

RESEARCH ARTICLE

Pediatric emergency care capacity in a low-resource setting: An assessment of district hospitals in Rwanda

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OPEN ACCESS

Citation: Hategeka C, Shoveller J, Tuyisenge L, Kenyon C, Cechetto DF, Lynd LD (2017) Pediatric emergency care capacity in a low-resource setting: An assessment of district hospitals in Rwanda. *PLoS ONE* 12(3): e0173233. doi:10.1371/journal.pone.0173233

Editor: Umberto Simeoni, Centre Hospitalier Universitaire Vaudois, FRANCE

Received: April 21, 2016

Accepted: February 19, 2017

Published: March 3, 2017

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Data Availability Statement: All relevant and summary data underlying the current study findings are within the paper. Nevertheless, as per ethics approval granted by the Research Ethics Board of the University of British Columbia (UBC BREB NUMBER: H1500964) and the authorization by the Rwanda Paediatric Association to use the data, the raw data must not be hosted in a public repository. Thus, access to these raw data would require further approval from both the Research Ethics Board of the University of British Columbia and the Rwanda Paediatric Association. The

Abstract

Background

Health system strengthening is crucial to improving infant and child health outcomes in low-resource countries. While the knowledge related to improving newborn and child survival has advanced remarkably over the past few decades, many healthcare systems in such settings remain unable to effectively deliver pediatric advanced life support management. With the introduction of the Emergency Triage, Assessment and Treatment *plus* Admission care (ETAT+)—a locally adapted pediatric advanced life support management program—in Rwandan district hospitals, we undertook this study to assess the extent to which these hospitals are prepared to provide this pediatric advanced life support management. The results of the study will shed light on the resources and support that are currently available to implement ETAT+, which aims to improve care for severely ill infants and children.

Methods

A cross-sectional survey was undertaken in eight district hospitals across Rwanda focusing on the availability of physical and human resources, as well as hospital services organizations to provide emergency triage, assessment and treatment plus admission care for severely ill infants and children.

Results

Many of essential resources deemed necessary for the provision of emergency care for severely ill infants and children were readily available (e.g. drugs and laboratory services). However, only 4/8 hospitals had BVM for newborns; while nebulizer and MDI were not available in 2/8 hospitals. Only 3/8 hospitals had F-75 and ReSoMal. Moreover, there was no

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Funding: DFC received a grant (CIDA—Maternal Newborn and Child Health in Rwanda, S065358) that contributed to funding the master's training for CH at the University of British Columbia. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

adequate triage system across any of the hospitals evaluated. Further, guidelines for neonatal resuscitation and management of malaria were available in 5/8 and in 7/8 hospitals, respectively; while those for child resuscitation and management of sepsis, pneumonia, dehydration and severe malnutrition were available in less than half of the hospitals evaluated.

Conclusions

Our assessment provides evidence to inform new strategies to enhance the capacity of Rwandan district hospitals to provide pediatric advanced life support management. Identifying key gaps in the health care system is required in order to facilitate the implementation and scale up of ETAT+ in Rwanda. These findings also highlight a need to establish an outreach/mentoring program, embedded within the ongoing ETAT+ program, to promote cross-hospital learning exchanges.

Introduction

Reducing mortality in children younger than five years by two-thirds in developing countries by the year 2015 was a Millennium Development Goal (MDG 4: reducing under-five mortality by two-thirds between 1990 and 2015) adopted by the international community [1]. While Rwanda achieved the MDG 4, the neonatal mortality rate and under-five mortality rate remain high, currently estimated at 20 deaths per 1000 live births and 50 deaths per 1000 live births, respectively [2]. The knowledge needed to improve newborn and child survival has advanced remarkably since the adoption of the MDGs. However, healthcare systems in many low-income countries continue to face many challenges in terms of effectively delivering recommended life-saving interventions for children younger than five years due to limited material and human resources and gaps in knowledge among healthcare professionals working within the health care system [3–6].

District hospitals—the backbone of the healthcare system—are the first-line referral sites in low-income countries like Rwanda. Thus, it is critical that these hospitals have the capacity to provide effective, efficient and high quality care to all patients including severely ill infants and children whose risk of death is greatest in the first 24 hours of admission [3, 7–9]. Accordingly, an intervention to improve emergency triage, assessment and treatment plus admission care (ETAT+) for severely ill infants and children has been implemented in Rwandan district hospitals [10]. Nevertheless, evidence-based interventions are rarely implemented with perfect fidelity under real-world conditions [10, 11]. Therefore, there is a need to understand the capacity of Rwandan district hospitals and identify resource and organizational gaps with respect to healthcare provision to severely ill infants and children in Rwanda. This information can guide further efforts, including the ETAT+ implementation, to improve survival of children younger than five years in Rwanda. Thus, the objective of this study was to assess the extent to which Rwandan district hospitals are prepared to provide care for severely ill infants and children, specifically shedding light on the resources and support systems that are available in the district hospitals in Rwanda.

