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RESEARCH ARTICLE

Point-of-care ultrasound needs assessment in a paediatric acute care setting in Malawi

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Abstract

Objective: To describe the use of point-of-care ultrasound (POCUS) in an acute-care paediatric setting in Malawi, including clinical indications, types of examinations and frequency of positive findings.

Methods: Retrospective, cross-sectional study of a convenience sample of POCUS examinations performed in one tertiary referral hospital in Lilongwe, Malawi over 1 year. POCUS examinations were performed by Paediatric Emergency Medicine physician consultants as part of routine clinical practice and at the request of local clinicians. Images were saved along with the clinical indication and physician interpretation for quality review. Ultrasounds performed by the radiology department and those examinations that were technically faulty, missing clinical application or interpretation were excluded.

Results: In total, 225 ultrasounds of 142 patients were analysed. The most common clinical indications for which examinations were completed were respiratory distress (23%), oedema (11.7%) and shock/arrest (6.2%). The most common examinations performed were cardiac (41.8%) and lung (15.1%), focused assessment with sonography in trauma (FAST; 12.9%) and ultrasound-guided procedural examinations (9.8%). Pathology was identified in 68% of non-procedural examinations. Cardiac examinations demonstrated significant pathology, including reduced cardiac function (12.8%), gross cardiac structural abnormality (11.8%) and pericardial effusion (10.3%).

Conclusions: POCUS was used for both clinical decision-making and procedural guidance, and a significant number of POCUS examinations yielded positive findings. Thus, we propose that cardiopulmonary, FAST and procedural examinations should be considered in future for the POCUS curriculum in this setting.

KEYWORDS
point-of-care, ultrasound global health, international health, Malawi, POCUS, ultrasound

INTRODUCTION

In many hospitals across the world, access to diagnostic imaging such as radiographs, computerised tomography (CT), or magnetic resonance imaging is insufficient due to lack of equipment, maintenance technicians and specialists to interpret the studies. It is estimated that 50% of radiography equipment in resource-limited settings (RLS) is nonfunctional [1]. A death audit performed in the paediatric ward in a hospital in Lilongwe, Malawi, found that an imaging study was ordered but not completed within 24 h in 15% of paediatric in-hospital deaths [2].

Point-of-care ultrasound (POCUS) involves the acquisition, interpretation and integration of specific ultrasound findings into real-time clinical decision-making by the treating clinician without the need for a technician or radiologist. Examinations are goal-directed and provide immediate clinical information for patients with traumatic and medical

Sustainable Development Goal: Good Health and Wellbeing emergencies. POCUS is inexpensive, non-irradiating, and can be used to improve diagnostic accuracy and to guide clinical management. Paediatric Emergency Medicine (PEM) physicians employ POCUS in daily practice, performing problem-focused assessments to narrow a differential diagnosis, rapidly diagnose life-threatening conditions, evaluate a patient's response to treatment, or assist with procedures at the bedside.

POCUS is an important diagnostic and therapeutic tool in RLS [3–6]. Multiple studies in RLS assessing different POCUS protocols or patient populations have demonstrated change in clinical management after POCUS in 29%–87% of patients [3, 7, 8]. However, problems arise in programmes teaching ultrasound in RLS when the curriculum does not match local disease burden or does not provide longitudinal education and quality assurance [9–11].

POCUS can be taught to providers with varying levels of clinical experience, especially important in settings with staff shortages. In sub-Saharan African, for example, there is ∼1 physician per 10,000 population, versus 26 physicians per 10,000 population in the United States [12]. The gap in subspecialty health workforce is especially large with a median of 0.5 paediatricians per 100,000 children (less than 18 years) in low-income countries, 6 per 100,000 in lower middle-income countries and 72 per 100,000 in high-income countries [13]. In locations with fewer physicians care is often provided by clinical officers and non-physician healthcare providers for whom POCUS is an attainable skill. Studies in non-RLS have demonstrated the effectiveness of POCUS training courses for learners as varied as medical students [14, 15], medical residents and fellows [16, 17] and attending physicians [18]. One study examined a mixed-participant training course that demonstrated equally significant improvements in image interpretation across all trainee groups [19]. Similar findings have been duplicated in RLS. Providers in RLS can accurately perform POCUS to identify various pathologies [6, 20–22].

