

# The costs of delivering emergency care at Regional Referral Hospitals in Uganda: A micro-costing study

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## Research article

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# Abstract

## BACKGROUND

Uganda experiences a high morbidity and mortality burden due to conditions amenable to emergency care, yet few public hospitals have dedicated emergency units. As a result, little is known about the costs and effects of delivering lifesaving emergency care, hindering health systems planning, budgeting and prioritization exercises. To determine healthcare costs of emergency care services at public facilities in Uganda, we estimate the median cost of care for five sentinel conditions and 13 interventions.

## METHODS

A direct, activity-based costing was carried out at five regional referral hospitals over a four-week period from September to October 2019. Hospital costs were determined using bottom-up micro-costing methodology from a provider perspective. Resource use was enumerated via observation and unit costs were derived from National Medical Stores lists. Cost per condition per patient and measures of central tendency for conditions and interventions were calculated. Kruskal-Wallis H-tests and Nemenyi post-hoc tests were conducted to determine significant differences between costs of the conditions.

## RESULTS

872 patient cases were captured with an overall median cost of care of \$15.17 USD (\$14.08 to \$18.85). The median cost per condition was highest for post-partum haemorrhage at \$16.87 (\$14.66 to \$20.99), followed by road traffic injuries at \$15.59 (\$14.15 to \$19.93), asthma at \$15.53 (\$14.39 to \$18.87), pneumonia at \$15.18 (\$14.28 to \$19.72), and paediatric diarrhoea at \$14.25 (\$13.38 to \$15.20). The median cost per intervention was highest for fracture reduction and splinting at \$27.41 (\$21.63 to \$31.14). Cost values differ between sentinel conditions ( $p < 0.05$ ) with treatments for paediatric diarrhoea having the lowest median cost of all conditions ( $p < 0.05$ ).

## CONCLUSION

This study is the first to describe the direct costs of emergency care in hospitals in Uganda by observing the delivery of clinical services, using robust activity-based costing and time motion methodology. We find that emergency care interventions for key drivers of morbidity and mortality can be delivered at considerably lower costs than many priority health interventions. Further research assessing acute care delivery would be useful in planning wider health care delivery systems development.

## Background

Emergency care (EC) encompasses a range of interventions delivered soon after the onset of acute disease or injury. Due to the time-sensitive nature of successfully managing these conditions, there is strong evidence that organized EC systems effectively reduce mortality and improve patient outcomes.<sup>1-4</sup> Globally, emergency conditions contribute to over half of total deaths, the majority of which occur in low- and middle-income countries (LMICs) where formal emergency care systems are rare.<sup>5-7</sup> Emergencies occur on a daily basis regardless of whether there is an organized effort to treat them, indicating that the consequences of neglecting EC systems may be disastrous.<sup>7,8</sup> With 1,191 deaths from emergency conditions per 100,000 and 52,441 DALYs from emergency conditions per 100,000<sup>7</sup> the burden of emergency conditions in Uganda is devastating.

There is a mounting body of evidence demonstrating the impact of emergency care in LMICs<sup>9,10</sup>; however, not enough is known about the cost and resources required to achieve these gains. The existing body of cost-effectiveness literature is

methodologically weak, often failing to use empirically derived local inputs, and focused on analysing single-intervention rather than the cost-effectiveness of system changes and process improvements.<sup>11</sup> Electronic medical records, digital billing systems, and dedicated emergency unit budgets available in high-income settings have supported efforts to evaluate the costs for many EC interventions in these settings.<sup>12,13</sup> However, data from high-income settings do not accurately reflect the fiscal environment more common in LMICs. Numerous additional research challenges, including: paper-based data management systems, unreliable supply chains with frequent stockouts and highly variable accounting practices, present further challenges in assessing local costs in LMIC environments to provide context-relevant guidance.<sup>14</sup> Under these circumstances, capturing accurate figures requires resource and time intensive methods such as direct observation via time-motion methodology – a likely reason for the paucity of published data surrounding performance and capability of delivering of EC in LMICs.<sup>15</sup>

Nevertheless, it is problematic to pledge resources to strengthen EC delivery systems without first understanding the cost. For this reason, knowing the true outlay of EC is essential to understanding the affordability or sustainability of scaling up services given already strained health care budgets in many LMICs. Hospital managers and decision makers require this information to engage in evidence-based decision making while setting priorities and improving efficiencies. While efforts have been made to quantify the pattern of resource use and procedure utilization in functional emergency units in Uganda, the actual cost of delivering these services in this setting remains unclear.<sup>16</sup>

In this study, we describe methods for performing an accurate costing of the provision of EC from a health care provider perspective at the facility level, illustrated through costing research performed at public facilities in Uganda. This study addresses some of the critical gaps in the economic evidence for EC in LMICs and accompanies ongoing research assessing the effectiveness of the World Health Organization (WHO) Emergency Care Toolkit in Uganda, whose methods are previously described.<sup>17</sup> To offer insights into the cost of implementing EC in an LMIC, a bottom-up micro-costing methodology is used to classify all relevant cost components of EC to the most exhaustive level by gathering detailed information on the quantity of resources used and their value at a patient-specific level. Precise cost estimates, which reflect the realities of resource use as it occurs in facility-based delivery of EC in a low-resource setting, are presented. These estimates may be used to demonstrate cost-effectiveness of EC interventions in future evidence-based decision making in resource scarce contexts.

## Methods

A direct, activity-based costing was carried out over a four-week period from September 2019 to October 2019. The cost analysis was conducted from the healthcare provider perspective following published methods guidelines on costing approaches performed in LMICs.<sup>18,19</sup> All costs were collected in 2017 Ugandan shillings, and later adjusted and reported in 2017 US Dollars using the annual average exchange rate (1 dollar = 3700 shillings).<sup>20</sup> Ethics approvals were obtained from the institutional review board at University of Cape Town and University of Makerere, and site approval was provided by the Uganda Ministry of Health (MoH) (Reference: 549/2019 & 2019-013).

### Setting

Data were collected by convenience sampling at five regional referral hospital sites (RRHs), which are tertiary level centres that offer both general and specialist clinical services and partake in teaching and research. The following criteria were used for site inclusion to the study: a public RRH, with an emergency/casualty/A&E unit, which had not received any of the

elements of the WHO EC Toolkit. Any sites which had received previous elements of the WHO toolkit were excluded from the study. All sites are funded by the Ugandan government and deliver most services free of user charges. The five sites are geographically diverse and serve various catchment sizes. In particular, Mbale RRH and Jinja RRH receive high numbers of mass casualties from road traffic accidents due to proximity of the nearby highway. There are currently no national guidelines for the layout of emergency units.<sup>14</sup> Consequently, each site demonstrated unique features to their physical space, staffing, equipment and supplies. A brief overview of key characteristics of each of the five sites, observed during site visits is provided in the **Table 1**.

