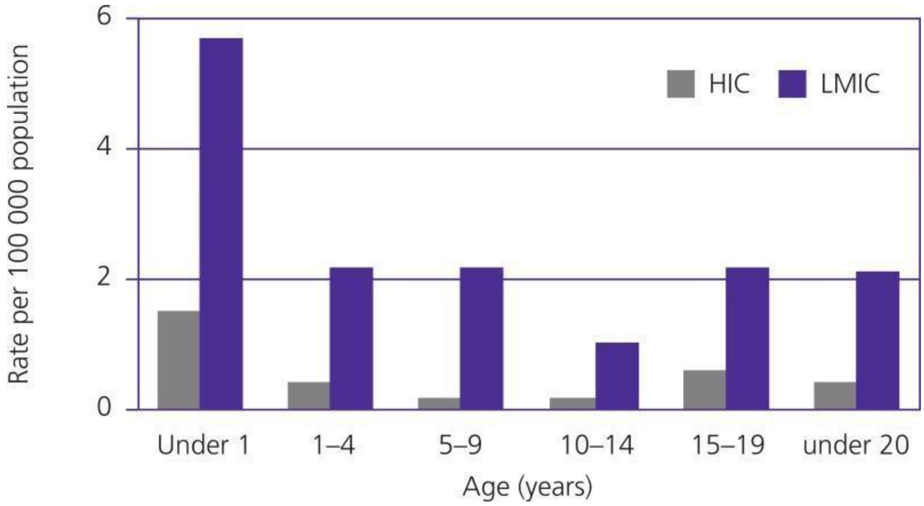


Figure 4: Fatal fall-related injury rates per 100 000 children by age and country income level, World, 2004. HIC = High-income countries; LMIC = low-income and middle-income countries. Source: WHO (2008), Global Burden of Disease: 2004 update.

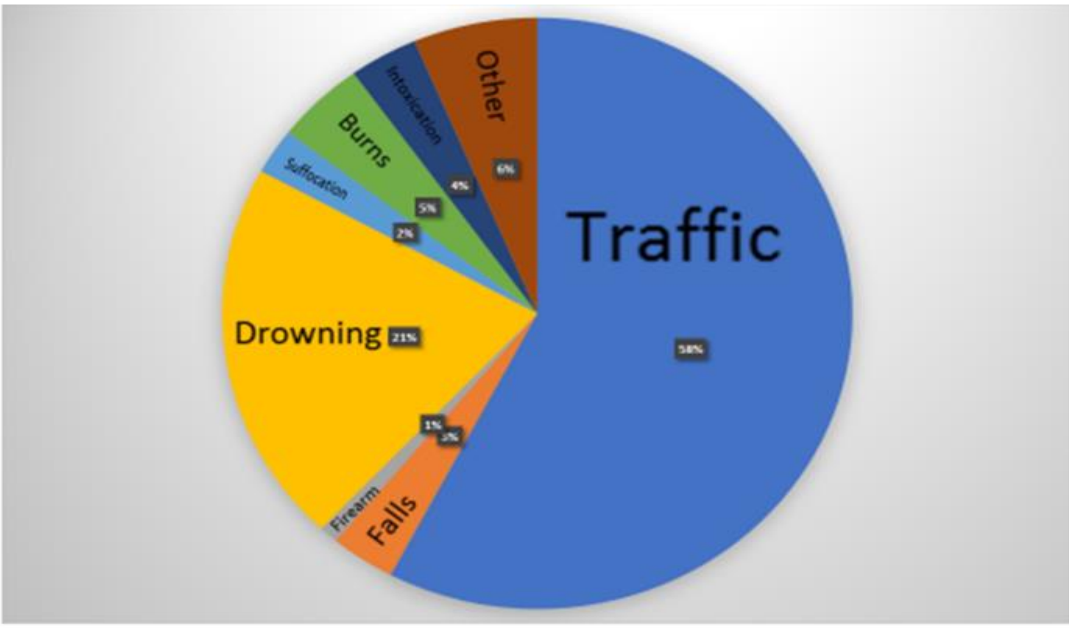


Figure 5: Deaths from unintentional injuries in children and adolescents 5–19-year-old in Brazil in 2018. Source: Official data from the Brazilian Ministry of Health (www.criancasegura.org.br)

Specific Anatomic Injuries of Public Health Importance

The following section will cover specific anatomic areas of importance such as head, chest, abdominal, and orthopedic injuries in children. Children's specific anatomy may play a role in the epidemiology and burden, such as the relatively larger size of the child's head compared to adults, and the relatively less protection of some solid viscera such as the spleen and bladder, compared to adults.

Traumatic Brain Injury

Traumatic brain injuries (TBI) affects over 3 million children annually and is a leading cause of death and disability worldwide (Dewan and others 2016). It was the 3rd most common injury in children in a multicentre prospective cohort study across 15 institutions and 11 countries, accounting for 10% of all paediatric trauma patients (Bradshaw and others 2018). Children suffering from TBI warrant particular concern given the developmental consequences from early brain damage. Reported incidence of TBI varies widely by country, ranging between 47 and 280 per 100,000 children (Dewan and others 2016). Studies show that TBI accounts for more than half of paediatric injuries in Iran, 20% of trauma emergency department admissions in India, and 30% of paediatric injuries in Korea (Dewan and others 2016). TBI spans a bimodal age distribution with very young children (<2years) and adolescents (15-18 years) more commonly injured (Dewan and others 2016). Male children suffer higher rates of TBI than females after the age of 3 years (Dewan and others 2016). Globally, RTAs are the leading cause of TBIs followed by falls (Dewan and others 2016). While in Africa and Asia pedestrians were most commonly injured, vehicle occupants were more likely involved in Australia, Europe and the US (Dewan and others 2016). Outcomes are worse in LMIC where neurosurgical intervention is often unavailable (Rubiano and others 2013).

Chest Trauma

Intra-thoracic trauma has a relatively low incidence in the paediatric trauma population, accounting for just 2% of injuries (Bradshaw and others 2018). Chest trauma is associated with high morbidity and mortality and is most commonly caused by blunt trauma following road traffic crashes (Nwafor and others 2014; Pearson, Fitzgerald, & Santore 2017). Forceful injuries are less likely to result in rib fractures in a young child as the chest wall is more compliant and cartilaginous. However, associated pulmonary/cardiac contusions, pneumothoraces, hemothoraces and mediastinal injuries are more common since the force transmits directly to the intrathoracic cavity (E. Ameh and others 2010; Pearson, Fitzgerald, & Santore 2017). Children are also more likely to develop hypoxia than adults given their lower functional residual capacity and higher tissue oxygen consumption, while their mobile mediastinum allows for faster conversion of a simple pneumothorax to a tension pneumothorax (Pearson, Fitzgerald, & Santore 2017).

Penetrating trauma is most commonly secondary to gunshot wounds as seen during the Syrian crisis, where there was a substantial upsurge in the incidence of paediatric thoracic trauma with a predominance of penetrating chest injuries (Darwish and others 2018). In many LMIC settings, the absence of equipment and trained staff precludes the feasibility of an ER thoracotomy (Kiragu and others 2018).

Abdominal Trauma

With a relatively low incidence of about 3% of paediatric injuries, abdominal injuries (AI) usually result from motor vehicle-related crashes and falls (Bradshaw and others 2018; Chirdan and others 2007; Gutierrez, Ben-Ishay, & Mooney 2013). AI often indicates a serious mechanism of injury and poor prognosis, and is associated with a significantly increased risk of death and disability when other injuries are present (Gutierrez, Ben-Ishay, &

Mooney 2013). Splenic and hepatic injuries are the most frequently noted AI's and bowel injuries are found in approximately 1–5% of blunt abdominal injuries (Gutierrez, Ben-Ishay, & Mooney 2013).

In HIC, initial imaging after abdominal trauma involves a Focused Assessment with Sonography for Trauma (FAST) evaluation. In both adults and children, FAST exams can rapidly identify intraperitoneal blood or fluid from a visceral injury non-invasively and without using radiation (Netherton and others 2019). FAST exams, however, miss roughly a third of visceral injuries in children (Chirdan and others 2007). Although FAST exams cost less than CT scans, and ultrasound machines are more readily available in LMIC, ultrasound is not always available and expertise in utilization is variable. In HIC, over 90% of blunt abdominal injuries are managed non operatively due to availability of advanced imaging like CT and MRI, in contrast to LMIC where such imaging modalities are limited, leading to higher rates of surgical exploration (Chirdan and others 2007).

Orthopaedic trauma

Fractures are a leading cause of injury in the paediatric trauma population, occurring in about 29% of paediatric trauma patients, second only to lacerations (30%) (Bradshaw and others 2018). Orthopedic trauma contributes substantially to the burden of injury in LMIC since most patients with these injuries are young (He and others 2014; Rivara 2012; World Health Organization 2018). Major causes of orthopedic trauma include falls, road traffic crashes, workplace accidents, child abuse, and injuries sustained in conflicts or other disasters. (He and others 2014; The Global Burden of Disease Child and Adolescent Health Collaboration and others 2017; World Health Organization 2018). The incidence of femur fractures is estimated to be over twice as high as LMIC compared to HIC (Cordero and others 2020).

In HIC, specialized orthopedic surgeons share interdisciplinary management decisions with plastic, vascular, trauma, general surgeons, and physical and occupational therapists (Conway and others 2017). However, in many LMIC, general surgeons carry a large burden of orthopedic trauma due to the lack of multidisciplinary care. Furthermore, families are often hesitant to provide consent for any procedures other than initial stabilization and traditional bonesetters (nonphysicians who are self-taught) offer a more affordable and accessible alternative (Nasir & Babalola 2008; Omololu, Ogunlade, & Gopaldasani 2008; Solagberu 2005, 2006). In a Nigerian hospital, trauma patients with long bone fractures often request to discharge against medical advice to seek alternate medical care and avoid financial constraints (Nasir & Babalola 2008). Surgeons are then sometimes tasked with the repercussions of mismanagement from bonesetters such as wet gangrene and compartment syndrome, prompting some to call for formalized training of bonesetters by orthodox orthopedic surgeons (Dada, Yinusa, & Giwa 2011; Omololu, Ogunlade, & Gopaldasani 2008). Another barrier is the lack of orthopedic surgical access in rural populations, as most orthopedic surgeons are located in urban areas and many centers simply do not have the adequate equipment to treat the fractures (Kiragu and others 2018; Wichlas and others 2021). Delay in expert surgical management of orthopedic injuries leads to a higher rate of limb amputations in LMIC, which further increases the cost and length of stay due to additional care needs and rehabilitation (Omololu, Ogunlade, & Gopaldasani 2008).

Presentation for common pediatric fractures such as supracondylar fractures of the humerus has been delayed by over a week on average in some prospective studies, with 98% of patients in a recent Kenyan study suffering abnormal range of motion in short-term follow up (Masumbuko and others 2019). Given that some pediatric fractures can be treated non-operatively through reduction, the critical role of the non-physician allied health workforce, such as orthopedic officers, cannot be overestimated (Guifo and others 2017). They play a vital role in limb saving interventions in rural areas of many LMIC (Wilhelm and others 2017; Zhao and others 2021). Follow up of non-operatively treated supracondylar fractures in children at a district hospital in Malawi also showed significant limitations in functional outcomes. Many of these children would have benefited from closed reduction and fixation and this surgical capacity was not available at the district hospital (Mlinde and others 2021; Mlinde, Chokotho, & Agarwal-Harding 2021). Femoral fractures in the similar context, all treated with traction, had good clinical outcomes at long term follow up.

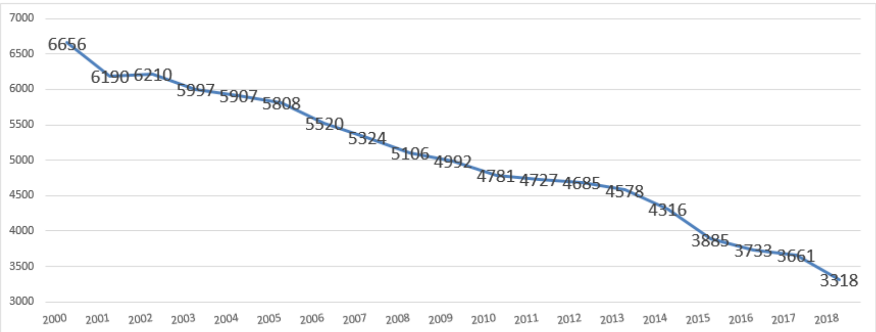


Figure 6: Unintentional paediatric trauma deaths - Brazil 2000 to 2018. www.criancasegura.org.br. Figure 8 Source: Official data from the Brazilian Ministry of Health - DATASUS

Disasters/Civil conflicts/Warfare

The United Nations Children's Fund estimates that 2 million children have been killed in wars, 4-5 million have been disabled, and 12 million have been left homeless after wars in the past 2 decades (Abdur-Rahman, van As, & Rode 2012). The number of children affected by disasters is projected to triple in coming decades due to climate change, which UNICEF refers to as a "threat multiplier that exacerbates inequality of children" (Kiragu and others 2018; United Nations Children's Fund (UNICEF) 2016). Children are likely to suffer not only from direct trauma, but also indirectly from chaos, lack of supervision, and perilous circumstances during armed conflict (Abdur-Rahman, van As, & Rode 2012; Van As 2011). During armed conflict, children are more likely to sustain injuries to multiple body regions and have a higher in-hospital mortality than adults (Haverkamp and others 2019). In modern warfare, there is frequently no defined battlefield and civilians are directly targeted, leading to unjust paediatric injuries and deaths (Slone & Mann 2016). Notably, the average number of 0–19 disability-adjusted life years (DALYs) due to war increased by 582% from 2005 to 2015 (He and others 2014). The conflicts in Iraq, Afghanistan, and Syria paint a stark portrait of the effects of war on children (Kiragu and others 2018). As the rise in global conflicts inflicts egregious harms on children, governments and international organizations such as the United Nations have a significant responsibility in mitigating the resulting trauma (Kiragu and others 2018).

Future Steps

Prevention

If the standards of trauma prevention and treatment in HIC were applied to LMIC, 2 million fewer children would die worldwide (Kotagal and others 2014). Resource limitations in LMIC necessitate trauma prevention to save on healthcare costs, and thoughtful resource allocation to the care of injured children (Kiragu and others 2018). In its World Report on Child Injury Prevention, the WHO recommends the following: establishing childhood injury prevention policy and plans as a part of an all-inclusive approach to child health, improving and increasing data collection on trauma as a priority, creating defined institution-driven research priorities, and raising awareness of and investment in child-injury prevention (Peden

& World Health Organization 2008). Prevention also has a central role as the majority of deaths occur outside the hospital setting.

