The Assessment, Evaluation, and Management of the Critically Ill Child in Resource-Limited International Settings

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Abstract

Providing evidence-based care to the critically ill child including assessment, evaluation, and management in resource-limited settings provides unique challenges and limitless opportunities to significantly impact morbidity and mortality in these settings. Difficulties encountered include: determining which disease processes will benefit most from critical care in resource-limited settings, lack of triage tools and adjuncts to help with assessment, finite laboratory and radiological tests, limited understanding of key findings in critically ill/injured pediatric patients, (especially by those without pediatric focused training), and finally, lack of supplies, medicines, equipment, and training of health care providers to appropriately treat critically ill children in these resource-limited settings. In this review, the most common problems encountered and possible solutions to overcome these obstacles are discussed.

Keywords
- intensive care unit
- critical care
- low-resource setting

Introduction

The management of a critically ill child who presents for care in a resource-limited setting is a daunting task. The global burden of disease disproportionately affects children in low- and middle-income countries (LMICs) where the amount of resources available to care for a critically ill child is limited. Each year more than 11.9 million children between the ages of 0 and 14 years die of an illness. The vast majority of these deaths occur in LMICs,[1] and up to 70% could be prevented if critical care was readily available.[1]

Six leading causes of death account for up to 73% of all deaths among children younger than the age of 5 years, which include acute respiratory infections, diarrheal disease, prematurity and low birth weight, neonatal infections such as sepsis, birth asphyxia, trauma, and malaria.[2] All of these diseases could potentially be treated with the availability of critical care for children. Although critical care for children has developed and flourished in higher income countries, the vast majority of the developing world lacks the monetary and personnel resources needed to implement many of the advances in critical care.

Moreover, children who present for critical care in resource-poor settings tend to be sicker on arrival due to underlying malnutrition, lack of access to basic immunization, and delayed presentation due to the difficulties of travel in remote regions. Ideal implementation of critical care for children requires a coordinated system of triage, emergency interventions, and continued care in the intensive care unit (ICU).

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As noted earlier, traumatic injuries are one of the significant causes of death and disability worldwide and require additional skills beyond those needed for medical illness. Unintentional injuries result in the death of approximately 830,000 children every year[3]; 95% of these deaths (both intentional and unintentional) occur in LMICs.[3] The top five etiologies for unintentional injuries reported by the World Health Organization (WHO) are road traffic injuries (RTIs), falls, burns, drowning, and poisoning.[3] The WHO estimates that by 2020, injuries will constitute the leading "disease" globally and will likely account for 20% of all disability-adjusted life year losses for the world's population.[4] Given limitations in the availability of the resources necessary to provide the levels of care found in high-income countries, strategies to make the best use of available resources and achieve the best possible outcomes for injured and critically ill children are vital.

Therefore, it is against this backdrop and burden of critically ill and injured children that recommendations must be developed that are context specific—cost effective care that provides the highest dividend when the total resources available to care for children are limited. Strategies for critical care must be adapted to function within low-resource settings where the diagnostic, therapeutic, and monitoring technologies available in high-income countries are typically unavailable.

Deciding to Intervene

The most fundamental difference in the approach to critical care for children in resource-limited settings as compared to high-resource areas is to appropriately choose children in whom to intervene and provide with critical care. This decision must be informed by the underlying diagnosis as well as the ability of the family and community to provide ongoing care after the acute treatment in the ICU. The vast majority of care in resource-limited areas are paid directly by patients and their family members[5] as opposed to the government or a third-party insurer as is standard in high-income countries.[6] This places significant constraints on possible treatment options because the burden of payment will largely be borne by the family and many times health care expenditures alone can push a family into poverty through the loss of a home, arable land, and the basic means of earning a livelihood. Thus, the pediatric intensivist in resource-limited settings must carefully weigh the potential for improvement in the child's condition as well as long-term prognosis against the potential for significant economic harm to a family that is seeking to provide care for a critically ill child.

The pediatric intensivist in the developing world must carefully consider the diagnosis of the patient and the likelihood of full recovery because in most resource-limited countries, ongoing community-based rehabilitation and help for children with chronic illnesses are limited at best. For example, when a child comes in with fulminant liver failure or a neonate presents with moderate to severe hypoxic ischemic encephalopathy from birth asphyxia, the intensivist must take into account that even if critical care is provided, the long-term prognosis is poor. For a poor family, liver transplantation will be out of reach and caring for a child with significant neurologic deficits due to hypoxia is almost impossible in an agrarian society when everyone in the family must work to cultivate crops for subsistence.