The objective of our study was to describe the use of POCUS in an acute care paediatric setting in Lilongwe, Malawi, over an 1-year period.

METHODS

Study design and population

This was a retrospective cross-sectional study of a convenience sample of POCUS examinations performed between October 2017 and October 2018 at Kamuzu Central Hospital (KCH) in Lilongwe, Malawi. Examinations were included if they were performed during the study period as part of routine clinical care and if they contained adequate images for interpretation conforming to predefined criteria [23–25]. Some patients were repeatedly examined during their clinical course. We included examinations completed by study investigators (Beth M. D'Amico, Liliana Morales-Pérez and Justin M. Moher) who are U.S.-trained PEM physicians with training in POCUS. Examinations performed by radiographers, cardiologists or other specialists, incomplete examinations and examinations performed prior to arrival in the paediatric ward were excluded.

Ethics

A waiver of consent was approved by institutional and international regulatory bodies, namely the National Health Sciences Research Committee of the Ministry of Health Malawi, and from Baylor College of Medicine (BCM) Institutional Review Board.

Study setting

Malawi is a sub-Saharan, east African nation with 3 million children under 5 years old and a mortality rate of 68/1000 for children under 5 years [26]. Essential health services are provided by the government at no cost to all citizens. Kamuzu Central Hospital is one of five tertiary care hospitals in Malawi providing internal medicine, paediatric, neonatal, critical care, general surgical, obstetric and orthopaedic services to an area with 4 million people. The patient population varies seasonally depending on the malaria burden and food insecurity, and the Department of Paediatrics admits between 40 and 120 children per day [2]. Children are cared for in general wards, an emergency zone (EZ), and a high-dependency unit (HDU). Admitted patients are resuscitated and stabilised in the EZ, whereas the HDU is a monitored critical care unit without the capacity for mechanical ventilation. A recent review of deaths in the paediatric ward at KCH documented a mortality rate of 3.3% [2]. The EZ and Paediatric HDU at KCH were the setting for this study between October 2017 and October 2018.

KCH has variable availability of diagnostic imaging. The Radiology Department serves both the Paediatric and Adult wards and performs radiography, ultrasound and CT. While bedside ultrasound machines had been used for echocardiography by Cardiology and one physician consultant prior to the study, there had not been any routine training or use of POCUS for patient care in the paediatric ward.

For over 10 years, several U.S. academic medical institutions have worked in conjunction with the KCH Paediatrics Department to support and improve paediatric care, formalising this relationship in 2017 with the formation of the *Paediatric Alliance for Child Health Improvement in Malawi at Kamuzu Central Hospital and Environs* (PACHIMAKE) consortium [27]. This project was completed with the support of this consortium.

Data collection (image acquisition)

U.S.-trained PEM physicians (Beth M. D'Amico, Liliana Morales-Pérez and Justin M. Moher) performed the POCUS

