Developing Pediatric Critical Care in Kenya

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Objective: To describe efforts to improve the care of critically ill children in a tertiary care public hospital in a resource-limited setting.
Design: Descriptive.
Setting: Pediatric wards at the Kenyatta National Hospital in Nairobi, Kenya.
Patients: Critically ill children admitted to the hospital.
Interventions: A graduated approach to improving critical care capacity in a resource-limited setting.
Measurements and Main Results: Pediatric mortality was tracked in the adult ICU and PICU following the engagement of a pediatric intensivist and creation of a critical care team. Mortality declined from 76.2% to 37.5% in the first 2 years of the new PICU.
Conclusions: Caring for critically ill children in resource-limited setting presents many challenges. The stepwise approach described here has led to a nearly 50% reduction in mortality among critically ill children at Kenyatta National Hospital. It is a viable strategy to begin to address the disproportionate number of critically ill and injured children in resource-limited setting. (*Pediatr Crit Care Med* 2019; XX:00–00)
Key Words: critical care unit; development of pediatric intensive care unit; low-resource settings; pediatric; pediatric intensive care unit; resource-limited settings

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Childhood mortality in resource-limited settings (RLSs) is "the result of a complex web of determinants on many levels" (1). Uneven or fragmented care can result from disproportionate burden of severe illness and injury in regions least equipt to bear it (1, 2). In recent years, Kenya has taken a number of steps to redress this glaring imbalance and improve the care of the severely ill and injured together with concrete initiatives to develop critical care capacity. Kenya's path toward developing pediatric critical care services for the public health system is described here, as are the challenges and lessons learned in this process, which may have broader applicability.

BACKGROUND

In spite of an overall decrease in global childhood mortality in the past decades, approximately 15,000 children under the age of 5 still die every day with more than 5.6 million deaths occurring annually (3). Half of the world's young children die in sub-Saharan Africa, where they have a 15 times greater likelihood of death before their fifth birthday than children in high-income countries (HICs) (4). The principal causes of these deaths are treatable conditions such as diarrhea and pneumonia. In addition, the impact of trauma increases; road trauma alone accounted for 16% of fatalities in low-income countries (LICs) in 2015 (5). Studies from Ethiopia and Nigeria have shown a high frequency of pediatric injury, and these levels are expected to rise throughout the region (6–8). Recent data from Kenya show up to 17% of ICU admissions attributable to traumatic head/brain injury (9–11).

In recent decades, Kenya has made a number of advances in public health: between 2003 and 2014, vaccine rates increased by roughly 40%, whereas stunting fell from 36% to 26%, and wasting from 7% to 4%. Trends in child mortality have improved as well. According to the 2010–2014 Kenya Demographic Health Survey, the infant and under-5 mortality rates were down to 39 and 52 deaths per 1,000 live births, respectively, from 2005 to 2009 levels of 43 and 60 (12). Under-5 mortality continued to fall in 2016 to 49.2 (13). These gains notwithstanding, approximately one in every 26 Kenyan children dies before reaching 1 year old, and about one in every 19 children does not survive to their fifth birthday.

The Kenyan Ministry of Health (MoH) has taken a number of steps to improve the care of children in the country's 48 public hospitals. These measures have included dissemination of an adopted version of the World Health Organization Emergency Triage And Training course and development of the Kenyan Basic Paediatric Protocols Pocketbook for use by all cadres of pediatric caregivers nationwide. In the private sector, the Pediatric Fundamentals of Critical Care Support course

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has also been conducted for pediatricians and medical officers at a few private hospitals.

Particular focus has been placed on the care of children in the country's largest public hospital, Kenyatta National Hospital (KNH), in Nairobi. With 2,100 beds (of which 320 are pediatric), KNH is the largest public referral center in East and Central Africa and serves as the regional training center for all major medical specialties. Importantly, KNH provides care for patients of lower socioeconomic status who are unable to afford private clinics. The pediatric service averages 1,450 pediatric admissions per month, a level comparable to that of the largest U.S. pediatric hospital (14). Bed occupancy at KNH is 154%, often with more than one patient per bed or on floor mats. The hospital has a high census, severity of illness, and mortality rate; on average, 17–22% of monthly pediatric admissions are critically ill, with an inpatient fatality rate of 13%. Many of these children would benefit from higher levels of care.