Triage and Treatment

The absence of a formal triage system in many LMIC hospitals often leads to potentially life-threatening delays in care for patients who are severely injured (Butler and others 2016). Contextually appropriate training must be part of the development of these triage systems (Botelho and others 2020). Trauma teams adapted to local conditions and resources in each LMIC should be developed (Botelho and others 2020; Kiragu and others 2018). In a busy Brazilian trauma center, providers frequently performed low quality assessments of paediatric trauma victims when evaluated by the guidelines of Advanced Trauma Life Support, which was an American based standardized course. A recent study of seven emergency departments in Pakistan noted that only ~17% of patients were appropriately triaged, and fewer than 25% had any vital signs documented (Hyder and others 2017). Conversely, locally developed, standardized trauma protocols in Colombia have been found to be effective in achieving timely interventions for trauma patients and were associated with decreased mortality rates, particularly in patients with severe traumatic brain injuries (Kesinger and others 2014). Additional training must be contextually appropriate and a part of a larger trauma system scheme. The South African Triage Scale for children helps identify acute illness earlier and allows for better stewardship of hospital resources (Turner and others 2016). Tele-simulation is another option for teaching and developing paediatric trauma resuscitation skills and systems in LMIC (Reynolds and others 2014). Incorporating trauma management training into the undergraduate medical school curriculum will also help ensure widespread dissemination of the skills required to manage paediatric trauma. Finally, improved hospital inventory with regular maintenance, demand assessment, and reliable financing of essential trauma care items were all identified as important steps to avoid long periods of equipment shortages (Ankomah and others 2015).

Trauma registries

An important gap exists in our ability to reliably capture disease burden in paediatric trauma patients and predict their associated outcomes in settings where resources are limited (St-Louis and others 2017). In many cases, trauma registries have been set up in LMIC, but most available data on paediatric trauma care capacity are heterogeneous and centered around hospital-based, single institution studies. Registries should be adapted to function sustainably in resource-limited settings (Kobusingye & Lett 2000). A growing body of research strives to define the minimum set of essential variables required to maintain a contextually appropriate and useful database (O'Reilly and others 2013; St-Louis and others 2017). Sustainable capacity building in LMIC depends on better data collection to accurately measure the true burden of surgical disease and deploy appropriate strategies to address this problem (Mock and others 2009; Murray and others 2012). Trauma represents a large component of the global burden of surgical disease, especially in paediatric patients, and should be perceived as a public health priority. Paediatric trauma registries in LMIC present an important opportunity for closing the aforementioned data gaps and improving the quality of trauma care (St-Louis and others 2017; World Health Organization, International Society of Surgery, & International Association of Trauma Surgery and Intensive Care 2009).

ANESTHESIA

KEY MESSAGES

- Pediatric patients in LMIC experience greater morbidity and mortality in the perioperative period when compared to those in HIC. The density of anesthesia providers with subspecialty training in pediatric anesthesia in LMIC is very low.
- More advanced training programs in pediatric anesthesia are needed to increase the number of leaders and educators in the field. Practicing anesthesia providers lack access to continuing education and deserve such opportunities, including short courses in standardized resuscitation, simulation, and pain management.
- The role of the anesthesia provider in LMICs often extends far beyond the operating room to the emergency room, clinics, intensive care units, and wards due to their skills in vascular access, airway management, procedural sedation, and critical care, among others.
- LMIC often lack the appropriate equipment, infrastructure, and medications to provide safe anesthesia care to children, and these deficiencies need urgent attention.
- The global anesthesia community has been working to support LMIC providers by establishing standards of care, providing educational courses and materials, and facilitating networking of anesthesia providers, but more work is needed.
- Further research measuring perioperative outcomes (and contributing factors) of children in LMIC is underway and merits continued support

Introduction and Perioperative outcomes

Perioperative mortality has declined over the past decades worldwide, but the magnitude of this reduction is greater in HIC, and patients in LMIC are more likely than their HIC counterparts to die in the perioperative period. Mortality attributed to anesthesia has also been declining, but this trend only applies to HIC, and patients in LMIC experience significantly higher mortality as a result of anesthesia care (Bainbridge and others 2012). A recent prospective study in 25 African countries revealed that patients undergoing elective surgery were twice as likely to die compared to patients in HIC, despite being younger and lower-risk (Biccard and others 2018).

There have been several recent estimates of perioperative mortality of children in LMIC. In South Africa, a cohort of pediatric surgical patients had a mortality rate that was ten times higher than a HIC cohort. Of note, the majority of the South African cohort were low-risk and presenting for elective, non-cardiac surgery (Torborg and others 2019). Similarly, a study in Kenya of predominantly low-risk, elective pediatric surgical patients reported a mortality rate that was at least 100 times higher than their HIC counterparts (Newton and others 2020). Clearly, there is an urgent need to identify contributing factors and address these disparities.

Workforce: Training and Skills

Several challenges in LMIC impede quality anesthesia care and contribute to the high mortality, and these challenges are magnified for children. First, there is a lack of trained anesthesia providers in most LMIC and, by extension, pediatric anesthesia providers (Gajewski and others 2020; Hodges 2016). A recent survey of anesthesia providers revealed that, in countries classified by the World Bank as low income, the density of physician anesthesia providers (PAPs) is 0.19 per 100,000. In countries classified as lower-middle income, the density is about 2 per 100,000. These stand in stark contrast to the density in HIC, which is estimated to be about 18 per 100,000. In addition, the distribution of PAPs between urban and rural areas is unequal with more trained PAPs in urban areas further worsening the disparity (Kalu and others 2014; Law and others 2021; Martin and others 2015). There is no standard anesthesia curriculum or assessment/examination process. The duration of training of PAPs varies widely among countries, and some countries report having no training available (Kempthorne and others 2017). A similar pattern seems to exist for non-physician anesthesia providers (NPAPs), although comparisons are more difficult as the definitions and responsibilities of NPAPs vary widely amongst countries (Kempthorne and others 2017).

Anesthesia providers often practice in highly stressful situations managing high-risk patients in complex work environments (Wainwright and others 2019) and have been reported to be at a high risk of stress, burnout and depression (Looseley and others 2019; Mumbwe and others 2020; Wainwright and others 2019). Increasing the density of surgical, anesthesia, and obstetric specialists is associated with an improvement in surgical patient safety (Meara and others 2016). In order to achieve the 2030 goals set forth by the LCoGS, it has been recommended that all countries aim to have at least 5 PAPs per 100,000. To meet this goal, task sharing with NPAPs trained by PAP wherever possible and under PAP supervision while providing long term support for the training of highly qualified PAPs and encourage post-graduate programs in every country, may be necessary to scale up the anesthesia workforce in some countries to meet the anesthesia needs (Kempthorne and others 2017).

In order to scale up the density of pediatric anesthesia providers in LMIC, more training opportunities need to be made available, especially in the countries where no training programs exist. Programs must also be standardized, which is often not the case. Curricula adopted from HIC training programs may not necessarily fit the local context. As noted above, the situation is exacerbated by a dearth of PAPs to serve as teachers to trainees (Tuyishime, Powell, & Evans 2021). Anesthesia providers at every level also have little or no access to continuing professional development opportunities or mentors (Akrimi & Bould n.d.). Furthermore, given the lack of training opportunities for general PAPs, there are even fewer opportunities for specialized training in pediatric anesthesia. Undertaking such training is essential for the provision of safe, quality anesthetic care to pediatric surgical patients, particularly neonates and infants who present with physiologies and problems not encountered in adults.

Despite evidence that anesthesia contributes to a large number of perioperative cardiac arrests, the management of perioperative crises and resuscitation is often not standardized in LMICs and improvements are needed. In HIC, anesthesia providers are required to have current certification in resuscitation; however, this is not the case in many LMIC and often these skills are inadequately developed (Braz and others 2021; Jung & Shilkofski 2016; Koga and others 2015). Trainings in systematic resuscitation following guidelines such as the American Heart Association or others can be costly and are rarely available in most LMIC. When children require resuscitation perioperatively, poor outcomes are common (Jung & Shilkofski 2016). These types of resuscitation courses run by in-country anesthesia providers for local staff should be encouraged and supported.

Simulation training is a new and evolving area in many LMIC to help perioperative providers address this training gap (Everett and others 2017; Mossenson and others 2021). Basic simulation training using task trainers has been variably available in LMIC for some years and can be useful for learning basic skills such as airway management. High realism simulation (which can be high or low fidelity) in which clinicians or clinical teams get to practice using their knowledge and skills in a clinical scenario, facilitates the learning of essential non-technical skills, a neglected area in many training programs. These types of opportunities exist but more are needed (Lin and others 2018; Mossenson and others 2021).

Infrastructure and Equipment

Provision of safe anesthetic care to pediatric patients also requires appropriate infrastructure, equipment and medications, which must be available at all times. Given that pediatric patients can greatly vary in size (under 1kg to adult-sized), the equipment used in their anesthetic care must be available in a variety of sizes. This can be particularly challenging in LMIC, where equipment and medications are already scarce. In Uganda, not only did anesthesia providers report not having reliable access to water, oxygen, and electricity in operating theaters, only 13% reported they could provide safe care to pediatric patients under 5 years of age. A lack of appropriately-sized equipment was specifically cited as a barrier to care (Hodges and others 2007). A similar pattern was seen in Tanzania, Zambia, and Malawi, with providers reporting inconsistent access to pediatric-sized equipment and a lack of comfort in caring for pediatric patients due to inadequate training (Gajewski and others 2020). Moreover, many items and medications that are considered standard of care for anesthesia provision in HIC, such as continuous capnography, are not consistently available (Hodges and others 2007). This problem is not specific to Africa. A recent survey of anesthesia providers at public-sector hospitals in Guatemala suggests that essential medications and pediatric equipment are not always available at lower-tier district and regional hospitals (Zha and others 2021).

Post-anesthetic Care and Analgesia

Post-anesthesia care is often limited or non-existent in LIMC. Formal recovery units are scarce and, when they do exist, they may simply consist of an unstaffed room or space adjacent to the operating theaters, possibly without monitors and equipment for adult size patients only. Alternatively, patients may be transferred directly back to the ward, but the wards are often overcrowded with a very low nurse to patient ratio and may have the appropriate equipment (Barbour & Deka 2017). Moreover, ICUs may also be limited or absent, and thus management of higher-acuity patients or patients who require postoperative intubation may not be an option.

Pain management is challenging for reasons outlined previously, particularly drug availability, appropriate monitoring, and lack of confidence by PAPs in the use of regional techniques and systemic analgesics especially for neonates, infants, and children. When local and regional anesthesia might be the preferred modality, it may not be feasible due to lack of skill or equipment. Providers may hesitate to administer opiates given the potential for respiratory depression and lack of monitoring (Barbour & Deka 2017). Uncontrolled pain, therefore, hinders or prolongs the recovery process. The Essential Pain Management (EPM) Course, developed to improve pain knowledge and provide a simple framework for managing pain, has been run in over 60 countries. EPM is an example as to how simple teaching programs can be embedded into health care systems and teaching programs. More efforts are needed for increased mentorship for instructors, assistance with overcoming local pain management barriers (Goucke and others 2015; Marun and others 2020).

Ongoing Programs and Efforts

The global anesthesia community has been working to address these disparities by supporting LMIC providers and programs. Since 1992, the WFSA and more recently in conjunction with the WHO, has maintained guidelines for the minimum standards for medications, equipment, and personnel when providing anesthetic care to patients in any setting (the International Standards for a Safe Practice of Anesthesia Workgroup and others 2018). In particular, WHO-WFSA International Standards for a safe practice of anesthesia indicates that appropriately-sized pediatric equipment should always be available. The OReCS document also enumerates a list of pediatric equipment that should be available for the safe provision of pediatric anesthesia (D. Grabski and others 2019). These documents are intended to serve references where no such standards exist, or where the minimum standards are not being met. Moreover, they could be used to persuade Ministries of Health or similar agencies to direct support towards improving and increasing anesthesia capacity in LMIC.

There are a variety of educational programs available to help strengthen the pediatric anesthesia workforce. The WFSA, along with other local and international organizations, sponsors several pediatric anesthesia fellowship programs (Kenya, Chile, India) for physician anesthesiologists to further their training in pediatric anesthesia (*Fellowship Programme - WFSA* n.d.). Several short educational anesthesia courses have been developed for continued professional development to fill the educational gap. These short courses have the potential for immediate impact by providing an opportunity for continuing professional development and relevant subspecialty training (Evans and others 2018). One such example specifically geared towards anesthetic care for children is the Safer Anaesthesia

From Education Paediatrics (SAFE Paeds) course. It is a three-day course aimed at practicing anesthesia providers that reviews best practices in the provision of pediatric anaesthesia (Boyd and others 2019). The course has been run in several LMIC and has been shown to increase knowledge and skills and promote their retention. Another course, Vital Anesthesia Simulation Training (VAST), was developed to provide low-fidelity simulation training to anesthesia providers, encompassing all aspects of anesthetic care, including pediatric patients, and has been run in several LMIC (Mossenson and others 2021). Managing Emergencies in Pediatric Anesthesia (MEPA) is another simulation course geared specifically towards pediatric scenarios, run originally in the UK and Canada, it has now been adapted and run in several LMICs aiming to reach a wider audience (Everett and others 2017). Each of these courses can be tailored to the local context and includes a Training of Trainers component to incorporate local teachers and facilitate sustained delivery of the courses.

For both trainees and practicing anesthesia providers, the WFSA maintains an online library of free, open-access tutorials, Anaesthesia Tutorial of the Week (ATOTW), on various topics related to anesthesia. These are peer-reviewed and include many topics related to pediatric anesthesia. In addition to text, each tutorial contains a quiz and users are issued completion certificates that could be applied to educational programmes (*Anaesthesia Tutorial of the Week : WFSA - Resources* n.d.).

The global pediatric anesthesia community has also initiated efforts to bring anesthesia clinicians together for networking, discussion, and collaboration on a regular basis. The Safe Pediatric Anesthesia Network (SPAN) hosts a monthly video conference case-based discussion that includes providers from both HIC and LMIC. The aim is to bring providers together to collaborate on issues and challenges and formulate solutions to problems that are tailored to the resources available in different settings (Newton & Evans 2018). There is also a WhatsApp group that connects pediatric anesthesia providers across the world where members can pose questions and get answers from their colleagues in real-time.

Finally, efforts to describe and improve the safety of anesthesia care in the pediatric population in LMIC are ongoing. Broad, prospective perioperative data collection is needed to better understand the problems including the burden of pediatric surgical complications. Risk factors and types of complications need to be identified to enable the development of appropriate, context-sensitive interventions. The African Peri-operative

Outcomes Research Group (APORG) is a research consortium engaged in developing, supporting and coordinating the efficient delivery of large-scale clinical studies and trials in Africa. It is hoped that the Paediatric African Surgical Outcomes Study (ASOS-Paeds), built on the strong research infrastructure developed during the ASOS I & II studies, will provide much needed perioperative outcome data from pediatric surgical cases in Africa (*ASOS - African Surgical Outcomes Study - ASOS-Paeds* n.d.; Biccard and others 2018, 2021).