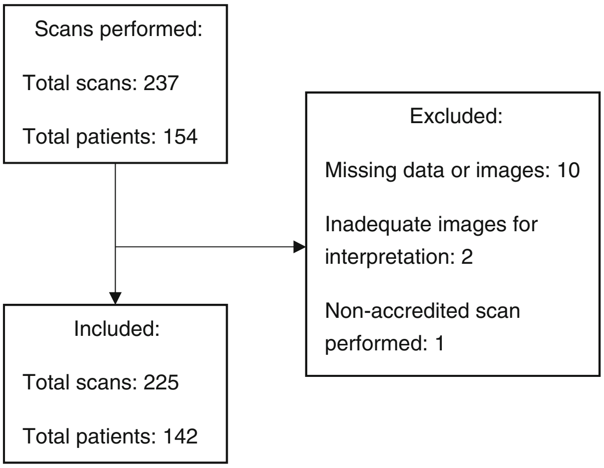


FIGURE 1 Flow diagram of needs assessment study

examinations, after the need for an examination had been determined by either a treating local clinician or U.S.-PEM physician as a part of routine clinical care. Since no ordering system was in place, local clinical and medical officers would request a POCUS in person or through a WhatsApp clinical group. All PEM physicians were competent in POCUS, having completed a minimum of 150 paediatric POCUS examinations with >90% accuracy of interpretation. One investigator (Beth M. D'Amico) completed fellowship training in Emergency Ultrasound (EUS). U.S.-PEM physicians were typically on site for 4–8 weeks, with a total of three sessions during the year. POCUS examinations were performed using a SonoSite M-Turbo (SonoSite Inc; Bothell, Washington) machine using a high-frequency linear, curvilinear or microconvex probe. Examinations were performed according to American College of Emergency Medicine (ACEP) guidelines for POCUS [25] and reviewed by the EUS fellowship-trained investigator (Beth M. D'Amico). Images and clips were saved according to Baylor College of Medicine PEM guidelines. Results were entered in the patient's paper chart.

Outcome measures and analysis

Our outcome measures were general descriptive statistics, including the number of patients receiving POCUS examinations and total POCUS examinations performed; frequencies of different types of POCUS examinations; clinical indications per examination type; frequency and description of pathology.

RESULTS

We performed 237 POCUS examinations of 154 patients during the study period, and 225 examinations of 142 patients met inclusion criteria (Figure 1). The median age of patients who received a POCUS examination was 2.42 years (Interquartile range, IQR: 0.58, 6.00). Clinical indications for specific POCUS examinations are listed in Figures 2–5. The overall most common clinical indications were respiratory distress (29%), oedema (15%) and shock/arrest (8%) (Table 1). Cardiac, focused assessment with sonography in trauma (FAST; 41.8%), lung (15.1%), procedural (9.8%) and inferior vena cava (IVC; 4%) were the most common examinations, and 68% resulted in positive findings.

Cardiac

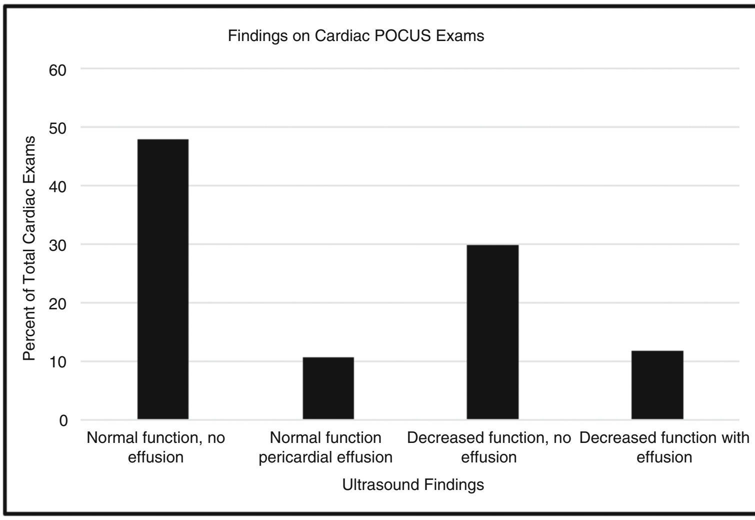
Limited cardiac examinations were performed with at least two views for each study. Respiratory distress and edema were the most common clinical indications for performing cardiac imaging. Examinations were performed to assess global function and for the presence of a pericardial effusion. Although the focus of limited cardiac examinations is typically not to assess for structural abnormalities, gross abnormalities were noted in multiple patients. Overall, imaging was abnormal in 69.1% of examinations with reduced function, the presence of an effusion and global structural abnormalities were the most frequent pathology identified (Figure 2).