Critical care in Kenya is in its infancy. In 2010, there were only 74 ICU beds in eight different hospitals serving a nation of 48 million people. Patients were managed by medical officers and/or anesthetists. Thirty-day ICU mortality at a large Kenyan public hospital was recently cited at 58%, double that of a private facility in Nairobi. Although more than 70% of the ICU patients in this study were adult, adjusted odds risk for mortality was highest in children less than 10 years (9). In fact, in most resource-limited regions, the critically ill child is fortunate to even find a bed in an adult or mixed ICU and is more commonly managed in the pediatric wards (15, 16).

Prior to 2010 at KNH, pediatric medical admissions to the nominally "mixed" ICU were extremely infrequent (with pediatric surgical admissions slightly more common). This was principally due to the reluctance of adult anesthesiologists to manage severely ill children, as well as chronic shortages of pediatric critical care–trained personnel. Thus, in an unfortunate but familiar situation in RLS, KNH had a large, adult ICU incongruously present in the same building as pediatric wards brimming with critically ill children (17). As a first step in addressing this conspicuous gap in care, the Department of Pediatrics, University of Nairobi (UoN)/KNH hired a trained pediatric intensivist.

THE FIRST STEP: INITIAL MANAGEMENT STRATEGIES AND CLEAR DEFINITION OF NEED

Kenya's first pediatric intensivist started work at KNH/UoN in January 2011, initially posted to one of the pediatric wards rather than the 21-bed adult ICU (**Fig. 1**). The challenge at that point was three-fold: first, work with residents and nursing staff to institute a system to identify the sickest patients; second, marshal existing resources for their care; and, finally, more clearly define the need for pediatric critical care services.

To begin, sick patients were identified by clinical assessment and the use of an adapted Pediatric Early Warning Signs, which is included in the MoH's Basic Pediatric Protocols Handbook. This tool, based on the Pediatric Early Warning Score, has been previously validated in RLS to identify patients in need of ICU transfer (18). Assessments were performed by triage nurses and medical officers in the pediatric emergency unit during first contact with the patient. A subsequent evaluation was done an hour later, after initial treatments, to determine disposition. At that time, the options were wards, "acute rooms," or, uncommonly, adult ICU. On the wards, once the critically ill patient was recognized by the residents/interns, the utmost resources and care feasible were mobilized in their management (e.g., fluid resuscitation, oxygen therapy, and 4-hourly clinical monitoring).

The most focused care available on each of the four wards was provided in the "acute rooms," spaces reserved for the sickest children. Each acute room had 6–8 beds equipped with oxygen ports and an assigned nurse 24 hours a day. Other than this dedicated nurse, these busy rooms were covered by ward personnel responsible for up to 50–60 patients. The staffing consisted of four nurses, 4–5 residents, and 1–2 interns during the day and much thinner nighttime coverage: 1–2 interns and 2–3 nurses. Yet, although serving as de facto step-down units, these spaces lack individual monitors, and with high acuity and understaffing, have not yet had an impact on mortality in the wards, which still ranges between 9% and 22%.