Despite improvements in perioperative safety over the past decades, children in LMIC experience higher morbidity and mortality compared to their HIC. There are many factors that contribute to these poorer outcomes including a lack of trained pediatric anesthesia providers as well as appropriate facilities, equipment, and medications. The global anesthesia community has been working to identify and address these disparities, but there is still much work that needs to be done. In concert with surgical colleagues, the anesthesia community will continue to support LMIC providers and programs to improve perioperative outcomes in children.

ONCOLOGY

Background

Although childhood cancer is curable with affordable interventions, it remains a leading cause of death for children and adolescents aged 19 years and below. The estimated global childhood cancer incidence is approximately 400,000 new cases per annum, of which an average of 43% (ranging from 3% in western Europe and North America, 49% in South Asia to 57% in West Africa) are undiagnosed (Ward, Yeh, Bhakta, Frazier, & Atun 2019). At current levels of health system performance, an estimated 2.9 million cases of childhood cancer will be missed between 2015 and 2030 and the total number of new cases by 2050 will be 13.7 million globally, of which 6.1 million will be undiagnosed (Ward, Yeh, Bhakta, Frazier, & Atun 2019). While survival rates of paediatric cancers are as high as 80% in HIC, survival in LMIC is less than 30% (Force and others 2019). Thus majority of childhood cancer deaths occur in LMIC where 90% of the world's children live (Al Lamki 2017) and 90% of childhood cancer deaths occur (Kellie & Howard 2008; van Heerden and others 2022).

It is a leading cause of non-accidental death in HIC and is the leading cause of death in a growing number of MICs (Gupta and others 2014). 6.5% and 18.6% of deaths among children aged 5 to 14 years in lower and upper middle income countries respectively are due to cancers (Magrath and others 2013). While North Africa reports survival rates of 30.3% for all malignancies, Southern Africa, West Africa and East Africa have survival rates of 21.7%, 8.5% and 8.1% respectively (Gupta and others 2015). Although the number of childhood cancers is declining or stable in most regions of the world, Africa is a notable exception with a substantial population growth and number of children aged 0-14years increasing from 485 million in 2015 to 625 million in 2030 (Ward, Yeh, Bhakta, Frazier, & Atun 2019).

Disability Adjusted Life Years (DALYs) attributable to children's cancer reflect a disproportionate impact in LMIC. 80% of these DALYs are in LMIC which have less than 5% of the global resources for cancer: cancer registries, palliative care, chemotherapy, radiation therapy and surgery (Rodriguez-Galindo and others 2013). Cancer registries covered only an estimated 11.4% of the world population aged 0-14 years in 2000-10 (Steliarova-Foucher and others 2017).

Pediatric cancers also compose the greatest component of DALY-related cancer burden in LMIC (Bhakta and others 2019). (Panel 1) Here we will cover several of the most common solid tumors in children, their burden, and management in LMIC. (Summarized in Table 3)

Panel 1: Childhood cancer burden

- Estimated 13.7 million new cases of childhood cancer will be diagnosed globally between 2030 to 2050.
- Without improving access to care, more than one third will be undiagnosed.
- Childhood cancer caused DALYs is predominantly impacting LMIC.

Table 3: Estimated Burden of Childhood and Adolescent Cancers and Three Index Surgically Amenable Tumors

	Burden (Incidence) [5]	**Global survival** [3]	**DALYs** [5]
All childhood cancer	416 500 (384 900–442 100) [5]	37·4% ranging from 8·1% in eastern Africa to 83·0% in North America [3]	11 549 600 (10 649 900–12 334 700) [5]
CNS tumors	67 400 (58 400–76 400) [5]	18·6% ranging from 2.5% in Africa to 77.3% in North America [3]	2 088 300 (1 802 700–2 389 500) [5]
Retinoblastoma	19 416 (15 025–28 512) [5]	24.0% ranging 5.2% in Africa to 94.0% in North America [3]	No estimates [1, 2, 3, 4, 5, 6, 13]
Renal tumor	24 400 (21 900–26 800) [5]	27.0% ranging from 5.7% in Africa to 97.4% in North America [3]	197 800 (181 800–214 700) [5]

Retinoblastoma

Retinoblastoma (RB) is the most common ocular cancer, and it typically presents before the age of 5 years in over 90% of cases (Ademola-Popoola, Opocher, & Reddy 2019). The estimated incidence is 1:16,000-1:18,000 live-births or 11/1 million children under 5 years

(Ademola-Popoola, Opocher, & Reddy 2019). Most of the world's RB cases are found in Asia and Africa while most RB treatment centres are in America and Europe (Ademola-Popoola, Opocher, & Reddy 2019). In high resource countries, RB patients tend to survive and retain their sight. However, in low-resource countries because of late presentation and delayed intervention, survival is low (Ademola-Popoola, Opocher, & Reddy 2019). Survival ranges from 20% to 60% in most low-income countries (LICs) while survival of retinoblastoma is more than 90% in high income countries (Chantada and others 2011). Delayed enucleation and refusal to adhere to treatment are still major concerns and remain a barrier to improving overall patient survival (Traoré and others 2018). Of the 8000 children diagnosed with retinoblastoma yearly, 66% live in LMIC, and these countries have 90% of the cases presenting with metastatic disease, revealing a significant deficiency in the early diagnosis and referral pathways (Chantada and others 2011). In LMIC, retinoblastoma educational and public awareness campaigns have been shown to increase referrals, decrease the rates of advanced disease, and improve outcomes (Leander and others 2007).

Neuroblastoma and Nephroblastoma

Neuroblastoma is the most common extracranial solid tumor in childhood in high income countries (HIC), where it accounts for 10% of paediatric cancers (Gurney and others 1996). In LMIC, however, it accounts for only 1–3% of cancers. In most LMIC its true incidence is unknown (Magrath and others 2013; Parkin and others 1988; Stiller & Parkin 1992). Consistent treatment approaches based on clinical and tumor biological risk stratification have steadily improved outcomes in HIC. In LMIC, however, late diagnosis, lack of access to accurate staging, risk stratification, optimal treatment, and treatment abandonment leads to survival rates much lower than those in HIC (Parikh and others 2015). Risk stratification with gene amplification is a mainstay of the neuroblastoma treatment algorithm. Chemotherapy is necessary for treatment of intermediate risk neuroblastoma. Intensive induction therapy, myeloablative chemotherapy, autologous stem cell rescue and residual disease treatment are necessary for patients with high-risk disease to have a chance at a cure. Few centers in LMIC have the ability for this level of treatment. Therefore, early diagnosis and stratification with implementation of a national treatment protocol given available resources should be a focus of any neuroblastoma healthcare planning (Van Heerden and others 2019).

Nephroblastoma, or Wilms tumor, is also one of the most prevalent solid tumors in children in LMIC, with substantial disparities in survival between HIC (97%) and LMIC (8-30%) (M.

E. Cunningham and others 2020; S. O. Ekenze and others 2020). Surgical resection is the mainstay of therapy although multimodal therapy is essential for long-term survival, and in contrast to some HIC, LMIC treatment protocols often require neoadjuvant therapy. Recent follow up of LMIC contextualized protocols for Wilms have shown improved outcomes in six African centers, with decreased abandonment of therapy and improved survival (Chagaluka and others 2020). Recent work has also emphasized key biologic differences including higher rates of more aggressive tumors (with anaplasia) in African cohorts, that remain under-investigated and have critical impact on treatment and survival (Apple & Lovvorn 2020).

Rhabdomyosarcoma

Rhabdomyosarcoma (RMS) is the most frequent soft-tissue sarcoma in children, accounting for approximately 3% to 4% of all childhood cancers, and ~60% of all soft-tissue sarcomas (Papyan and others 2019). RMS treatment relies on multiagent chemotherapy, surgery, radiotherapy, or a combination of these treatments. In HIC patients with localized disease have an overall 5-year survival of more than 80% with the combined use of surgery, radiation therapy, and chemotherapy (Punyko and others 2005). However, in patients with metastatic disease, little progress has been made in survival rates, with a 5-year event-free survival rate less than 30% (Oberlin and others 2008). RMS treatment in LMIC can be exceptionally challenging due to the need for multidisciplinary management and oncologic, surgical, and radiation therapy expertise (Papyan and others 2019). Limitations in low resource settings include lack of surgical expertise and/or radiation therapy, advanced stage of disease, and absence of health insurance. Although very poor outcomes are prevalent, good outcomes in middle income countries (MICs) are achievable when multidisciplinary therapy and financial coverage of medical care are available. Outcomes in low income countries (LICs) were difficult to determine due to the paucity of data on rhabdomyosarcoma in LICs (Papyan and others 2019).

Status of Paediatric Surgical Oncologic Services

In 2017, it was estimated that less 8% of children and adolescents in LMIC had access to surgical care (Mullapudi and others 2019). There are critical shortages of cancer surgeons and specialty surgeons in LMIC including paediatric surgeons, neurosurgeons, and ophthalmic surgeons in the context of limited training opportunities, scarce number of workforce and low retention rate of workforce.

While children and adolescents diagnosed and treated early have improved survival and generally require lower intensity therapy, management of advanced cancer is more costly with lower salvage rate. Improvements in delayed presentation through targeted interventions is essential. Delay seeking and reaching appropriate care can be mitigated with public childhood cancer awareness and development of strong prehospital networks and referral system. Overall health system strengthening is required to prevent delay in receiving appropriate care (Ward, Yeh, Bhakta, Frazier, Girardi, and others 2019). The recent COVID 19 pandemic has exacerbated global inequities in childhood cancer care overall, and specifically in children with cancer and COVID 19 infection.

The most common childhood and adolescent tumors require complex and specialized surgery where achieving adequate resection and mitigation of complications is fundamental to cancer control and recovery. A more complex infrastructure, training, support services, and referral networks is required to provide childhood cancer quality care. Although urban childhood cancer centers with variable surgical capacity are available in many LMIC, intra-country development disparity is a major cause of distributional inequality limiting access for children from underdeveloped areas. Prohibitive distance to childhood cancer centers and the cost of transportation and lodging is prohibitive even in countries where the cost of therapy is supported.

The quality of surgical documentation is essential for quality assurance and for staging many tumors and often not performed. For example, inadequate operative notes prevent accurate staging of Wilms tumor in many LMIC. Furthermore, in many LMIC there are no onco-surgical guidelines, standard of care is not clearly defined, and onco-surgical practice is not peer reviewed (World Health Organization n.d.-d).

Panel 2: Building capacity and improving quality (Atun and others 2020; World Health Organization n.d.-d)

- The allocation of onco-surgery service is dictated by the availability of diagnostic and therapeutic multidisciplinary childhood cancer services linking radiologists, pathologist, oncologists, radiation oncologist, and surgical specialist.
- Adapted onco-surgical guidance is essential to standardize care, optimize quality, and address knowledge-practice gap.
- Training surgical workforce and expanding the skills of the existing workforce to provide quality paediatric onco-surgical services will improve outcomes and maximize health gains. However, measures to improve retention of trained workforce are paramount.
- Developing continuous medical education program to maintain quality
- Regular review of outcome data is fundamental to inform intervention and adaptations

Developing Paediatric Surgical Oncology Services and Strengthening Surgical Systems

Reduction of communicable diseases, emergence of new infections, improvement of nutrition, industrialization and urbanization are factors that have contributed to increased burden of paediatric cancers. Avoidable deaths from childhood cancers in LMIC result from obstacles to accessing care, misdiagnosis, delayed diagnosis, limited capacity to treat cancer, abandonment of treatment and treatment related mortality.

Childhood cancer is rarely given appropriate funding in LMIC. This lack of prioritization is rooted in the misconceptions that caring for children with cancer in LMIC is expensive, inaccessible, and inappropriate because of other competing health priorities.

Most children diagnosed with solid tumors will need surgical intervention and the surgeon's adherence to sound onco-surgical principles is closely associated with local control and survival. Surgery plays a pivotal role in diagnosis, staging, reconstruction, management of complications, prevention, and palliation. Sub-optimal onco-surgical care results in high local recurrence, low survival, need for therapy intensification and increased cost. Inadequate paediatric surgical workforce, shortage of equipment and supplies have negatively impacted

= onco-surgical services in LMIC. The availability of trained surgeons to develop adapted interventions and innovations relevant to local resource setting have will have the greatest impact on surgically curable paediatric cancers.

The quality of childhood cancer surgery is highly dependent on the quality of many other services including imaging, anesthesiology, pathology, and supportive care yet the capacity and quality of these services are inadequate in many LMIC.

The future of onco-surgical services globally is dependent on advances in education and training. Improved training in safe and adequate onco-surgical care is deliverable by implementation of competence-based training curriculum addressing the local needs. The model of training oncology surgeons outside their local and regional context led to “brain drain” and deprived LMIC from valuable human resources. The model of local and regional training is more promising in terms of retention. Delivering safe, affordable, and timely childhood cancer surgery to all must be at the heart of national surgery planning. (Panel 3)

Traditionally, oncology care is provided in either a low capacity cancer wards (cancer units), multispecialty cancer centers, or comprehensive cancer centers (CCC) that have the capacity to deliver complex cancer care, research, training, and education.(National Cancer Institute 2011). When scaling up onco-surgical care, it is fundamental to balance the competing priorities of quality and access. Cancer units may have the capacity to offer common diagnostic and treatment services, however childhood cancer surgery requires multidisciplinary capacity available in national cancer referral centers. National cancer centers should be accessible and well connected with a network of cancer centers or cancer units, to deliver affordable, equitable, and high-quality care. The cost effectiveness of treating cancer in centers with higher capabilities was shown in the DCP3 (Gelband and others 2015). Public sector strategic direction is fundamental to build infrastructure and human resources required to sustain national cancer centers, design polices addressing local needs and build on international experience. Needs assessments should preceded workforce planning to guide the development of curriculum delivering outcome/competency-based training programs. International collaboration to support in-country or regional training results in very high retention rate and build local expertise providing high quality care adapted to context (Atun and others 2020).

Three tumors may function as bellwethers of a system functioning at a level of complexity advanced enough to do most other childhood cancer surgery. Low grade glioma, retinoblastoma, and Wilms tumor would have high impact in country and regional childhood tumors overall survival when scaling up capacity to deliver quality care. These three tumors are prevalent in all regions, can be cured with high success rate using affordable evidence-based interventions. Low grade glioma, retinoblastoma, and Wilms tumor are among the index cancers for the WHO Global Initiative for Childhood Cancer (World Health Organization n.d.-d). Early diagnosis and stage shifting are achievable through strengthening referral network and public awareness leading to decrease therapy intensity and cost, and improved survival (World Health Organization n.d.-d). This initiative has set 60% survival for all childhood cancers as a global goal.