Lung

Lung examinations were performed by examining at least three pleural spaces in at least two lung fields and were evaluated for the presence of pneumothorax, pleural effusion, B lines or consolidation. Lung ultrasounds were performed most frequently for respiratory distress or presumed respiratory infection (Figure 3). Overall, pathology was identified in 82.4% of images (Figure 3).

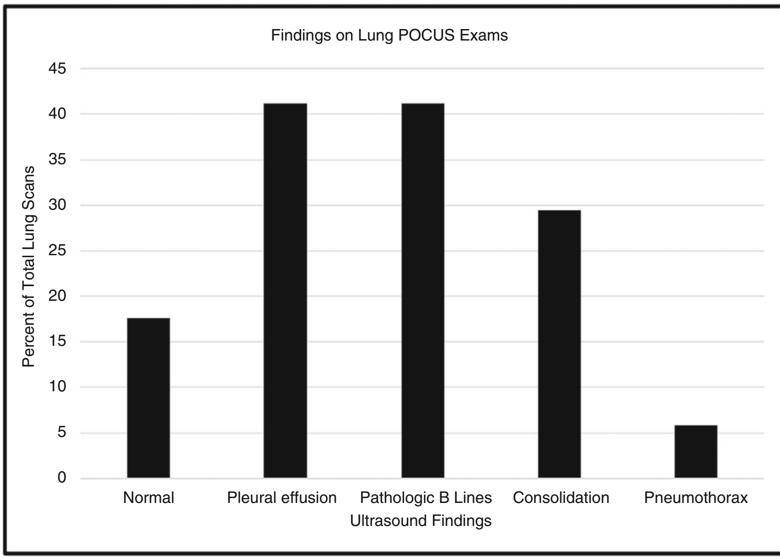
Focused assessment with sonography in trauma

FAST was used for patients both with and without trauma as a means of checking for the presence of intra-abdominal free fluid. 17.2% of patients receiving a FAST had a clinical indication of trauma, whereas edema, respiratory distress and suspected infection were the other common indications for the majority of FAST examinations (Figure 4). FAST was positive in 44.8% of examinations. Free fluid was most frequently found in the suprapubic space (79%), followed by the left upper quadrant (64%) and the right upper quadrant (57%). A small number of focus assessment of sonography in TB/HIV (FASH; $n = 5$) and rapid ultrasound for shock and hypotension (RUSH; $n = 2$) examinations were performed which contain, in part, similar images to those in the FAST. FAST and RUSH examinations were not included when analysing FAST results. Abdominal ultrasounds not containing all views of the FAST were excluded from the analysis.



Indications for Cardiac POCUS Exams	
Respiratory distress	30 (31.9%)
Edema	13 (13.8%)
Known pericardial effusion/tamponade	9 (9.6%)
Shock arrest	9 (9.6%)
Heart failure	9 (9.6%)
Genetic/congenital syndrome/CHD	9 (9.6%)
Abnormal heart exam	9 (9.6%)

FIGURE 2 Indications and findings of cardiac point-of-care ultrasound (POCUS) exams. CHD, congenital heart disease



Indications for Lung POCUS Exams, n(%)	
Respiratory distress	21 (61.8%)
Infection	10 (29.4%)
Pleural effusion	4 (11.8%)

FIGURE 3 Indications and findings of lung point-of-care ultrasound (POCUS) exams.