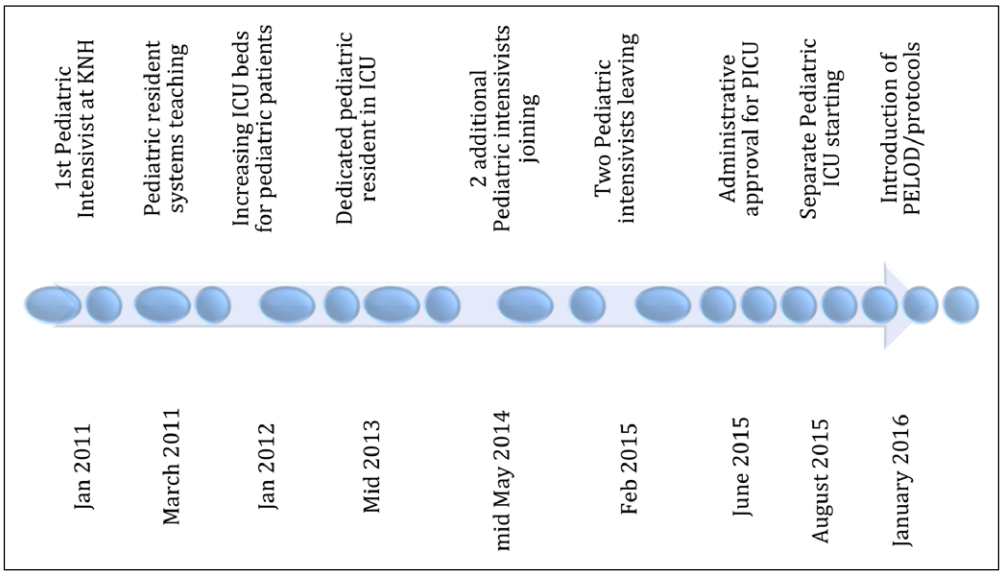

Figure 1. Timeline of pediatric critical care development in Kenya. KNH = Kenyatta National Hospital, PELOD = Pediatric Logistic Organ Dysfunction.

Training house staff in the first steps of managing sick

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patients with limited resources proved a demanding task. To help emphasize the essential first steps of care, a mnemonic was introduced to guide and standardize care (F.R.I.C.H.M.A.N.S: Fluids, Respiratory, Infectious, Cardiovascular, Hematological, Metabolic, Abdominal, Neurologic, Skin). Other centers have created similar mnemonics to help caregivers recall the key issues involved in the care of critically ill patients and keep focused on a systematic approach (19). At KNH, this invaluable, rigorous method assured more consistent and thorough history taking, clinical examination, grounded decision-making and reporting, and establishment of more comprehensive patient management plans.

SECOND STEP: DEVELOPING A TEAM

The pediatric intensivist, with the pediatric and anesthesia residents, conducted daily rounds in the pediatric wards and adult ICU. Understanding the working environment and bed allotment policies in the ICU was an early priority. Because the relationship with the ICU evolved, bed spaces were increasingly available for children whose needs surpassed what could be provided in the "acute rooms." Close communication and collaboration with the ICU charge nurse and ICU anesthesiology leadership helped secure more beds to accommodate deteriorating children. In 1-year time, the percentage of pediatric admissions to the ICU increased from 5 to 25.

The comanagement of the increasing number of pediatric patients by adult ICU and pediatric teams invariably led to disagreements. However, this discord was in part eased by dialogue and education on the latest evidence-based pediatric practices. The pediatric team also introduced a "systems" approach to presentations and care, emphasizing holistic care of the child. This was an important step in harmonizing practices, improving teamwork, and changing the general culture in ICU. The pediatric presence was further reinforced when the pediatric department approved a compulsory ICU rotation for pediatric residents. The permanent presence of pediatric residents in the ICU enhanced education and training of the ICU staff on pediatric-specific problems and promoted streamlining of care for the critically ill pediatric patients. In this environment, the percent of PICU admission increased from a sparse 4.7 to 38 between 2011 and 2013 (**Fig. 2**).

During this period, two more pediatric intensivists joined the KNH practice, adding greatly to the quality of care for severely ill children. From 2013 to 2015, pediatric patients accounted for 75–90% of ICU occupancy; at times, 19 out of 21 ICU beds were occupied by pediatric patients. Although ICU nursing staff became increasingly comfortable admitting pediatric patients and outcomes improved, this complete reversal of admission trends resulted in understandable tensions between ICU staff and pediatric providers. These strains notwithstanding, PICU mortality decreased from greater than 60% to less than 40% (**Table 1**). Recognizing this shortage of ICU beds and the contributions made by the pediatric intensivists' service (Fig. 2), the hospital administration took steps to create a separate, tertiary care PICU.

THIRD STEP: CREATING A PICU

The creation of a functional PICU at KNH was the final step on the path to developing pediatric critical care services in a RLS (20, 21). Although some parallels exist between the historical development of PICUs in HIC and the undertaking at KNH, most of the problems encountered in Kenya are particular to this type of endeavor in a RLS (22, 23).