Panel 3: Strengthening health system for childhood cancer surgery

- Political and cancer center leadership alignment is paramount to synergize efforts and eliminate competitive market strategies
- Childhood cancer control plan should be developed within the context of national planning for health systems, workforce, and infrastructure. Cancer surgery plan is an integral part of national surgery plan.
- Adopt a balanced approach providing quality and efficiency and at the same time optimizing access and coverage. However, childhood cancer surgery should be centralized to build and maintain expertise and improve quality.
- Strengthening referral network is essential to facilitate access to quality onco-surgical care. Childhood tumor surgery can be effective only if presentation is early enough.
- Focus initially on childhood cancers that are prevalent and have the greatest cure rate with surgery.

Economic considerations of Paediatric Surgical Oncologic Care in LMIC

Informed decision for resource allocation should be based on evidence of value for money especially when these resources are scarce. Assessment of both the health and economic benefits of scaling up onco-surgical services is urgently needed; however, extrapolations can’t be made from high income countries that may be less cost-conscious or adaptive to resource limitations. Due to limited availability of quality outcome data and the complex interdependencies between different modalities and interventions, linking onco-surgery with outcomes data remains challenging. The Lancet commissions on global surgery 2030 showed that investing in onco-surgical care and trauma surgical care will have the greatest effect on economic output (Meara and others 2015). Long term investment in training cancer surgeons and strengthening systems must take place to avert significant loss of cumulative gross domestic product. The Lancet commission on global surgery estimated that without investment in surgical services, more than US$6 trillion will be lost in cumulative gross domestic product by 2030 (Meara and others 2015). Children and adolescence make up to 50% of the population in some countries and they have a longer life expectancy. Comprehensive scale-up of childhood cancer care interventions could avert more than 50% of childhood cancer death between 2020 and 2050, more than 6 million lives (Atun and others 2020).

The cost of radiotherapy and surgery is mostly a capital cost, consumables and running costs are generally not high in LMIC and accounts for a small percentage of the total running cost of childhood cancer centers. Inadequate information and poor management are the main causes of consumable shortages, this challenge should be addressed by applying standards of supply chain management, standardization of process, and informed central procurement decisions (Atun and others 2020). Recent work has emphasized the compelling cost-effectiveness of childhood cancer treatments requiring multimodal therapy in LMIC, strengthening the economic case for investment and expansion of services (Bhakta 2019; Denburg and others 2019; Githang'a and others 2021). Despite the economic benefit of cancer care children and adolescents with malignancy in many LMIC have no access to financial protection. Unsurprisingly, catastrophic expenditure is a major cause of treatment abandonment and poor outcomes (Atun and others 2020). (Panel 4)

The WHO Global Initiative for Childhood Cancer is leveraging the political commitment to provide universal health coverage for childhood cancer (Balagadde-Kambugu and others 2022). Innovative financing instruments can help fill the gap to supplement public funds for sustainable financing. For example, once targets are achieved funders could repay investors their principal plus interest (Atun and others 2020; World Health Organization n.d.-d).

There are also many institutions and charitable organizations that contribute to scaling capacity in countries with limited resources. For example, Kids OR provided the first dedicated paediatric operating room in many sub-Saharan countries with a projected cumulative capacity of ~60,000 operations annually by the end of 2020.

Panel 4: Economic considerations for onco-surgical services (Atun and others 2020)

- Long term investment is required in training cancer surgeons and strengthening systems to avert significant loss of cumulative gross domestic product. Childhood cancer surgery is highly cost-effective investment
- Catastrophic expenditure is linked to the lack of universal coverage and a major cause of treatment abandonment and poor outcome

Conclusion

A systems-based approach is required to improve childhood cancer outcomes including improved financial protection and quality service delivery. However, in many LMIC the health systems are not well prepared to address the challenges of childhood cancer burden. Measures to improve the health system functioning include development of adequate referral networks, improved quality, evaluation and monitoring, sustainable financing mechanisms and financial protection.

CONGENITAL ANOMALIES

Background

Congenital anomalies are one of the top 20 causes of global morbidity and mortality and are the 5^{th} leading cause of death in children less than 5 years globally (Wright 2019) It is estimated that ~6% of all newborns are born with a serious birth defect(*Congenital Anomalies* n.d.-a) and 94% of these occur in LMIC (*Congenital Anomalies* n.d.-b) accounting for 9% of the surgical burden of disease.

The Modell Global Database of Congenital Disorders (MGD) in 2018 estimated that over 5 million births are affected annually, resulting in over 400,000 fetal deaths, 2.5 million under-5 deaths and 2 million survivors with a significant disability at 5 years (Modell and others 2018). The WHO Global Burden of diseases study also estimated that congenital anomalies account for up to 38.8 million DALYs lost annually.[4] Recent multi-country prospective work has highlighted the substantial disparities between gastrointestinal intestinal anomalies between high and low income countries (Wright and others 2021).

According to the WHO, the congenital anomalies of the musculoskeletal system and nervous system were most common. In other studies, the cardiovascular and gastrointestinal systems predominated. These differing reports reveal that most available data is heterogenous and hospital based. Monitoring and measuring this burden of disease is challenging but experts agree that large multi-site approximations are likely underestimates (Sitkin and others 2015). Nonetheless, prompt surgery or other medical treatment can prevent over 50% of DALY's lost each year due to congenital anomalies (*Congenital Anomalies* n.d.-a). This section will cover some of the most common structural congenital anomalies amenable to surgical intervention.

Neural Tube Defects

Spina Bifida: In 2014 roughly 190,000 children were born with neural tube defects (NTD) in LMIC. They are responsible for hundreds of thousands of deaths in the 0–4 years age group, with a similar number of surviving with a lifelong disability (Lo, Polšek, & Sidhu 2014). In sub-Saharan Africa Spina Bifida mortality ranges from 6-14% (Livingston and others 2015) but limited available data on NTD in LMIC indicates the need for additional research that would improve the estimated burden of NTD (Lo, Polšek, & Sidhu 2014). Neural tube defects would uniquely benefit from both greater prevention and correction. Not only is there less prenatal folate administration in LMIC (Congenital Disorders Expert Group and others 2018) but also 76% of the burden of neural tube defects in LMIC is amenable to correction with surgery.(Higashi and others 2015). There have been increasing calls for mandatory folate administration early in pregnancy as a prevention strategy, with potential resulting benefits on the limited neurosurgical workforce in LMIC (Atlaw and others 2021; Estevez-Ordonez and others 2018; Kancherla and others 2021; Wadman 2019).

Hydrocephalus: Developing countries face the greatest burden of paediatric hydrocephalus due to high birth rates and greater risk of neonatal infections. In sub-Saharan Africa, it is estimated that more than 100,000 newborns annually develop hydrocephalus before age one (Muir, Wang, & Warf 2016). In Nigeria, hydrocephalus accounts for 32% of congenital neurosurgical conditions (Afolabi, AO & Shokunbi, MT 2012); in Kenya, hydrocephalus represents the highest surgical burden of disease in male children (Wu, Poenaru, & Poley 2013); and in Uganda, hydrocephalus accounts for 59% of neurosurgical conditions (Warf 2010). With more than half of Africa's population younger than 18 years, it is remarkable that fewer than 10% of neurosurgeons have subspecialty training in paediatric neurosurgery (Muir, Wang, & Warf 2016). In many impoverished countries of Central and South America, CSF-diverting procedures account for nearly 40% of total neurosurgical procedures (Mainthia and others 2009).

There is convincing evidence that surgery is a cost-effective means of dramatically reducing the burden of congenital hydrocephalus. For example, a recent report from Uganda showed that congenital hydrocephalus can be surgically managed for USD $59–$126 per DALY averted while antiretroviral therapy for HIV is roughly $550/DALY averted or BCG vaccine for prevention of tuberculosis is $120/DALY averted (Sitkin & Farmer 2016). The demonstrated burden and cost effective treatment for hydrocephalus reveals that untreated hydrocephalus in infants exacts an enormous price (Warf 2010). Recently, costs of common neurosurgical procedures, such as drainage for hydrocephalus, were also estimated in Nigeria, and found to be 40% of the GDP per patient. This mirrored evidence from Kenya that out-of-pocket costs for common pediatric neurosurgical procedures were significant, even with substantial subsidies (Awori and others 2016; Sale & Amos 2021).

Cleft lip and palate

In a systematic review of the incidence and prevalence of congenital anomalies in LMIC the incidence of orofacial cleft was 11/10,000 live births similar to the incidence of 10-20/10,000 live births in HIC. Sub-Saharan Africa and South Asia, however, with a large prevalence of unrepaired clefts, have the greatest proportion of surgically addressable burden for clefts (68%) (Higashi and others 2015). Recently, maternal increased indoor cooking smoke exposure in LMIC has been associated with an increased risk in cleft anomalies (Auslander and others 2020; Kruppa and others 2021). Orofacial cleft repair has estimates from $48 -$73 cost per DALY gained (significantly less than the WHO recommendation of <3x GDP per capita) (Corlew 2010; Meara and others 2015). These measures of cost-effectiveness favorably compare to more traditional global public health initiatives, such as the provision of antiretroviral drugs in sub-Saharan Africa (USD $350–$1494 per DALY averted) (Sitkin & Farmer 2016). Given the elective nature of these procedures remote digital assessments have also proven a reliable way to preoperatively diagnose cleft lip and palate in the context of short-term plastic surgical interventions in low- and middle-income countries (Hughes and others 2017). Numerous long-term global initiatives by non-governmental organizations in collaboration with local partners have supported training and service delivery for cleft care in LMIC for decades (Wester and others 2021).

Congenital Heart disease

Congenital heart disease accounts for nearly one-third of all congenital birth defects (van der Linde and others 2011) and focus on congenital heart disease is integral in eliminating preventable childhood deaths worldwide (Zimmerman and others 2020). Nine-tenths of the world's children born with congenital heart disease live in locations with little to no care and where mortality remains high (Tchervenkov and others 2008). The burden of congenital heart disease falls most heavily on countries with the lowest incomes and the highest fertility rates (Hoffman 2013). Mortality rates for infants with congenital heart disease range from 3% to 7% (Bernier and others 2010); while in LMIC, mortality rates range from 8.8% to 23.5% (Sitkin & Farmer 2016). Previous publications have estimated 250,000 annual congenital heart disease deaths globally, 1.35 million annual births of neonates with congenital heart disease globally, and 2.4 million people living with congenital heart disease in the USA alone (Zimmerman and others 2020).

Abdominal Wall and Gastrointestinal Anomalies

There is limited data on the true burden of gastrointestinal and abdominal anomalies in LMIC. This includes but is not limited to gastroschisis, omphalocele, intestinal atresia, anorectal malformations (ARM) and Hirschsprung's disease. Studies that do exist are heterogenous and hospital based, systematic reviews are based on those studies and not on regional or national anomaly registries. We will briefly highlight some of those key studies - which demonstrate the burden of these diseases and the gap in the literature on the worldwide

Abdominal wall defects (omphalocele/gastroschisis): In a systematic literature review of the incidence and prevalence of congenital anomalies in LMIC, the incidence of gastroschisis in HIC was 2-6/10,000 live births vs 2/10,000. Similarly omphalocele was 2-3/10,000 in HIC and 2/10,000 in LMIC (Toobaie and others 2019). Despite similar prevalence, gastroschisis represents a particularly glaring example of resource and outcome disparity between LMIC and HIC. The 30-day mortality rate for infants born with gastroschisis in HIC is 1%; while in LMIC, reported mortality rates range from 14% to 100% (Sitkin & Farmer 2016). One review at a tertiary care center in Uganda, reported 159 cases of omphalocele and 151 cases of gastroschisis, while gastroschisis demonstrated a mortality of 90.1% (Cheung and others 2019).

Intestinal atresia: In a systematic literature review of the incidence and prevalence of congenital anomalies in low and middle income countries the incidence of atresia in the Western literature was 1.3-25/10,000 live births and the estimated incidence in LMIC was 0.2/10,000 live births (Toobaie and others 2019). The annual estimated number of cases seen at a paediatric center in Chittagong, Bangladesh was 60-80. Similarly, at a tertiary care center in Uganda 57 cases were recorded in one year. At the same center a mortality rate for ileal atresia was 70.6% and 59.6% for jejunal atresia (Cheung and others 2019). Slightly lower mortality rates were found in a comprehensive literature review on paediatric surgical outcomes in African LMIC with jejunoileal atresia pooled mortality rate of 35% and duodenal atresia with a pooled mortality rate of 14%. It should be noted however that the range for jejunoileal atresia was 14-56% and duodenal atresia was 0-40%, revealing significant variation among institutions (Livingston and others 2015).

Anorectal malformations and Hirschsprung's disease: In a systematic literature review of the incidence and prevalence of congenital anomalies in low and middle income countries the incidence of ARM was 2/10,000 live births in LMIC and HIC (Toobaie and others 2019). In Africa, anorectal malformation (ARM) is the leading cause of congenital intestinal obstruction (E. A. Ameh & Chirdan 2000; Ogundoyin and others 2009). and the most common major structural congenital malformation presenting to paediatric surgeons (Lawal 2019). At a tertiary care center in Uganda, ARM was reported as the most common congenital malformation, with an overall mortality of 20% and Hirschsprung's disease was reported as the second most common congenital malformation with an overall mortality of 41% (Cheung and others 2019). In Bogota, Colombia anorectal malformations was cited as the third most common congenital anomaly at their center with a prevalence of 2.2/100,000 (Correa and others 2014) and in South Africa prevalence ranges from 1.79-3.26/100,000 births (Theron & Numanoglu 2017). A comprehensive literature review on paediatric surgical outcomes in African LMIC demonstrated ARM mortality ranging from 0-25% and Hirschsprung mortality ranging from 0-23% (Livingston and others 2015). Meanwhile in a paediatric surgical ward in Bangladesh anorectal malformations were the most common cause of death (Chowdhury and others 2020). ARM was also possibly associated with consanguinity as suggested in a recent epidemiological review in Bangladesh (Karim and others 2018).

Club foot

Clubfoot occurs in nearly 1 in every 1,000 live births worldwide, representing a significant burden of disease (Harmer & Rhatigan 2014). Clubfoot is a particularly burdensome cause of morbidity in low- and middle-income countries (LMIC), where 80 % of the 200,000 children born with clubfeet annually live (Saltzman 2009). Unfortunately, treatment is unavailable to the vast majority of these children, so there is a high prevalence of preventable disability (Harmer & Rhatigan 2014). Analysis of the Clubfoot "Care Delivery Value Chain" (CDVC) model suggests six best practices that are essential to successfully scaling up clubfoot treatment programs: (1) diagnosing clubfoot early; (2) organizing high-volume Ponseti casting centers; (3) using nonphysician health workers; (4) engaging families in care; (5) addressing barriers to access; (6) providing follow-up in the patient's community. Applying them will optimize outcomes when designing public health programs that deliver clubfoot care in LMIC (Harmer & Rhatigan 2014).