**Table 1: Key characteristics of study sites**

	Jinja	Mbale	Gulu	Hoima	Kabale
<b>Distance from Kampala (km)</b>	80km E	224km E	333km N	200km W	426km SW
<b>Population served</b>	3.5 million	2 million	2 million	Over 3 million	2 million
<b>Region</b>	Eastern central region	Mid-eastern region	Mid-northern region	Mid-western region	Kigezi region
<b>Districts served</b>	Bugiri, Buyende, Iganga, Jinja, Kaliro, Kamuli, Kayunga, Luuka, Mayuge, Namutumba, Namayingo	Busia, Budaka, Bududa, Kibuku, Kapchorwa, Kween Bukwo, Butalega, Manafwa, Mbale, Pallisa, Sironko, Tororo	Amuru, Gulu, Kitgum, Lamwo, Pader, Nwyoa, Oyam	Hoima, Kibale, Masindi, Bulisa, Kiryandongo, Kyankwanzi, Kiboga, and Easter part of DRC	Kabale, Kisoro, Rukungiri, Kanungu and some parts of Ntungamo (as well as ppl from neighboring Rwanda and DRC)
<b>Estimated annual number of visits to EU<sup>1</sup></b>	10,788 Inpatient	9,156 Inpatient 9,540 Outpatient	4,452 Inpatient 8,172 Outpatient	2,952 Inpatient	2,076 Inpatient 3,240 Outpatient
<b>No. of beds in hospital<sup>2</sup></b>	500	302	335	300	280
<b>No. of staff in EU department over 24 hr period<sup>3</sup></b>	8 Nurses 2 Doctors	7 Nurses 3 Interns 4 Clinical Officers 1 Medical Officer	3 Nurses 2 interns 1 Medical Officer	6 Nurses	5 Nurses *Medical Officer as needed from Inpatient Ward

<sup>1</sup> Estimation taken from extrapolation of monthly registers from July 2019 site visits.

<sup>2</sup> <https://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/PNSD/2010MOHStatAbst.pdf> and <https://health.go.ug/affiliated-institutions/hospitals>

<sup>3</sup> Figures provided by EU staff during site visits in July 2019

### ***Specifying the production process***

In alignment with ongoing monitoring and evaluation by WHO and MoH, five sentinel conditions were selected by an expert panel as representative of conditions highly amenable to timely and appropriate EC.<sup>21,22</sup> Conditions were process mapped to identify equipment and supplies involved in the current practice of care. For each condition, a range of likeliest treatment pathways were first identified using procedures outlined in the AFEM 2nd edition Handbook<sup>23</sup> and later validated in discussions with global emergency care experts, Ugandan health care providers, and during visits to the hospital sites. This process resulted in the identification of 13 crucial interventions in the delivery of care for the five sentinel conditions. A table of these treatments processes can be found in the supplementary materials. Our expert panel identified a list of single use supplies (such as sundries and consumables), reusable supplies (such as medical equipment and devices), medication received, labour and diagnostic tests required for each intervention. Our approach in costing for care was to define the

incremental cost associated with implementing EC described in the WHO EC Toolkit at existing hospitals. These hospitals were assumed to include some infrastructure capacities, such as building and utilities, which were not considered in our costs.

The sample population for the study was comprised of patients receiving unscheduled care for the treatment of five sentinel conditions; post-partum haemorrhage (PPH), road traffic incident (RTI), asthma, pneumonia, paediatric diarrhoea. Patients presenting to the unit with one of the selected conditions but whom did not receive one of the 13 identified treatments were excluded from the sample.

### ***Enumerating inputs for each process***

Each instance of resource utilization was counted at the individual patient level. Enumeration of inputs followed Hendricks et al guidelines, using the bottom-up micro-costing method.<sup>24</sup> Study data were collected and managed using REDCap (Research Electronic Data Capture, a secure, web-based software platform designed to support data capture for research studies, hosted at the University of Cape Town.<sup>25</sup>

All efforts were made to observe a minimum of 25 cases for each intervention, and data collectors were instructed to observe the same intervention at different points across the four-week period to ensure time-based data was representative of various providers. Data were largely collected from the emergency unit, although occasional cases of PPH and paediatric cases were captured in the Maternal and Children's wards respectively. Six Ugandan data collectors were on site, daily, to observe all eligible cases. Data collectors identified potential cases as they arrived on site and followed providers throughout the duration of the delivery of intervention. During observation, data collectors noted all supplies, medicines and medical devices used throughout the intervention, as well as the occurrence of any diagnostic tests. The number of medical supplies used in the delivery of the interventions were tallied on a daily basis. Data clerks either entered data directly to REDCap using tablets, or first captured data on paper tools which were later uploaded into the online system.

Although services at government facilities are free of charge, anecdotal evidence suggest that due to extreme resource constraints patients may be asked to purchase their own medical supplies in order to receive timely care. To capture instances of out-of-pocket payment for single use items, medications and diagnostic tests, data collectors were asked to indicate if the item was paid for by the patient, presumably from a nearby pharmacy or private hospital or clinic.

Time-motion methodology was used to capture the resource use of labour.<sup>18</sup> Labour time was defined as hands-on time of providers in the delivery of an intervention, from the moment a provider decides on a course of action in treatment to the completion of that action. Tablet and phone timers were used to capture time spent in delivering care. Only activities and tasks which could be observed by the data clerk were captured, including diagnosis, stabilization and treatment of patients. In addition, data collectors captured the cadre of providers and number of each cadre present while delivering the intervention.

### ***Costs***

A series of assumptions were made in our analytical approach to costing these services. A table including details is provided in the supplementary materials **S2 Table**. Unit costs of single use supplies, medicines and diagnostic tests were obtained from the National Medical Stores (NMS) price survey report, the primary provider of medical supplies to government hospitals.<sup>26</sup> The price of any items missing from the NMS report were obtained from Joint Medical Stores (JMS) – one of the largest private medical supply providers in the country. Estimated costs for diagnostics tests were taken from the literature.<sup>27–30</sup> Labour unit costs were expressed as cost per minute, calculated by dividing each cadre's annual salary – obtained online from Ministry of Public Service salary structure for the fiscal year 2018-2019 – by the working minutes in each year (252 working days x 8 hrs per day x 60 mins per hour = 120,960).<sup>31</sup>

Reusable items, such as monitors and forceps, were distilled to a cost per each use. This was derived from the purchasing cost of each device, at an annualized value of the useful lifespan divided by the presumed usage of once per day. Certain high use items, such as stethoscopes, were assumed to be used fifteen times per day based on expert opinion of in-country physicians and amended accordingly. All costs were converted from Ugandan Shillings to US Dollars at annual exchange average rate for 2017 (1 dollar = 3700 shilling).<sup>20</sup> Resource use and unit costs attributable the interventions are listed in **Table 2 (additional materials)**.