The hospital administration provided a modest physical space that could barely accommodate five beds with the requisite equipment, including electrical outlets, oxygen ports, five Hamilton ventilators, and cardiorespiratory monitors. There did remain numerous issues to be confronted before a functional and effective unit could be operational, such as personnel shortages, inadequate training, deficiencies in material and support services, as well as lack of policies and procedures to standardize patient care. Yet, even while contending with these many difficulties, the new PICU at KNH admitted its first patient, a child with septic shock and multiple organ dysfunction, on August 28, 2015. Since that time, the unit has faced an endless demand for its services.

Staffing the new PICU was a trying task, reflecting the chronic healthcare personnel crisis that plagues much of the continent (24). Inauspiciously, two of the three pediatric intensivists relocated before the PICU even opened its doors, leaving the original

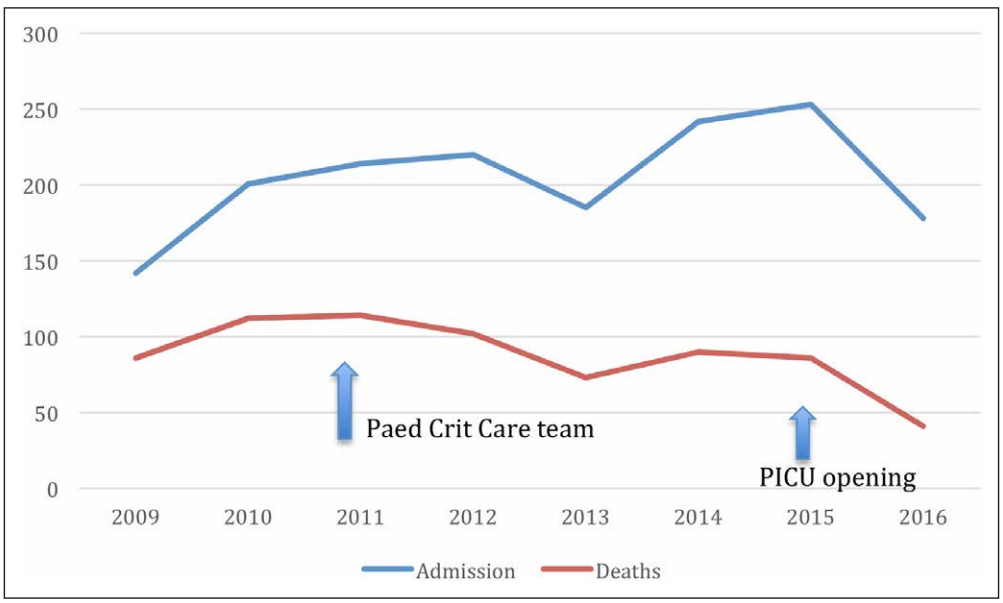

Figure 2. Pediatric admission to the adult ICU and mortality: 2009–2016.

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TABLE 1. Adult ICU Pediatric Admissions and Deaths Trend: 2009–2016

Year	Admissions	Deaths	Mortality Rate (%)
2016	178	41	23
2015	253	86	33.9
2014	242	90	37.1
2013	165	73	44.2
2012	220	102	46.3
2011	214	114	53.2
2010	201	112	55.7
2009	139	86	61.8

intensivist to coordinate the opening and guide the management of patients in the new unit. As a result, the PICU could only be fully staffed with pediatric trainees and an intensivist during the daytime. This shortfall was amplified by inadequate nighttime nursing coverage. Recruitment of nurses with critical care training and pediatric experience had only been partially successful. Although a daytime nurse-to-patient ratio of 1:2 could be achieved, the ratio at night was an unsatisfactory 1:3. This inadequate nighttime coverage, so common in RLS, has led to a predictably higher incidence of nocturnal adverse events. Hiring overnight, moonlighting resident doctors, paid by KNH administration, has not yet resolved this disparity (**Fig. 3**).

General infrastructure and physical plant deficiencies, occasional interruption of water and electricity, and absence of functional back-up generators for the ventilators undermined care in the new unit. Limited floor space made it essential to secure storage units, patient cupboards, cabinets for medical supplies, and patient files to allow ready access to patient and equipment. The Global Center for Integrated Health of Women, Adolescents and Children grant from the University of Washington financed the purchase of furniture and cabinets, greatly relieving the congestion. This improved the PICU's internal design and work flow and made the unit more child and health worker friendly.