Thus, at the institution of one of our authors (C.P.) (Duncan Hospital) in Raxaul, Bihar, India, where the vast majority of patients earn less than $1(US) per day, one of the first conversations with the family before initiating critical care is the likely long-term prognosis and likelihood of return to the premorbid state. There are instances where the child is critically ill and will require a significant expenditure of resources, but one that will likely have a good outcome, where we can choose to intervene. One example of this is tetanus in the pediatric population. Even though tetanus requires intensive care and often requires airway support and excellent nursing care for several weeks, the vast majority of children will leave the hospital neurologically intact and be able to return to their preillness state. In such a situation, a case can be made for intervention since the ongoing burden on a poor family will be minimal after the acute hospitalization. Another example would be a child who has been envenomed by a cobra bite, which causes neurotoxic symptoms including respiratory paralysis and death due to asphyxia. However, with good critical care including early intubation and ventilation, the vast majority of children recover with normal neurologic function with just 1 to 2 days of ventilatory support and are able to return to their preillness state. However, in the case of a child who presents in septic shock secondary to a hematologic malignancy there is little justification for intensive care, because even if the child survives the acute infection, most families in resource-poor settings cannot afford the costs for treatment of a blood-borne cancer. In addition, as pointed out by Argent, treating illness without long-term therapy may not be the best use of ICU resources in this setting.[7] Thus, unlike resource-rich areas where every effort is made to give every child the best chance for recovery in spite of the costs of treatment, the pediatric intensivist in a resource-limited setting must have clear inclusion and exclusion criteria to discern which child would be benefitted by critical care (►**Table 1**).

Early Recognition of the Critically Ill Child

Early recognition of the critically ill child begins with the development of an appropriate triage system. As noted previously, patients often present for care after more than 24 hours of symptoms and, thus, prompt recognition of their acutely ill state is essential to providing rapid and appropriate care. Triage systems and scores have been developed for use in resource-limited settings such as the "South African triage scale."[8] This scale is one example of a tool that ensures that patients receive the most appropriate level of care according to their clinical status. It uses a physiologically-based scoring system with a list of discriminators to triage patients into specific color-coded priority groups so that they can be attended to appropriately. Improved triage and emergency care have been shown to reduce inpatient mortality in

Table 1 Conditions based on prognosis

Conditions that would benefit from critical care in resource-poor settings where there is *good* long-term prognosis	Conditions that would not benefit from critical care in resource-poor settings where there is *poor* long-term prognosis
Pneumonia with septic shock	Severe hypoxic encephalopathy
Diarrhea with hypovolemic shock	Very low birth weight infants
Acute renal failure	Chronic renal failure
Malaria	Fulminant liver failure
Status asthmaticus	Cardiomyopathy
Accidental poisonings	Traumatic brain injury with GCS < 8
Meningitis	Inborn errors of metabolism
Skin and soft tissue infections	End-stage rheumatic heart disease with heart failure
Blunt abdominal injury with hemorrhagic shock	Complications related to cancer
Tetanus	Necrotizing enterocolitis with perforation
Neurotoxic snake bites	Complex congenital heart disease

Abbreviation: GCS, Glasgow Coma Score.

Malawi[9] and South Africa.[10] Similarly, an overall decreased mortality was seen in children enrolled in the Fluid Expansion As Supportive Therapy (FEAST) trial compared with severely ill children enrolled in previous studies (9.4 vs. 28.2%).[11] One potential explanation given by Jacob et al for the unexpected decreased mortality was training of all health staff on triage and monitoring before commencement of the study.[12]

Although the practice of evidence-based medicine remains an important tenet in health care in all settings, many of the protocols that have been designed for use in high-resource settings require frequent laboratory or invasive monitoring that is not feasible in resource-limited settings. For example, the surviving sepsis guidelines call for monitoring of lactate and systemic venous oxygen saturation (SvO_2) measures that are not likely to be easily obtained in the low-resource setting. WHO has developed guidelines that are more appropriate for low-resource settings that include careful monitoring of the patient rather than diagnostic tests. Therapy is adjusted based on vital signs and physical exam findings rather than on lactate and SvO_2.[13] This concept of evaluating the patient based on physiologic signs and symptoms is essential to medical care in resource-limited settings where expensive diagnostics are not appropriate and cannot be obtained in a timely manner.