Table 2  
Resource unit costs

Items	Unit	Cost per unit (Ugandan Shilling)	Cost per unit (USD)	Source
<b>Labour</b>				
Nursing Student (U8)	minute	22	0.01	FY 2018-19 Salary Structure <sup>30</sup>
Nurse (U5)	minute	79	0.02	FY 2018-19 Salary Structure <sup>30</sup>
Interns (U5)	minute	79	0.02	FY 2018-19 Salary Structure <sup>30</sup>
Medical Officer (U4- Med 1)	minute	292	0.08	FY 2018-19 Salary Structure <sup>30</sup>
Clinical Officer (U4- Med 2)	minute	93	0.03	FY 2018-19 Salary Structure <sup>30</sup>
<b>Single use supplies</b>				
Adhesive tape	roll	39183	10.59	Joint Medical Stores
Endotracheal tube 3MM	each	1300	0.35	National Medical Stores <sup>25</sup>
Alcohol swabs	each	113.53	0.03	Estimate
Antiseptic solution (iodine)	200 ml	3240	0.88	National Medical Stores <sup>25</sup>
Nebulizer mask	each	38394	10.38	Joint Medical Stores
Cotton roll	500 g roll	8590	2.32	National Medical Stores <sup>25</sup>
Compression bandage	each	1412	0.38	National Medical Stores <sup>25</sup>
Non sterile gloves	pair	105.53	0.03	National Medical Stores <sup>25</sup>
Sterile gloves	pair	691.1	0.19	National Medical Stores <sup>25</sup>
Gauze dressing	90 cm x 90 m	41346	11.17	National Medical Stores <sup>25</sup>
Crepe bandage 4in	roll	954	0.26	National Medical Stores <sup>25</sup>
Crepe bandage 6in	roll	1702	0.46	National Medical Stores <sup>25</sup>
Blood transfusion giving set	each	615	0.17	National Medical Stores <sup>25</sup>
IV giving set	each	502.93	0.14	National Medical Stores <sup>25</sup>

Items	Unit	Cost per unit (Ugandan Shilling)	Cost per unit (USD)	Source
Suction catheter (FG 16)	each	361	0.10	National Medical Stores <sup>25</sup>
Non adhesive dressing	90 cm x91m	36492	9.86	National Medical Stores <sup>25</sup>
Plaster of Paris 6in	roll	3559	0.96	National Medical Stores <sup>25</sup>
Plaster of Paris 8in	roll	3559	0.96	National Medical Stores <sup>25</sup>
Gauze roll	roll	783.75	0.21	National Medical Stores <sup>25</sup>
Nonbreather mask	each	12199	3.30	Joint Medical Stores
Lubricant (KY jelly)	42 g tube	3770	1.02	National Medical Stores <sup>25</sup>
NG tube size 10	each	908	0.25	National Medical Stores <sup>25</sup>
NG tube size 14	each	489	0.13	National Medical Stores <sup>25</sup>
NG tube size 16	each	454	0.12	National Medical Stores <sup>25</sup>
Average NG tube	each	617	0.17	National Medical Stores <sup>25</sup>
Tongue depressor	each	50	0.01	National Medical Stores <sup>25</sup>
Water for injection	10 ml vial	80	0.02	National Medical Stores <sup>25</sup>
Surgical blade average	each	237.81	0.06	National Medical Stores <sup>25</sup>
Average IV Cannula	each	366.29	0.10	National Medical Stores <sup>25</sup>
Average Syringe	each	232.83	0.06	National Medical Stores <sup>25</sup>
<b>Reusable supplies</b>	Useful life years			
Cervical collar	5	49.35	0.01	Joint Medical Stores
Bucket	2	12.67	0.003	Joint Medical Stores
Artery forceps	7	6.06	0.002	Joint Medical Stores
Needle holder	7	3.67	0.001	Joint Medical Stores
Laryngoscope	7	37.69	0.01	Joint Medical Stores

Items	Unit	Cost per unit (Ugandan Shilling)	Cost per unit (USD)	Source
Kidney dish	10	2.08	0.001	Joint Medical Stores
Bag valve mask	5	27.94	0.01	Joint Medical Stores
O2 cylinder	5	10.96	0.003	National Medical Stores <sup>25</sup>
Scalpels	5	0.07	0.00002	National Medical Stores <sup>25</sup>
Scissors	10	2.34	0.001	Joint Medical Stores
O2 concentrator	10	544.40	0.15	Joint Medical Stores
Thermometer	10	1.28	0.00	Joint Medical Stores
ECG	7	896.59	0.24	Joint Medical Stores
Nebulizer machine	10	125.38	0.03	Joint Medical Stores
Mechanical ventilator	7	10801.34	2.92	Joint Medical Stores
Stethoscope	5	93.70	0.03	Joint Medical Stores
Blood pressure cuff	2	89.04	0.02	Joint Medical Stores
IV infusion pump	10	502.44	0.14	Joint Medical Stores
Cardiac monitor	10	307.74	0.08	Joint Medical Stores
Glucometer	7	21.14	0.01	Joint Medical Stores
Vital signs monitor	10	307.74	0.08	Joint Medical Stores
Defibrillator	7	2749.97	0.74	Joint Medical Stores
Portable ultrasound	10	7248.35	1.96	Joint Medical Stores
Pulse Oximeter	7	1366.16	0.37	Joint Medical Stores
Suction device	10	389.61	0.11	Joint Medical Stores
<b>Medicines</b>	Unit			
Iodine	200 ml	3240	0.88	National Medical Stores <sup>25</sup>
Misoprostol	200mcg	360.08	0.10	National Medical Stores <sup>25</sup>
Oxytocin	10 IU	194.05	0.05	National Medical Stores <sup>25</sup>
Tranexamic acid	500 mg	3600	0.97	Joint Medical Stores
Diazepam	5 mg tab	4.5	0.00	National Medical Stores <sup>25</sup>
Hydrocortisone	100 mg	1224.32	0.33	National Medical Stores <sup>25</sup>

Items	Unit	Cost per unit (Ugandan Shilling)	Cost per unit (USD)	Source
Salbutamol	2.5 ml vial	2559.8	0.69	National Medical Stores <sup>25</sup>
Aminophylline	250 mg/10 ml	700	0.19	National Medical Stores <sup>25</sup>
Atropine	1 mg/1 ml	126.62	0.03	National Medical Stores <sup>25</sup>
Diazepam Injection	10 mg/2 ml	296.16	0.08	National Medical Stores <sup>25</sup>
Diclofenac Tab	tab	9.58	0.00	National Medical Stores <sup>25</sup>
Diclofenac injection	75 mg/3 ml	117.72	0.03	National Medical Stores <sup>25</sup>
Bupivacaine	4 ml amp	5940	1.61	National Medical Stores <sup>25</sup>
Trap	325mcg tab	323.78	0.09	Joint Medical Stores
Zinc sulphite tablet	20 mg tablet	31.2	0.01	National Medical Stores <sup>25</sup>
Lidocaine injection	5 ml	2318	0.63	National Medical Stores <sup>25</sup>
Lignocaine injection	20 ml	3536	0.96	National Medical Stores <sup>25</sup>
Misoprostol tablet	200mcg	255.54	0.07	National Medical Stores <sup>25</sup>
Paracetamol tablets	500 mg tab	11.5	0.00	National Medical Stores <sup>25</sup>
Paracetamol syrup	125 mg	1363	0.37	National Medical Stores <sup>25</sup>
Paracetamol vial	100 ml	7233	1.95	Joint Medical Stores
Paracetamol suppository	125 mg	960	0.26	National Medical Stores <sup>25</sup>
Tramadol ampoule	100 mg/2 ml	897.8	0.24	National Medical Stores <sup>25</sup>
Tolfree	100mcg tab	348	0.09	Joint Medical Stores
Pethidine	100 mg/2 ml	2257.8	0.61	National Medical Stores <sup>25</sup>
Ampiclox tab	250 mg	95	0.03	National Medical Stores <sup>25</sup>
Ampiclox IV	250 mg	634.43	0.17	National Medical Stores <sup>25</sup>