Healthcare provision in Rwanda

Rwanda has one of the fastest growing populations, currently more than 11 million with a median age of 18.7 years [12]. Rwanda provides healthcare through a mainly publicly funded and operated healthcare system that includes: national referral hospitals, district hospitals, health centers, dispensaries or community health posts, and community health workers [13–15]. Community health workers (CHWs) fulfill important roles in the country's healthcare system. Generally, the first contact between patients and the formal public health system is the country's peripheral health units that consist of health centers, dispensaries or community health posts, and CHWs. People also consult private health clinics, pharmacies, and traditional healers. Peripheral health units—staffed by nurses, most of whom have completed the minimum level of nursing training available (A2 level)—provide primary package of health care and are supported by the district hospitals. The district hospitals are generally staffed by nurses mostly with A2 level training, approximately five midwives, and on average, 10 generalist physicians with basic medical training. These district hospitals provide secondary level medical care, including caring for very sick infants and children usually referred from health centers, whilst national referral hospitals provide tertiary specialist care. As of 2012, Rwanda had 41 district hospitals that serve as first-line referral hospitals, and receive all referrals from peripheral health facilities [16]. The Ministry of Health of Rwanda (MOH) sets standards, formulates policy, ensures quality assurance, and is responsible for mobilizing resources and monitoring and evaluation countrywide [14, 15].

Methods

Study design and setting

A cross-sectional survey was undertaken to assess district hospital capacity for providing emergency care for severely ill infants and children in Rwanda. The survey was conducted in 2012/2013 during the implementation of the ETAT+ program in Rwandan district hospitals [10], and was carried out in a sample of eight (~20%) district hospitals that were purposely selected out of 41 Rwandan district hospitals to ensure reasonable regional representation. Rwanda has four provinces (East, North, South and West) and the city of Kigali. At least one district hospital in each province and one in the city of Kigali was surveyed, thus resulting in reasonable regional representation. Five of the eight hospitals were located in the Kigali city or a major provincial city, while the remaining three were located in the rural areas.

Indicators and hospital survey

This assessment of district hospital capacity to provide emergency pediatric and neonatal care included indicators that were selected based on the evidence based clinical practice guidelines as outlined in the MOH adopted “Basic Pediatric Protocols 2011” and previous research in sub-Saharan Africa [17–23]. These indicators focus on the ‘structure’ domain of Donabedian's framework for measuring quality of healthcare. According to the framework, structure refers to the attributes of the setting in which the care occurs and includes material resources, human resources, and organizational structure [24].

In our assessment, the availability of key resources and hospital organization were assessed by direct observation in the specific district hospital units including the newborn unit, pediatric ward, maternity ward, emergency room, outpatient clinic, and pharmacy, with a standard checklist. These structural indicators were recorded as ‘present’ or ‘absent’ on the survey day.

Analysis

Availability of key resources was scored using dichotomous indicators (absent or present) for each structural indicator for each hospital, and are presented as frequencies (and proportions) across all district hospitals surveyed.

Ethics statement

This study received approval from the Research Ethics Board of the University of British Columbia and from the Rwanda Pediatric Association. The current study used existing data that were collected during the implementation of the ETAT+ course in Rwanda, and district hospitals' information were anonymized and de-identified prior to analysis.

Results

The current assessment included 8 district hospitals sampled from across Rwanda. The size of these hospitals differed, with the number of pediatric beds per hospital evaluated ranging from 25 to 54 beds and the number of pediatric admission per day per hospital from 4 to 15 admissions (Table 1).

Health human resources

With respect to human resources, three of the eight hospitals had at least one pediatrician. In all hospitals, admissions were done by either a generalist physician (doctor with basic seven years of medical training including one year of internship in a district hospital) or a pediatrician. During the day shift, in nearly all hospitals, there was at least one doctor per pediatric

Table 1. Hospital size, triage and ward organization.

| Hospital size | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 |
|--|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Number of pediatric beds per hospital | 41 | 54 | 35 | 30 | 30 | 25 | 43 | 40 |
| Number of admission per day per hospital | 4 | 15 | 5 | 8 | 6 | 10 | 10 | 6 |
| Number of ambulance per hospital | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 3 |
| Triage system | | | | | | | | |
| Triage and job aids for triage | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable |
| Triage system staffed by a trained person at least during the day | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable |
| Severely ill children seen in a child specific area | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Available | Unavailable |
| Specific clinician to immediately attend to very sick children during the day | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Available | Unavailable |
| Observation area for administering ORS or treating asthma in children's OPD area | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable |
| Ward organization | | | | | | | | |
| Separate ward or room for children | Available | Available | Available | Available | Available | Available | Available | Available |
| Most seriously ill babies are cared for in a section near nursing station | Unavailable | Unavailable | Unavailable | Unavailable | Available | Unavailable | Available | Unavailable |
| Isolation pediatric unit | Unavailable | Available | Unavailable | Available | Available | Unavailable | Available | Unavailable |
| Separate admission area for babies born out of the hospital | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Available | Unavailable |
| Sickest children nursed in direct view of nursing station in the ward | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Unavailable | Available | Unavailable |
| Children with surgical conditions nursed separate from adults with surgical problems | Available | Available | Available | Unavailable | Unavailable | Available | Available | Unavailable |
| Defined area for emergencies | Unavailable | Unavailable | Available | Available | Available | Available | Available | Available |
| Mothers of sick newborns facilitated to room in with their babies in the ward | Available | Available | Available | Available | Available | Available | Available | Available |
| Kangaroo Mother Care | Available | Available | Available | Available | Available | Unavailable | Available | Available |

— Available — Unavailable; ORS, oral rehydration solution; OPD, outpatient department; H1, 4 and 6 are rural located hospitals while the remaining are in urban areas.

doi:10.1371/journal.pone.0173233.t001

and neonatal department who may leave the hospital after completing ward rounds; while night clinical coverage was done by one generalist doctor covering all hospital wards in three (all rural hospitals) of the eight hospitals, and one doctor covering maternity, pediatric and neonatology in five remaining hospitals. For the day shift, the median number of nurses was 2 (range 1–4) on both general pediatric wards and newborn units. However, while night shift coverage was provided by one dedicated nurse per pediatric ward across all hospitals surveyed, only half of the hospitals had dedicated neonatal unit coverage by one nurse. In the remaining four hospitals, one nurse permanently based in the maternity ward would also attend to patients in the newborn unit.