The PICU's material/equipment needs spanned the very basic, such as IV stands, to the essentials, including, endotracheal tubes, central venous and urinary catheters, sedation medications, inotropes and vasopressors, and broad-spectrum antibiotics. Constraints on crucial PICU support services further hampered care. For example, there was limited x-ray availability, unpredictable hospital laboratory services, and lack of ICU blood gases and electrolyte machines as well as timely access to blood products. In addition, a respiratory physiotherapist shared with the adult ICU had restricted availability to once or bid, increasing workload of the already overworked PICU nursing staff. Unfortunately, many of these deficiencies remain chronic.

The standardization of care, through use of protocols and checklists, has proven important in RLS to help compensate for limitations in resources and trained personnel (25, 26). In the busy, early days of PICU operation at KNH, broader efforts to create these tools had to be deferred. Nonetheless, early data gathering helped identify some of the shortcomings and pitfalls of early PICU management, informing and motivating work on the first protocols. These protocols guided the provision of optimal nutrition (with reduced intolerance, at minimal cost), and rational, targeted antibiotic use. In addition, to address the high observed rate of extubation failure and subsequent tracheostomy, locally appropriate intubation-extubation criteria were established (**Appendix 1**, Supplemental Digital Content 1, http://links.lww.com/PCC/B62).

Although the demand for PICU services was limitless, bed space was not. The PICU remained a five-bed unit, with the uncertain possibility of admitting an additional 3–6 patients to the adult ICU. As a result, PICU admission (and exclusion) criteria were established to assure the reasonable and equitable allocation of resources (27). At KNH, admission decisions involved discussions among the PICU nursing team, residents, and consultants in the general pediatric wards. Assessment of patients was based on clinical examinations and Pediatric Logistic Organ Dysfunction (PELOD)-2 scoring. Although it was recognized that the PELOD-2 score was not designed to predict individual mortality, it was inserted into the assessments to add a degree of objectivity. In our evaluations, patients with a PELOD-2 score greater than 23 (predicting mortality of > 98.5%) were not given priority. In addition, patients with evidence of catastrophic and irreversible neurologic dysfunction (e.g., fixed and

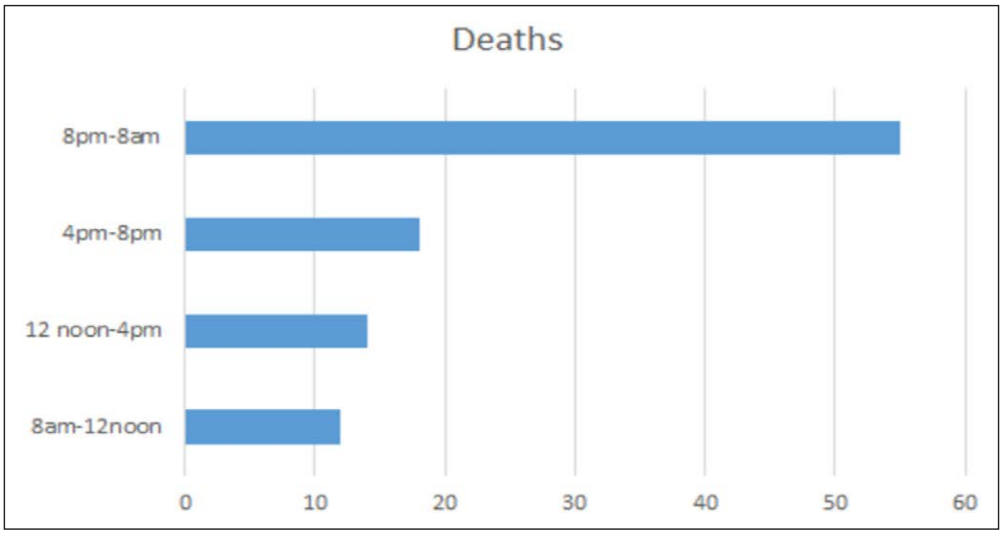

Figure 3. Mortality versus time of day: July 2016–June 2017.

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dilated pupils), severe congenital cardiac and multiple anomalies, were excluded from PICU admission. Exclusion of these patients likely improved PICU mortality but, more importantly, freed up beds for patients who might better benefit from PICU care.