Items	Unit	Cost per unit (Ugandan Shilling)	Cost per unit (USD)	Source
Ampicillin	500 mg	376.12	0.10	National Medical Stores <sup>25</sup>
Aminophylline IV	250 mg/10 ml	700	0.19	Joint Medical Stores
Amoxicillin tab	tab	78	0.02	Joint Medical Stores
Amoxicillin syrup	100 ml	3765	1.02	National Medical Stores <sup>25</sup>
Ascoril Syrup	100 ml	5033	1.36	National Medical Stores <sup>25</sup>
Azithromycin tab	500 mg	614.67	0.17	National Medical Stores <sup>25</sup>
Cloxacillin IV	500 mg	396.88	0.11	National Medical Stores <sup>25</sup>
Cefotaxime	1 g	11971	3.24	National Medical Stores <sup>25</sup>
Ceftriaxone	1 g	973	0.26	National Medical Stores <sup>25</sup>
Cefixime tabs	200 mg	1576	0.43	Joint Medical Stores
Cefixime syrup	50 mg/5 ml	1200	0.32	Joint Medical Stores
Ciprofloxacin tab	500 mg	84.79	0.02	National Medical Stores <sup>25</sup>
Folic Acid pill	5 mg	500	0.14	National Medical Stores <sup>25</sup>
Gentamycin	80 mg/2 ml	127.44	0.03	National Medical Stores <sup>25</sup>
Hydrocortisone	100 mg	1224.32	0.33	National Medical Stores <sup>25</sup>
Ibuprofen Syrup		1257	0.34	National Medical Stores <sup>25</sup>
Metronidazole tab	200 mg	13.5	0.00	National Medical Stores <sup>25</sup>
Metronidazole IV	500 mg/100 ml	794	0.21	National Medical Stores <sup>25</sup>
Metronidazole Suspension	100 mg	1322	0.36	National Medical Stores <sup>25</sup>
Penicillin	600 mg	270	0.07	National Medical Stores <sup>25</sup>
Phenobarbiton	30 mg tab	32.22	0.01	Joint Medical Stores

Items	Unit	Cost per unit (Ugandan Shilling)	Cost per unit (USD)	Source
D5	250 ml	137.5	0.04	National Medical Stores <sup>25</sup>
D10	250 ml	1200	0.32	Joint Medical Stores
D50	100 ml	1397	0.38	National Medical Stores <sup>25</sup>
Dextrose	5% 500 ml	1375	0.37	National Medical Stores <sup>25</sup>
Fenobabitone (Phenobarbital)	200 mg/2 ml	12100	3.27	National Medical Stores <sup>25</sup>
Manitol	100 ml	2800	0.76	National Medical Stores <sup>25</sup>
Normal saline	250 ml	1100	0.30	National Medical Stores <sup>25</sup>
Ringers Lactate	250 ml	1000	0.27	National Medical Stores <sup>25</sup>
Tranexamic acid	500 mg inj	3600	0.97	Joint Medical Stores
<b>Diagnostic tests</b>				
Complete Blood Count		14763	3.99	Amukele et al. <sup>26</sup>
Malaria test		6253	1.69	Schroeder et al. <sup>27</sup>
Stool		8880	2.40	Schroeder et al. <sup>27</sup>
Urine sample		9657	2.61	Schroeder et al. <sup>27</sup>
Sputum		7770	2.10	Whitelaw et al. <sup>28</sup>
Gene Xpert		77700	21.00	Hsiang et al. <sup>29</sup>
Cross matching		9324	2.52	Schroeder et al. <sup>27</sup>
Typhoid test		12543	3.39	Schroeder et al. <sup>27</sup>
Ultrasound		15000	4.05	Expert estimation
X-ray		10000	2.70	Expert estimation
CT Scan		200000	54.05	Expert estimation

The following items were included in calculating the total direct costs; personnel time, equipment/reusable supplies, single use supplies, diagnostic tests and medications (Supplementary materials). Costs were calculated at patient level by multiplying the frequency of use for each item used by the unit price, and time spent conducting the intervention by staff multiplied by labour costs per minute, to determine the total cost. Data was analysed for measures of central tendency for each condition and each intervention using Microsoft Excel (Microsoft Redmond, WA), and STATA 13 software (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP). A Kruskal-Wallis H test was conducted to

determine if total cost was different for the sentinel conditions. A post-hoc Nemenyi test was performed to make pairwise comparisons between the conditions.

## Results

872 cases across the five sites were captured for this study. The distribution of the cases by condition and intervention, as well as the median costs of treatment, are summarised in **Table 3**. RTI is the most common presentation observed across hospital sites accounting for over 42% of all cases captured. Delivery of IV fluids was the most commonly observed intervention (20.41%), followed by delivery of antibiotics (18.35%), analgesia (11%) and oral rehydration (10.4%). The overall median (IQR) cost of care across all conditions is \$15.18 (14.10 to 18.92). The median (IQR) cost per condition was highest for PPH at \$17.01(14.66 to 21.01), followed by \$15.64(14.15 to 19.95) for RTI, \$15.54(14.39 to 19.09) for asthma, \$15.20(14.30 to 19.93) for pneumonia, and \$14.25(13.38 to 15.22) for paediatric diarrhoea. Cost of care for a patient with RTI varied the most significantly, with a mean(SD) of \$21.24(25.15) and median(IQR) \$15.64(14.15 to 19.95) as compared to paediatric diarrhoea which varies the least, with mean(SD) \$15.40(3.50) and median(IQR) \$14.25(13.38 to 15.22). The median cost per intervention was highest for fracture reduction & splinting (\$27.16), wound closure (\$18.59) and haemorrhage control (\$17.71). Cost of care per case for these interventions varied the most significantly, fracture reduction and splinting with a mean(SD) of \$37.49(56.49) and median(IQR) \$27.16(21.64 to 31.14) as compared to paediatric diarrhoea which varies the least, with mean(SD) \$15.40(3.50) and median(IQR) \$14.25(13.38 to 15.22). A Kruskal-Wallis test yielded statistically significant difference in cost values between sentinel conditions  $H=94.89$ ,  $p=1.20E-19$ . At a  $P$  value of  $< .05$ , the post-hoc Nemenyi test revealed paediatric diarrhoea has a statistically significant lower median cost compared to all other conditions but did not yield any significant differences in median cost between the remaining four sentinel conditions (**Table 4**).