Physical resources and organization

Emergency triage and ward organization. In all outpatient and emergency departments of the surveyed hospitals, there was neither a functional triage system nor guidelines for triage to help identify and attend immediately to severely ill infants and children, and only one had a specific area with a dedicated physician for severely sick children during the day shift (Table 1). While all the hospitals had newborn and pediatric wards, only three hospitals had organized their wards in a way to allow severely sick newborns (n = 2) and children (n = 1) to be viewed and cared for directly from the nursing station (Table 1). All the hospitals assessed had ambulances for transporting/transferring patients with emergency conditions. Six hospitals had defined areas for emergency care within their newborn and pediatric wards, while seven hospitals had space for Kangaroo Mother Care—a method of care for preterm infants involving infants being carried, usually by the mother, with skin-to-skin contact [25].

Guidelines and structured admission record. The availability of updated clinical practice guidelines varied across the surveyed hospitals (Table 2). Guidelines for neonatal resuscitation and management of malaria were available in 5/8 and in 7/8 hospitals, respectively; while those for management of neonatal sepsis, pneumonia, dehydration and severe malnutrition were available in three or fewer hospitals (Table 2). With respect to a structured admission record, a neonatal admission record (NAR) was available in six hospitals and was out of stock in two hospitals; a pediatric admission record (PAR) was not part of care in any institution studied. Neonatal feeding guidelines were readily available but were not consistent within and across hospitals evaluated. Stratification of overall availability of guidelines (Table 2) by hospital

Table 2. Availability of up to date clinical practice guidelines and checklists by district hospital.

| Up to date guidelines | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 |
|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Neonatal resuscitation appropriate for clinical area | Available | Available | Available | Available | Available | Available | Available | Available |
| Child resuscitation appropriate for clinical area | Available | Available | Available | Available | Available | Available | Available | Available |
| Neonatal infection or sepsis | Available | Available | Available | Available | Available | Available | Available | Available |
| Management of pneumonia in children | Available | Available | Available | Available | Available | Available | Available | Available |
| Management of dehydration in children | Available | Available | Available | Available | Available | Available | Available | Available |
| Management of malaria in children | Available | Available | Available | Available | Available | Available | Available | Available |
| Management of severe malnutrition (WHO 10 Steps Approach) | Available | Available | Available | Available | Available | Available | Available | Available |
| Neonatal feeding | Available | Available | Available | Available | Available | Available | Available | Available |
| Checklist or admission records | | | | | | | | |
| Checklist for emergency materials | Available | Available | Available | Available | Available | Available | Available | Available |
| Neonatal Admission Record (NAR) | Available | Available | Available | Available | Available | Available | Available | Available |
| Pediatric admission Record (PAR) | Available | Available | Available | Available | Available | Available | Available | Available |

— Available — Unavailable; WHO, World Health Organization; H1, 4 and 6 are rural located hospitals while the remaining are in urban areas.

doi:10.1371/journal.pone.0173233.t002

Table 3. Hygiene and safety by district hospital.

| Hygiene and safety | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 |
|---|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Sink, clean running water and soap | Available | Unavailable | Available | Available | Unavailable | Available | Available | Available |
| Alcohol hand rub or sanitizer | Unavailable | Unavailable | Available | Available | Available | Unavailable | Available | Unavailable |
| Sharps put in safety boxes and not overflowing safety boxes | Available | Available | Available | Available | Available | Available | Available | Available |
| Lockable area for keeping away dangerous items including drugs | Available | Available | Unavailable | Available | Available | Unavailable | Available | Available |
| Toilets clean, dry and accessible to child and /or mother | Unavailable | Unavailable | Available | Available | Available | Available | Unavailable | Available |
| All beds in good repair | Available | Available | Available | Unavailable | Available | Available | Available | Available |
| All mattresses covered with a Mackintosh, and clean | Available | Unavailable | Available | Available | Available | Available | Available | Unavailable |
| All beds covered with mosquito nets (<i>in malaria prone areas</i>) | Available | Available | Available | Available | Available | Available | Available | Available |

— Available — Unavailable; H1, 4 and 6 are rural located hospitals while the remaining are in urban areas.

doi:10.1371/journal.pone.0173233.t003

location (rural or urban) suggested major rural-urban differences (overall score of 6/24 (25%) and 24/40 (60%) for rural hospitals and urban hospitals respectively).

Hygiene and safety. Hygiene and safety measures were considered acceptable in many hospitals. However, while there was limited availability of alcohol hand rub or sanitizer, soap was available in all hospitals. Mosquito nets were available in all hospitals regardless of malaria endemicity of the region, while only five hospitals had a checklist for regularly checking on the availability of emergency drugs in newborn, pediatric and emergency departments (Table 3).