Another aspect of care that can impact early recognition is the importance of well-trained personnel. In low-resource settings, most ICUs are not managed by intensivists. Doctors are often stretched thin caring for large numbers of patients and working outside their area of formal training. Thus, it becomes imperative to have well-trained, dedicated ICU nurses caring for these patients. Without adequately trained nurses available 24 hours a day, few lives will be saved by having a critical care unit. There is little justification to purchase expensive equipment such as ventilators and defibrillators for a resource-limited setting if the nurses caring for patients do not understand how to operate the machine properly or recognize when the machine is not functioning correctly. Empowering well-trained nurses can significantly improve delivery of care and is an overall low-cost critical intervention.

Choosing Appropriate Diagnostic Testing

In developed countries, a great deal of laboratory and radiographic images are often performed to guide therapy and arrive at a final diagnosis. In low-resource countries, if laboratory and imaging are available, they are often quite costly and not readily available in a timely manner to impact care. It is important that clinical decisions should be generally made based on the most likely diagnosis and the patient's response to appropriate medical intervention, with laboratory and other testing reserved for cases where there is a high likelihood that it will change treatment. An understanding of local prevalence of common diseases and seasonal variation is very helpful in appropriately limiting testing to those most essential. For example, in developing countries, tuberculosis (TB) has a disproportionately high burden of disease and thus, the differential diagnosis for many symptoms often begins with ruling out TB before entertaining more esoteric diagnoses. There are laboratory and imaging tests that are exceedingly helpful in guiding some therapies such as insulin therapy in diabetic keto-acidosis, exchange transfusion for hyperbilirubinemia, cultures to help with antibiotic selection in sepsis, a chest X-ray (CXR) in complicated pneumonia to look for effusion, or a computed tomography scan to look for an epidural hematoma. Yet the emphasis must be on cost containment to limit the economic burden on the patient and his or her family.

Although advanced radiographic imaging is often not feasible in a resource-limited setting, ultrasound can be an excellent low-cost tool in low-resource countries. Ultrasound

can be a useful tool to guide fluid therapy, diagnose pulmonary disease (pneumonia, pneumothorax, effusion), evaluate cardiac function, and place venous catheters if necessary.[14] Ultrasound technology has developed rapidly over the past few decades to where the machine is now portable and can be transported easily to very remote settings. Ultrasound can often make a significant change in management for a patient, including deciding if a patient should go to surgery after blunt trauma based on a FAST (focused assessment with sonography for trauma) exam or deciding on the best course of treatment for a soft tissue infection based on whether an abscess is present.[15]

Deciding which laboratory and imaging technology will be a priority in the setting of critical care will be dependent on the level of care possible in a given unit coupled with the diseases commonly seen. For instance, all critical care units in malaria endemic regions should have as an absolute minimum malaria testing, hematocrit levels, glucose screening, cerebrospinal fluid (CSF) cell count and differential with Gram stain, CXR, and complete blood counts. As resources become available that unit should strive to add complete electrolytes, blood, urine, and CSF cultures, and ancillary tests such as C-reactive protein and basic ultrasound.

Treatment and Management of Critically Ill Children

Treatment and management must always balance the burden of the cost of care with the potential for improvement and recovery to the premorbid state. Management decisions must be made while acknowledging that many interventions might not work as planned due to under trained staff, lack of access to reliable electricity, and difficulty in preventing nosocomial infections when the baseline level of hygiene is marginal.

It is beyond the scope of this article to talk about management of critical care illnesses and injuries in detail; however, we have attempted to provide some examples of suggested management of some of the more common illnesses and injuries seen in low-resource settings. We have included a tiered approach to management depending on supplies and