**TABLE 3: Cost of care per sentinel condition and intervention in 2017 US Dollars**

						Kruskal Wallis H
	n	Median (IQR)	Mean (SD)	Min	Max	
<b>TOTALS</b>	<b>872</b>	<b>15.18 (14.10-18.92)</b>	<b>18.73 (16.99)</b>	<b>13.30</b>	<b>412.73</b>	
<i>Cost in USD by sentinel condition</i>						
RTI	371	15.64 (14.15-19.95)	21.24 (25.15)	13.34	412.73	H =94.89
PPH	59	17.01 (14.66-21.01)	19.66 (9.13)	13.39	73.63	$p < .0001$
Asthma	66	15.54 (14.39-19.09)	17.18 (3.71)	13.34	27.64	n= 872
Pneumonia	186	15.20 (14.30-19.93)	15.20 (4.41)	13.30	37.90	
Paediatric diarrhoea	190	14.25 (13.38-15.22)	15.40 (3.50)	13.30	29.91	
<i>Cost in USD by intervention</i>						
Wound closure	69	18.57 (16.27-21.43)	20.39 (8.52)	13.82	73.21	
Fracture reduction & splinting	55	27.41 (21.64-31.14)	37.89 (56.93)	14.07	412.73	
Haemorrhage Control	56	17.71 (16.73-22.62)	25.21 (19.50)	13.58	83.68	
IV fluids	178	15.43 (14.69-17.52)	18.09 (8.56)	13.60	83.53	
Oral Rehydration	91	13.38 (13.34-13.47)	13.77 (1.44)	13.30	23.35	
Antibiotics	160	15.11 (14.40-17.72)	16.59 (3.52)	13.53	37.90	
Oxygen	80	14.32 (13.62-19.77)	16.68 (4.04)	13.34	29.30	
Nebulisation	39	15.49 (14.79-18.36)	17.03 (3.53)	13.62	27.64	
Analgesia	96	13.88 (3.60-14.16)	14.37 (2.60)	13.30	37.53	
Transfusion/blood given	33	15.19 (14.32-18.15)	17.71 (9.75)	13.65	70.84	
Oral or Nasal Pharyngeal Airway*	2	16.37 (16.33-16.41)	16.37 (0.12)	16.29	16.45	
Needle decompression*	6	15.40 (15.24-15.65)	15.50 (0.51)	14.90	16.38	
Intubation*	7	29.06 (17.10-35.64)	26.80 (10.25)	14.90	38.18	

\*Small sample size

**TABLE 4: Correlation results matrix of Nemenyi test of sentinel conditions**

	RTI	PPH	Asthma	Pneumonia	Paediatric diarrhoea
		<i>q-stat</i> = 2.410	<i>q-stat</i> = 0.242	<i>q-stat</i> = 1.891	<i>q-stat</i> = 12.491
RTI	-	<i>p</i> = 0.432	<i>p</i> = 0.999	<i>p</i> = 0.668	<i>p</i> < 0.001*
			<i>q-stat</i> = 2.066	<i>q-stat</i> = 3.399	<i>q-stat</i> = 9.744
PPH		-	<i>p</i> = 0.588	<i>p</i> = 0.116	<i>p</i> < 0.001*
				<i>q-stat</i> = .960	<i>q-stat</i> = 7.573
Asthma			-	<i>p</i> = 0.9609	<i>p</i> < 0.001*
					<i>q-stat</i> = 9.157
Pneumonia				-	<i>p</i> < 0.001*
Paediatric diarrhoea					-

\*significant at the 0.05 level, *q-crit* 3.875

Single use supplies contributed considerably to the total cost of care (67%), followed by reusable supplies (16%) and diagnostic tests (8%). Medications (5%) and labour (4%) were the least significant drivers of cost (Table 5). This similar distribution pattern held true across most conditions and interventions with the exception of haemorrhage control, where labour costs contributed to 22% of total costs.

**TABLE 5: Components of direct cost of care per sentinel condition and intervention**

	Single Use Supplies	Reusable Supplies	Medications	Labour	Diagnostics
<b>TOTALS</b>	<b>67%</b>	<b>16%</b>	<b>5%</b>	<b>4%</b>	<b>8%</b>
<b>Proportion of total cost by sentinel condition</b>					
RTI	69%	14%	5%	4%	8%
PPH	64%	15%	8%	7%	6%
Asthma	62%	18%	6%	6%	8%
Pneumonia	64%	18%	3%	4%	11%
Paediatric diarrhoea	70%	19%	3%	3%	4%
<b>Proportion of total cost by intervention</b>					
Wound closure	69%	15%	3%	7%	6%
Fracture reduction & splinting	76%	8%	7%	5%	3%
Haemorrhage Control	57%	12%	5%	4%	22%
IV fluids	62%	17%	9%	4%	8%
Oral Rehydration	76%	21%	0%	1%	2%
Antibiotics	68%	18%	2%	3%	8%
Oxygen	64%	19%	1%	6%	10%
Nebulisation	62%	18%	9%	5%	6%
Analgesia	75%	21%	3%	1%	1%
Transfusion/blood given	63%	17%	0%	5%	15%
Oral or Nasal Pharyngeal Airway*	64%	18%	0%	17%	0%
Needle decompression*	70%	19%	0%	11%	0%
Intubation*	55%	12%	1%	22%	10%

<sup>1</sup> Single use supplies includes all supplies and equipment which are discarded after one use such as gauze.

<sup>2</sup> Reusable supplies include all supplies and equipment which are used more than once such as stethoscopes, monitors and kidney dishes.

<sup>3</sup> Medications includes all drugs used in treatment.

<sup>4</sup> Labour includes all observed time of care delivered by health care workers.

<sup>5</sup> Diagnostics include all tests and procedures used in identification and treatment such as, radiology and labs.

\*Small sample size, therefore results unreliable at intervention level.

Median labour time and proportional time of care by cadres is presented in Table 6. Providers spent the most time in care for patients with asthma 24.5 minutes (10 to 69) and PPH at 23 minutes (9 to 46), and the least time on interventions with patients with paediatric diarrhoea at 8 minutes (3 to 25). Labour time was highest for the intervention of fracture reduction & splinting at 42.5 minutes (21.75 to 64.25) and wound closure at 39.5 minutes (25 to 64). RTI care had a higher proportion of medical specialist time than any other condition (12%). Care for paediatric diarrhoea was almost exclusively delivered

by nurses (90%). 64% of labour was provided was provided by nurses or nursing student, which is in alignment with the literature regarding delivery of care in sub-Saharan Africa.<sup>32</sup>