Laboratory services, equipment, consumables, and drugs. While essential laboratory services were available in all hospitals evaluated, there was limited availability of other laboratory services assessed (Table 4). In terms of specific equipment and consumables, most were available in all hospitals except for intra-osseous (IO) needles, metered dose inhalers (MDI) with spacer, bag valve mask (BVM) for preterm infants and pediatric IV administration sets that were rarely or never stocked in most hospitals (Table 5). Two of the eight hospitals had neither MDI/spacer nor nebulizer. Stratification of availability of resources (e.g., laboratory services, equipment, consumables and drugs) by hospital location (rural or urban) did not suggest any major differences.

Drugs judged to be essential first-line treatment for the most common conditions, adapted from the WHO essential drug list that was endorsed by the MOH [22], were readily available in most of the hospitals evaluated, and drugs deemed necessary for resuscitation or emergency care were also available in all hospitals (Table 6); however, although adrenaline was available in all hospitals, it was expired in one hospital. Pediatric HAART (highly anti-retrovirus therapy) was available in only 4 of the 8 hospitals (50%). Supportive care medications for severe acute malnutrition including therapeutic milk for severe acute malnutrition (F75) and oral rehydration salts for severely malnourished infants and children (ReSoMal) were available in only 3 of the 8 hospitals (37.5%). Formula for term and preterm babies for short-term supplementation were not available in 5 and 8 hospitals respectively. However, it should be noted that formula for term and preterm babies for short-term supplementation are not on the Rwanda essential drug list [22].

Discussion

The current study aimed to assess the capacity of district hospitals to provide quality care to severely ill infants and children in Rwanda. Our findings suggest that many of the physical resources judged necessary to provide emergency care to very sick children in a typical district hospital in Rwanda were available. In addition, clinical practice guidelines for the management of malaria and neonatal resuscitation were readily available across the district hospitals

Table 4. Availability of laboratory and radiology services by district hospital.

| Laboratory and radiology services | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 |
|--|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| Biochemistry | | | | | | | | |
| Glycaemia [§] | Available | Available | Available | Available | Available | Available | Available | Available |
| Bilirubin | Available | Rarely or never available | Available | Available | Rarely or never available | Rarely or never available | Available | Available |
| Hematology | | | | | | | | |
| Hemoglobin [§] | Available | Available | Available | Available | Available | Available | Available | Available |
| Full Blood Count | Available | Available | Available | Available | Available | Available | Available | Available |
| Sickle cell test | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available |
| Cross match & blood bank [§] | Available | Available | Available | Available | Available | Available | Available | Available |
| Microbiology and Parasitology | | | | | | | | |
| CSF microscopy & Gram stain [§] | Available | Available | Available | Available | Available | Rarely or never available | Available | Rarely or never available |
| Malaria microscopy [§] | Available | Available | Available | Available | Available | Available | Available | Available |
| Stool microscopy | Available | Available | Available | Available | Available | Available | Available | Available |
| CSF culture | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Available |
| Pleural fluid culture | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Available |
| Joint aspirates culture | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Available |
| Urine culture | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Available |
| Blood culture | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Available |
| Immunology | | | | | | | | |
| HIV testing | Available | Available | Available | Available | Available | Available | Available | Available |
| Radiology | | | | | | | | |
| Plain radiography service ^{¶ §} | Available | Available | Available | Available | Available | Rarely or never available | Available | Available |

Available Rarely or never available

[§] Essential laboratory services.

[¶] Available 7 days/week at least daytime

H1, 4 and 6 are rural located hospitals while the remaining are in urban areas.

doi:10.1371/journal.pone.0173233.t004

included in the current assessment. However, gaps remain pertaining to hospital services organization (e.g., non-functional triage system) and limited availability of pediatric clinical practice guidelines pertaining to the leading causes of hospital admission and mortality in children younger than five years in Rwanda (e.g., management of pneumonia, sepsis, dehydration, WHO 10 step approach to management of severe malnutrition).

Consistent with prior research that described inadequate triage for severely ill infants and children in health facilities across low-income countries [3, 4, 26], our assessment points to non-functional triage system along with lack of job aids for triage across all district hospitals surveyed. Further, previous research in such settings has suggested that inadequate emergency, triage, assessment, and treatment of severely ill children is one of the major contributing factors to high hospital mortality rates among children younger than five years within the first 24 to 48 hours of admission [6, 27–29]. A such, an intervention to improve emergency triage, assessment and treatment plus admission care for severely ill infants and children (ETAT+) is currently being implemented in Rwandan district hospitals [10], and we believe that it will help establish a functional triage system in these health facilities and, ultimately, contribute to improvement infant and child health outcomes in Rwanda. For example, training hospital staff in emergency, triage assessment and treatment in Malawi was associated with a reduction in early hospital mortality in children under-five from 47.6 to 37.9 deaths per 1000 admissions after the intervention [26].

Table 5. Availability of equipment and consumables by district hospital.