RESULTS

Not surprisingly, pediatric admissions to the adult ICU declined as those to the new PICU increased. During the first 2 years of the new PICU's operation, there were 413 admissions, averaging 206 PICU admissions per year (**Table 2**). The three leading diagnoses for medical patients were septic shock, meningoencephalitis, and severe pneumonia/acute respiratory distress syndrome. Surgical cases accounted for 10.4% ($n = 43$) of admissions.

From its inception, patients admitted to the PICU at KNH have been extremely ill, with mean and median admission PELOD-2 score of 14 and 18 (interquartile range [IQR], 10–22), respectively, with a predicted mortality of 86.4%. By comparison, the maximum median PELOD-2 score among PICU admissions in a multicenter European study was 5 (IQR, 2–7) with a median score noted among nonsurvivors of 12 (IQR, 8–18) (28). This is similar to the median score of 13 (IQR, 9.5–17) seen among nonsurvivors in a North African (Egyptian) PICU (29). In addition to their acute illnesses, extensive comorbidities like malnutrition, congenital heart disease, anemia, and rickets complicate many (59%) of the pediatric hospital admissions (12, 30–32).

During the first 2 years of operation, 98% of PICU medical admissions and 79% of surgical patients required mechanical ventilation. This compares to rates of 22% described in PICUs in Southern India, 55% during respiratory viral season in Latin American and less than 10% in a mixed PICU population in the United States in 2017 (33–36). The median duration of PICU stay for medical and surgical patients at KNH was 11 days (IQR, 4–15 d) and 3 days (IQR, 2–5 d), respectively. A recent study from a PICU in Mozambique cited a median PICU length of stay of 2 days (32).

TABLE 2. PICU Sociodemographic Data: August 2015–July 2017

Variable	Characteristics	Frequency $n = 413$ (%)
Age (mo)	0 to ≤ 2	47 (11.4)
	> 2 to ≤ 12	189 (45.8)
	> 12 to ≤ 60	123 (29.8)
	> 60	54 (13.1)
Gender	Male	252 (61)
	Female	161 (39)
Referred from another hospital	No	134 (32.4)
	Yes	279 (67.6)

In spite of advances in public health, no changes have been detected in the number of hospital admissions at KNH, general trends in diagnoses or severity of illness at admission; about 75–85% of patients admitted to this tertiary care facility continue to be referrals. Even as certain conditions like HIV, severe acute malnutrition and pneumonia have become less prominent, and respiratory and neurologic illnesses (including TBI) remain the most common causes of mortality (**Fig. 4**). In the new PICU setting, mortality decreased from 16 per month (76.2%) in November 2015 to six (37.5%) in August 2016. Put in a regional context, PICU mortality in Rwanda was recently cited at 50%, 59% for septic PICU patients in Mozambique, and 40% overall pediatric mortality in a mixed unit in Uganda (32, 37, 38). Unfortunately, this decline at KNH has been inconsistent, but more recent data show an encouraging downward trend in monthly mortality (18–26%). We believe that these mortality gains are attributable not only to improved care in the PICU itself but also in other pediatric care settings such as the emergency department and pediatric wards, as well as the continued education in triage and emergency treatment.

DISCUSSION: ETHICAL ISSUES, REMAINING CHALLENGES, AND FUTURE DIRECTIONS

In settings of universal need and limited public healthcare budgets encountered in RLS, the role of intensive care has been questioned on economic, practical, and ethical grounds. Highly relevant concerns have been raised about levels of investment required to provide PICU-level care and the possible diversion of public funds from other patient care activities, which, in the absence of long-term outcomes data, are difficult to reconcile (39). Nonetheless, a comprehensive and humane discussion of care in RLS might also recognize: first, that in spite of the successes of preventive medicine, children become critically ill and injured requiring hospitalization; second, that this occurs with an increasing and unequal abundance in RLS; and, third, that improved hospital care of these patients could impact mortality, and do so in cost-effective ways (38, 40–46).

We have described the concrete steps taken at KNH in Nairobi to address the needs of the critically ill child. In spite of the impressive progress to date, including a 50% reduction in mortality, outcomes in the PICU at KNH remain suboptimal. The ongoing issues are listed below.