Urology (undescended testes, hypospadias, disorders of sexual differentiation)
Congenital anomalies of the GU tract are the third most common group of non-chromosomal congenital anomalies behind congenital heart defects and limb defects (Van Batavia and others 2018). Hypospadias itself is one of the most common birth defects and occurs in 1 of every 150 to 300 live male births. The number of new hypospadias cases in sub-Saharan Africa alone with an estimated 40 million live births per year dwarfs the number of new cases in the United States (Van Batavia and others 2018). Likewise, in India, where the paediatric population is almost 500 million, there is estimated to be more than 58,000 new congenital GU malformations each year with at least 15,000 of these new cases being hypospadias (Van Batavia and others 2018).

1990	Global	Low SDI	Low-middle SDI	Middle SDI	High-middle SDI	High SDI
Lower respiratory infections	1	1	1	1	2	7
Neonatal preterm birth	2	3	2	2	1	1
Diarrhoeal diseases	3	2	3	4	5	18
Neonatal encephalopathy due to birth asphyxia and trauma	4	4	4	3	3	4
Other neonatal disorders	5	5	5	6	6	6
Congenital heart disease	6	13	8	5	4	2
Neonatal sepsis and other neonatal infections	7	9	6	7	9	8
Tetanus	8	6	10	10	22	82
Protein-energy malnutrition	9	8	9	9	12	53
Measles	10	10	7	13	17	62
Malaria	11	7	11	35	86	115
Other congenital anomalies	12	17	13	8	7	5
Haemolytic disease and other neonatal jaundice	13	12	12	16	15	30
Syphilis	14	11	14	12	18	23
Whooping cough	15	15	17	14	14	51
Drug-susceptible tuberculosis	16	14	16	17	21	49
Neural tube defects	17	19	19	15	8	12
Other meningitis	18	16	15	19	23	19
Digestive congenital anomalies	19	23	20	18	10	10
Sudden infant death syndrome	20	20	21	22	13	3
Pulmonary aspiration and foreign body in airway	21	29	22	11	11	9
H influenzae type B meningitis	22	21	18	21	16	22
Paralytic ileus and intestinal obstruction	23	28	23	20	19	24
Other unspecified infectious diseases	24	24	25	26	25	25
Visceral leishmaniasis	25	18	43	89	96	102

2017	Global	Low SDI	Low-middle SDI	Middle SDI	High-middle SDI	High SDI
Neonatal preterm birth	1	2	1	1	1	1
Lower respiratory infections	2	1	2	2	5	10
Neonatal encephalopathy due to birth asphyxia and trauma	3	3	3	3	3	3
Other neonatal disorders	4	5	5	5	4	2
Diarrhoeal diseases	5	4	4	7	11	15
Neonatal sepsis and other neonatal infections	6	6	6	6	7	8
Congenital heart disease	7	8	7	4	2	4
Malaria	8	7	8	30	80	117
Syphilis	9	9	10	9	10	19
Other congenital anomalies	10	11	9	8	6	6
Protein-energy malnutrition	11	10	12	12	29	60
Haemolytic disease and other neonatal jaundice	12	15	11	16	19	37
Neural tube defects	13	13	16	13	12	12
Digestive congenital anomalies	14	17	15	11	8	11
Other meningitis	15	14	13	20	30	27
Whooping cough	16	12	17	19	33	53
Sudden infant death syndrome	17	16	18	15	13	5
HIV/AIDS resulting in other diseases	18	18	14	17	22	39
Pulmonary aspiration and foreign body in airway	19	27	22	10	9	9
Drug-susceptible tuberculosis	20	19	20	23	44	78
Measles	21	20	21	22	40	86
H influenzae type B meningitis	22	23	19	25	23	30
Paralytic ileus and intestinal obstruction	23	25	23	14	17	21
Other unspecified infectious diseases	24	22	27	29	18	20
Tetanus	25	21	24	36	68	97

Death rate per 100 000 children

0·0 to 8·27 · >8·27 to 24·01 · >24·01 to 47·23 · >47·23 to 88·16 · >88·16 to 227·63 · >227·63 to 2214·30

Figure 7: This heat map depicts the rank order of causes of death (by death rate per 100,000) in children younger than 1 year in 1990 and 2017. Surgical problems such as digestive congenital anomalies, congenital heart disease and neural tube moved up in ranking (Zimmerman and others 2020)

Cost of Birth Defects: DALY's and Economic Impact

The WHO Global Burden of diseases study estimated that congenital anomalies accounted for up to 38.8 million DALYs lost annually in 2010 (Murray and others 2012). Lifetime costs have been estimated at $6 billion for infants born in a single year with 1 or more of 17 major birth defects (Centers for Disease Control and Prevention (CDC) 1995). A population-based study in Kenya in 2015 found that eight prevalent anomalies caused 54–126 DALYs per 1000 children (Poenaru and others 2015). In Uganda, using estimates from the national referral hospital in 2012, only 3.5% of neonatal surgical need is met, resulting in 145,225 avertable DALYs lost annually due to the six most prevalent anomalies (Badrinath and others 2014). Strikingly, congenital anomalies may be responsible for up to 120 DALYs lost per 1,000 children, while the GBD study reports an even higher number with 361 DALYs per 1,000 population globally.TEMP This is comparable in magnitude to more traditional targets of health development like neglected tropical disease (Sitkin and others 2015).

The burden of disease also weighs more heavily on LMIC. The frequency of pregnancy termination following prenatal diagnosis of a congenital anomaly is lower in many LMIC than in HIC (Sitkin and others 2015). In addition, higher fertility rates translate to higher birth rates and net prevalence of anomalies - it is estimated that a total of 94 % of anomalies occur in LMIC (*Congenital Anomalies* n.d.-a).

Of the conditions measured in the GBD study, cardiac defects represent the greatest overall burden; but several areas, including inguinal hernia repair, trichiasis surgery, cleft lip and palate repair, circumcision, congenital heart surgery and orthopedic procedures, should be considered "Essential Paediatric Surgical Procedures" as they offer considerable economic value.

Selected paediatric surgical interventions such as cleft lip or palate repair ($48/DALY averted), general surgery ($82/DALY averted), or hydrocephalus repair ($108/DALY averted) are similarly cost-effective compared to antiretroviral therapy for HIV ($550/DALY averted) or BCG vaccine for prevention of tuberculosis ($120/DALY averted) (Butler and others 2017). Neural tube defects have the largest potential with 76% of burden amenable by surgery, followed by clefts (59%) and congenital heart anomalies (49%). Of the estimated 21.6 million DALYs caused by these three conditions in LMIC, 12.4 million DALYs (57%)

are potentially addressable by surgical care among the population born with such conditions. Sub-Saharan Africa and South Asia have the greatest proportion of surgically addressable burden for clefts (68%), North Africa and Middle East for congenital heart anomalies (73%), and South Asia for neural tube defects (81%) (Higashi and others 2015).

People who underwent cleft lip correction saw a lifetime increase in economic productivity of $143,363 or $56,919, again depending on whether age weighting and discounting were considered. For all patients with cleft lip, these figures were $57,631,770 and $22,881,627, respectively. For cleft palate, these figures were $375,412 and $152,372, respectively. Aggregate total for these patients was $62,318,395 and $25,293,709 (Corlew 2010). In 2005 in Uganda, among 297 patients (median age 4 months) treated, the total cost of neurosurgical intervention was $350,410, and the cost per DALY averted ranged from $59 to $126. The economic benefit was estimated to be between $3.1 million and $5.2 million using a human capital approach and $4.6 million-$188 million using a value of a statistical life (VSL) approach. The total economic benefit of treating the conservatively estimated 82,000 annual cases of hydrocephalus in infants in SSA ranged from $930 million to $1.6 billion using a human capital approach and $1.4 billion-$56 billion using a VSL approach. The minimum benefit-cost ratio of treating hydrocephalus in infants was estimated to be 7:1 (Warf and others 2011). Newly available estimates of avoided infant CCHD deaths in several US states that implemented mandatory CCHD screening policies during 2011–2013 suggest a substantially larger reduction in deaths than was projected in the previous US cost-effectiveness analysis. Taking into account these new estimates, we estimate that cost per life-year gained could be as low as USD 12,000 (Grosse and others 2017).

Access Barriers

Poor and delayed access to care has resulted in increased morbidity and mortality especially for life-threatening congenital anomalies. Surgical workforce shortages hinder the ability to cope with the burden of surgical disease. Funding priorities in LMIC have favored infectious diseases with a neglect of surgery and perioperative care. Care, however, does not start and stop after congenital anomaly correction. A Cohort study in three American states that followed children with birth defects found a 3 fold increase in incidence in 123 types of childhood cancer in this cohort (Botto and others 2013). The support for care for children with birth defects therefore needs to continue past the neonatal period, throughout adolescence.

A Way Forward

- Birth Defect screening - Prenatal & Neonatal
- Birth Defect Registry
- Provision of Skilled Manpower
- Implementation of the Optimal Resources for Children Surgical Care of the Global Initiative for Children's Surgery

Collective expert experience suggests that a Neonatal Mortality Rate (NMR) > 30/1000 indicates very limited access to health services. Access increases rapidly as countries pass through the development window, and an NMR < 5/1000 indicates near 100% access (Congenital Disorders Expert Group and others 2018). Previous international policy has focused on preventing environmental congenital disorders. Public health initiatives like micronutrient supplementation, avoidance of harmful exposures, anti-Rhesus administration, appropriate pregnancy care, and genetic and ultrasound prenatal screening has reduced the global prevalence of environmental congenital disorders amongst all types of congenital anomalies to 15%. Congenital anomalies that cannot be prevented, however, have remained largely ignored in low and middle income countries (Congenital Disorders Expert Group and others 2018).

Efforts to improve the burden of congenital anomalies must move beyond preventative measures. Surgery has proven itself to be a cost-effective means to improve congenital anomaly outcomes across multiple children's surgical disciplines.

Treating congenital anomalies may translate into a significantly greater reduction in the economic burden of disease than that cited earlier. Children represent the future economic engine powering LMIC and the value of investing in paediatric surgery also encompasses the future socioeconomic well-being of LMIC (Sitkin and others 2015). Most available data on congenital anomalies in LMIC is heterogeneous, single institution, and hospital based. The lack of high-quality, population-based data in LMIC is overcome using estimates based on high income settings, expert opinion, and literature reviews. To better assess the true burden of congenital anomalies and allocate resources appropriately measures to improve data collection such as national congenital anomaly registries should be considered. A recent

WHO birth defects surveillance program has been launched but is in very early stages and evidence of implementation is lacking (Chriscaden 2020).

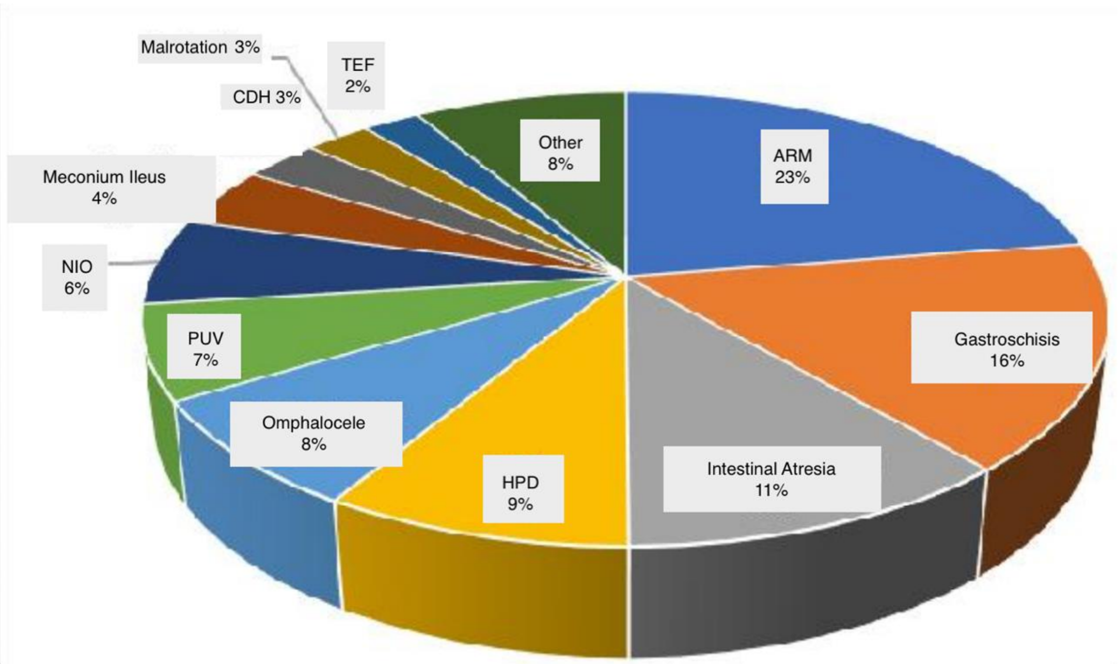


Figure 8: disability from birth defects in a tertiary center in Bangladesh over 12 years. (n=657). ARM: anorectal malformation; HPD: Hirschsprung disease; PUV: posterior urethral valves; NIO: neonatal intestinal obstruction; CDH: congenital diaphragmatic hernia; TEF: Tracheoesophageal fistula(Chowdhury and others 2020)

ROUTINE EMERGENCIES

Background

Data on emergency surgical care among children in LMIC remains limited. However, many of the most common congenital surgical anomalies, including esophageal atresia, congenital diaphragmatic hernia, intestinal atresia, gastroschisis, exomphalos, anorectal malformation and Hirschsprung's disease require emergency surgical care within the first few days of life. Acute appendicitis and associated complications, ileal perforation secondary to enteric fever, and intussusception continue to be the most common abdominal emergencies among children, especially in low- and middle-income countries (LMIC) (GlobalSurg Collaborative 2016). This section will cover some of the existing priorities for emergency general surgical care and for one key musculoskeletal condition (osteomyelitis) for children in LMIC.

Emergency procedures, therefore, utilize a considerable portion of healthcare resources. Across two major referral hospitals in Uganda 51% of the paediatric surgical capacity was devoted to emergency procedures (D. F. Grabski and others 2020). Abantanga and colleagues studied the range of abdominal surgical emergencies in children between 1-15 years of age at a teaching hospital in Ghana (Abantanga, Nimako, & Amoah 2009). Among the 955 children included in the study, typhoid intestinal perforation (68%); acute appendicitis (16%); abdominal trauma and intestinal obstruction including intussusception (4.7% each); irreducible external hernias (2.5%); primary peritonitis, (1.0%); gallbladder disease and gastric perforation (0.8% each) were the most common pathologies (Abantanga, Nimako, & Amoah 2009). The highest number of abdominal emergencies was seen among the 10-14 year age group (261 males; 169 females) followed by the 5-9 age group (251 males; 173 females) and the 1-4 age group (Abantanga, Nimako, & Amoah 2009).

