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Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana

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Abstract

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Conflict of interest statement

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Background—This study aimed to assess the availability of pediatric trauma care items (i.e. equipment, supplies, technology) and factors contributing to deficiencies in Ghana.

Methods—Ten universal and 9 pediatric-sized items were selected from the World Health Organization's *Guidelines for Essential Trauma Care*. Direct inspection and structured interviews with administrative, clinical and biomedical engineering staff were used to assess item availability at 40 purposively sampled district, regional and tertiary hospitals in Ghana.

Results—Hospital assessments demonstrated marked deficiencies for a number of essential items (e.g. basic airway supplies, chest tubes, blood pressure cuffs, electrolyte determination, portable Xray). Lack of pediatric-sized items resulting from equipment absence, lack of training, frequent stock-outs and technology breakage were common. Pediatric items were consistently less available than adult-sized items at each hospital level.

Conclusion—This study identified several successes and problems with pediatric trauma care item availability in Ghana. Item availability could be improved, both affordably and reliably, by better organization and planning (e.g. regular assessment of demand and inventory, reliable financing for essential trauma care items). In addition, technology items were often broken. Developing local service and biomedical engineering capability was highlighted as a priority to avoid long periods of equipment breakage.

Keywords

trauma; pediatric; capacity; operations management; developing country; global surgery

Introduction

Trauma accounts for more than 25% of pediatric deaths and even more disability worldwide. [1] After infancy, injuries are responsible for more deaths than malaria, neglected tropical diseases and malnutrition combined in sub-Saharan Africa.[1] However, funding for injury prevention, treatment and rehabilitation capacity improvement accounts for less than 1% of international financial assistance to low- and middle-income countries (LMICs).[2] Investment in trauma care capacity is urgently needed to reduce this burden.[3]

However, planning and organizing trauma care can substantially reduce disability and preventable deaths as well.[4-7] Mandatory for successful trauma systems is reliable and timely availability of equipment, supplies and appropriately trained personnel.[8] To define minimum standards for necessary injury care resources the World Health Organization (WHO) published *Guidelines for Essential Trauma Care* (GETC).

More than twenty national assessments of surgical and trauma care capacity in LMICs have been performed using GETC and similar assessment tools.[9-18] These assessments reported critical deficiencies in infrastructure, equipment and supplies. Though most of these assessments have not specifically addressed pediatric trauma and surgical capacity, they have been important for establishing a case for advocacy and providing baseline data from which capacity improvements can be benchmarked. Nonetheless, caring for injured children requires reliable stock of pediatric-sized non-drug consumables and familiarity with the unique aspects of pediatric surgical care.

Until recently, assessments have not focused on the factors contributing to item deficiencies; and therefore, have not been able to identify targets for capacity improvement interventions. Shah et al performed an assessment of trauma care technology availability in Gujarat State, India.[14] A lack of numerous specific items, many of which were low cost, due to stock outs and equipment breakdowns was common. Moreover, there was a mismatch of equipment and trained personnel. However, locally manufactured items were fairly well supplied. The authors advocated for better procurement and stock-management, optimizing training for use of existing resources, and strengthening service contracts and local repair capabilities. Similar deficiency cause analyses, useful for planning targeted health systems strengthening interventions, have not been done in other LMICs.

This study aimed to assess the availability of pediatric trauma care items (i.e. equipment, supplies, technology) in district-level, regional and tertiary hospitals in Ghana. It also sought to identify factors contributing to these deficiencies, as well as good availability. By doing so, potential solutions to inefficient aspects of health systems management and maladapted equipment and technology for trauma care could be identified.

Methods

Setting

Ghana is a lower-middle income country in West Africa with a population of 26 million people and an annual per capita income of US\$ 1,760.[19] Ghana has 10 regions divided into 110 districts. Most districts have several primary health centers (PHC) and a government or mission hospital that serves as a district (first-level) hospital. PHCs provide only basic public health and primary care services; therefore, they were not included in the study. District-level hospitals are staffed by medical officers and nurse anesthetists, usually offer general and very basic pediatric surgical services and have between 50 – 100 beds.[20] In addition to medical officers and nurse anesthetists, regional hospitals are often staffed by specialist providers (pediatricians, general and orthopedic surgeons) and contain between 100 – 400 beds. Though surgical services offered at regional hospitals are broader in scope, advanced pediatric surgical care is not provided. There are four tertiary care hospitals in Ghana (one of which doubles as a regional hospital); all are affiliated with a medical school or residency program and offer specialist pediatric surgical care.[21]

Sampling—All regional and tertiary facilities and a selection of district-level hospitals (totaling 40 facilities) were purposively sampled to represent hospitals most likely to care for injuries, the diversity of trauma care development, geography and local socioeconomics. Permission and assistance in selecting hospitals using the aforementioned criteria was sought from each regional health directorate prior to hospital surveys. At least one district-level hospital in each region was selected by being:

- In a populous area, near heavily-trafficked roads likely to produce traffic injuries;
or
- Identified by the respective regional health directorate as caring for a higher injury volume than others within the region; *or*

- Designated as a trauma hospital; *and*
- Outside of an hour's transport to a regional or tertiary hospital.

