Paediatric point-of-care ultrasound in a resource-limited Melanesian setting: A case series

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Abstract

Point-of-care ultrasound (POCUS) is an imaging modality with high potential impact on the practice of paediatric emergency medicine in resource-limited settings. Aside from the obvious diagnostic utility, it facilitates safe procedural guidance at the bedside and provides haemodynamic information to guide resuscitation of shocked states. This five-patient paediatric case series illustrates the range of POCUS modalities used while working in emergency medicine at a regional referral hospital in Vanuatu. Cases described include a teenager with meningococcaemia, femoral central line insertion in an infant, ventricular septal defect in an infant, a child with a leg abscess, and a child with rheumatic heart disease.

Keywords: paediatrics, POCUS, resource-limited setting, echocardiography, Pacific Islands.

Introduction

The use of portable and point-of-care ultrasound (POCUS) has been demonstrated to have a high utility in resource-limited settings (RLS).[1–14] For 6 months, the author worked as an emergency physician at Northern Provincial Hospital on Santo Espiritu in Vanuatu, the regional referral centre for a primarily rural population of approximately 150,000 in the northern islands. Vanuatu has high fertility rates, and almost half of Vanuatu's population are under nineteen years of age.[15] This led to a high proportion of paediatric presentations, but unfortunately human resource and funding limitations meant there was no paediatric trainee or specialist staffing the paediatric ward. In addition, the X-ray machine was rendered out of action for half of the six-month period, and the radiology department is not staffed by a radiologist. For all these reasons, POCUS was heavily relied on as an adjunct for diagnosis, resuscitation and procedural guidance in children. The following series is a representative sample of cases to demonstrate POCUS modalities which may be useful when providing emergency and critical care for children in low- and middle-income countries (LMIC).

Methods

POCUS was performed in the emergency department (ED), and also in the inpatient wards as a continuation of initial care or as requested by the paediatric team. Junior doctors performed POCUS under the author's supervision as part of their training, but the imaging for all of the cases included below was performed and interpreted solely by the author. On average, approximately three to six scans were performed per day across all age groups by the author. In some cases, the author only became involved in a patient's care part way through their admission, so POCUS was not performed until hours or days after initial presentation.

A Sonosite M-Turbo was used for imaging. Four probes were used: C60x curvilinear probe (5–2 MHz), HFL50x linear probe (15–6 MHz), P21x phased array adult cardiology probe (5–1 MHz), and for a limited time, the P10x neonatal cardiology probe (8–4 MHz).

Retrospective review of all archived paediatric POCUS images was undertaken, and a representative sample selected to illustrate a variety of modalities.

A local doctor who is a native Bislama speaker obtained written consent from each patient's parent/guardian to publish the cases, except for one patient who had turned eighteen years old and provided their own consent.

CASE 1 – Meningococcal septic shock

A seventeen-year-old female patient presented to the Emergency Department (ED) in the evening after 12 h of fever, generalised aches, vomiting and loose stools. This occurred on a background of 3 months of large joint arthralgias, borderline thrombocytopenia, and mild anaemia.

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Her family history included systemic lupus erythematosus, her mother having died of disease complications the year prior.

On examination, she had an elevated temperature of 39.2 degrees Celsius, low blood pressure (BP) of 80/40 mmHg, and a thready radial pulse of 139 beats per minutes (bpm).

Despite administering three litres of intravenous (IV) crystalloid fluids, her systolic BP dropped further to between 40 and 60 mmHg, and she became progressively hypoxic with lung crackles, requiring the administration of oxygen.

Bedside ultrasound was performed to guide resuscitation. Her IVC was dilated with minimal respirophasic variation, consistent with adequate right ventricular (RV) preload (Figure 1 a). Left ventricular (LV) systolic function was mildly impaired. Though there was no baseline echocardiogram for comparison, the absence of a hyperdynamic left heart in a vasoplegic patient with septic shock was indicative of septic myocardial dysfunction. Her RV was not dilated, tricuspid annular plane systolic excursion (TAPSE) was >2.0 cm, and pulmonary artery pressures (PAPs) were normal, excluding right heart dysfunction as the cause of shock.