**Table 6: Median time spent by providers and distribution by cadre**

	Time Median (IQR) in minutes	Proportion of total time specialist care <sup>1</sup>	Proportion of total time nurse care <sup>2</sup>	Proportion of total time medical care <sup>3</sup>
<b>TOTALS</b>	<b>15 (5- 45)</b>	<b>2%</b>	<b>64%</b>	<b>30%</b>
<b>By condition</b>				
RTI	18 (7-42)	12%	53%	35%
PPH	23 (9-46)	0%	56%	43%
Asthma	24.5 (10-69)	0%	61%	38%
Pneumonia	15 (5-70)	1%	72%	26%
Paediatric diarrhoea	8 (3-25)	0%	90%	9%
<b>By intervention</b>				
Would closure	39.5 (25-64)	2%	48%	39%
Fracture reduction & splinting	42.5 (21.75-64.25)	12%	49%	23%
Haemorrhage Control	22.5 (9.5-58.5)	0%	54%	41%
IV fluids	20 (10.25-43.5)	1%	80%	18%
Oral Rehydration	3 (2-5)	0%	92%	7%
Antibiotics	14 (8-38)	0%	85%	14%
Oxygen	15 (4-73.25)	0%	52%	45%
Nebulisation	25 (11-63)	0%	64%	36%
Intubation*	128 (68.5-295)	0%	46%	52%
Analgesia	5 (1-9.25)	4%	82%	13%
Transfusion/blood given	25 (8-45)	0%	57%	41%
Oral or Nasal Pharyngeal Airway*	83 (80-86)	0%	0%	92%
Needle decompression*	22 (16.25-25.5)	0%	0%	89%

<sup>1</sup> Specialist care includes all specialists including: surgical, paediatric, obstetrics, internal medicine and other

<sup>2</sup> Nurse care includes nursing students and nurses

<sup>3</sup> Medical care includes interns, medical officers and clinical officers

\*Small sample size, therefore results unreliable at intervention level.

Most supplies, medications and screening tests were provided by the hospital (94%). Only 6% of the 5490 items captured were paid for by patients. Over 50% of all screening tests (Ultrasound, X-ray, CT Scan) were paid for by patients as presented in **Table 7**.

**TABLE 7: Proportion of out-of-pocket payment by patients for screening tests**

	Ultrasound	X-ray	CT Scan	Other*
<b>TOTALS (N)</b>	<b>1</b>	<b>79</b>	<b>9</b>	<b>123</b>
Hospital provided (n)	0	39	0	89
Out of pocket by patient (n)	1	40	9	34
% out of pocket by patient	100%	51%	100%	28%

\*Other includes complete blood counts, urine, stool and sputum tests.

## Discussion

This study is the first to describe the direct costs of EC in hospitals in Uganda by observing the delivery of clinical services, using robust activity-based costing and time motion methodology. The costs for EC interventions are found to be considerably lower than other health programmes in the Ugandan setting such as tuberculosis treatment (\$151), HIV anti-

retroviral therapy (\$628) and obstetric fistula repair (\$378).<sup>33-35</sup> Emergency care could be highly impactful in Uganda, where injuries from trauma and road traffic incidents are a leading cause of death<sup>36</sup>, accounting for 7% of all mortality in public health facilities in 2017 to 2018.<sup>37</sup>

Our methodology attempted to capture all relevant costs for implementing WHO recommended care delivery in the emergency care setting. Our analysis finds that single use supplies, as opposed to multiuse supplies, are the most important cost drivers to the total cost of EC. Reusable resources which have a cost of use and are broadly less sensitive to variations in patient load, such as reusable medical equipment and labour, contributed significantly less to the total cost. This finding implies that marginal costs contribute sizeably to the total cost of EC care; as such, economies of scale – where unit cost decreases as the volume of output increases – may not be as significant to EC care interventions as previously suggested.<sup>38</sup> This finding aligns with current evidence of the higher than expected marginal costs of outpatient EC in HIC.<sup>12</sup>

These findings hint that a further cost saving may be realized if additional reuse of supplies is promoted where reasonable. To recommend such an approach, the impact on effectiveness of patient care, which falls outside of the scope of this work, would need to be better understood. In many ways this practice of reuse is already routine in LMIC settings where supplies such as suturing tools, disposed after a single use in HIC settings, are commonly sterilised and reused in LMICs. During our study we observed the use of cardboard boxes for splints or gloves as tourniquets, further demonstrating the extreme resourcefulness of practitioners in this setting. In the absence of EC guidelines and recommendations many hospitals have improvised walls made of tarps, and IV bags zip-tied to walls rather than hanging from drip stands. Future research should endeavour to better understand the impact which operating under resource scarcity has on the delivery of EC and how local adaptations may provide further cost-savings.

Although we suspected that patients would be responsible to pay for many supply items if unstocked, from our limited data we found little evidence of this practice and low frequencies of out-of-pocket payment made by patients. On the other hand, 100% of CT Scans and Ultrasounds and over 50% of X-Rays were paid for by patients, likely because almost no sites had CT Scanners at their facility, and many had limited x-ray machines or film. This pattern indicates particular challenges in diagnostic testing resources and access which could interrupt patient care.

Assessing the economic cost of EC is complex because of the heterogenous nature of EC conditions and their wide-ranging clinical features. Inconsistent cost data further convolutes the sparsity of information regarding EC in LMICs. In South Africa, a \$6,749 difference was observed between a top-down and bottom-up costing approach of the average healthcare cost per road traffic injury patient.<sup>39</sup> While efforts have been made to quantify the pattern of resource use and procedure utilization in functional emergency units in Uganda, the actual cost of delivering these services in this setting remains unclear.<sup>16</sup> As a result, we rather unconventionally approach the costing of EC services by presenting the cost of care for five sentinel conditions, as well as the cost per intervention conducted. We predicted finding a high variation in cost for each condition. Interestingly, our results show that the cost of delivering care is relatively stable across conditions, and only statistically lower for paediatric diarrhoea. As expected, costs of RTIs had the highest variability in cost, due to the wide range of injuries which fall under that condition; but overall RTI interventions do not have significantly higher costs than other conditions (except paediatric diarrhoea). This finding suggests that there may be a set of basic, low-cost, high impact, lifesaving approaches and interventions such as IV support or blood transfusion, which provide significant value

for money. Benefits of economies of scope—where unit cost of production decrease as variety of products increase—may still apply to extending EC services in the context of existing health systems.<sup>40</sup>

Our time-motion study found that nurses provided most of the labour for all interventions, which is supported by their representation of 80% of the healthcare workforce.<sup>41</sup> This pattern touches on the significance of the nursing workforce in the delivery of emergency care in LMICs, which may impact the planning of training and labour budgets for delivering EC, and aligns with broader discussions of task-shifting acute care to nursing cadres.<sup>42</sup>

This study illuminates some of the key challenges to pursuing a research agenda in cost-effectiveness research for EC in LMICs. Collecting rigorous data is costly and time consuming, and in contexts where care delivery may be fractured it can be challenging to identify the emergency centre's contributions to both the budget and patient survival of a hospital. As such, strengthening routine data collection systems to better understand supply use in public facilities could greatly aid future economic analyses and cost-effectiveness studies. Further research to better understand the impact creative material use and reuse may have on practice and budgets in a resource limited setting is also essential. Through these findings we can begin to understand what it means to operate EC services under resource scarcity.