Table 2 Management of common pediatric diseases in resource-limited settings

Disease process	Evidenced-based adaptations for low-resource PICU	Evidenced-based adaptations for extremely limited PICU
Asthma	1. Beta-agonist via nebulizers 2. IV steroids 3. IV magnesium via continuous infusion 4. Nebulized ipratropium bromide or atropine 5. IV aminophylline 6. IV ketamine drip or intermittent bolus 7. Inhaled anesthetics	1. Beta-agonist via MDI with a spacer (homemade from bottle appropriate) 2. Steroids by mouth 3. IV magnesium via intermittent bolus Q2–4 h 4. SQ epinephrine or terbutaline 5. PO theophylline or aminophylline
Traumatic brain injury	1. Recognition of altered consciousness and lateralizing signs 2. Oxygen and if indicated, intubation and mechanical ventilation for children unable to protect their airway 3. IV fluid resuscitation with isotonic fluids (avoid overhydration) 4. CT scan if available 5. Hyperosmolar therapy (hypertonic saline (goal sodium 145–155), mannitol) 6. ICP monitoring with ventriculostomy (GCS 3–8). Goal ICP $<$ 15 mm Hg 7. Surgical drainage of extra-axial blood (SDH, EDH) 8. Maintenance of euthermia 9. Provision of adequate nutrition via early enteral feeding and avoid hyperglycemia 10. IV sedation and analgesia for patient comfort 11. Antiseizure prophylaxis (phenytoin or fosphenytoin) for 7 d postinjury	1. Oxygen (via cylinder or concentrator) and if indicated, intubation with BVM ventilation for transport to higher level of care 2. Cranial X-ray to evaluate for fracture (four views) 3. Hyperosmolar therapy with intermittent mannitol to keep serum osmolality 300–320 mmol/L. Avoid hyponatremia 4. Ongoing close neurologic examination. Recognition of lateralizing signs 5. Burr hole if equipment and skilled provider available 6. IV or PO sedation and analgesia as needed for patient comfort 7. Antiseizure prophylaxis (phenobarbital or phenytoin) for 7 d postinjury
Blunt abdominal trauma	1. FAST exam to look for intraperitoneal fluid/blood. Where available, consider CT scan. If not available, get abdominal X-ray 2. Urinalysis 3. Fluid resuscitation with isotonic fluids 4. Close and ongoing monitoring of vital signs and hematologic indices 5. Transfusion with whole blood or PRBCs for Hb $<$ 7 g/dL or hemodynamic instability 6. Surgical intervention for hemodynamic instability that persists despite fluids/blood products or free air on radiographic studies	1. If ultrasound not available, consider abdominal X-ray and/or diagnostic peritoneal lavage 2. If no transfusion capability, consider transfer to higher level of care for transfusion/surgical intervention

(*Continued*)

Table 2 (*Continued*)

Disease process	Evidenced-based adaptations for low-resource PICU	Evidenced-based adaptations for extremely limited PICU
Sepsis[16]	1. Recognize sepsis early and initiate treatment rapidly 2. Use adequate tissue perfusion as principal end point of resuscitation and target normal BP and HR in children 3. Maintain $Spo_2 > 90\%$ with supplemental O_2. If Spo_2 unknown, place on NC O_2 empirically 4. Establish IV access immediately (IO if needed) 5. Within 15 min of presentation, start aggressive fluid resuscitation with 20 mL/kg crystalloid infusion[a] 6. In the first hour of presentation, treat infection with antibiotics based on suspected pathogen or with broad-spectrum empiric treatment. Repeat IV crystalloid boluses up to total of 60 mL/kg if continued signs of tissue hypoperfusion, but noted improvement after infusion 7. 2–6 h: If persistent hypotension and/or signs of poor perfusion after aggressive fluid resuscitation, start inotropes if available (epinephrine or dopamine). Continue to aggressively give fluid paying close attention to signs of fluid overload (hepatomegaly, rales, respiratory distress).[b] If signs of fluid overload, you must weigh risk/benefit of additional fluid depending on your ability to support respiratory status (NIPPV, vent) 8. Send appropriate diagnostic tests of tissue/fluid based on suspected site of infection and drain/debride infected tissue	No change in therapy in extremely limited settings other than continued vigilance at recognizing signs of fluid overload due to lack of respiratory support options
Respiratory failure	1. Recognize signs of central cyanosis and/or respiratory distress: tachypnea, retractions, nasal flaring, $Spo_2 < 90\%$ 2. Oxygen therapy to maintain $Spo_2 > 90\%$ (improve cyanosis) via nasal prongs 3. If hypoxia not improved, or signs of respiratory distress, use NIPPV with CPAP (conventional or bubble) 4. Salbutamol nebulizer if wheezing (see asthma therapy above) 5. Antibiotics for presumed pneumonia/infection. Testing as available for malaria, TB/AFB, CXR, blood cultures 6. If poor response, consider pneumothorax, pleural effusion, heart failure, poisoning, TB, HIV with PCP	1. Bubble CPAP 2. Salbutamol via MDI with spacer (see asthma therapy above)
Snakebites, poisonous	*Neurotoxic snakes*: 1. Early identification of neurotoxic symptoms using a single breath count, recognition of ptosis, dysphagia, and dysarthria. Continuous Spo_2 monitoring if possible 2. Treatment with antisnake venom (lyophilized if possible since it does not require a cold chain) as soon as symptoms recognized 3. Early ventilatory support for children showing signs of respiratory failure *Hemotoxic snakes*: 1. Early identification of hematologic symptoms by measuring platelet count, PT/PTT, and fibrinogen, if available. Checking renal function by measuring creatinine and BUN 2. Treatment with antisnake venom for envenomed children 3. If bleeding complications, consider giving whole blood or blood products 4. Treatment of renal failure with peritoneal[18] or hemodialysis if available	*Neurotoxic snakes*: 1. As before except consider adding neostigmine as an adjunct in snake bites that affect the postsynaptic membrane (*Naja naja*) 2. Early intubation and manual bagging of an envenomed child until neurotoxic symptoms improve (usually improve in 24–48 h) *Hemotoxic snakes*: 1. Early identification of hematologic symptoms by using the 20-min whole blood clotting time[19] 2. Treatment of renal failure with careful fluid restriction and furosemide until renal function improves