On lung ultrasound, there were diffuse B lines bilaterally, consistent with iatrogenic fluid overload in the setting of anuria and raised left atrial filling pressures.

Focused abdominal ultrasound showed easily visualised bowel loops with 'to-and-fro' movement of bowel contents and absence of peristalsis, consistent with ileus as a cause for vomiting (Figure 1 b). No free abdominal fluid was seen.

After urinary catheter insertion, there was no urinary output, raising the possibility of a misplaced catheter. However, using POCUS, the catheter balloon was confirmed to be correctly situated inside an empty bladder.

Synthesising the ultrasound findings with the clinical scenario, it appeared the patient was in septic shock with severe vasoplegia and mild systolic impairment. Initial fluid resuscitation had optimised the patient's preload, but had also caused fluid overload and pulmonary oedema.

Hydrocortisone 100 mg IV and ceftriaxone 2 g IV were administered. Labwork returned after a few hours, revealing a metabolic acidosis with pH 7.08, lactate 14.8, acute kidney injury with creatinine of 188 μmol/L, transaminitis, hypoglycaemia, and anaemia with Hb 8.6 g/dL. Once the anaemia and pulmonary oedema were recognised, crystalloid resuscitation was stopped, and replaced with cautious packed red cell transfusion. Low doses of push-dose adrenaline were used to increase her systemic vascular resistance and improve her inotropy,[16,17] as adrenaline and dopamine were the only vasoactive agents available, and infusion pumps were not easily accessible overnight. Once her blood pressure and hypoxia had improved 12 h after presentation, adrenaline was stopped and the patient was admitted to the medical ward.

Blood culture gram staining showed gram-negative diplococci, consistent with Neisseria meningitidis as the cause of septicaemia. The patient developed anuric renal failure with a creatinine peak of 651 μmol/L; on day 4, >20 mL/kg/h urine output was re-established, and thereafter, urinary output and renal biomarkers gradually normalised. The patient was discharged after fourteen days of IV antibiotics. Exposed healthcare workers were required to take prophylactic rifampicin for 3 days.

An anti-dsDNA level checked 2 weeks after discharge was >80.0 IU/mL (<7), highly specific for systemic lupus erythematosus. She was then commenced on oral prednisolone. It is notable that an association between Neisseria meningitidis infection and systemic lupus erythematosus has been described previously,[18] potentially due to functional hyposplenism resulting in reduced bacterial clearance.[19]

Cardiac, IVC, lung, renal and bladder ultrasound are all valuable haemodynamic data points when undertaking resuscitation. The American Society of Echocardiography (ASE) published guidelines in 2015 for the use of echo as a monitor for therapeutic intervention in adults.[20] Algorithms such as the Echo-Guided Life Support have simplified this for everyday clinical practice.[21] Similar principles have been translated to paediatrics, with more research occurring recently in this field.[22–25]

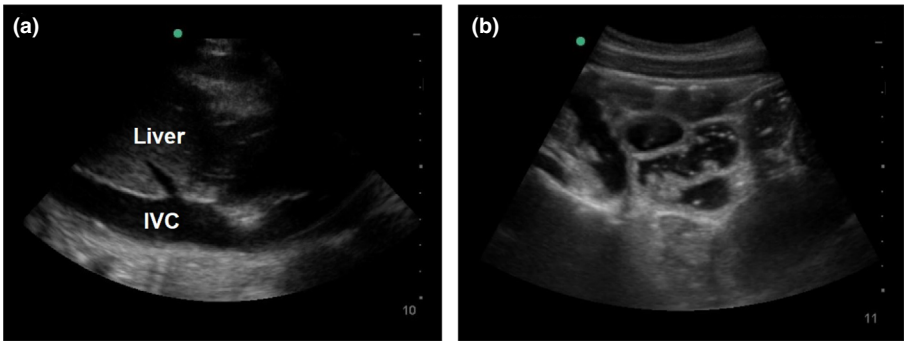

Figure 1: (a) Dilated IVC in a teenager with meningococcal septic shock after 3 L of IV crystalloid administration. (b) Midline abdominal view showing prominent dilated bowel loops without active peristalsis, consistent with ileus.