Procedural examinations

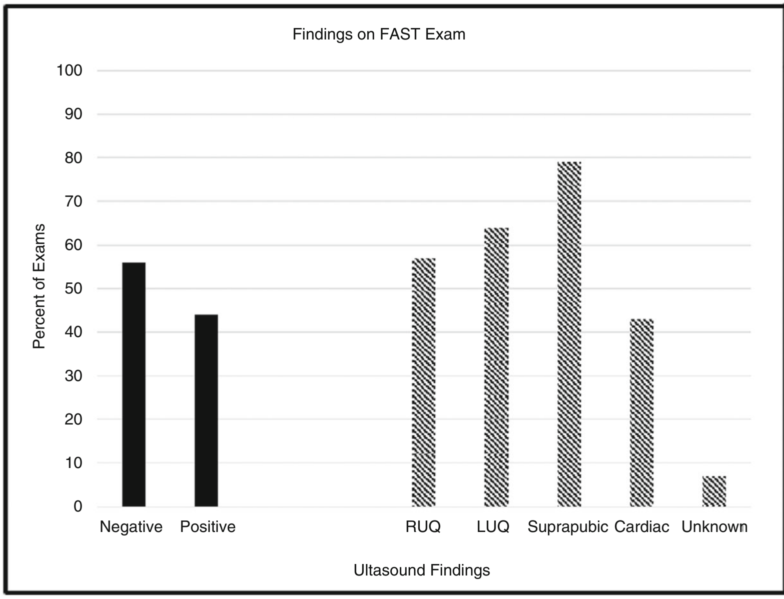
Procedural examinations were performed using ultrasound to either localise or guide a procedure. Procedural examinations were predominantly used for patients with edema and included pericardiocentesis, thoracentesis and paracentesis (Figure 5).

Intravascular collapse

IVC was evaluated in inspiration and exhalation for collapse as a potential source of information about intravascular volume status. While 44.4% of all studies were abnormal, the pathology identified in all cases was a hyper-collapsible IVC, with no plethoric IVCs noted. Clinical indication was for respiratory distress (44.4%), shock/arrest (33.3%) or known infection (33.3%).

DISCUSSION

POCUS is an inexpensive, clinician-performed imaging method that can directly impact patient care and benefit adult [3–8, 20, 21, 28] and paediatric [5, 29–33] patients in RLS. Training programmes in POCUS, however, must meet local needs and match local resources in order to be sustainable [9]. A needs assessment is essential to the



Indications for FAST Exam, n(%)	
Respiratory distress	6 (20.7%)
Edema	6 (20.7%)
Trauma	5 (17.2%)
Infectious	5 (17.2%)

FIGURE 4 Indications and findings of focused assessment of sonography in trauma (FAST) exams. Black bars represent the percentage of positive and negative exams out of all FAST exams. Striped bars represented the localization of fluid found on positive FAST exams as a percentage of all positive exams. LUQ, left upper quadrant; RUQ, right upper quadrant

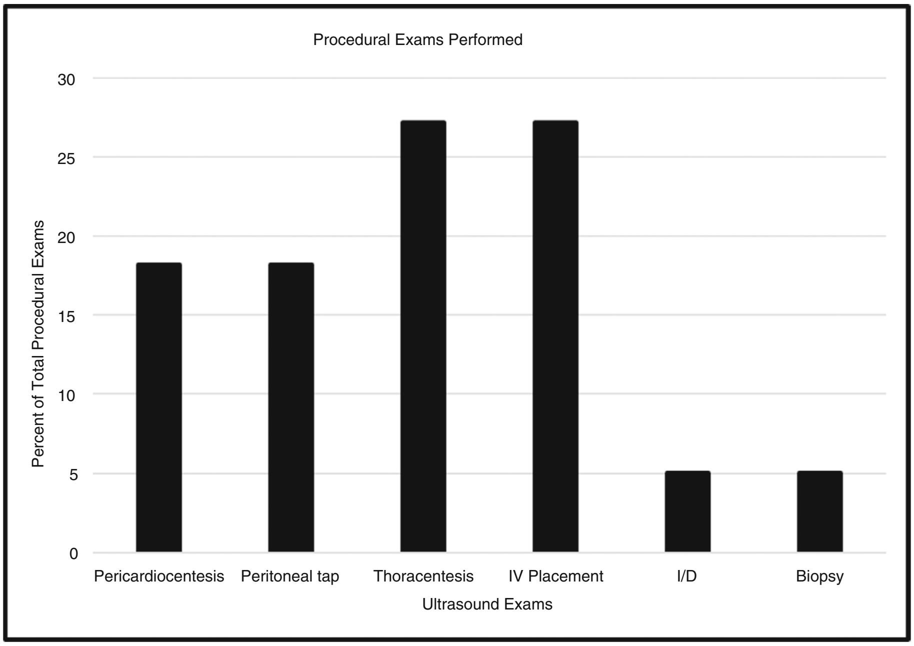


FIGURE 5 Procedural point-of-care ultrasound exams performed. I/D, incision and drainage; IV, intravenous [catheter]