Table 2 (*Continued*)

Disease process	Evidenced-based adaptations for low-resource PICU	Evidenced-based adaptations for extremely limited PICU
Severe malaria	1. IV artesunate until able to take orally then switch to oral ACTs 2. IV quinine (alternative) 3. Treat hypoglycemia 4. Transfuse if severe anemia (Hb $<$ 5 g/dL) 5. Treat seizures 6. Correct fluid and electrolyte imbalance; sodium bicarbonate if severe acidosis 7. Maintenance fluids via IV and/or NGT[20]	1. IM artemether 2. IV/IM quinine—can be given as one dose and referred to higher center or treatment continued till patient can take the ACTs orally to complete course 3. Glucose solution through NGT for hypoglycemia 4. Treatment of convulsions with rectal/IM diazepam
Poisonings	*OP*: 1. Early treatment with atropine in patients with cholinergic symptoms. Titrate atropine until bronchorrhea resolves. Avoid oximes in therapy due to cost and lack of efficacy[21] 2. Recognition of IMS by daily assessment of neck flexion strength[22] 3. Ventilatory support for patients with respiratory failure, consider tracheostomy if development of IMS since recovery can take several weeks *Hydrocarbons*: 1. Early recognition of aspiration based on respiratory distress or infiltrate on CXR 2. For children with respiratory distress, give oxygen, BiPAP, or intubation depending on severity	*OP and hydrocarbons*: 1. Same except palliative care for patients with severe IMS due to OP or ARDS due to hydrocarbon aspiration due to lack of access to ventilatory support. Usually unable to manually bag patients for the time required to recover from IMS
Tetanus	1. Treat with combination of benzodiazepines, phenobarbital, and IV magnesium. Consider switching to oral benzodiazepines via NGT to limit cost 2. If resources allow, consider magnesium infusion (can titrate with symptoms, presence or absence of knee jerks if levels unavailable) 3. Monitor with continuous pulse oximeter 4. Have positive pressure bag and mask available at all times 5. Intubation and ventilation may be best alternative if resources allow	1. Treat with combination of benzodiazepines, phenobarbital, and IV magnesium via intermittent bolus dosing every 2–4 h as needed 2. Remainder as previously mentioned
Seizures	*Neonate*: 1. IV/IM phenobarbitone 20 mg/kg stat, further 10 mg/kg can be given within 24 h, then maintenance doses of 5 mg/kg/d *Age $>$ 1 mo*: 1. Quick ABC assessment, start oxygen 2. Rectal diazepam 0.5 mg/kg/dose or IV diazepam 0.3 mg/kg/dose for up to 2 doses only, 10 min apart 3. Give IV D10W 5 mL/kg 4. If seizures do not stop, IV phenobarbitone 15–20 mg/kg. May top up with 5–10 mg/kg if seizures do not stop in 20 min, then maintenance dose of 5 mg/kg/d 5. If seizures do not stop at 45 min, load with phenytoin 20 mg/kg 6. If at 1 h seizures continue, give midazolam 0.3 mg stat then infusion 0.01 mg/kg/h	Same up to step 4, then refer[11]
Hypoglycemia	1. Treat neonates with 2–4 mL/kg of D10W 2. Older infants and young children with 1–2 mL/kg of D25W 3. Older children and adolescents with 0.5–1 mL/kg of D50W 4. May use IV bolus of any of these fluids if IV patency assured, however, if running continuously cannot use higher than D12.5W without central line	Same