#### **Limitations:**

This study has potential limitations. First, free text entry of data by non-medically trained research assistants resulted in a small amount of data (0.5%) regarding medications being lost due to misspelling, incorrect transcription or unidentified unit measurements. Second, a widespread lack of basic equipment and medicines for EC has been well categorized in Uganda<sup>14</sup> and treatment decisions and resource used in the care of patients may be influenced by this scarcity. In order to appropriately represent the context, we adopted a direct observation approach using activity-based costing and time motion methodology. As a result, while accurately reflecting the actual costs of care, our findings may underestimate the costs of ideal care that is uncompromised by persistent resource limitation. Future research could examine the impact of resource scarcity on care delivery behaviour. Similarly, the full costs of EC are likely underestimated, as indirect costs are not captured in this study due to resource limitations. Nevertheless, this study provides detailed direct cost information that can inform future research which aims to consider indirect costs such as social opportunity costs and patient and caretaker time.

Additionally, restocking at hospitals occurs on a monthly basis and may impact the supply use patterns of providers where patients at the beginning of the month receive more services, or medicines and supplies are reserved for high-risk patients. To account for these variations data were collected for a full period of a month but the impacts of inventory upon patterns of resource use fall beyond the scope of this paper and should be prioritized in future research. Certain interventions, such as intubation, oral or nasal pharyngeal airway insertion and needle decompression, are extraordinarily rare in the Ugandan setting likely due to the absence of the next step in the chain of care such as intensive care units. Therefore, these interventions are under-powered in our findings. We included these interventions in our aggregated analysis to further shed light on EC healthcare utilizations but were unable to draw any conclusions at the intervention level given the small sample size.

Despite best efforts to move towards formalized EC in Uganda, there is still much to be done to systematize the approach to EC. Staffing, equipment and physical space differ greatly between hospitals. Due to the unique, country-specific characteristics of Uganda, the data and findings here reflect site-specific practices with specific patient populations within the particulars of the public Ugandan health care system and local prices. Therefore the results of our study are not generalizable to other LMICs.

## Conclusion

This study finds that EC in Uganda is managed at considerably lower costs compared to many priority health interventions in low-resource settings. Given the prevalence of these conditions and our research findings, it is likely that allocating resources to strengthening EC may be an extremely valuable investment to the health system. The results provide evidence on the direct costs of delivering EC in LMICs, which can be further used to estimate the health care costs faced by LMICs looking to expand access to EC services. Further research assessing acute care delivery and the impact of creative material use and reuse in resource scarce settings would be useful in planning wider health care delivery systems development.

## Abbreviations

**EC** Emergency Care

**HIC** High income countries

**LMIC** Low-and middle income countries

**MoH** Ministry of Health

**PPH** Post-partum haemorrhage

**RRH** Regional Referral Hospital

**RTI** Road traffic incident

**USD** United States Dollar

**WHO** World Health Organisation

## Declarations

### Ethics approval

Ethics approvals were obtained from the institutional review board at University of Cape Town and University of Makerere, and site approval was provided by the Uganda Ministry of Health (MoH) and respective health authorities (Reference: 549/2019 & 2019-013).

## Consent for publication

Not applicable

## Availability of data and materials

The datasets used and/or analysed during the current study are available on reasonable request. The corresponding author [KW] can work with interested researchers to secure approval from the relevant authorities (Ministry of Health) to reuse the dataset for research.

### **Competing interests**

MO is a paid advisor to the Ugandan MoH. The authors declare no further conflict of interest.

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### **Authors' contributions**

KW, TL, NR and JK contributed to the concept and design of the study. MO, JK and KW supervised data collection. KW conducted the analysis, interpretation of data, and drafted the first version of the manuscript. TL, NR and LW provided a critical review of the manuscript. All authors reviewed and approved the final manuscript.

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## **References**

1. MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, et al. A National Evaluation of the Effect of Trauma-Center Care on Mortality. *NEJM*. 2006;354(4):366–7. Available from: [https://www.nejm.org/doi/full/10.1056/NEJMsa052049?url\\_ver=Z39.88-2003&rfr\\_id=ori:rid:crossref.org&rfr\\_dat=cr\\_pub 0pubmed](https://www.nejm.org/doi/full/10.1056/NEJMsa052049?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub 0pubmed)
2. Roudsari BS, Nathens AB, Arreola-Risa C, Cameron P, Civil I, Grigoriou G, et al. Emergency Medical Service (EMS) systems in developed and developing countries. *Injury*. 2007 Sep 1;38(9):1001–13.
3. Peleg K, Aharonson-Daniel L, Stein M, Kluger Y, Michaelson M, Rivkind A, et al. Increased survival among severe trauma patients: The impact of a national trauma system. *Arch Surg*. 2004 Nov 1;139(11):1231–6.
4. Nathans AB, Jurkovich GJ, Rivara FP, Maier R V. Effectiveness of State Trauma Systems in Reducing Injury-Related Mortality: A National Evaluation. *J Trauma Acute Care Surg*. 2000;48(1):25. Available from: [https://journals.lww.com/jtrauma/Fulltext/2000/01000/Effectiveness\\_of\\_State\\_Trauma\\_Systems\\_in\\_Reducing.5.aspx](https://journals.lww.com/jtrauma/Fulltext/2000/01000/Effectiveness_of_State_Trauma_Systems_in_Reducing.5.aspx)
5. Razzak J, Usmani MF, Bhutta ZA. Global, regional and national burden of emergency medical diseases using specific emergency disease indicators: analysis of the 2015 Global Burden of Disease Study. *BMJ Glob Heal*. 2019;4:733. Available from: <http://gh.bmj.com/>