Furthermore, among the 614 children who had a bowel perforation, 9 died postoperatively. Uncomplicated appendicitis was seen in only 20 children, whereas 131 children had complicated acute appendicitis and 1 child died following surgery. More than 35% of these children underwent bowel resection for gangrenous bowel, indicating delayed presentations. Twenty four children had an irreducible hernia and eight required emergency laparotomy for gallbladder disease (Abantanga, Nimako, & Amoah 2009). A prospective database of clinical admissions to the paediatric surgery ward in Gambia found that 46.9% of admission were for injuries including burns and 14.5% were for infections requiring surgery (Bickler & Sanno-

Duanda 2000). A retrospective study of paediatric surgical admissions in Nigeria found that the most common diagnoses at admission were trauma (36.7%), congenital anomalies (27.9%), and surgical infections (22.6%) (Thanni, Shonubi, & Akiode 2005). A tertiary paediatric surgery service in Uganda prospectively reviewed 3,494 patients between 2012 and 2016. 20% of paediatric patients presented with an infection and 64% of patients with an infection underwent an operation. In-hospital mortality rate for operative patients was 12.5% (Kakembo and others 2020). Among the 591 paediatric admissions, the highest number of cases were due to ileal perforation, appendicitis, intussusception, and necrotizing fasciitis, whereas the highest post-operative deaths were due to Typhoid ileal perforation and perforated intussusception (Kakembo and others 2020). Table 1 in this section summarizes characteristics of recent literature on abdominal emergencies in children in LMIC.

Appendicitis

Acute appendicitis in South Africa is associated with higher morbidity than in the developed world. Individuals living in rural settings presented with longer duration of symptoms and higher rates of perforation compared to individuals who lived in urban settings (Kong, Sartorius, & Clarke 2015). Based upon available data consisting of mostly single-institution, retrospective chart reviews from hospitals in Gambia, Uganda, and Nigeria, 0.9-17.1% of surgeries were performed for appendicitis (Bickler 2018; Kakembo and others 2020; Seyi-Olajide, Ezidiegwu, & Ameh 2020).

Intestinal Perforation

While many bowel resections in developed countries are due to congenital anomalies, indications for bowel resections in developing countries are mainly from preventable causes (Ezomike, Ituen, & Ekpemo 2014). Typhoid ileal perforation is a major problem in developing countries with attendant high mortality. The incidence of typhoid ileal perforation in typhoid-endemic areas varies widely and many studies are single institution retrospective chart reviews. A scoping review on the morbidity and mortality associated with TIP in six sub-Saharan African countries over 20 years revealed postoperative mortality rates ranging from 16-100% (Birkhold and others 2020). More importantly, non-fatal complications such as wound infections, dehiscence, and enterocutaneous fistulae, occurred in 40-60% of patients in the majority of studies. In a review of 12 paediatric TIP cases in Nigeria, all the patients presented late after being initially reviewed by a general practitioner (Ogiemwonyi & Osifo 2010). All children experienced one or more postoperative complications, including wound infection, ECF, sepsis, shock, anterior abdominal wall fasciitis and multi-organ failure, with 9 out of 12 children dying postoperatively. In a Tanzanian report on TIP, the peak age of incidence was 11-20 years (Chalya and others 2012). A more recent study from Pakistan studied the clinical presentation patterns and surgical outcome among 97 children with bowel perforation due to enteric fever (Azhar and others 2020). In this study, the majority of the patients (n=79, 81.4%) had a single perforation, 14 had multiple and 4 had sealed perforations. 71 (73.2%) patients received operative management within 24 hours of perforation and overall mortality was 12.4% (Azhar and others 2020). Further work on this condition has emphasized the consequences of delayed diagnosis due to multifactorial causes and resource shortfalls in surgical systems. In addition, most reviews have also emphasized the need for prevention of this condition through distribution of the typhoid vaccine and through the urgent need for improved sanitation (Carey & Steele 2019). Table 2 summarizes recent literature on typhoid intestinal perforation and expands on a prior scoping review.

Intussusception

Intussusception is the leading cause of bowel obstruction in infants. The majority of studies on intussusception are also retrospective chart reviews of admissions at single institutions (World Health Organization 2002). Retrospective hospital-based studies may underestimate the incidence of intussusception as they do not take account of patients who may present to other facilities within the same region, died or were being treated for an alternative diagnosis (World Health Organization 2002). For this reason accurate estimates of the incidence of intussusception are not available for most developing countries and many developed countries (World Health Organization 2002).

Based on available data, the estimated annual incidence of childhood intussusception in Africa is 71.9/100,000.(World Health Organization 2002) Reported incidence in Tanzania in children up to the age of 10 was 1:7557 (Carneiro & Kisusi 2004). In India, the lack of demographic data made it difficult to calculate incidence but there appears to be regional variability with hospital-based studies reporting the number of intussusception cases ranging from 1.9 to 54.4 per year (World Health Organization 2002). In China, there is a similar lack of demographic data and the number of cases ranges from 279 to 829 per year (World Health Organization 2002). while in Vietnam incidence is estimated between 472 to 722 cases per year despite the lack of demographic data (World Health Organization 2002). Annual incidence in Venezuela and Brazil is 24 per 100,000 children <1 year of age and 3.5 per 100,000 infants <1 year of age respectively (World Health Organization 2002).

The treatment of intussusception remains almost exclusively surgical in most countries of Africa due to late presentation (World Health Organization 2002). The lack of radiological facilities and expertise in some regions means that the diagnosis cannot be established prior to laparotomy and pneumatic or hydrostatic reduction can only be performed in a few centers (World Health Organization 2002). Lack of access to paediatric surgical expertise leads to delayed intervention and outcomes (World Health Organization 2002). In Africa, the intestinal resection rates in patients presenting after more than 48 hours ranged from 60% to 100% while for patients presenting within 48 hours the corresponding value was 12.4% (World Health Organization 2002). This paradigm leads to a higher morbidity and mortality from intussusception in Africa than in other regions of the world (Pindyck and others 2020). In contrast, in high income countries, approximately 80% of children with intussusception will have successful radiographic reduction without need for further intervention, and with negligible mortality (Edwards and others 2017).

In intussusception, early post-operative complications such as septicemia, hemorrhage and abscess formation were more frequent in the late presenters (World Health Organization 2002). Children who presented after 24 hours of symptoms have a higher incidence of bowel complications and greater risk of failed operative reduction and requirement of bowel resection at time of operation. Higher socioeconomic status and availability of radiologic diagnosis reduced the likelihood of undergoing resection.

Table 4: Characteristics of articles on abdominal surgical emergencies among children in LMIC.

Country	Study Years	Author	Condition	Age	Incidence	Prevalence	Complications/ Morbidity	Mortality
Original								
Nigeria	2014-2017	Seyi-Olajide et al.	Typhoid intestinal perforation	2-15 years	✓		✓	✓

Nigeria	1996 - 2005	Uba et al.	Typhoid intestinal perforation	4-15 years	✓		✓	✓
Pakistan	2016-2019	Azhar et al.	Typhoid intestinal perforation	3-12 years	✓		✓	✓
Ghana	2001 - 2005	Abantanga et al.	Typhoid intestinal perforation, appendicitis, abdominal trauma, intestinal obstruction, irreducible hernia, gallbladder disease	1-14 years	✓	✓	✓	✓
Tanzania	2006 - 2011	Chalya et al.	Typhoid intestinal perforation	8-76 years	✓	✓	✓	✓
Nigeria	1993 - 2007	David Osifo et al.	Typhoid ileal perforation	5-13 years	✓		✓	✓
Nigeria	2014 - 2018	Chukwubuike	Typhoid ileal perforation and ileal hemorrhage	6-14 years	✓		✓	✓
Review								
Multiple		Jiang et al.	Intussusception	< 18 years	✓			✓

Nigeria, Mali, Ghana, Niger, Ivory Coast, Central African Republic	1995-2019	Birkhold et al.	Typhoid Intestinal Perforation	2 months - 15 years			✓	✓

Table 5: Most common complications and mortality rates due to typhoid intestinal perforation in LMIC as reported in the literature. Many details of this table have been adapted from Birkhold et al.'s study and then updated with additional studies and details.(Birkhold and others 2020)

Country	**Study Years**	**Author**	**Top three Complications**	**Mortality Rate n (%)**
LMIC other than Nigeria				
Abidjan, Ivory Coast	1990–2000	Kouame et al.	Surgical Site Infections (SSI), Enterocutaneous Fistula (ECF), Incisional hernia	3 (6)
Kumasi, Ghana	1995–1997	Abantanga et al.	SSI, Wound dehiscence, chest infection	15 (12.4)

Bangui, Central African Republic	1997–1998	Bobossi Se´re´ngbe´ et al.	SSI, incisional hernia, evisceration	9 (29)
Kumasi, Ghana	2001–2005	Abantanga et al.	Sepsis, postoperative continuing peritonitis, wound infection and wound dehiscence	82 (12.6)
Bamako, Mali	2005–2010	Coulibaly et al.	(Could not find full text article in English)	16 (15.2)
Tanzania*	2006 - 2011	Chalya et al.	SSI, chest infection, septic shock	24 (23.1%)
Zinder, Niger	2013–2015	Adamou et al.	(Could not find full text article in English)	22 (14.4)
Pakistan	2016-2019	Azhar et al.	SSI, intra-abdominal collection, burst abdomen	12 (12.37)
Nigeria				
Ilorin, Nigeria	1984–1999	Rahman et al.	SSI, ECF	25 (23.6)
Ibadan, Nigeria	1985–2000	Irabor	SSI, wound dehiscence, incisional hernia	39 (21.3)
Zaria, Nigeria	1987–1996	Ameh	SSI, chest infection, wound dehiscence	25 (39)

Benin City, Nigeria	1993–2007	Osifo et al.	ECF, SSI, evisceration	9 (75)
Ile-Ife, Nigeria	1994–2004	Usang et al.	SSI, wound dehiscence, intra-abdominal abscess, and ECF (equal percentage for last two)	9 (23.7)
Enugu, Nigeria	1995–2004	Ekenze et al.	SSI, chest infection, re-perforation	17 (19.1)
Jos, Nigeria	1996–2005	Uba et al.	SSI, wound dehiscence, chest infection	42 (22.8)
Enugu, Nigeria	2001–2006	Ekenze et al	SSI, chest infection, wound dehiscence	21 (25.3)
Ilorin, Nigeria	2002–2009	Nasir et al.	ECF, wound dehiscence, evisceration	16 (10.4)
Azare, Nigeria	2004–2008	Nuhu et al.	SSI, re-perforation, wound dehiscence	13 (28.3)
Ife, Nigeria	2005–2013	Talabi et al	SSI, wound dehiscence, evisceration	9 (20)
Calabar, Nigeria	2006–2015	Usang et al.	SSI, chest infection, ECF	4 (8.2)
Kano, Nigeria	2007–2012	Ibrahim et al.	SSI, ECF, evisceration	42 (4.6)

Enugu, Nigeria	2008–2009	Ekenze et al.	SSI, wound dehiscence, incisional hernia	3 (13.6)
Ado-Ekiti, Nigeria	2008–2010	Adegoke et al.	(Not mentioned)	6 (12.8)
Kano, Nigeria	2009–2013	Anyanwu et al.	SSI, wound dehiscence, evisceration	14 (10.9)
Ibadan, Nigeria	2010–2017	Ajao et al.	(Complications after surgery for typhoid ileal perforation not stated clearly as the paper focused on indications of bowel resection)	1 (11.1)
Aba, Nigeria	2016–2018	Ekpemo et al.	SSI, chest infection, intra-abdominal abscess	5 (8.3)
Nigeria	2014 - 2018	Chukwubuike	SSI, chest infection, ECF	3 (6.8%)

*Patient population not limited to paediatric age group.

Musculoskeletal Infections

Bone and joint infections such as acute osteomyelitis and septic arthritis are high burden common conditions encountered in LMIC district and regional hospitals, with up to 12 million children affected in low-income countries (Meier & Rouma 2001). In HIC many can be treated in the acute phase with non-operative treatment and for children requiring surgery, an increasing number can be treated in one stage in HICs. In LMIC, treatment of this disease requires multiple stages, and is often complicated by delayed and-or inadequate treatment in the acute setting as 60-80% only present in the chronic phase (Geurts and others 2017). The incidence is higher in LMIC partly due to close association with sickle cell disease. These multiple factors lead to long hospital stays, economic burden, and compromised limb function. The optimal surgical approach in the acute setting requires a basic instrument tray and a soft tissue and bone incision to drain pus under the periosteum. An increasing number of cheap drills have been introduced in LMIC to increase access to bone surgery (Buchan and others 2015; Selhorst and others 2021) Meanwhile, insufficient treatment of acutely infected joints also causes long-term morbidity if treatment cannot be commenced within 2-3 days of presentation. Most patients with septic arthritis are age 3 or younger. Again, due to varied epidemiology in LMIC, distinguishing an infected joint from a non-infected inflamed joint also poses additional challenges (Upfill-Brown and others 2020).

Conclusion

Overall, the literature underscores high mortality and morbidity in LMIC from common abdominal emergencies such as TIP and intussusception as well as musculoskeletal infection. The findings underscore the urgent need to improve resources for children's surgery, as well as to pursue public health prevention strategies (such as vaccination for TIP) and earlier diagnosis of these life-threatening conditions.

REPRODUCTIVE HEALTH

Background

Although both paediatric surgery and reproductive health are global health priorities, surgery on the reproductive organ system in children is often overlooked as reproductive health services in LMIC primarily focus on non-surgical interventions (Desrosiers and others 2020). In many settings, paediatric gynaecological procedures are elective and are often delayed, resulting in significant backlog and impact in quality of life (S. O. Ekenze and others 2014). There have been remarkable advances in fetal surgery and minimally invasive gynaecological surgery, but their benefits reside almost exclusively in high-income-countries (Maselli & Badillo 2016; Ruano & Vega 2019). Among reproductive surgical conditions in the paediatric population, teenage pregnancies and complications from sexual violence are most common (Johnson & Moore 2016; Sully and others 2020; World Health Organization 2014a).

Teenage Pregnancy

Teenage pregnancy can lead to a perpetual state of ill-health and poverty worldwide. In South Africa, teenage pregnancy is a multifaceted problem associated with poverty, gender inequality, gender-based violence, substance use, poor access to contraceptives, insufficient healthcare resources, limited sex education, and issues with termination of pregnancy (Yakubu & Salisu 2018).

According to the WHO, approximately 12 million girls aged 15 to 19 give birth every year in developing nations, and at least 10 million of these are unintended (World Health Organization 2020a). Around 2.5 million births occur to girls aged under 16 in low resource countries each year.(Neal and others 2012) Eastern Asia and Western Africa hold the largest number of adolescent births (World Health Organization 2020a). Compared with mothers aged 20-24 years, adolescent mothers in LMIC are more likely to be single, less educated, and nulliparous (Yakubu & Salisu 2018). Sexual risk-taking behaviors, including early sexual debut, unprotected sex, multiple sex-partners and low contraceptive use are common among young people in Sub-Saharan Africa. In least developed countries, at least 39% of girls marry before they are 18 years of age and 12% before the age of 15 (Efevbera & Bhabha 2020; Yaya, Odusina, & Bishwajit 2019).