development of appropriate training programmes. As such this study describes the clinical use of POCUS and its relevant findings over the course of a year in a paediatric emergency department in Lilongwe, Malawi, as the first step in developing a locally relevant POCUS training programme. To our knowledge, this is the first needs assessment for POCUS in paediatrics in RLS, and it could be adjusted to and implemented in training programmes in other RLS.

Clinical examinations and indications

Overall, the most common clinical indications for POCUS examinations were respiratory distress, oedema and shock/arrest. These clinical findings likely represent a wide spectrum of disease commonly encountered in paediatric patients in Malawi [34]. A death audit of cases in the KCH Paediatrics department found that the five most common causes of mortality (excluding unknown) were malaria,

TABLE 1 POCUS exams performed

Category	Scan	*N* (%)
Cardiovascular	Cardiac	94 (41.8)
	IVC	9 (4)
Gastroenterological	FAST	29 (12.9)
	Abdomen (other)	8 (3.6)
	Intussusception	3 (1.3)
	Biliary	1 (0.4)
	Pylorus	1 (0.4)
Respiratory	Lung	34 (15.1)
	Other	3 (1.3)
Procedure	Pericardiocentesis	4 (1.8)
	Peritoneal tap	4 (1.8)
	Thoracentesis	6 (2.7)
	IV placement	6 (2.7)
	Incision and Drainage	1 (0.4)
	Biopsy	1 (0.4)
Genitourinary	Renal	5 (2.2)
	Bladder	4 (1.8)
Superficial	Soft tissue	7 (3.1)
Other	FASH	5 (2.2)

Abbreviations: FASH, Focused assessment with sonography for HIV-associated tuberculosis; IV, intravenous; IVC, inferior vena cava; POCUS, Point-of-care ultrasound.

malnutrition, HIV-related illness, sepsis and respiratory disease [35]. Respiratory distress can be associated with all these illnesses. Respiratory distress may result from severe anaemia in patients with malaria or from heart failure in patients with malnutrition. HIV-positive patients are more likely to be affected by *Pneumocystis jiroveci* pneumonia or pulmonary and extrapulmonary tuberculosis, all of which may lead to respiratory distress. Patients with cardiac disease, in particular rheumatic heart disease [28, 35], may also present with respiratory distress in advanced stages. Perhaps not surprisingly, the clinical indication of 'respiratory distress' led clinicians to initiate multiple types of examinations beyond lung examination, given the variety of serious pathology that can manifest as respiratory distress in this clinical setting.

The most common clinical examinations performed during the study period were cardiac, lung, FAST and procedural, and knowing this allows for the implementation of locally relevant trainings when introducing POCUS into this setting. Given the significant burden of both congenital and acquired cardiac disease in children and the paucity of paediatricians and specialists to evaluate and treat these conditions, many children evaluated at KCH have advanced cardiac disease not previously diagnosed [28,35,36]. Identifying patients with cardiac dysfunction and/or gross structural abnormalities suggestive of congenital or acquired cardiac disease within the emergency department at KCH often permitted clinicians to initiate referral to the paediatric cardiology clinic on-site.

Our study suggests that POCUS examinations were used for a more broad set of indications than is typical in a high-resource setting. For example, the FAST examination, intended for use in trauma patients, was used predominantly to evaluate patients with swelling or oedema, for intra-abdominal free fluid, as described in the literature as examination views to assess for intra-abdominal free fluid in non-trauma patients, termed the focused assessment for free fluid [37]. By considering local disease burden, traditional POCUS examination protocols can be modified and adapted locally for evaluation of common pathology.