6. Roth GA, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1736–88.
7. Chang CY, Abujaber S, Reynolds TA, Camargo CA, Obermeyer Z. Burden of emergency conditions and emergency care usage: new estimates from 40 countries. *Emerg Med J*. 2016 Nov;33(11):794–800. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/27334758>
8. Obermeyer Z, Abujaber S, Makar M, Stoll S, Kayden SR, Wallis LA, et al. Emergency care in 59 low- and middle-income countries: a systematic review. *Bull World Health Organ*. 2015;93(8):577-586G.
9. Razzak JA, Kellermann AL. Emergency medical care in developing countries: Is it worthwhile? *Bull World Health Organ*. 2002;80(11):900–5.
10. Reynolds TA, Stewart B, Drewett I, Salerno S, Sawe HR, Toroyan T, et al. The Impact of Trauma Care Systems in Low- and Middle-Income Countries. *Annu Rev Public Health*. 2017 Mar 20;38(1):507–32. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/28125389>
11. Werner K, Risko N, Burkholder T, Munge K, Wallis L, Reynolds T. Cost–effectiveness of emergency care interventions in low and middle-income countries: A systematic review. *Bull World Health Organ*. 2020 May 1;98(5):341–52. Available from: <http://www.who.int/bulletin/volumes/98/5/19-241158/en/>
12. Bamezai A, Melnick G, Nawathe A. The cost of an emergency department visit and its relationship to emergency department volume. *Ann Emerg Med*. 2005 May 1;45(5):483–90.
13. Stanford R, McLaughlin T, Okamoto LJ. The cost of asthma in the emergency department and hospital. *Am J Respir Crit Care Med*. 1999 Jul 14;160(1):211–5. Available from: <http://www.atsjournals.org/doi/abs/10.1164/ajrccm.160.1.9811040>
14. Ningwa A, Muni K, Oporia F, Kalanzi J, Zziwa EB, Biribawa C, et al. The State of Emergency Medical Services and Acute Health Facility Care in Uganda: Findings from a National Cross-Sectional Survey [Internet]. Research Square; 2019. Available from: <https://doi.org/10.21203/rs.2.10966/v1>
15. Wesson HKH, Boikhutso N, Bachani AM, Hofman KJ, Hyder AA. The cost of injury and trauma care in low-and middle-income countries: A review of economic evidence. *Health Policy Plan*. 2013;29(6):795–808.
16. Bitter CC, Rice B, Periyannayagam U, Dreifuss B, Hammerstedt H, Nelson SW, et al. What resources are used in emergency departments in rural sub-Saharan Africa? A retrospective analysis of patient care in a district-level hospital in Uganda. *BMJ Open*. 2018;8(2):1–7.
17. Adam H, Reynolds T, Officer SH. Improving emergency care in Uganda. *Bull World Health Organ*. 2019;97(5):314–5.
18. Frick KD. Microcosting quantity data collection methods. *Med Care*. 2009 Jul;47(7 Suppl 1):S76-81. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/19536026>
19. Cunnam L, Sinanovic E, Ramma L, Foster N, Berrie L, Stevens W, et al. Using Top-down and Bottom-up Costing Approaches in LMICs: The Case for Using Both to Assess the Incremental Costs of New Technologies at Scale. *Health Econ*. 2016 Feb;25:53–66. Available from: <http://doi.wiley.com/10.1002/hec.3295>
20. xe [Internet]. Available from: [xe.com](http://xe.com)
21. Kivelehan S, Dixon J, Kalanzi J, Sawe H, Chien E, Robert J, et al. Implementation of the WHO Basic Emergency Care Course in Tanzania and Uganda.
22. Assessing the impact of a low-cost WHO intervention package for emergency units in two hospitals in Uganda.
23. Wallis L, Checkett K, Reynolds T. *AFEM Handbook of Acute and Emergency Care*. South Africa: Oxford University Press; 2018.
24. Hendriks ME, Kundu P, Boers AC, Bolarinwa OA, Te Pas MJ, Akande TM, et al. Step-by-step guideline for disease-specific costing studies in low- and middle-income countries: a mixed methodology. *Glob Health Action*. 2014;7:23573. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/24685170>

25. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) - A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inf.* 2009;42(2):377–81.
26. NMS. 6th edition of the price survey report. 2017.
27. Amukele TK, Jones R, Elbireer A. Test Cost and Test Accuracy in Clinical Laboratories in Kampala, Uganda. *Am J Clin Pathol.* 2018 Apr 25;149(6):522–9.
28. Schroeder LF, Elbireer A, Jackson JB, Amukele TK. Laboratory diagnostics market in East Africa: A survey of test types, test availability, and test prices in Kampala, Uganda. *PLoS One.* 2015 Jul 30;10(7).
29. Whitelaw A, Peter J, Sohn H, Viljoen D, Theron G, Badri M, et al. Comparative cost and performance of light-emitting diode microscopy in HIV-tuberculosis-co-infected patients. *Eur Respir J.* 2011 Dec 1;38(6):1393–7. Available from: [/pmc/articles/PMC5454486/?report=abstract](http://pmc/articles/PMC5454486/?report=abstract)
30. Hsiang E, Little KM, Haguma P, Hanrahan CF, Katamba A, Cattamanchi A, et al. Higher cost of implementing Xpert® MTB/RIF in Ugandan peripheral settings: Implications for cost-effectiveness. *Int J Tuberc Lung Dis.* 2016 Sep 1;20(9):1212. Available from: [/pmc/articles/PMC5018405/?report=abstract](http://pmc/articles/PMC5018405/?report=abstract)
31. Ministry of Public Service. Salary Structure FY 2018/19 Schedule [Internet]. 2018. Available from: <https://publicservice.go.ug/download/salary-structure-fy-2018-2019-schedule-1-12/>
32. Ugochukwu CG, Uys LR, Karani AK, Okoronkwo IL, Diop BN. Roles of nurses in Sub-Saharan African region. *Int J Nurs Midwifery.* 2013;5(7):117–31. Available from: <http://www.academicjournals.org/IJNM>
33. Okello D, Floyd K, Adatu F, Odeke R, Gargioni G. Cost and cost-effectiveness of community-based care for tuberculosis patients in rural Uganda. *Int J Tuberc Lung Dis Off J Int Union against Tuberc Lung Dis.* 2003 Sep;7(9 Suppl 1):S72-9.
34. Jain V, Chang W, Byonanebye DM, Owaraganise A, Twinomuhwezi E, Amanyire G, et al. Estimated costs for delivery of HIV antiretroviral therapy to individuals with CD4+ T-cell counts >350 cells/uL in rural Uganda. *PLoS One.* 2015 Dec 1;10(12).
35. Epiu I, Alia G, Mukisa J, Tavrow P, Lamorde M, Kuznik A. Estimating the cost and cost-effectiveness for obstetric fistula repair in hospitals in Uganda: a low income country. *Health Policy Plan.* 2018 Sep 24;33(9):999–1008. Available from: <https://doi.org/10.1093/heapol/czy078>
36. Kimuli Balikuddembe J, Ardalan A, Khorasani-Zavareh D, Nejati Kasiima Stephen Munanura A. Road Traffic Incidents in Uganda: A Systematic Review of a Five-Year Trend. *J Inj Violence Res.* 2017;9(1):17–25.
37. Ministry of Health R of U. Annual Health Sector Performance Report Financial Year 2017/18. 2017.
38. Blank JLT, van Hulst BL, Valdmanis VG. Concentrating Emergency Rooms: Penny-Wise and Pound-Foolish? An Empirical Research on Scale Economies and Chain Economies in Emergency Rooms in Dutch Hospitals. *Heal Econ (United Kingdom).* 2017 Nov 1;26(11):1353–65. Available from: [/pmc/articles/PMC5655724/?report=abstract](http://pmc/articles/PMC5655724/?report=abstract)
39. Parkinson F, Kent SJW, Aldous C, Oosthuizen G, Clarke D. The hospital cost of road traffic accidents at a South African regional trauma centre: a micro-costing study. *Injury.* 2014 Jan 1;45(1):342–5. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/23731494>
40. Freeman M, Savva N, Scholtes S. Economies of Scale and Scope in Hospitals. 2016.
41. Ministry of Health Uganda. Departments of Ministry of Health.
42. Chamberlain S, Stolz U, Dreifuss B, Nelson SW, Hammerstedt H, Andinda J, et al. Mortality related to acute illness and injury in rural Uganda: Task shifting to improve outcomes. *PLoS One.* 2015;10(4):1–11.

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