| Equipment and consumables | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 |
|---|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| Oxygen delivery, Monitor, Defibrillator | | | | | | | | |
| Oxygen (Tank or concentrator) | Available | Available | Available | Available | Available | Available | Available | Available |
| Oxygen monitor [†] | Available | Available | Available | Available | Available | Available | Available | Available |
| BVM for children | Available | Available | Available | Available | Available | Available | Available | Available |
| BVM for newborns | Rarely or never available | Rarely or never available | Available | Available | Rarely or never available | Rarely or never available | Available | Available |
| Nasal prongs | Available | Available | Available | Available | Available | Available | Available | Available |
| Oxygen mask with reservoir | Rarely or never available | Available | Available | Available | Rarely or never available | Available | Available | Available |
| CPAP device (bubble CPAP) | Rarely or never available | Available | Available | Available | Available | Rarely or never available | Available | Available |
| Cardiac monitor/defibrillator | Rarely or never available | Rarely or never available | Available | Available | Available | Rarely or never available | Available | Available |
| Automatic External Defibrillator (AED) | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available |
| Suction | | | | | | | | |
| Suction machine | Available | Available | Available | Available | Available | Available | Available | Available |
| Nasogastric tubes | Available | Available | Available | Available | Available | Available | Available | Available |
| Warming | | | | | | | | |
| Incubator | Available | Available | Available | Available | Available | Available | Available | Available |
| Asthma | | | | | | | | |
| Nebulizer | Available | Rarely or never available | Available | Available | Available | Rarely or never available | Available | Available |
| MDI and spacer | Rarely or never available | Rarely or never available | Available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available |
| BP measurement, Infusion and Transfusion | | | | | | | | |
| Pediatric IV giving sets | Rarely or never available | Rarely or never available | Available | Available | Rarely or never available | Rarely or never available | Available | Available |
| Pediatric cannula | Available | Available | Available | Available | Available | Available | Available | Available |
| Blood transfusion sets | Available | Available | Available | Available | Available | Available | Available | Available |
| Intra-osseous needle | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available |
| Age appropriate BP cuff | Available | Available | Available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available | Rarely or never available |
| Phototherapy | | | | | | | | |
| Phototherapy machine | Available | Available | Available | Available | Available | Available | Available | Available |
| Weighing scale | | | | | | | | |
| Infants | Available | Available | Available | Available | Available | Available | Available | Available |
| Children | Available | Available | Available | Available | Available | Available | Available | Available |

— Available — Rarely or never available

[†] Not available in all departments—moved from one department to another when needed.

BVM, bag valve mask; MDI, metered dose inhaler; IV, intravenous; BP, blood pressure; CPAP, continuous positive airway pressure

doi:10.1371/journal.pone.0173233.t005

Previous studies in low-income countries have consistently described a limited availability of resources to provide emergency care to sick children [3–5]. For example, in a survey of pediatric care conducted in Kenya, English and colleagues found that many essential items for care of severely ill children were lacking in many hospitals [4]. Likewise, shortages of drugs, equipment, and disposable materials made it difficult to implement sepsis management guidelines in resource-constrained settings [5]. While resources may not be as depleted as found in prior studies in other settings, the findings from our survey of district hospital resources also identified major gaps in resource availability (e.g., 50% of hospitals without BVM for newborns or pediatric IV sets, no intra-osseous needles for the management of shock in all hospitals surveyed, no nebulizer or MDI in 25% of the hospitals, and no F-75 and ReSoMal for management of severe acute malnutrition in 5/8 hospitals) that would require improvement in order to enhance the capacity of Rwandan district hospitals to provide emergency care to severely ill infants and children. While basic bacteriology services were readily available across the

Table 6. Availability of drugs included in the pediatric and neonatal standards of hospital care audit tool.

| Available in all 8 hospitals | Available in 5–7 hospitals | Available in 2–4 hospitals | Available in 0–1 hospital |
|--|----------------------------|----------------------------|--|
| Fluids, antibiotics, HAART & antimalarial | | | |
| Glucose 5% | Chloramphenicol oral | Benzylpenicillin | Half strength Darrows with 5% dextrose * |
| Ringers lactate and normal saline | Cotrimazole cream/paint | Pediatric HAART | Neonatal ampiclox * |
| Amoxicillin | Flu/cloxacillin IV | | |
| Chloramphenicol IV | | | |
| Flucloxacillin oral | | | |
| Ampicillin IV | | | |
| Cotromoxazole | | | |
| Gentamicin | | | |
| Metronidazole IV and oral | | | |
| Ciprofloxacin | | | |
| Nystatin | | | |
| Fluconazole | | | |
| Tuberculosis drugs | | | |
| Tetracycline EO | | | |
| 1 st line ACT | | | |
| Quinine IV and oral | | | |
| Supportive care | | | |
| Glucose 50% or 10% | Salbutamol inhaled | Potassium oral | Oral morphine |
| Adrenaline | IV salbutamol | Term formula feeds *† | Preterm formula feeds*† |
| Diazepam | Iron syrup | Phenobarbitone IV | Diphtheria antitoxin |
| Hydrocortisone IV | Zinc supplement | F75 | |
| Ibuprofen | Digoxin | ReSoMal | |
| Paracetamol | ORS | | |
| Multivitamins, vitamins A and K | Phenobarbitone oral | | |
| IV furosemide | | | |
| Mebendazole/Albendazole | | | |
| Metoclopramide | | | |
| Prednisolone tablets | | | |
| F100 or RTUF | | | |
| Tetanus prophylaxis | | | |

RTUF, ready to use food; EO, eye ointment; ORS, oral rehydration solution; IV, intra-venous; HIV, Human Immunodeficiency Virus; HAART, Highly anti-retrovirus therapy; ACT, artemisinin based combination therapy; F100 and F75, therapeutic milk for severe malnutrition

* Drugs that are NOT on the Rwandan essential medicine list, thus, explaining their scarce availability in Rwandan health facilities.

† For short term feeding supplementation

doi:10.1371/journal.pone.0173233.t006

hospitals surveyed, the lack of bacteriology services including culture potentially leads to empirical treatment without knowledge of bacterial causes of infections, and therefore lack of evidence based prescribing and the development of bacterial resistance. Pediatric HAART were available in only half of the hospitals, perhaps related to stock-outs at the time our survey was conducted.