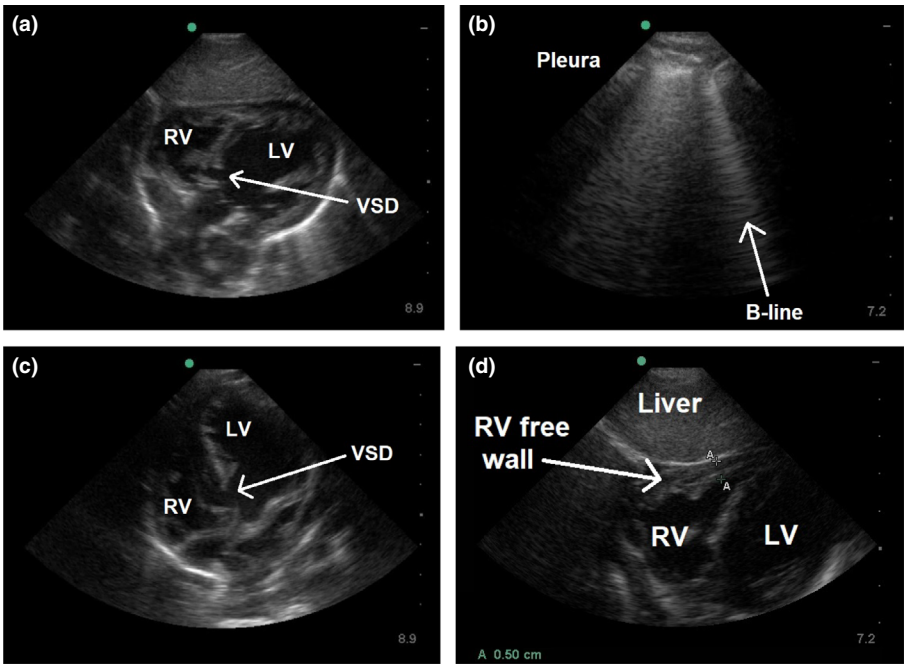

Figure 2: (a) Subcostal cardiac view in an infant with a perimembranous VSD and small pericardial effusion. (b) B lines seen throughout the lungs in an infant with hypoxia and VSD, consistent with pulmonary oedema. (c) Apical four-chamber view in an infant with a perimembranous VSD, 48 h after diuresis commenced, with pericardial effusion now resolved. (d) Subcostal measurement of RV free wall in an infant with VSD and suspected right heart sequelae, 48 h after diuresis commenced.

CASE 2 – Ventricular septal defect

A 3-month-old female patient presented with cough and dyspnoea and was admitted with a working diagnosis of bronchiolitis. Despite appropriate supportive care, she had shown no clinical improvement after a week. The infant was persistently tachypnoeic with normal oxygen saturations, and variable chest auscultation findings including crackles, wheeze, and a clear chest.

After the treating team noted a pan-systolic murmur, bedside echocardiography was performed using a neonatal phased array probe. A small pericardial effusion was present (Figure 2 a). A four-chamber heart with normal aortic outflow was seen. LV systolic function was grossly normal. A ventricular septal defect (VSD) was identified on colour doppler imaging with left-to-right flow. Using colour doppler on the parasternal short axis (PSAX) view, the septal defect was visible at the 10 o'clock position, consistent with a perimembranous VSD. The diameter of the VSD was measured between 3 and 5 mm on four different views: apical four-chamber (A4C) (Figure 2 c), parasternal long axis (PLAX), parasternal short axis (PSAX), and subcostal (SC). These measurements were then interpreted relative to the AV annular diameter of 10mm, classifying the VSD size as small-to-moderate. Peak VSD velocity was measured at 3.4 m/s. The RV wall was severely hypertrophied, with RV wall thickness appearing similar to the LV, and a measured diameter of 5mm on the subcostal view. Pulmonary valve opening appeared grossly normal. The IVC was collapsing.

Lung ultrasound revealed diffuse B lines consistent with pulmonary oedema (Figure 2 b), and absence of pleural effusions.