(*Continued*)

Table 2 (*Continued*)

Disease process	Evidenced-based adaptations for low-resource PICU	Evidenced-based adaptations for extremely limited PICU
Vomiting, dehydration, diarrhea with shock	1. 20–30 mL/kg IV over first 1–2 h re-evaluating frequently and increasing or decreasing rate as appropriate based on ongoing losses, perfusion, urine output, and signs of volume overload 2. Use only isotonic fluids for rehydration (i.e., NSS, RL) without glucose 3. Continue maintenance fluids at 1.5–2X maintenance. Add ORS as soon as shock resolved 4. Treat hypoglycemia with bolus glucose as needed during treatment of shock. Add glucose to maintenance fluids	1. As with higher resourced areas but consider ORS per nasogastric tube if unable to start IVFs or IO fluids

Abbreviations: ACT, activated clotting time; AFB, acid fast bacilli; ARDS, acute respiratory distress syndrome; BiPAP, Bilevel Positive Airway Pressure; BP, blood pressure; BVM, bag mask ventilation; CT, computed tomography; CXR, chest X-ray; EDH, epidural hematoma; FAST, focused assessment with sonography for trauma; GCS, Glasgow Coma Score; Hb, hemoglobin; HIV, human immunodeficiency virus; HR, heart rate; ICP, intracranial pressure; IMS, intermediate syndrome; IVFs, intravenous fluids; IV, intravenous; MDI, metered-dose inhaler; NC, nasal canula; NGT, nasogastric tube; NIPPV, noninvasive positive pressure ventilation; NSS, normal saline solution; OP, organophosphates; ORS, oral rehydration solution; PCP, pneumocystis carinii pneumonia; PICU, pediatric intensive care unit; PO, per os/by mouth; PRBC, packed red blood cell; PT, prothrombin time; PTT, partial thromboplastin time; RL, Ringer's Lactate; SDH, subdural hematoma; TB, tuberculosis.

[a]If dengue fever suspected, start fluid resuscitation with colloid if available rather than crystalloid.

[b]Due to studies in children in Malawi with sepsis who were found to have increased mortality with overly aggressive fluid resuscitation be very attentive to signs of fluid overload. Higher risk noted in severely anemic patients and patients with malaria.[11]

Table 3 Supplies/training needed for critical care in resource-limited settings

Essential equipment list	1. Positive pressure bags and mask in infant, child, and adult sizes 2. Oral and nasopharyngeal airways 3. Pulse oximeter for each PICU bed 4. Suction machine 5. Oxygen concentrator or cylinders with nasal cannula, simple facemask, and non-rebreather facemask 6. IV cannulas (multiple sizes) and delivery sets (micro- and macrodrip) 7. Blankets to warm patients 8. Foley catheter supplies 9. BP cuffs in infant, child, and adult sizes with stethoscope 10. Nebulizer 11. Blood glucose strips/machine 12. Generator for electricity backup
Nice to have equipment	1. Chest tubes and bottles 2. Laryngoscope, Macintosh and Miller blades, ETTs (sizes 3–7 with stylettes) 3. IV pump with disposable tubing 4. Multiparameter monitors 5. Air compressor to help titrate Fio_2 and for future use with ventilator
Essential courses	NRP or HBB, PALS, APLS, and/or ETAT
Essential drugs	1. Epinephrine/adrenaline 2. IVFs—NS and RL 3. Broad spectrum antibiotics 4. Antimalarials 5. Pain medications (narcotics, if possible) 6. Albuterol or salbutamol 7. Atropine 8. Insulin and D_{50} 9. Steroids 10. Benzodiazepines, phenobarbital 11. Diuretics, IV antihypertensives (hydralazine, labetalol)
Nice to have drugs	1. Dopamine and/or dobutamine 2. Calcium, magnesium 3. Phenytoin, theophylline, midazolam 4. H_2 blockers

Abbreviations: APLS, advanced pediatric life support; BP, blood pressure; ETAT, emergency triage assessment and treatment; ETT, endotracheal tube; HBB, helping babies breathe; IV, intravenous; IVFs, intravenous fluids; NRP, neonatal resuscitation program; NSS, normal saline solution; PALS, pediatric advanced life support; PICU, pediatric intensive care unit; RL, Ringer's Lactate.