In Rwanda, previous surveys have highlighted the lack of availability of necessary resources [16, 30]. For example, a survey of quality of care in Rwanda conducted by the Maternal, New-born, and Child Health in Rwanda (MNCHR) project in 2010 through interviewing healthcare providers, patients and hospital administrators highlighted a lack of physical and human resources as the most important barrier to providing high quality care [30]. Moreover, the

2011 MOH integrated health systems strengthening project mid-term review that focused broadly on structural domain of quality of care delivery found that the main challenges to the health care system in Rwanda included, but were not limited to, insufficient health infrastructure and the use of insufficient and outdated equipment in health facilities [14]. As compared with the current study, previous studies assessed resources *in general*, without special attention to resources required to provide emergency care for children. The current study assessed specifically the availability of resources deemed necessary to provide basic emergency care to severely ill children and infants. Moreover, in the current study, we inventoried whether consumables and drugs were available in wards, whereas previous studies might have relied on self-reports from staff.

Furthermore, in this study, we did not assess whether equipment was outdated, nor did we check whether they were in working order or if the staff knew how to use it. It is important to assess the quality of equipment as poor quality or outdated equipment has been reported in resource-poor settings and might be associated with poor outcomes. For example, Slusher and colleagues found that many phototherapy machines available in sub-Saharan Africa were sub-standard and could not provide enough light to adequately treat neonatal jaundice [31]. Additionally, we found in one facility for example that some drugs (e.g., epinephrine) were available but expired. One of the limitations of our study is also the quantity of physical resources—we just checked whether they were available; however, they might be available but not in sufficient quantities to care for several children. Also, what was not available at the time of the survey was considered not available (out of stock), but it is possible that they were usually available before survey. While using a purposeful sampling approach for selecting the study sample ($n = 8$ district hospitals) resulted in a reasonable regional representation, this sampling approach might have introduced selection bias that could limit the generalizability of our study findings.

While the current assessment found that there was a limited availability of up to date clinical guidelines in many hospitals that were evaluated, some guidelines that were available were not consistent. For example, treatment (e.g., dosage, frequency) recommendations (e.g., neonatal feeding) varied across the hospitals. Thus, there is a need to harmonize clinical practice guidelines as one of the efforts to improve communication among staff and uptake of these guidelines in Rwanda. Accordingly, continuous medication education (CME) program implementers and policy and decision makers should harmonize CME training in Rwanda. Guidelines of management of malaria were readily available, and this might be explained, at least in part, by existence of malaria-specific programs including malaria surveillance and monitoring. Previous research suggests that use of a standardized admission record (e.g., neonatal (NAR) and pediatric (PAR) admission record) is associated with improved documentation of illness, and that the uptake of these admission records by healthcare professionals in sub-Saharan Africa is quite high [20, 32, 33]. While a NAR was readily available in newborn units, a PAR was not available in any district hospital pediatric wards surveyed. As such, the use of standardized admission records should be recommended in Rwandan district hospitals, especially, given that these hospitals are staffed by healthcare providers with only basic professional training who are generally required to take care of severely ill infants and children without specialist supervision. Nevertheless, efforts are underway to train specialists who will be deploying in all hospitals across the country [34].

In particular, our findings highlight a substantial need to enhance the capacity of Rwandan district hospitals to provide emergency care to severely ill infants and children in the context of the ETAT+ program. Recognizing that not all missing items are necessarily equally important to providing emergency triage, assessment and treatment plus admission care for severely ill infants and children, priority should focus on items that are most needed. First, establishing

an adequate triage system across Rwandan district hospitals—this is the focus of the ETAT+ program currently being implemented in Rwanda. Second, efforts should be deployed to ensure appropriate dissemination of clinical practice guidelines endorsed by the Rwanda MoH to district hospitals. Clearly, availing up to date clinical practice guidelines are significantly less expensive to address than what is required to start up bacteriology services. Further, as described earlier, emergency checklist and standardized admission records should be available and their routine use should be enforced in district hospitals. Third, investment in capacity building of health human resources cannot be overemphasized. Multiple efforts are currently underway to train healthcare workers in Rwanda. For example, there is a 7-year partnership between United States and Rwanda to increase the number of healthcare providers including specialist physicians, nurses and midwives [34]. In addition, strengthening CME for in-service healthcare providers is another priority. In response, a 5-year Canadian funded project (Train Support Access Model (TSAM) for Maternal Newborn and Child Health in Rwanda and Burundi) will focus on training in-service healthcare providers across Rwandan district hospitals to increase their competence with regards to management of emergency maternal newborn and child health emergencies.

Fourth, investing in critical resources required to implement ETAT+ in Rwandan district hospitals (e.g., BVM for newborns, IO needles, pediatric giving sets, nebulizer/MDI with spacer). For example, IO access equipment should be readily available in the district hospitals in Rwanda, especially given that dehydration/shock due to diarrheal diseases is one of the leading causes of morbidity and mortality among children younger than five years and the evidence from prior research recommending IO access if IV cannot be promptly established and suggesting that IO access may be ‘easily established’ by healthcare providers with little training and is ‘more rapidly achieved’ than IV access [35, 36]. While IO needles are the most appropriate option to obtain IO access, normal butterfly needles or puncture needles can also be used [17], and are usually widely available in hospitals. Therefore, the lack of IO needles may not hamper successful implementation of ETAT+ in Rwanda. For management of asthma/bronchospasm, 25% of district hospitals lacked both nebulizer and MDI and, therefore efforts should be deployed to have at least one of these items. For spacer, district hospitals can use spacers locally made from plastic bottles that are ubiquitous instead of commercial spacers. This is discussed in the ETAT+ training for healthcare providers in Rwanda. Given that malnutrition is not uncommon, resources for management of severe acute malnutrition in infants and children (e.g., F-75 and ReSoMal) should be available. Alternatively, district hospitals can make F-75 and ReSoMal locally using recommended recipes [17, 18].