After the VSD was diagnosed, oral frusemide was started and the child improved within 24 h. Repeat echocardiography after 48 h of diuresis showed resolution of the pericardial effusion (Figure 2 d). The patient was discharged home on frusemide, for outpatient review at the next clinic run by a paediatric cardiologist and echocardiographer visiting from overseas.

Paediatric echocardiography is an advanced skill set, and POCUS practitioners will not be able to identify all congenital cardiac lesions and quantify them accurately. However, in this case, a VSD was diagnosed, and its location and severity were estimated. This meant provisional management steps could be taken, outpatient review could be organised at appropriate intervals, referral to a paediatric cardiologist made, and discussions commenced with the child's parents regarding the possibility of future travel overseas for surgical repair if the VSD did not close spontaneously.

Focused cardiac ultrasound (FoCUS) in adults has been described as restricted to the assessment of five E's: pericardial Effusion, LV Ejection fraction, ventricular Equality, Exit (aortic root diameter), and Entrance (IVC).[26] Although infants with critical illness due to cardiac disease will often manifest clear

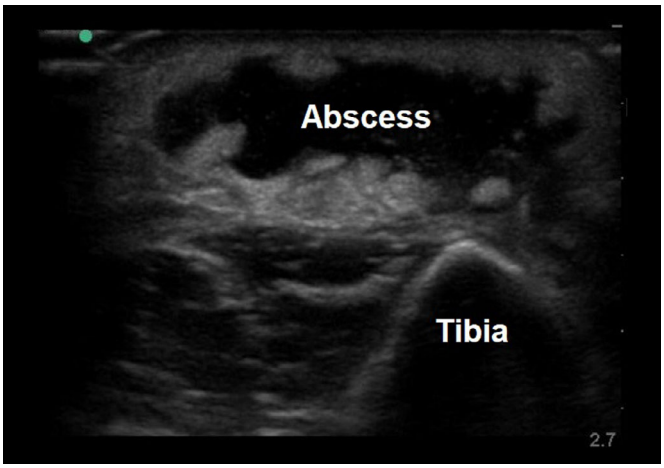

Figure 3: Transverse anterior right leg view, demonstrating a collection overlying the anterior tibia.

sonographic findings, clinicians with adult FoCUS skills must exercise caution translating their adult experience over to paediatric imaging. It should be strongly emphasised that POCUS users cannot adequately rule out structural heart disease, so children with an apparently normal bedside echocardiogram, but ongoing suspicion for a cardiac defect, must always be referred for paediatric cardiology assessment if and when available.

CASE 3 – Leg abscess

A 7-year-old girl was admitted with five days of pain, fever, difficulty walking, and swelling of the right anterior leg. Examination revealed a fever of 38.3 °C, and a tender, warm lump anterior to the tibia.

On bedside ultrasound, a discrete compressible fluid collection was seen, measuring 22 × 30 mm with a depth of 10 mm. Contents of the collection appeared heterogeneous and hypoechoic, with no vascular flow on colour doppler imaging (Figure 3).

The girl was admitted on cloxacillin. The collection was drained in the operating theatre the following day, with pus drained and an intact periosteum found.

In children with acute infectious swellings, clinical examination often correctly rules in or out abscess formation by the presence of features such as fluctuance and induration. However, the addition of POCUS to the assessment in ED will increase accuracy. A recent meta-analysis of PEM POCUS for soft tissue infections demonstrated a sensitivity of 93.9% and specificity of 82.9% for identifying abscess.[27] A negative likelihood ratio of 0.07 suggests POCUS may be particularly useful for ruling out abscess in the PEM setting.

CASE 4 – Rheumatic heart disease

An 11-year-old male patient presented with one week of right knee swelling and 2 days of right plantar foot pain. He had been well prior, aside from a possible history of several episodes over the last year of similar large joint swelling, which had fully resolved. He had no fever, dyspnoea, chest pain, and no recent sore throat or skin infection. His prior history included admission for pneumonia as an infant, and for gastroenteritis. He had no known cardiorespiratory history. He was vaccinated. He was on no regular medications and had not taken any medication for this event.