One regional and one tertiary hospital declined participation.

Data collection—The WHO GETC lists 260 items of personnel and physical resources *essential or desirable* at different levels within a healthcare system. Although items posed by the WHO GETC are generic with regards to patient size or age, amendments have been made to the recommendations to make them specific to pediatric trauma care. In addition, the WHO GETC recommends that pediatric-sized items be present at the same hospital level as one would expect for adult-sized items. This study examined 9 pediatric-sized items for pediatric trauma resuscitation (e.g. airway supplies, IV catheters, cervical collars), in addition to 10 universal items from the parent study (e.g. electronic cardiac monitoring, blood transfusion capabilities, stationary Xray).[22] Technology items were defined as electronic medical equipment (e.g. pulse oximetry, Xray). The parent study examined 32 items from the WHO GETC, including both *essential* and *desirable* items; the study focused on adult trauma care item availability and included a root causes analysis of item deficiencies.[22]

After leadership approval at each facility, one or more of the following (depending on the local context) were asked to complete their respective part of the survey: surgeons, anesthetists, medical officers, professionals, technicians and/or in-charge nurses from the casualty, theatre, critical care, laboratory, radiology, physiotherapy, procurement, accounts and engineering departments. Item availability was rated as:

- 0 – Absent but should be present;
- 1 – Inadequate, available to less than half of those who need it;
- 2 – Partially adequate, available to more than half, but not to most who need it; or
- 3 – Adequate, present and readily available to almost everyone in need and used when needed.

For items rated 0 - 2, contributing factors were systematically asked and not considered mutually exclusive (except when items had never been present at a facility). These were, 'The item or service has/is:

- Never been present;
- Present but broken and awaiting repairs;
- Present and staff able to use it, but when they go home at night or on the weekend no one is available to fill the position;
- No staff member trained in using the available item;
- Available, but lacks reagents or supplies;
- Necessary equipment or supplies out of stock or insufficient in number;

- Available, but only after pre-payment that prevents many from receiving the service or item; and/or
- Other, with explanation.'

Direct inspection of items was performed to corroborate ratings and further troubleshoot reason(s) for non-availability. By doing so, deficiencies related to ineffective healthcare system management practices, personnel or training deficiencies, and insufficient financing mechanisms could be identified.

Data collection and analysis—Data were collected on paper forms and transcribed to Microsoft Excel (Redmond, Washington). Item availability rating (median and range) and factors contributing to non-availability (percent of hospitals reporting that factor) were described using Stata v13 (College Station, Texas). Wilcoxon signed-rank test was used to determine if there was a difference in pediatric and adult trauma care item availability at each hospital level.

Ethics—The Kwame Nkrumah University of Science and Technology and Komfo Anokye Teaching Hospital Committee for Human Research and Publication Ethics and the University of Washington Institutional Review Board gave approval for the study. In addition, the Chief Director of the Ghana Ministry of Health, Director General of the Ghana Health Service and respective Regional Health Directors granted research permission and facilitated hospital visits.

Results

Of the 40 facilities assessed, 29 were district-level (23 government and 6 mission), 8 were regional and 3 were tertiary hospitals (Table 1).

District-level hospitals

Most pediatric resuscitation items had median availability ratings of 2 or 3 (i.e. airway equipment, oxygen supply, pulse oximeters, peripheral IV catheters, urinary catheters, blood transfusion capacity). However, there was considerable variation in the availability of the aforementioned items within the district-hospital level (rating range 0 – 3). For instance, 57% and 38% of district-level hospitals had median availability ratings less than 2 for pediatric basic airway supplies and urinary catheters, respectively. Further, pediatric cervical collars and chest tubes were often absent (median rating 0) despite their low-cost.

Though the median rating for hemoglobin test determination was 3, electrolyte testing and small-volume lab sampling were rarely available (median rating 0). Stationary X-ray had median rating of 2 or 3 at 61% of hospitals, but portable X-ray and focused assessment with sonography for trauma (FAST) scan were seldom available (median rating 0 or 1).