In conclusion, our assessment provides evidence on the capacity of Rwandan district hospitals while highlighting gaps in essential resources that can undermine healthcare provision to severely ill infants and children in Rwanda. Identifying these gaps in the Rwandan district health care system is required in order to inform new strategies to facilitate the implementation and scale up on the ETAT+ program, and ultimately, the improvement in infant and child health outcomes in Rwanda. Further, our findings highlight a need to establish an outreach/mentoring program (that could be overseen by the Rwanda Paediatric Association in collaboration with Maternal and Child Health Department of the Rwanda Ministry of Health and other newborn and child health stakeholders) to ensure that adopted clinical practice guidelines are available and used appropriately in these district hospitals, that available equipment is working, that staff know how to use it, and that they do use it. This outreach or mentoring program could be embedded within the ongoing ETAT+ program, to promote cross-hospital learning exchanges.

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References

1. United Nations. Millennium Development Goals 2000. [cited 2015 October 20]. <http://www.un.org/millenniumgoals/childhealth.shtml>.
2. National Institute of Statistics of Rwanda (NISR) [Rwanda], Ministry of Health (MOH) [Rwanda] and ICF International. Rwanda Demographic and Health Survey 2014–15. 2015.
3. Ralston ME, Day LT, Slusher TM, Musa NL, Doss HS. Global paediatric advanced life support: improving child survival in limited-resource settings. *The Lancet*. 2013; 381(9862):256–65.
4. English M, Esamai F, Wasunna A, Were F, Ogutu B, Wamae A, et al. Delivery of paediatric care at the first-referral level in Kenya. *The Lancet*. 2004; 364(9445):1622–9.
5. Khilnani P, Singhi S, Lodha R, Santhanam I, Sachdev A, Chugh K, et al. Pediatric Sepsis Guidelines: Summary for resource-limited countries. *Indian journal of critical care medicine: peer-reviewed, official publication of Indian Society of Critical Care Medicine*. 2010; 14(1):41.
6. Nolan T, Angos P, Cunha AJ, Muhe L, Qazi S, Simoes EA, et al. Quality of hospital care for seriously ill children in less-developed countries. *The Lancet*. 2001; 357(9250):106–10.
7. Mabey D, Gill G, Weber MW, Whitty CJ. *Principles of medicine in Africa*: Cambridge University Press; 2013.
8. World Health Organization. *Hospitals and health for all: report of a WHO Expert Committee on the Role of Hospitals at the First Referral Level* [meeting held in Geneva from 9 to 17 December 1985]. 1987.
9. Hategekimana C, Nshuti S, Mucumbitsi J, Muvunyi C, Mutesa L, Rusingiza E. Management challenges of pediatric infective endocarditis at tertiary level in Rwanda. *Rwanda Medical Journal*. 2012; 69(3):34–42.
10. Hategekimana C, Shoveller J, Tuyisenge L, Kenyon C, Cechetto DF, Lynd LD. Correlates of Performance of Healthcare Workers in Emergency, Triage, Assessment and Treatment plus Admission care (ETAT+) course in Rwanda: Context matters. *PloS one*. 2016; 11(3):e0152882. doi: [10.1371/journal.pone.0152882](https://doi.org/10.1371/journal.pone.0152882) PMID: 27030974
11. Shoveller J, Viehbeck S, Di Ruggiero E, Greyson D, Thomson K, Knight R. A critical examination of representations of context within research on population health interventions. *Critical Public Health*. 2016 Oct 19; 26(5):487–500.
12. National Institute of Statistics of Rwanda. *Rwanda Population and Housing Census (RPHC4) Thematic Report: Population Size, Structure and Distribution*. 2014. [cited 2017 January 19]. <http://statistics.gov.rw/publication/rphc4-thematic-report-population-size-structure-and-distribution>
13. Ministry of Health of Rwanda. *Service Provision Assessment Survey*. 2008. [cited 2017 January 19]. <https://dhsprogram.com/pubs/pdf/SPA15/SPA15.pdf>
14. Ministry of Health of Rwanda. *Integrated health systems strengthening project (IHSSP) II mid-term review Kigali, Rwanda: 2011*. [cited 2017 January 19]. <http://www.moh.gov.rw/fileadmin/templates/Clinical/service-packages-for-health-facilities-at-different-levels-of-service-delivery-last-version.pdf>