Table 4 Essential principles of pediatric care in resource-limited settings

Oxygen therapy	1. Know from where the oxygen source is coming and what the maximum possible liter flow is 2. Consistent electricity is a must if you are depending on oxygen concentrators 3. Nasal cannulas work best with low-flow systems such as concentrators 4. Non-rebreather/partial rebreather masks require high-flow oxygen to use
Pulse oximetry	1. Important monitoring tool for both the ward and the operating room 2. Heart rate reading must match the patient's actual heart rate in order for pulse oximeter readings to be accurate 3. Set the limits appropriate to child's condition and the limits the nurse should respond to (i.e., if a HR of 180 is acceptable in 14 mo with asthma, then set the high heart rate at 180 not 140 and expect the nurse to respond to the alarm 4. Pulse oximeter readings are dependent on pulsatile flow and usually accurate at 70–99%. Below 70 or at 100%, they are not accurate. Make pulse oximeter monitor audible with saturation changes which can be helpful in noting that a patient is having desaturation episodes 5. Potential inaccuracies with pulse oximetry may include decreased pulsatile flow caused by severe vasoconstriction in situations such as hypovolemia, hypotension, cold; cardiac failure can result in inability of pulse oximeter to pick up; bright overhead lights can cause the pulse oximeter to read inaccurately and pulse oximeter cannot distinguish between different forms of hemoglobin such as carboxyhemoglobin (CO poisoning) or methemoglobin. Nail polish, venous congestion of limbs, and badly placed lead can affect readings 6. Pulse oximetry is not affected by dark skin, jaundice, or anemia 7. Teach staff to respond to all alarms by checking patient first before assuming that the pulse oximeter reading is wrong!
Delivery of drugs	1. Know which drugs can be IV, IM, or po 2. Know whether something is to be given IM vs. subcutaneous vs. intradermal 3. Whenever giving IV drips, use either an IV pump (ideal) or if IV pumps unavailable look for microdrip giving sets with buretrol/burette or chamber. Calculate carefully how to dilute drug and how to ensure that rate is correct 4. Dilute drugs the same way every time when possible. If diluting IV aminophylline ampoule for neonate and ampoule is 250 mg/10 mL, then 1 mL = 25 mg; if you add 9 mL of sterile water to 1 mL of aminophylline, you now have 1 mL = 2.5 mg which is then easy to dose for a neonate
BP	1. Low normal BP for a neonate is < 60; for a 1–2 y is 60, and child is 70 + 2X age in years 2. BP in a child with shock is the last thing to deteriorate and BP cuffs often not available in the developing world. Look for other signs of decreased end organ perfusion such as change in mental status, decreased peripheral perfusion and capillary refill, tachycardia, decreased urinary output, and hypoxia
Glucose dilutions	1. Use $D_{10}W$ for neonates and young infants (can make by diluting $D_{50}W$, i.e., take 2 mL of D50W and add 8 mL of sterile water) 2. $D_{25}W$ in children (10 mL of D50 + 10 mL sterile water) 3. $D_{50}W$ in adolescents/adults 4. Research glucometers before purchasing—ensure strips are available and affordable
Fluid management	1. Calculate maintenance fluids total; first 10 kg–100 mL/kg, second 10 kg–50 mL/kg, and greater than 20 kg–20 mL/kg 2. Microdrip giving set = 60 drops/mL (gtts/min = mL/h. Microdrip giving set has a tiny wire in the drip chamber) 3. The standard giving set is often 20 drops/mL (mL ÷ 3 = no. of gtts/min) 4. Blood giving set is often 15 drops/mL (mL ÷ 4 = no. of gtts/min) 5. If unsure about the drops/mL, then place drops in a cup and measure with a syringe, i.e., if the giving set is a 20 gtts/mL giving set, then 20 drops in a syringe should be about 1 mL 6. Teach calculating and writing fluids as mL/h and drops per min and amount per unit time, i.e., mL in 4 or 8 h
Blood products	1. Must be screened for at least HIV and hepatitis B or do not give 2. Determine if whole blood, settled cells or true packed cells as this will determine the volume needed for a given patient
Strict intake and output	1. Urine output is one of most valuable tools longitudinally to help determine adequacy of cardiac output and tissue perfusion 2. If Foley catheter in place must follow intake and output