Regional hospitals

Regional hospitals had higher median availability ratings than district-level hospitals for several pediatric items: blood pressure cuffs (3 vs 1), urinary catheters (2.5 vs 2) and electrolyte testing capacity (1 vs 0). However, advanced airway equipment, cervical collars,

chest tubes, mechanical ventilators and electronic cardiac monitors were frequently not available (median rating less than 2) at regional hospitals.

As in district hospitals, blood electrolyte test capacity, small-volume lab sampling, portable X-ray and FAST scan were not often available (median rating less than 2).

Tertiary hospitals

Median availability rating for most pediatric resuscitation items was 3. However, basic airway equipment, cervical collars, blood pressure cuffs, blood transfusion capacity and electronic cardiac monitoring were not dependably available (median rating less than 3).

Small-volume lab sampling was only available at one tertiary hospital. Similarly, only one hospital was able to perform portable X-ray consistently.

Pediatric vs adult item availability

Nasogastric tubes and peripheral IV catheters were consistently supplied in all sizes and at all levels of care. Placement of any size chest tube was seldom available at the district and regional level (median rating 0), though dependable available for all sizes at tertiary hospitals (median rating 3) Pediatric cervical collars were rarely available at any level (median rating 0 – 1).

There was a discrepancy between availability of pediatric sizes and adult sizes for several items: airway equipment, blood pressure cuffs and urinary catheters. These differences were not unique to a specific level of care.

Though there was weak evidence for a difference in pediatric compared to adult item availability at district or tertiary hospitals ($p=0.09$ for both); there appeared to be greater difference between the two item groups at regional hospitals ($p=0.05$).

Factors contributing to non-availability

Non-availability in both district-level and large (regional and tertiary) hospitals was predominantly related to item absence (having never been present), insufficient supply or stock-outs or lack of training. Specifically, 18% of hospitals reported stock-outs for airway equipment, blood pressure cuffs, cervical collars and nasogastric tubes and 46% reported stock-outs for urinary catheters. A number of hospitals reported never having several essential items, specifically cervical collars (72% of district-level hospitals; 73% of large hospitals) and chest tubes (79% of district-level hospitals; 64% of large hospitals). All hospitals reported that item absence and stock-outs were, in part, the result of untimely National Health Insurance Scheme (NHIS) reimbursement rates, resulting insufficient operating budgets and being denied procurement requests when purchasing on credit.

Technology item non-availability was often due to breakage: 45% of X-ray, 27% of mechanical ventilator, 21% of pulse oximetry and 18% of electronic cardiac monitoring non-availability. Blood pressure cuffs were often not available as a result of loss Velcro (14% of district-level and 18% of large hospitals).

Lack of training resulted in non-availability of chest tubes at 18% of hospitals. Lastly, prohibitively expensive user fees prevented most children from having cervical collars, X-rays or mechanical ventilator support at 10% of large hospitals.

Discussion

This study aimed to identify health systems management (i.e. procurement, supply chain management, financing, training) and product development (i.e. developing more durable medical equipment) priorities for strengthening availability of resources pediatric trauma care in Ghana and other LMICs. Hospital assessments demonstrated marked essential deficiencies and lack of pediatric-sized items resulting from equipment absence, frequent stock-outs, lack of training, and technology breakage.

There have been few other assessments of pediatric trauma or surgical capacity in LMICs. In Sierra Leone, other than airway supplies, most pediatric items were considerably more deficient than were found in Ghana (e.g. IV and urinary catheters, NG tubes); trauma-related items, such as chest tubes and cervical collars, or factors contributing to deficiencies were not assessed for comparison.[23] Similar resuscitation item deficiencies were found in Uganda.[24] Using an assessment tool adapted from the Sierra Leone assessment (PediPIPES), a survey was distributed to surgeons at 37 hospitals in 10 African countries; most of which were tertiary hospitals.[25] Skill for chest tube insertion and essential non-drug consumables were reported to be widely variable (i.e. present in 49 – 95% of facilities). Chest tubes were noted to be among the least available supplies in both the multi-national survey and in this study. Aggregate results of these studies demonstrate not only deficiencies in essential items for pediatric trauma care, but items that are inexpensive and relatively easy to ship and store. Meanwhile, the successful availability of items requiring advanced inputs (e.g. laboratory equipment for hemoglobin determination, pulse oximetry, blood banking, ultrasonography) discovered by this study suggest that procurement and stock management practices could be improved with sustained commitment to provide more reliable availability of other essential trauma care items. Moreover, laboratory equipment that was procured and maintained with vertical programming funds (e.g hemoglobin determination, blood banking) was not found to suffer from long periods of breakage, highlighting the beneficial effect of ensuring regular service and timely repairs by trained technicians on essential item availability.