On examination, he was afebrile with normal vital signs and weighed 34 kg. He walked with a limp. Examination revealed mild intra-articular swelling of the right knee, with normal range of motion, and mild plantar tenderness of the right foot. He had grade 3/6 diastolic and systolic murmurs.

Electrocardiogram (ECG) showed a PR interval at the age-adjusted upper limit of normal – 0.16 s. Blood tests revealed an erythrocyte sedimentation rate (ESR) of 60 mm/h and borderline elevated WBC.

Bedside echo demonstrated thickened mitral valve leaflets with reduced mobility, and diastolic doming of the anterior mitral valve leaflet (AMVL) (Figure 4a, 4b). Mitral stenosis was present but did not appear severe on qualitative 2D assessment. There was a moderate jet of mitral regurgitation. The left atrium was mild-to-moderately enlarged. The aortic valve appeared tricuspid, with mild-to-moderate aortic regurgitation. Otherwise, ventricular function was not significantly impaired, and no pericardial effusion was present. These findings were consistent with mitral and aortic valvulopathies, in the setting of likely acute-on-chronic rheumatic fever.

Eventually a send away laboratory test for anti-streptolysin-O titre (ASOT) eventually returned at 543.2 IU/mL, providing evidence for a recent streptococcal infection, which had triggered an immune response.

The boy was commenced on intramuscular penicillin injections as secondary rheumatic heart disease prevention and referred to a visiting paediatric cardiology team for review.

There is a high burden of rheumatic heart disease in the Pacific.[28–32] Primary prevention of rheumatic fever is achieved through widespread use of antibiotics for children and young adults with suspected streptococcal throat and skin infections. After patients have had their first episode of rheumatic fever, early identification of rheumatic valvulopathies will allow secondary prevention with long-term penicillin administration and regular assessment for deteriorating cardiac function. Echocardiographic screening programs, including nurse-led programs,[33] are one method for identifying asymptomatic cases. Children in RLS may also attend ED with cardiac or non-cardiac complaints, and have a murmur auscultated. Due to geographical isolation, these families may have poor compliance with follow-up or attendance at scheduled cardiac clinic. The ability to identify valvulopathies opportunistically at point-of-care allows for earlier treatment and referral, and will decrease a child's chance of worsening valvulopathy and heart failure with each successive rheumatic fever episode.