Patient Selection and Ethical Dilemmas

Screening PICU admissions in RLS is important from an institutional, resource allocation, and family perspective. For this reason, it is necessary to enforce and, in time, revise admission criteria based on changing/improving PICU outcomes. This approach must prioritize those patients most likely to benefit from PICU care. It is also more culturally acceptable to withhold PICU care than to ultimately recommend withdrawing it. In cases where patients are not granted admission due to exclusion or bed unavailability, guardians are appropriately counseled, and the best care possible provided on the wards. Counseling regarding the futility of ongoing or escalating care was also provided to guardians of patients who failed

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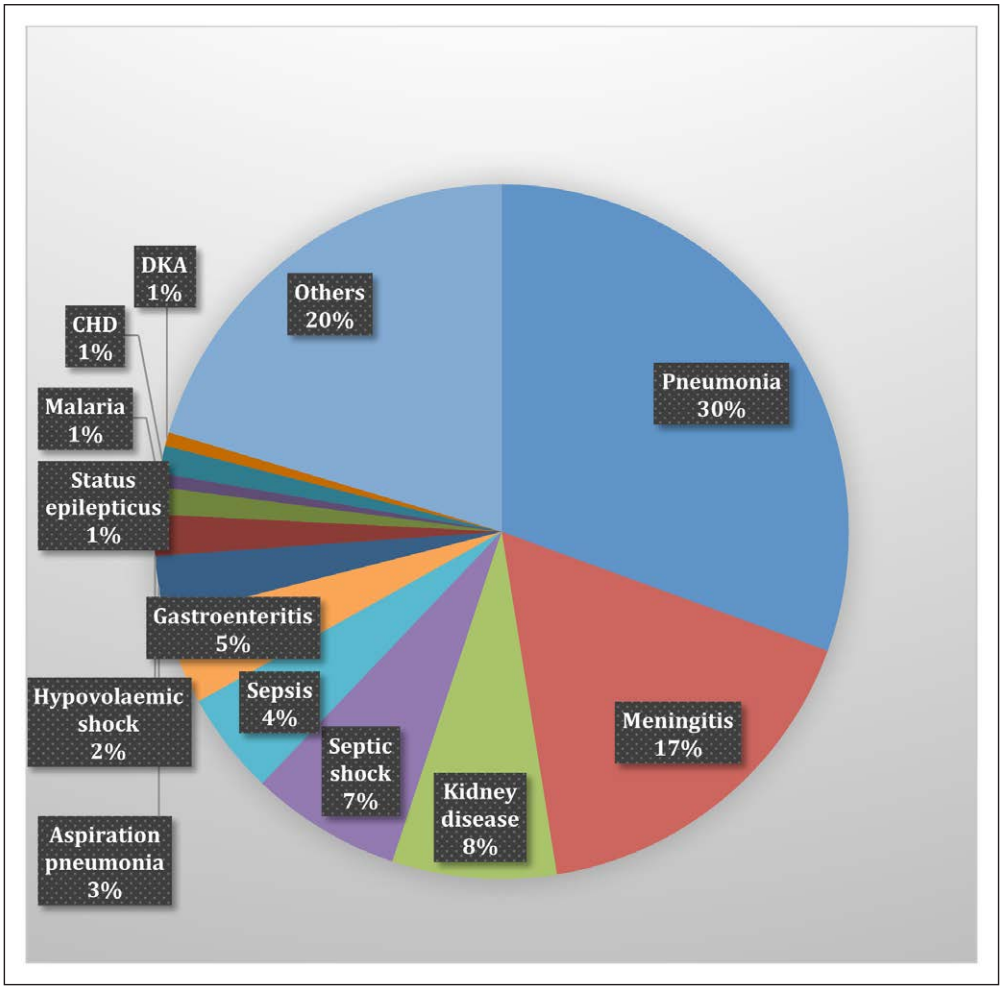

Figure 4. Kenyatta National Hospital PICU mortality by diagnosis: September 2015–August 2018. CHD = congenital heart disease, DKA = diabetic ketoacidosis.

to respond to initial measures and had, therefore, worsening prognoses. Encouragingly, decisions surrounding escalation of care were not made on the basis of the financial means of the family; the hospital management had a waiver system for the extremely impoverished. In fact, the majority of patients (55–70%) possessed national health insurance coverage, which helped defray the treatment costs at KNH. This spares many families the painful dilemma of agreeing to care that could impoverish their whole family, while still begging larger questions of institutional/societal priorities.