15. Ministry of Health of Rwanda. Rwanda's Health Sector Policy. 2005. [cited 2017 January 19]. https://www.internationalhealthpartnership.net/fileadmin/uploads/ihp/Documents/Country_Pages/Rwanda/HealthSectorPolicy.pdf
16. Ministry of Health of Rwanda. Rwanda Annual Health Statistics Booklet. 2012. [cited 2017 January 19]. http://www.moh.gov.rw/fileadmin/templates/MOH-Reports/MOH_Booklet_2012_final_September_2013.pdf
17. World Health Organization. Pocket book of hospital care for children: guidelines for the management of common illnesses with limited resources. Geneva: World Health Organization; 2005.
18. Ministry of Health of Rwanda. Basic Pediatric Protocols. 2011. [cited 2016 November 12]. http://www.etatcourserwanda.org/wp-content/uploads/2013/06/Rwanda-Pediatric-Protocols_oct-2011.pdf
19. Aluvaala J, Nyamai R, Were F, Wasunna A, Kosgei R, Karumbi J, et al. Assessment of neonatal care in clinical training facilities in Kenya. *Archives of disease in childhood*. 2014;archdischild-2014-306423.
20. Gathara D, Nyamai R, Were F, Mogo W, Karumbi J, Kihuba E, et al. Moving towards Routine Evaluation of Quality of Inpatient Pediatric Care in Kenya. *PloS one*. 2015; 10(3):e0117048. doi: [10.1371/journal.pone.0117048](https://doi.org/10.1371/journal.pone.0117048) PMID: [25822492](https://pubmed.ncbi.nlm.nih.gov/25822492/)
21. Irimu GW, Gathara D, Zurovac D, Kihara H, Maina C, Mwangi J, et al. Performance of health workers in the management of seriously sick children at a Kenyan tertiary hospital: before and after a training intervention. *PloS one*. 2012; 7(7):e39964. doi: [10.1371/journal.pone.0039964](https://doi.org/10.1371/journal.pone.0039964) PMID: [22859945](https://pubmed.ncbi.nlm.nih.gov/22859945/)
22. Ministry of Health of Rwanda. La Liste Nationale des Medicaments Essentiels. 2010. [cited 2017 January 20]. <http://www.moh.gov.rw/fileadmin/templates/Clinical/MEDICAMENTS-ESSENTIELS.pdf>
23. Ntoburi S, Hutchings A, Sanderson C, Carpenter J, Weber M, English M. Development of paediatric quality of inpatient care indicators for low-income countries-A Delphi study. *BMC pediatrics*. 2010; 10(1):90.
24. Donabedian A. The quality of care: How can it be assessed? *Jama*. 1988; 260(12):1743–8. PMID: [3045356](https://pubmed.ncbi.nlm.nih.gov/3045356/)
25. World Health Organization. Kangaroo mother care: a practical guide. 2003. 48 p. [cited 2017 January 20]. http://www.who.int/maternal_child_adolescent/documents/9241590351/en/
26. Robison JA, Ahmad ZP, Nosek CA, Durand C, Namathanga A, Milazi R, et al. Decreased pediatric hospital mortality after an intervention to improve emergency care in Lilongwe, Malawi. *Pediatrics*. 2012; 130(3):e676–e82. doi: [10.1542/peds.2012-0026](https://doi.org/10.1542/peds.2012-0026) PMID: [22891229](https://pubmed.ncbi.nlm.nih.gov/22891229/)
27. Berkley J, Ross A, Mwangi I, Osier F, Mohammed M, Shebbe M, et al. Prognostic indicators of early and late death in children admitted to district hospital in Kenya: cohort study. *Bmj*. 2003; 326(7385):361. PMID: [12586667](https://pubmed.ncbi.nlm.nih.gov/12586667/)
28. Molyneux E. Paediatric emergency care in resource-constrained health services is usually neglected: time for change. *Annals of Tropical Paediatrics: International Child Health*. 2010; 30(3):165–76.
29. Menge I, Esamai F, Van Reken D, Anabwani G. Paediatric morbidity and mortality at the Eldoret District Hospital, Kenya. *East African medical journal*. 1995; 72(3):165–9. PMID: [7796768](https://pubmed.ncbi.nlm.nih.gov/7796768/)
30. Maternal Newborn and Child Health in Rwanda (MNCHR). Report on quality of health care in Rwanda. 2010.
31. Slusher TM, Zipursky A, Bhutani VK, editors. A global need for affordable neonatal jaundice technologies. *Seminars in perinatology*; 2011: Elsevier.
32. Hategekimana C. Evaluating the implementation of the emergency, triage, assessment and treatment plus admission care intervention in Rwanda. Vancouver, Canada: University of British Columbia; 2015.
33. Mwakysa S, Wamae A, Wasunna A, Were F, Esamai F, Ogutu B, et al. Implementation of a structured paediatric admission record for district hospitals in Kenya—results of a pilot study. *BMC international health and human rights*. 2006; 6(1):9.
34. Binagwaho A, Kyamanywa P, Farmer PE, Nuthulaganti T, Umubyeyi B, Nyemazi JP, et al. The human resources for health program in Rwanda—a new partnership. *New England Journal of Medicine*. 2013; 369(21):2054–9. doi: [10.1056/NEJMs1302176](https://doi.org/10.1056/NEJMs1302176) PMID: [24256385](https://pubmed.ncbi.nlm.nih.gov/24256385/)
35. Abe KK, Blum GT, Yamamoto LG. Intraosseous is faster and easier than umbilical venous catheterization in newborn emergency vascular access models. *The American journal of emergency medicine*. 2000; 18(2):126–9. PMID: [10750913](https://pubmed.ncbi.nlm.nih.gov/10750913/)
36. Association AH. 2005 American Heart Association (AHA) guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiovascular care (ECC) of pediatric and neonatal patients: pediatric basic life support. *Pediatrics*. 2006; 117(5):e989–e1004. doi: [10.1542/peds.2006-0219](https://doi.org/10.1542/peds.2006-0219) PMID: [16651298](https://pubmed.ncbi.nlm.nih.gov/16651298/)