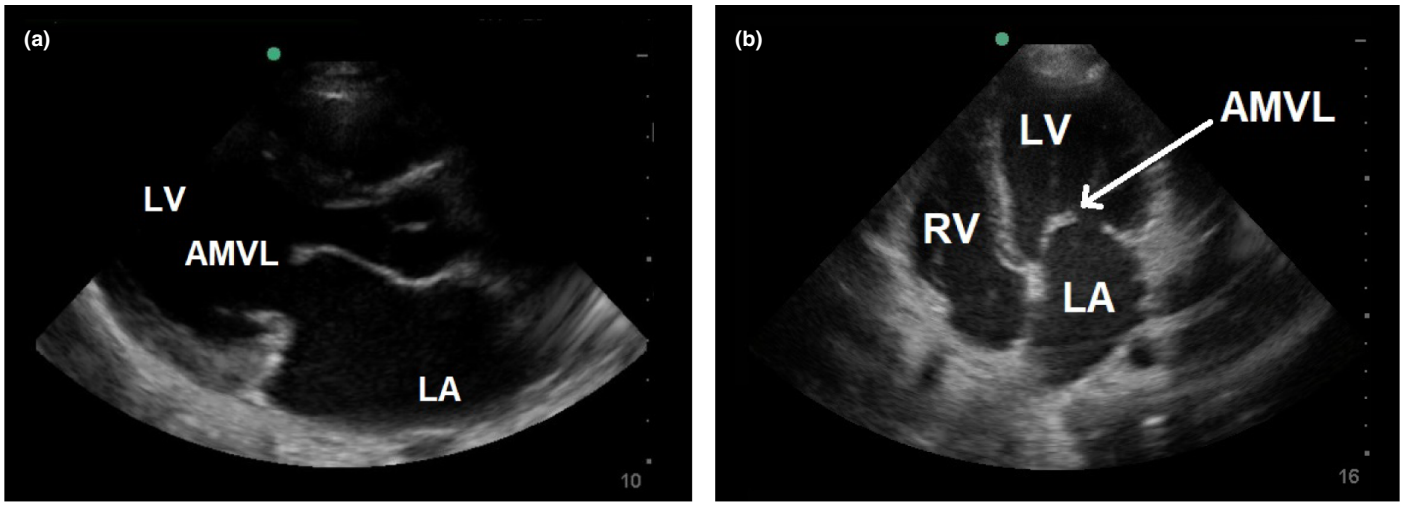

Figure 4: (a) PLAX cardiac view showing thickened mitral valves, enlarged left atrium, and diastolic doming of the AMVL. (b) A4C cardiac view showing thickened mitral valves, enlarged left atrium, and diastolic doming of the AMVL.

CASE 5 – Femoral venous line insertion

An infant was admitted repeatedly from age 8–13 months. Though their diagnosis was unclear, the infant was suspected to be suffering from cerebral palsy complicated by seizures, recurrent episodes of meningitis, sepsis and electrolyte derangement. Though local nursing and medical staff were usually highly competent at obtaining IV access, this particular child often spent days on the ward without an IV line and/or laboratory results, due to their exceedingly difficult access.

On two separate admissions when presenting critically unwell, ultrasound-guided femoral venous lines were placed to expedite investigation and management.

Maintaining a sterile field as per available equipment, the groin was prepped with iodine. Eighteen- or 20-gauge IV needles were selected as an appropriate calibre to allow rapid fluid bolusing and to reduce the likelihood of blood samples haemolysing.

The infant was positioned supine, with externally rotated hips. The anechoic lumen of the femoral vein was visualised in transverse view below the inguinal ligament; then, its path visualised over the course of several centimetres distally. The depth of the vein was estimated; then, a puncture site chosen inferiorly, approximately double that depth. The needle tip was advanced slowly and incrementally at a shallow thirty degree angle, maintaining constant sight of the echogenic needle tip, until the tip was visualised hovering above the vein. After puncturing the wall and entering the vein lumen, blood was aspirated and the plastic cannula fully advanced and secured to the skin. Laboratory samples could then be drawn, and IV fluid and antibiotics administered.

POCUS users should strive for the optimal level of sterility in all environments, and central venous access is a particularly high-risk procedure for nosocomial infection. Along with standard sterilisation of insertion site and equipments, a supply of probe covers and sterile gel sachets will help to achieve optional sterility in a RLS. In addition, the probe should always be thoroughly cleaned with an appropriate product post-procedure.

Discussion

Beyond the cases described, POCUS was used to assess for a wide variety of diagnoses in children including pneumonia, pleural effusions, appendicitis, ovarian torsion, and hip joint effusions. Other modalities with a high yield in PEM POCUS include the diagnosis of intussusception, and identification of soft tissue foreign bodies.[34,35] In environments with a high incidence of communicable diseases, sonologists use the FASH examination[36] to screen for suspected TB effusions, assess for oedematous states in dengue patients to guide fluid management and identify patients at high risk for deterioration,[37,38] and assess the presence and degree of hepatomegaly or splenomegaly in patients with malaria.

With CT and also often X-ray unavailable, POCUS assessment for limb and skull fractures was particularly useful too. Sound energy is almost completely reflected at the soft tissue–bone interface, providing a crisp image of the cortical line and straightforward identification of cortical defects. For some bones such as ribs, the sensitivity of ultrasound for fracture in non-obese patients equals or even surpasses that of X-ray.[39,40] The midline symmetry of a human body allows for bilateral comparison, to help differentiate normal from abnormal. A common pitfall to note in paediatric bone POCUS is mistaking a growth plate for a fracture.

POCUS diagnosis of fractures in PEM is developing a stronger evidence base in recent years, with the goals of faster diagnosis, shortened length of stay, and reduced irradiation.

Ultrasound-guided fracture manipulation also eliminates the need for a portable X-ray machine and radiographer. Currently, orthopaedic surgeons have a preference for diagnosis with X-ray, as X-ray is less operator-dependent, and current orthopaedic treatment algorithms are based on X-ray findings. More multidisciplinary research is required to guide how ultrasound can accurately guide orthopaedic decision-making in RLS.