Pathology

The paediatric population studied had a high rate of positive POCUS findings. While there are studies in RLS of specific pathologies examined by ultrasound or indications, data on the overall pathology in a single population are rare and data specifically on the paediatric population are nonexistent to our knowledge. Our study identified pathology on 68% of examinations, which was notably higher than that observed by Stolz et al. [33], who identified pathology on 46% of examinations performed in a rural Ugandan emergency department. Although the demographics of the population are lacking, only ~25% of the visits to this Ugandan emergency department were by paediatric patients. A study performed on TB and HIV-positive adults in a facility serving the same region as our own saw a similarly high rate of pathology with 77% of patients with findings on ultrasound [7]. It is difficult to compare the pathology on ultrasonography in adults with paediatric patients given different burdens of disease and chronic illness. Further, selection bias may contribute to high rates of positive examinations since the use of POCUS is dependent on clinical decision-making of the practitioner. For example, our patient population came from the EZ and HDU, where the most critically ill and injured children are found. Despite this, the overall large number of positive findings in our paediatric population supports the clinical utility of this critical tool in this population.

Finally, traditional POCUS examinations were used for broad indications. In our study, FAST examinations were positive in 44% of cases, which were predominantly non-trauma patients. It is likely that FAST was used to evaluate presence of intra-abdominal free fluid caused by diseases such as heart failure, tuberculosis, nephrotic syndrome, malnutrition and intestinal infections such as typhoid. Despite performing the FAST for non-trauma paediatric patients, we found that fluid was most commonly localised in the suprapubic region. This conforms with previous studies demonstrating the suprapubic region as the most common location of free fluid in paediatric trauma patients with a positive FAST [38].

Implications for practice

This needs assessment demonstrates the usefulness of POCUS use in acutely ill and injured children in RLS and highlights the importance of working with local clinicians prior to curriculum development. Local needs and pathology must be understood to create a relevant paediatric POCUS training programme. Knowing the most frequent clinical indications for POCUS examinations and the pathology identified may help in the creation of local symptom or complaint-based POCUS protocols. Symptoms such as tachypnea or oedema can prompt certain examinations to aid in narrowing the differential diagnosis. In a setting where a large portion of the clinical work is performed by non-physicians and where tests may not be available, ultrasound examination protocols based on patient symptoms may be most applicable to practice.

Limitations

We acknowledge several limitations in our study. First, there may have been selection bias in the identification of patients who received POCUS examinations. Given that POCUS had not yet been introduced in this site and use of ultrasound by radiology was uncommon, local clinician unfamiliarity with POCUS may have precluded requests for POCUS examinations to be performed in patients with relevant clinical indications. In addition, the visiting PEM physicians' unfamiliarity with local pathology and disease presentation also may have biased patient selection, although all visiting PEM physicians performing POCUS examinations had worked clinically at this site before.

Another limitation of the study was that it was a convenience sample of POCUS examinations performed by three physicians who were simultaneously working clinically in the department, and findings may have been affected by confirmation bias. Though there was no immediate review of POCUS studies to confirm accuracy, all studies were reviewed by the POCUS fellowship trained investigator (Beth M. D'Amico), as is typical in emergency medicine practice. Also, as the hospital is a referral centre for ill children and the patients who received POCUS examinations were located in the highest acuity areas of the paediatric ward, the number of positive findings may not be representative of the pathology of the entire ward.

Finally, the physicians were in Malawi only intermittently throughout the 1-year study period. Thus, seasonal variability of disease burden (e.g., higher rates of malaria in the rainy season), may have also led to certain pathology being over-represented or under-represented.

CONCLUSION

This study gives insight into the role of POCUS in the care of acutely ill children in Malawi, where a significant amount of pathology was identified. Common pathology identifiable on POCUS, clinical indications for examinations, and the most used examination modalities were determined. With this information, locally relevant POCUS curricula and protocols will be developed to improve training for clinicians at KCH. To better understand the utility of POCUS in paediatric RLS, future studies should assess the clinical impact of the tool through assessing changes in decision-making and outcomes.

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