Several factors contribute to adolescent pregnancies and births. In many LMIC societies, girls are pressured to marry and bear children early (Kassa and others 2018). Child brides (<18 years old) are often unable to effectively negotiate safer sex, leaving themselves vulnerable to sexually transmitted infections such as HIV and early pregnancy. Adolescent specific barriers to contraceptive use include restrictive policies on contraceptive utilization that exclude teenagers, healthcare worker bias against adolescents' sexual health needs, and adolescents' own limitations to obtain and correctly use contraceptives (Chandra-Mouli, Camacho, & Michaud 2013). Sexual violence is another prevalent cause of unintended pregnancies, with some LMIC reporting a coerced sexual experience in up to a third of girls and the most common perpetrator being a current or previous intimate partner (Stamatakis and others 2020). In the context of the COVID 19 pandemic, teenage pregnancy, rape, and sexual violence have increased in LMIC, with the UNFPA reporting a 20% increase in domestic and sexual violence during the pandemic (Sifat 2020). For example, teen pregnancies spiked by 60% in one province in South Africa during the pandemic, attributed to the effects of lockdowns (Save the Children 2021).

The consequences of teenage pregnancy can be damaging and profound. Pregnant adolescents are at higher risk being exposed to violence within a marriage or intimate relationship (Raj & Boehmer 2013). These adolescents are also more prone to dropping out of school, compromising future educational and career prospects (World Health Organization & UNAIDS 2015). Rural resident teenagers who were married, uneducated, lacked paternal education, and lacked parent to child communication on sexual and reproductive health issues were more likely to start childbearing. Pregnancy may result in a miscarriage, a termination, a caesarean section or an assisted vaginal delivery, all which come with surgical complications. In fact, complications of pregnancy and childbirth are a leading cause of death in adolescents in LMIC (Neal and others 2012).

Female genital mutilation and circumcision

Female genital mutilation (FGM) is defined as the deliberate alteration or removal of female genitalia for non-medical reasons and is recognized as an international human rights violation. Over 4 million girls are at risk of FGM before the age of 15 annually (United Nations Children's Fund (UNICEF) 2017). Complications from FGM can range from excruciating pain to sepsis, hemorrhage and even death. The majority of FGM occurs in developing countries with inadequate surgical delivery systems and an unmet surgical disease burden, further compromising outcomes of children with complications from FGM (Kandala and others 2018). UNICEF encourages countries to establish policies that outlaw FGM to protect girls at risk and survivors (Ferguson 2021).

Obstetric surgical services should also be a core component of every healthcare system, as the cesarean section is deemed as an essential and Bellwether procedure by the 2015 Lancet Commission (Meara and others 2015). Although first-tier experimental evidence is lacking in developing countries, a systematic review of 8 observational and ecological studies show strong support for emergency obstetric care in reducing maternal mortality (Paxton and others 2005) Midwife programs are also a cornerstone in reducing morbidity and mortality in both mother and newborn in LMIC (Renfrew and others 2014). According to the Lancet Series on Midwifery, a projected 83% of all maternal and newborn deaths could be prevented by providing quality midwife services (Homer and others 2014). Unfortunately, midwifery education and training in LMIC is currently inadequate and underfunded, so should be strengthened to meet international standards (Gavine and others 2019). Reproductive health promotion, medical, and surgical services should also be well-integrated into child health and surgical programs as much as possible.

Complications of adolescent pregnancies

Adolescent childbirth is associated with greater health complications for the mother (Wall 2012). Risk of obstetric fistula is substantially increased in adolescents, which can lead to a lifetime of social and economic disadvantage. Among mothers in LMIC, severe anemia (hemoglobin < 7mg/dl), malaria and dengue fever were more common in adolescents (Ganchimeg and others 2014). Compared with adult mothers, adolescent mothers have higher risks of pre-eclampsia, eclampsia, puerperal endometritis, systematic infections, preterm delivery, while their newborns have a higher tendency to present with low birth weight and severe neonatal conditions (Grønvik & Fossgard Sandøy 2018). In LMIC, the youngest mothers aged 15 years or younger suffer the highest rates of eclampsia (75%) and c-section rates (28%), compared to adult mothers (Ganchimeg and others 2014).

Obstetric fistula

The World Health Organization estimates that more than 2 million women live with an obstetric fistula and up to 100,000 new cases occur annually (World Health Organization n.d.-c). However, these figures may be a severe underestimation. Girls ages 10–15 years are especially vulnerable to developing an obstetric fistula because their pelvic bones are not mature enough to handle childbearing and delivery. Thus, a girl's risk for an obstetric fistula can be up to 88% (Semere & Nour 2008). If left untreated, these fistulas lead to prolonged fecal or urinary incontinence, which can be a source of tremendous humiliation and depression, ostracizing the child from society and rendering any future childbearing impossible (Nour 2006). Fortunately, most obstetric fistulas can be successfully repaired surgically, restoring dignity and well-being in these women and girls to allow appropriate reengagement with society (United Nations Secretary-General 2018). Nevertheless, access to fistula surgery remains unacceptably scarce in LMIC, especially for young adolescents (Baker and others 2017).

Maternal Mortality

Maternal related deaths rank second among causes of mortality in 15-19 year old females worldwide, with minimal improvement since 2000 (World Health Organization 2014c). About 800 women die every day from preventable causes related to pregnancy and childbirth, with 94% of all maternal deaths occurring in developing countries (World Health Organization 2019). In LMIC, complications of pregnancy and childbirth are the leading cause of death in young women aged 15-19 years (Neal and others 2012). More than half of deaths from preventable causes related to pregnancy and childbirth globally occur in sub-Saharan Africa, while a third occur in South Asia (World Health Organization 2014b). Young adolescents face the highest risk of pregnancy-related complications and death, especially in girls under 15 years old (Althabe and others 2015; Ganchimeg and others 2014). Furthermore, 70% of the 5.6 million abortions adolescent girls undergo each year are unsafe, leading to an enormous amount of preventable maternal morbidity and mortality (Darroch and others 2016).

Recommendations for Reducing Maternal Mortality

Global health initiatives aimed at reducing maternal mortality should prioritize improving access and quality of labor and delivery, contraception and safe abortion services (Kendall & Langer 2015). Effective obstetric delivery models that are contextually appropriate should be identified prevent the main causes of maternal death at scale. To sustain maternal healthcare coverage over time, tools should be developed to measure quality of care and promote ongoing quality improvement from the facility to national level.

IMPLICATIONS OF DELAYED TREATMENT

Socioeconomic Impact

The socioeconomic impact of physical impairment from paediatric surgical conditions have not been previously discussed in the DCP. Chronic disability due to untreated, partially treated, or unsuccessful surgical treatment leads to marginalization, disengagement from school, and undue burden on caregivers. Substantial challenges in surgical access within LMIC perpetuate due to financial constraints. Surgical diseases can originate from delay in diagnosis or misdiagnosis of medical conditions, which can result in a large hidden mortality as some avertable surgical deaths are misclassified as medical or unavertable. Mistreatment of medical conditions can also lead to surgical sequelae, such as the case of gluteal fibrosis due to quinine injection injury secondary to treatment of malaria (Alves and others 2018). Overall, delay in patient presentation often leads to increased morbidity and mortality and exacerbates the socioeconomic impact on the patient and family. In all the conditions discussed in this background paper, delayed presentation plays a major role.

For example, in a Nigerian study on the implications of delayed presentation on intussusception, late presentation was associated with a higher incidence of bowel complications and greater risk of failed operative reduction, need for bowel resection, and increased risk of mortality (S. Ekenze & Mgbor 2011). Late presentation plays a major role in the unacceptably high neonatal surgical morbidity and mortality in most parts of Africa. Newborns with neural tube defects often present with rupture of the sac with infection, anemia, and malnutrition (Idowu & Apemiye 2008). Babies with inguinal hernias may present with incarceration, which may lead to enterocutaneous fistula and life threatening necrotizing fasciitis (Bamigbola and others 2012). Indeed, delayed presentation of surgical infections often require surgical management, as showcased in a Ugandan tertiary referral hospital prospective study, where 20% of over 3000 pediatric surgical patients were admitted for infection, and 12.5% died in the hospital (Kakembo and others 2020). Many neonates with emergent surgical conditions present with hypothermia, sepsis and hemodynamic unstability (S. O. Ekenze, Ajuzieogu, & Nwomeh 2015; S. O. Ekenze and others 2017). Coupled with inadequate workforce and poorly equipped facilities that lack neonatal intensive care units, many neonates with surgically correctable life-threatening diseases do not survive in LMIC (S. O. Ekenze and others 2017).

A child with a disability due to a congenital anomaly who receives delayed surgical treatment in late childhood or adolescence suffers an unredeemable burden of disease, as an evaluation in disability adjusted life years (DALYs) demonstrates. Surgical delay generates a significant unmet surgical burden and surgical backlog in many African countries. A review of 5 congenital anomalies in 12 African countries showed that surgical repair delays averaged 2 years across all conditions, with the longest wait times for hypospadias and cryptorchidism (Yousef and others 2019). Neither cryptorchidism nor hypospadias are urgent conditions and were not prioritized in a system where limited resources are siphoned off to emergency cases. As a result, the total surgical backlog for cryptorchidism amounted to 320,777 cases across 4 countries, while hypospadias had 59,180 cases backlogged across 6 countries (Yousef and others 2019). Though not life-threatening, such conditions can be associated with significant disability, responsible for 75,000 DALYs. Of the 12 countries studied, Nigeria has the largest population in Africa and one of highest live birth rates resulting in the largest surgical backlog and unmet need, demonstrating a positive correlation between population size and surgical delay (Yousef and others 2019). Scaling up the children's surgical infrastructure and workforce needs to be made a priority to address the surgical backlog and unmet need.

A study on the paediatric surgical epidemiology in Uganda reported that 32% of hernias presented with incarceration, emphasizing the need for timely access to care due to the emergent nature of many paediatric surgical conditions (D. F. Grabski and others 2020). Similarly, The proportion of colorectal congenital cases that were delayed due to emergency procedures was ~50% (D. F. Grabski and others 2020). For example, while most children with congenital colorectal conditions such as anorectal malformations and Hirschsprung Disease would be definitively repaired in the first year of life in HICs, in many LMIC definitive repair requires three operations instead of one, three or more years living with an ostomy, definitive repair at older ages (Commander and others 2021; Oyania and others 2020). Children with stomas of course, do not attend school. In Somaliland, long delays in presentation for children with congenital anomalies led to 2362 DALYs in 280 children, or an average of 8.4 avertable DALYs per child (Smith and others 2020). Household surveys in the same country illustrate downward poverty trajectories for families who have child with a surgical condition, regardless of whether it was treated (Smith and others 2019). This economic impact is also underscored by an increasing number of studies highlighting the catastrophic expenditure incurred by families in LMIC accessing surgical care for children (Phull and others 2021; Platt and others 2021; Yap, Cheung, and others 2018). Furthermore, delayed treatment for many conditions leads to increasing cost of care, by requiring more and staged operations (rather than a single operation), and by often increasing the complexity and the resources required to minimize morbidity and mortality. There has been even less work on the most effective public or private strategies for financial risk protection for children, but existing studies mostly document the lack of a public safety net for children accessing care and high costs in the private sector. For children in Bangladesh having herniotomy, private hospital costs were 15 times higher in private hospitals than as a day case in a public facility (Figure 9) (Banu and others 2018; Tahsina and others 2018). This group recommended specialist outreach for select conditions as the best economic options for families to get care "at the doorstep" (Banu and others 2013).

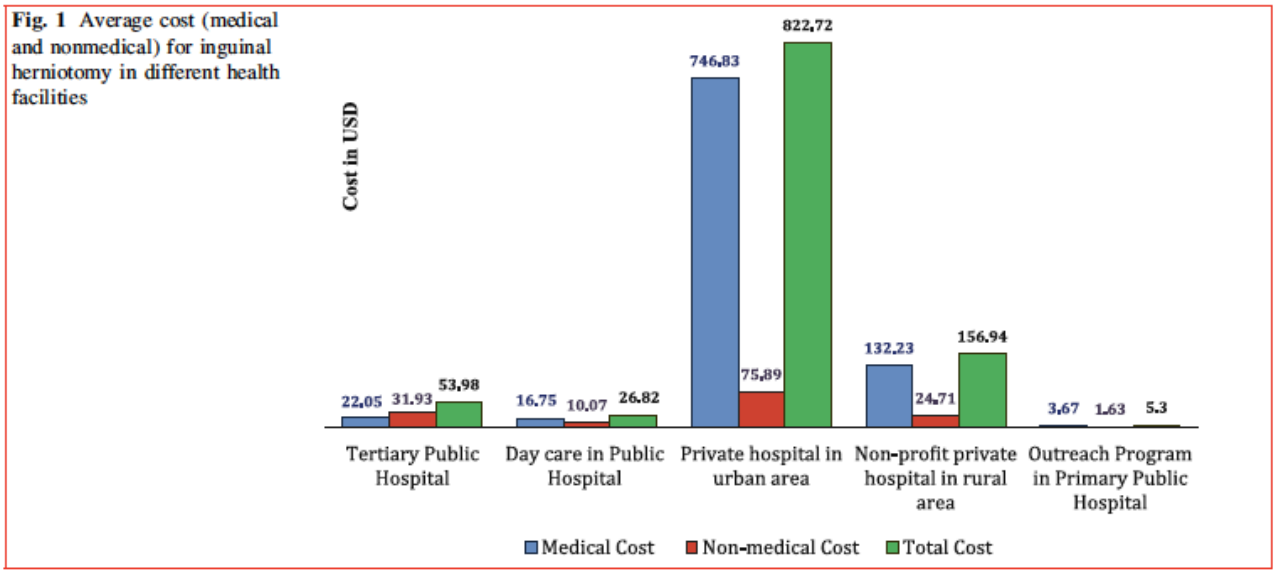


Figure 9: Sourced from Banu et al. World J Surg 2018.(Banu and others 2018)

Cost effectiveness of interventions

The perception that surgery is prohibitively expensive and complex in LMIC historically posed perhaps the most substantial barrier to including surgical interventions in global health efforts. However, this "de facto" belief has been refuted by ongoing evidence including the Lancet Commission of Global Surgery, highlighting that surgical services are affordable and promote economic growth (Meara and others 2015). Defining the economic value of health interventions can be a powerful advocacy tool to aid decision making by policy makers for resource allocation. Several areas of children's surgical care still lack adequate economic analysis, and available information should be locally contextualized.