With decreasing cost of ultrasound and improving quality of mobile networks worldwide, there is increasing potential for telemedicine in RLS. If a POCUS user in an isolated environment can obtain a standardised set of images, they can then receive remote assistance in interpretation and synthesis of those images by radiologists or other sonologists.[41–43]

POCUS users travelling to a RLS should anticipate that insuring ultrasound equipment, particularly machines donated on long-term loan basis, may be challenging. Depending on the availability of in-country financial services, a local insurer may be easier to find than an insurer based in the visitor's home country.

Clinicians using POCUS as an adjunct to emergency care provision in a RLS should be aware of a number of potential pitfalls:

1 De-skilling local sonographers by removing a portion of their workload. Where necessary or potentially helpful, POCUS imaging can usually be followed by a comprehensive departmental scan, with a collaborative attitude by both EM and sonography staff leading to best outcomes.
2 Both visiting and local POCUS users should be careful not to undermine the credibility of staff sonographers. This may occur in cases where POCUS and comprehensive ultrasound results are discordant, and local clinicians are left unsure which report is more accurate.
3 Failure to pass on skills to local staff. When engaging long-term in a resource-limited health system, formalised training and credentialing will be crucial to sustainably build local capacity and create a culture of high quality sonography.[44,45]
4 When teaching, prioritising modalities which are not high yield for the local setting. For example, a patient with an abdominal aortic aneurysm (AAA) in Vanuatu has no surgical option unless they are wealthy or insured, and can travel overseas. Though identifying a AAA may provide prognostic information or avoid a futile laparotomy in a patient with a ruptured aneurysm, the diagnosis of pathology that is treatable locally should be prioritised when training local staff.
5 Lack of oversight, peer review, and quality control in isolated environments. POCUS users should collaborate with local sonography and radiology staff as able, and engage in remote secure image sharing and discussion with experienced ultrasound mentors and teachers from overseas.
6 POCUS users in a RLS should anticipate the need to attempt imaging which is outside their formal training scope. Situations will arise where the POCUS operator may be the best available operator to perform an urgent scan, where the alternative for a patient would be no imaging at all. One such situation might be a clinician experienced in adult echocardiography attempting focused paediatric echocardiography. Common sense should prevail in these circumstances by obtaining remote review of images through pre-established mentoring networks, using guidelines and reference texts to guide imaging technique, openly disclosing to colleagues one's degree of uncertainty regarding the findings, serial examinations to confirm findings, and recognising the fine line where attempting a complex/unfamiliar modality may result in more harm than benefit.
7 Failing to achieve an acceptable degree of probe sterility and cleaning. Most care provided in a RLS will occur in a lower level of sterility than that achieved in resource-rich environments. However, POCUS users should always strive to achieve the highest possible degree of probe cleaning, within the resource constraints of the local setting.

Conclusion

Doctors practicing emergency medicine in resource-limited settings will provide improved care to all age groups by using POCUS when indicated. Cardiac, pulmonary, abdominal, muskuloskeletal, procedural guidance and haemodynamic assessment were some ultrasound modalities found to be useful when providing paediatric acute care in a Melanesian setting. Further research is needed to establish which POCUS modalities will have the highest potential impact on the emergency and critical care of children in low- and middle-income countries.

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Conflict of interest

An M-Turbo ultrasound machine was provided free of charge as a six month long-term loan by Fujifilm Sonosite Australia Pty Ltd and was subsequently donated to the Vila Central Hospital Emergency Department.

Ethics approval

Dr Andy Ilo, the Acting Medical Superintendent of Northern Provincial Hospital, has approved the publication of this case series. Written consent was obtained from the parents of the children in all 5 cases, and from the patient herself in Case 1, as

she had turned 18 years old by date of submission. An information sheet was provided in written English and Bislama. The information was discussed in Bislama by a local doctor, Dr Linda Kitawi. A clinical trial was not registered. Participant registration occurred during the author's stay in Vanuatu, which was from March-September 2019.

Authorship statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the AJUM.

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