Improving availability of consumables requires continual assessment of demand, regular inventory of supply and responsive feedback mechanisms to procurement agencies.[26, 27] Given the relatively recent recognition of injury as a public health dilemma in LMICs, particularly in the young population, lessons from other disease surveillance systems and established mechanisms for supply chain management of medical consumables are instructive. For instance, fifteen years of integrated community- and hospital-based surveillance of a number of communicable diseases (e.g. cholera, yellow fever, plague, meningitis) by national health systems and the WHO has led to a responsive network that adequately assesses, responds to and appropriately resources health facilities for changes in disease epidemiology; resultantly, timely care can be provided and prevention interventions accurately targeted.[28] Such mechanisms could be mirrored for injury surveillance and

medical input supply, or better, utilized in tandem to continually gather data useful for planning precise allocation of scarce resources. For assessing supply and activating restocking mechanisms before critical shortages occur, a recent mobile-health model has proven successful in East Africa. *SMS for Life*, a public-private partnership that uses text-messaging to flag low-stocks of anti-malarial drugs, was able to reduce stock-outs from 79 to 26% at health centers in rural Tanzania.[29] Given *SMS for Life* costs less than US\$ 80 per facility per year, similar systems for non-drug consumables (e.g. airway supplies, chest tubes) could be readily implemented in LMIC health systems.[26]

All hospitals were financially strained and often unable to purchase essential non-drug consumables due to untimely reimbursement rates by the NHIS. Though initially successful in improving access to care for Ghanaians and increasing hospital revenue, the NHIS has become unable to reimburse hospitals for the services rendered in a timely manner.[30, 31] Among the reasons for untimely reimbursements are: increasing reliance on a narrow tax base; caring for large informal populations; and witnessing greater than expected healthcare utilization.[30, 32, 33] In 2009, Atinga et al reported that half of hospital insurance claims were not reimbursed for 6 months, straining abilities to maintain predictable cash flow and deliver essential services.[34] During this study, most hospital administrations reported that reimbursements have been delayed 6 to 11 months. Further, Atinga et al reported that the current NHIS tariff structure does not adequately compensate hospitals for the services they provide given currency depreciation and increasing cost of many supplies; resultantly, healthcare delivery was challenging.[34] The intermittent reliance on purchasing essential supplies on credit discovered in 2009 was reported to be uniform practice during this assessment;[34] more concerning, some suppliers were no longer willing to accept procurement requests for essential trauma care items due to lack of ability to pay in cash. Given the high and increasing burden of trauma in LMICs and the significant loss of productivity resulting from injury and untimely service delivery, prioritizing financing of essential trauma care is vitally important.[1, 35-37] Studies from China and Turkey reported that productivity losses from injury resulted in tens of billions of US\$ per year.[36, 37] In LMICs where manual labor, sustenance work and high rates of family dependence on a single earner's income are common, identifying innovative ways to disrupt the perpetuating cycle of death and disability from injury and low development is imperative.[38] Not the least of these would be ensuring that hospitals are reliably resourced to provide timely essential trauma care to minimize death and disability after injury.[12, 39]

This study has several limitations that should be considered when interpreting its results. The rating scheme (0 – 3) was somewhat subjective. In an attempt to strengthen its validity, key informants from several departments that interact with the same item (i.e. X-ray – emergency room doctors, emergency room nurses, surgeons, nurse anesthetists, X-ray technicians, biomedical engineers) were asked about its availability to triangulate responses. Further, direct observation of equipment and supplies was performed. One regional and one tertiary hospital in a highly populated area declined participation. Their resource availability may be more or less than other facilities within the same healthcare level. The study did not systematically ensure that every pediatric size of each item was available. However, survey teams did ensure that a sufficient variety was present to care for

children of all ages, from neonates to adolescents. Attempts were made to understand the root causes of deficiencies; however, there were many externalities (i.e. beyond the hospital level) that we were unable to examine. Despite aforementioned limitations, these results provide a more useful assessment of pediatric trauma care capacity than previously reported from any LMIC. They allow reasonable conclusions to be drawn about ways to improve the reliability of trauma care items and services in Ghana. In addition, since several other LMICs have reported similar deficiencies, this study provides useful methods and instructive lessons for other healthcare systems that are attempting to understand and improve pediatric trauma care capacity.