For example, construction of a charity funded dedicated paediatric operating room in Uganda averted 6447 DALYs per year and cost $41,182 per year from the charity's perspective, with an incremental cost-effectiveness ratio (ICER) of $6.39 per DALY averted or $397.95 per life saved (Yap, Muzira, and others 2018). From the broader societal perspective, which included local hospital and patient costs, the same operating room had an ICER of $37.25 per DALY averted, or $3,321 per life saved (Yap and others 2021). A similar recent analysis of operating room installation in Abuja, Nigeria estimated a comparable ICER of $137/DALY averted.(E. Ameh 2021) A systematic review and analysis of 26 cost effectiveness studies that assessed surgical interventions in LMIC, showed that many essential surgical interventions are cost effective or very cost effective.(Chao and others 2014) The median ICER of cleft lip or palate repair ($47.74 per DALY averted) and hydrocephalus surgery ($108.74 per DALY averted) were similar to that of BCG vaccine ($51.86 – 220.39 per DALY averted) (Chao and others 2014). A systematic review of 86 economic analyses spanning 36 groups of children's surgical interventions in LMIC concluded that many paediatric procedures, such as cleft lip and palate repair, trichiasis surgery, congenital heart surgery, and circumcision are considerably cost effective (Saxton and others 2016). Inguinal hernias had the lowest median ICER at $15 per DALY, while neurosurgical procedures had the highest median societal economic benefit at $58,977 (Saxton and others 2016). Despite the growing literature on procedure-specific cost-effectiveness analyses on paediatric surgical procedures, more research is needed to accurately define the cost and value of children's surgical care over a diverse range of countries and healthcare settings to make these findings generalizable. Meanwhile, a companion paper to this report has estimated the substantial number of preventable deaths in children if surgical services were to be scaled at the first level hospital in LMIC (The Global Initiative for Children's Surgery Collaborators 2021).

Increasing Children's Surgical Capacity: Care Guidelines, Policy, and Child Health

The Optimal Resources for Children's Surgery (OReCS) document was developed by GICS to promote standards of care that will improve surgical care of children worldwide, especially in LMIC (D. Grabski and others 2019). OReCS defines essential children surgical services and resources that should be made available by hospital level within any national health system. Guidelines were developed through review of evidence, experience, and consensus of thirteen working groups over 18 months. The resources outlined are tailored to support levels of care from basic to intermediate to complex/advanced surgical care for children. This template of optimal services serves as a guide for stakeholders planning the scale-up of surgical services for children in low resource settings by setting minimum standards of care. It provides pragmatic comprehensive recommendations regarding resources, training and research priorities required for safe and high quality surgical services for children (D. Grabski and others 2019). Advocacy is needed to increase awareness of OReCS to key stakeholders involved in policy making and implementation, relevant organizations and Ministries of Health. In countries developing their National Surgical Obstetrics and Anaesthesia Plans (NSOAPs), this document has the capacity to become a benchmark tool for the inclusion of children's surgery, to complement other proposed. An increasing number of groups have used ORECS for gap assessment and planning (Cotache-Condor and others 2021; El Vilaly and others 2021; Wamala and others 2021).

Aligning with the World Health Assembly resolution 68.15, (NSOAPs) direct the development of emergency and essential surgical care and anaesthesia services within a healthcare system as integral components of Universal Health Coverage(Price, Makasa, & Hollands 2015). However, with the exception of Nigeria's NSOAP, currently published plans have not given specific attention to or laid emphasis on the unique surgical needs of children.(Federal Ministry of Health 2019; Landrum and others 2021). The GICS promoted and supported efforts to include children's surgery in NSOAPs through the creation of the Children Surgical Assessment Tool (CSAT) (a modification of the Surgical Assessment Tool (SAT)), which was executed for the first time in Nigeria's plan. Given the heavy disease burden driven by children's surgical conditions, Universal Health Coverage and other health-related sustainable development goals cannot be achieved without improved access to safe and affordable surgical care for children. Integration of children's surgical care in the NSOAPs and in ongoing child health programmes, such as those run by key stakeholders in global child health, will ensure that the surgical needs of children and adolescents across all stages of growth and development are deliberately catered to and planned for. Execution of NSOAPs should be paired with periodic monitoring and evaluation of implementation goals. Meeting children's surgical needs will be instrumental to achievement of many of the SDGs driving global health efforts.

One of the areas in global child health to scale that has been raised are school-based interventions, as there has been substantially greater investment in schooling in the age 5-19 (D. A. P. Bundy and others 2017b, 2017a). A diverse range of areas that have overlap with the prevention and care of surgical conditions include injury prevention programs, provider physical examination for missed structural congenital anomalies, reproductive health education, and education about basic common surgical conditions. Previous work from the DCP 3 has stressed the comparative underinvestment in health of children in the 5-19 age group compared to the under 5 age group. Children's surgical needs extend across all phases of the 5-19 span (middle childhood, adolescent growth spurt, and adolescent consolidation). Even some congenital diseases require surgical treatment in middle childhood or beyond due to delays in treatment. Trauma, oncology, and other emergencies predominate in these age brackets.

Infrastructure

Creating sustainable model for tackling the LMIC infrastructure crisis in children's surgery is key to the successful delivery of paediatric surgical care worldwide. Kids OR, a Scottish registered charity that creates and equips children's operating rooms in LMIC, provides a potential example of such a model by constructing high quality infrastructure designed around the local team's skillset (KidsOR n.d.). The charity provides dedicated specialist equipment and facilities for children's surgery in low resource settings, supports and funds the training of existing surgical teams to deliver safe surgery, and advocates for children's right to surgery through impact evaluation of its facilities. The charity has partnered with other leading organizations such as GICS, Smile Train, and regional professional associations to deliver these projects. Kids OR sites have been established in countries including Burkina Faso, Democratic Republic of Congo, Ecuador, Ethiopia, Haiti, Ivory Coast, Kenya, Malawi, Nigeria, Peru, Rwanda, Senegal, Sierra Leone, Tanzania, Uganda, Zambia, Zimbabwe, and many more are planned for the future (D. Cunningham & Fedatto 2021; Kids Operating Room n.d.).

Workforce Capacity, Training, and Service Delivery

The West African College of Surgeons, College of Surgeons of East, Central and Southern Africa and national surgical colleges of various sub-Saharan African countries have all contributed to strengthening the overall surgical workforce in the region, including the training of paediatric and other specialty surgical providers. The Royal Australasian College of Surgeons administered a program through the involvement and support of the Pacific Islands Project to provide a sustainable paediatric surgical service in Vanuatu (Leodoro, Beasley, & Maoate 2015). These colleges promote, organize and conduct postgraduate surgical education in related specialties and disciplines while fostering academic research.

Non-governmental organizations also have enhanced LMIC local surgical capacity in various ways. Smile Train, the largest facial cleft charity, provides training, funding and resources to empower local medical professionals in over 90 countries to provide free cleft surgery and comprehensive cleft care in their own communities (SmileTrain n.d.). Operation Smile, another cleft charity, partners with Ministries of Health and corporations to empower local health professionals through training and education (Operation Smile n.d.). The Global Clubfoot Initiative works to prevent disability from untreated clubfoot through resource provision, international collaborations and information dissemination (Global Clubfoot Initiative n.d.). SIGN Fracture Care International works with LMIC centers to provide appropriate orthopedic training and prosthetics that do not require intra-operative x-rays for implantation (SIGN n.d.). Context appropriate training and technology has resulted in fracture treatments and outcomes that are comparable to those in HIC. Lack of implants, for example has been shown to severely limited orthopedic care provision in LMIC (Wichlas and others 2021).

Table 6: Selection of International Professional and Non-Governmental Organizations and their roles in surgical and anesthesia capacity strengthening

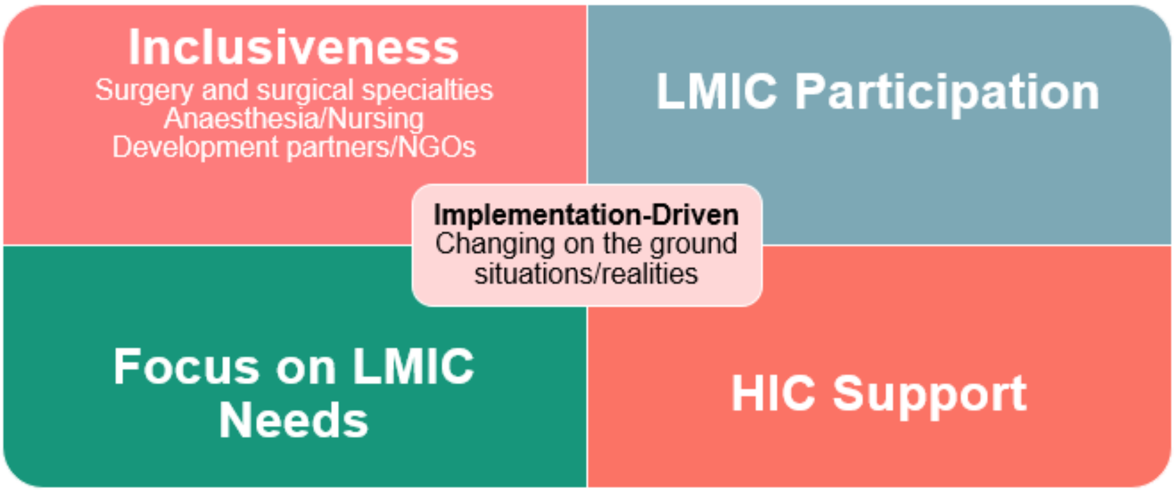
Organization	Activity
College of Surgeons of East, Central and Southern Africa	Accreditation, postgraduate education and training in paediatric surgery
West African College of Surgeons	Accreditation, postgraduate education and training in paediatric surgery
Royal Australasian College of Surgeons	Developing paediatric surgery in the Pacific Islands
World Federation of Societies of Anesthesiologists (WFSA)	Advancing training, policy guidelines, and advocacy for anesthesia and perioperative care in LMIC
Smile Train	Provision of funding resource and training to local practitioners for the provision of free cleft surgery and comprehensive cleft care.
Operation Smile	Empowering local practitioners to training and education for the provision of cleft care and provision of funding for cleft care
KIDS OR	Infrastructure, training, and advocacy for children's surgery in LMIC
Global Club Foot Initiative	Resource provision for club foot care and promotion of international collaboration
SIGN Fracture Care International	Provision of implants and training

International collaborations with significant LMIC participation

The World Health Assembly resolution 68.15(94) and the Lancet Commission of Global Surgery metrics (95) lacked a specific focus on children's surgery (Meara and others 2015; Price, Makasa, & Hollands 2015). Nevertheless, universal health coverage and the United Nations' (UN) Sustainable Development Goals (SDG) cannot be achieved without deliberate efforts to scale up access to children's surgical care. Therefore, GICS was formed with a mission to define and promote optimal resources for children's surgery in resource limited regions of the world (GICS n.d.). Composed of providers and allies from a wide range of LMIC and HIC, GICS strives to assess the current state of surgical care for children in LMIC, develop global, regional, national and local health priorities for the improvement of delivery of children surgical care, and pool resources to address these priorities.

Cooperation among developmental partners to ensure inclusivity and equity cannot be overemphasized. Smile Train has partnered with Kids OR to supply an initial 20 paediatric operating room across Africa for the provision of essential life-saving surgical care to more than 12,000 children by the end of 2021 (Diggs & Tas n.d.). With significant LMIC participation, these collaborations ensure sustainability of interventions which are contextualized and suited for the highest priorities of the local community. (Figure 10)

Figure 10: Pillars facilitating success of GICS in Strengthening Children's Surgery in LMIC.



Conclusions

As outlined in this report, a broad range of surgical conditions impact the first 8,000 days of life with substantial impact on the burden of disease in this age group. The attached panel highlights priority areas for research and development in this space. The continuum of prevention to treatment of these conditions remains under-supported in LMIC with substantial disparities between high and low-income countries in death and disability from these conditions. Cost-effective interventions to scale surgical care exist and can be scaled by coordinating investments across the public and private sector, through international organizations and through philanthropy. While surgical conditions intersect with many priority areas of child health, integrated approaches in recommended packages of care remain limited and should be expanded. Finally, equitable partnerships should guide capacity-strengthening, with LMIC champions and community priorities clearly integrated into development and delivery of packages of care.

PANEL: Research, Development, and Policy Priorities for Surgery in the first 8000 days of life

Obtain high quality data about the gaps in provision of surgical, anesthesia, and perioperative services through childhood adapting the Optimal Resources for Children's Surgical Care Guidelines

- Define lean and efficient data sets to guide quality improvement and catalyze investment in surgical care through the various stages of childhood (neonatal and infant, under five, middle childhood, and adolescence)
- Address lack of anesthesia, analgesia, and palliative care services across the spectrum of care
- Foster and catalyze an inclusive approach to research and development led by LMIC communities and ensure local ownership and stewardship of such data in LMIC

Address Critical Role of Social Determinants of Health on Children's Surgical Inequities

- Further define diverse care access barriers such as culture, language, geography, transport, and poverty and design context-appropriate strategies to address these challenges

Pilot implementation of children's surgical service delivery packages through the health care system in LMIC and ensure integration into health planning and policy

- Design and implement workforce development, infrastructure, and policy interventions within and between countries and regions at all levels of the health care system
- Define care areas more suited to specialized platforms for delivery versus those best approached through development across the entire health care system

Prioritize Visibility and Impact of Neglected Children's Surgical Conditions disproportionately present in LMIC (many absent in HIC) leading to early death and disability

- Untreated or partially treated congenital anomalies (colorectal conditions, clubfoot, cleft lip and palate, neural tube defects, cardiac anomalies), injuries (such as burns and fractures), cancers, infections (such as typhoid fever and osteomyelitis), obstetric and other conditions requiring surgery lead to early death or long-term disability in LMIC
- These sequelae require increased resources to treat in life, are preventable with earlier intervention or treatment, and hamper development

Integrate surgical care with existing global initiatives in child health

- Engage policymakers and leading global child health organizations to ensure prevention and treatment of surgical conditions in key areas of work such as congenital anomalies, injuries, and non-communicable diseases

- Ensure that key surgical and anesthesia initiatives explicitly address children with clear accountability metrics.

Maximize sharing of best practices between LMIC and with HIC through communities of practice

- Highlight and share innovations in workforce development (including diversity, equity, inclusion) technology, communications, and community engagement
- Translate LMIC advances to address HIC inefficiencies
- Prioritize sustainable practices of surgery and anesthesia care through minimizing environmental impact

Strengthen LMIC institutional capacity in workforce development, research, policy development, and finance

- Ensure investments sustain future capacity in these areas rather than promoting stop-gap solutions
- Develop resilient systems to political, environmental, and other shocks

Harmonize NGO sector with government and international agencies and organizations as well as the private sector and philanthropy to define synergies, promote co-investment, and areas of possible shared resources

- Landscape and share various models of effective cooperative agreements

Ensure children and families are adequately represented in research and policy development

- Strengthen community advocacy networks across the range of surgical conditions
- Capture health and non-health outcomes such as stigma, social integration, educational participation, equity in gender and ethnicity, and overall development of human capacity
- Develop and implement a global advocacy network to raise visibility and promote collective action

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