Materials and Procedures

Chronic shortages of material and services which undermine care in the PICU at KNH (and in other RLS) may require a greater commitment of resources, adaption of newer, more sustainable technologies/techniques. For example, using kitchen-prepared feeds can replace expensive commercial products. Also, encouraging practices that adapt care to chronic deficiencies ("work arounds") has proven effective. As a result, when central venous catheters are out of stock, larger IV cannulas are used in external jugular veins, and, in the absence of x-ray support, rigorous assessment of patient color, vital signs, symmetrical air entry into the lungs, and ventilator pressures and volumes are employed to verify proper endotracheal tube placement. Finally, the PICU team recognizes the need to devise and apply site-appropriate policies and protocols (e.g., methods to prevent extubation failure and subsequent tracheostomy [**Appendix 2**, Supplemental Digital Content 2, http://links.lww.com/PCC/B63]) and continuing education and simulation to maintain and enhance team skills (47, 48).

Personnel

Although one of the original intensivists rejoined the faculty in late 2016, the most intractable and long-term threat to the PICU at KNH is the shortage of trained personnel (49). Sufficiently trained or experienced nurses are difficult to find and often leave jobs because of long work hours, increased workload, and understaffing, together with poor leadership and management. This pervasive scarcity of trained healthcare workers at all levels in sub-Saharan Africa erodes public health initiatives throughout the region (50, 51). There is insufficient local training capacity throughout RLS, and the problem is further compounded by the well-described, attenuating effects of international brain drain and intranational shifts (i.e., providers leaving rural areas for cities, or the public sector for more lucrative opportunities in private clinics) (52, 53). Unfortunately, this movement has been mirrored in the PICU at KNH.

Providers in low- and middle-income countries feel that the lack of trained nurses and training opportunities handicaps the care of the critically ill (54). Expanded and improved regional or in-country training may have a role in combating this limitation (55, 56). Kenya currently has seven centers, including KNH, that provide higher diploma nurse degrees in critical care. Unfortunately, only one of these facilities provides training in pediatric critical care. There are also regrettably few training sites for pediatric emergency and critical care physicians in LIC (57, 58). However, in Kenya, the groundbreaking Pediatric Emergency and Critical Care-Kenya (PECC-Kenya) program has started its postgraduate fellowships for pediatricians. This initiative is the fruit of a partnership among UoN/KNH, two other Kenyan institutions, and the University of Washington. PECC's educational curriculum will be adapted

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to the needs and limitations of the local healthcare systems, address relevant diseases and cultural issues, and targets long-term sustainability. Finally, critical care training for both physicians and nurses could be further enhanced through visiting temporary trainers from HIC countries and the use of short-term courses, until local critical care educational capacity is self-sufficient.

LIMITATIONS

We have presented all the relevant data available. Unfortunately, there were a number of areas where more data would have enhanced the study, like on benefits of the acute care rooms on inpatient mortality and severity of illness scores for the pediatric patient admitted to the adult ICU to contrast with subsequent pediatric scores. Because we gather more data on national trends, we can possibly compare PICU and overall hospital severity of illness and mortality over time to evaluate changes with improved vaccinations and nutrition, for example. Finally, although we acknowledge its value, we have not conducted any cost-benefit analysis in this article due to the complexity of such an undertaking.

CONCLUSIONS

Care of the child with critical but reversible illness or injury should be a universal goal for pediatric caregivers. Achieving this goal does not require replication of strategies pursued in HIC, but adaptation to each region's needs and realities. Pediatric critical care at KNH has developed in a stepwise fashion over the past decade—each step with its own benefits and limitations. This steady development of capacity has improved patient outcomes. Although formidable challenges and many hurdles remain, results to date suggest that the incremental model implemented at KNH is a reasonable response to the massive burden of pediatric critical illness and injury (12). This approach may be applicable in other RLS.

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