Conclusion

This study identified several successes and problems with the availability of pediatric trauma care item availability in Ghana. Item availability could be improved, both affordably and reliably, by better organization and planning, such as: regular assessment of demand using established disease surveillance mechanisms; real-time bed-side inventory and feedback to procurement agencies to avoid stock-outs; and garnering political will to make provision of essential trauma care a healthcare financing priority in the setting of strained NHIS reimbursement. In addition, technology items were often broken. Developing local service and technical support capability was highlighted as a priority to avoid long periods of equipment breakage leading to essential item non-availability.

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Table 1
Availability ratings of pediatric resuscitation items and services at hospitals in Ghana

	Median item availability rating (range)					
	District-level		Regional		Tertiary	
Number assessed	29		8		3	
Airway						
Basic equipment *	2	(0-2)	1	(0-2)	1.5	(1-2)
Advanced equipment *	2	(0-2)	0.5	(0-2)	3	
Nasogastric tube *	3	(0-3)	3	(0-3)	3	(2-3)
Cervical collar *	0	(0-3)	0	(0-1)	1	(0-1)
Breathing						
Oxygen supply	3	(1-3)	3	(2-3)	3	(2-3)
Chest tubes and water seal *	0	(0-2)	0	(0-2)	3	
Pulse oximetry	3	(0-3)	2	(2-3)	3	
Mechanical ventilator	2	(0-2)	1	(0-3)	3	(1-3)
Circulation						
Blood pressure cuff *	1	(0-3)	2.5	(0-3)	1	(0-3)
Peripheral IV catheter *	3	(1-3)	3	(2-3)	3	
Blood transfusion ability	2	(1-3)	2	(1-3)	2	(2-3)
Electronic cardiac monitoring	0	(0-2)	1	(0-2)	2	(1-2)
Urinary catheter *	2	(0-3)	2.5	(0-3)	2	(1-3)
Laboratory						
Hemoglobin	3	(1-3)	3	(2-3)	3	
Electrolytes	0	(0-3)	1	(0-2)	2	(0-2)
Small-volume sampling *	0	(0-3)	0	(0-1)	0	(0-3)
Imaging						
X-rays	2	(0-3)	2	(0-3)	2	(2-3)
Portable X-rays	0	(0-3)	0	(0-1)	1	(0-3)
FAST scan	0	(0-3)	0	(0-2)	3	(0-3)

IV – intravenous; FAST - focused assessment with sonography for trauma

* pediatric sizes

Table 2
Pediatric and adult trauma resuscitation item availability in Ghana

Item	Median item availability rating					
	District-level		Regional		Tertiary	
	Pediatric	Adult	Pediatric	Adult	Pediatric	Adult
Basic airway equipment	2	2	1	2	1.5	2
Advanced airway equipment	2	3	0.5	3	3	3
Nasogastric tube	3	3	3	3	3	3
Cervical collar	0	0	0	0	1	1
Chest tubes and water seal	0	0	0	0	3	3
Blood pressure cuff	1	3	3	3	1	3
Peripheral IV catheter	3	3	3	3	3	3
Urinary catheter	2	3	2.5	3	2	3
Comparison						
Assessment median	2	3	2.5	3	1	3
<i>p</i> -value*	0.09		0.05		0.09	

IV – intravenous; *p*-value for difference between pediatric and adult item availability at each hospital level using Wilcoxon signed-rank test

Table 3
Contributing factors for pediatric trauma care item non-availability at hospitals in Ghana

	Equipment absence	Broken	Personnel shortage	Lack of training	Lack of reagents	Stock-out, insufficient quantity	User fees necessary
District and mission hospitals							
Basic airway equipment *						21	
Advanced airway equipment *	10			4		45	
Nasogastric tube *	7					10	
Cervical collar *	72					28	
Chest tube and underwater seal *	79			17		4	
Blood pressure cuff*	24	14				24	
Peripheral IV catheter *						7	
Urinary catheter *	24					28	
Small-volume lab sampling *	79		10	4		4	
Pulse oximetry	7	21				24	
X-ray	24	45	14	4		10	
Regional and tertiary hospitals							
Basic airway equipment *						28	
Advanced airway equipment *						28	
Nasogastric tube *						18	
Cervical collar *	73					18	9
Chest tube and underwater seal *	64			18		9	
Blood pressure cuff*	27	18				18	
Peripheral IV catheter *						9	
Urinary catheter *	9					46	
Small-volume lab sampling *	82		9				
Pulse oximetry		27				36	
X-ray	9	46	27			9	9
Mechanical ventilator	18	27				27	9
Electronic cardiac monitoring	27	18				55	

IV – intravenous

* pediatric-specific items; Contributing factors were not considered mutually exclusive except when items had never been present at a facility. Therefore, some totals sum to more than 100%.