(*Continued*)

Table 4 (*Continued*)

Nebulizers and MDIs	1. Delivery of nebulized drug is facilitated by use of a commercially available nebulizer. When using wall oxygen or air to deliver drugs, correct gas flow rate is crucial. Most devices require 10–12 L/min gas flow to generate correct particle size 2. Homemade spacers are useful in therapy for children with acute asthma.[23] Use of bottle spacers should be incorporated into guidelines for asthma management in developing countries. (A) Homemade spacers can be made utilizing 500 mL plastic cold drink bottles. (B) Cut hole in base to fit size and shape of MDI. (C) Seal bottle-MDI perimeter with glue, and (D) Use opposite end as mouthpiece 3. For infants and young children MDI can be placed in the mouthpiece end and a mask created from the cut end of the bottle
Body temperature maintenance	1. Except in the case of hypoxic ischemic encephalopathy of the newborn or postcardiac arrest, cold infants and children should be warmed 2. External warming is essential in hypothermic infants/children 3. Skin-to-skin care can be used for infants and even young children beyond the neonate and when coupled with a hat and wrap around the infant provides one of the most effective ways to warm 4. Beware of hot water bottles as can cause severe burns; never put skin-to-skin (always wrap)
Nutrition	A good estimation of maintenance calories is maintenance fluids based on ideal body weight, i.e., 10 kg child needs about 1,000 mL/d and about 1,000 calories/d
Universal precautions	1. Good hand washing and/or hand sanitation must be made available to all health care workers 2. Gloves must be worn whenever potential contact with blood or body fluids (minimum) 3. Sharps must be disposed of in puncture proof containers which can be homemade if needed 4. Dispose of all blood and body fluids in a way that others can not be accidentally exposed 5. Have HIV prophylaxis and testing available 24/7 for all health care workers

Abbreviations: BP, blood pressure; HIV, human immunodeficiency virus; IM, intramuscular; IV, intravenous; HR, heart rate; MDI, metered-dose inhaler.

equipment available in ►**Table 2**. Supplies are addressed in ►**Table 3**, while basic principles are addressed in ►**Table 4**. As alluded to frequently in this article, treatment has to be adapted to the resources available in each setting.

Upgrading Critical Care Infrastructure

In areas looking to build critical care units for children, it is imperative to consider the cost of the care to be provided. The wisest investment begins with training the nursing staff early recognition, assessment, resuscitation, and stabilization of the critically ill child. As a hospital considers building up critical care infrastructure for children, they must have realistic goals, a training plan for all staff involved, and decide beforehand which patients can benefit the most from critical care interventions. The key is to start small, make sure staff understand the treatment and monitoring of critically ill children, and, as competence improves, then consider expanding the range of critical care available through the use of more advanced technology and therapies.[16] Unfortunately, many hospitals in low-resource settings are littered with supplies and expensive equipment rotting and rusting because this simple principle was not followed.

A disciplined approach must be taken in helping to improve critical care services—the critical care staff should first be equipped and trained to measure vital signs, record intake and output, learn how to appropriately use a multiparameter monitor, including setting and understanding age appropriate limits, adjust and use simple respiratory support devices such as oxygen, nebulizers, metered-dose inhalers with spacers, and understand how to mix and titrate intravenous fluids (IVFs) and medications. After learning how to do these basic first steps and demonstrating proficiency over time, it is appropriate to add next steps such as bilevel positive airway pressure or inotropic drips with intravenous pumps again demonstrating proficiency over time, then moving up, if appropriate, to ventilators, central lines and invasive hemodynamic monitoring. Such a disciplined approach allows staff to gradually gain confidence as they build upon a solid foundation of critical care expertise.

Summary

Pediatric critical care is urgently needed in low-resource settings. Obstacles abound but can be overcome with a careful systematic approach to providing this care. A tiered stepwise approach is crucial, building upon initial training, supplies, medications, and diagnostics as staff become familiar with and competent in these. With this approach, high-quality pediatric critical care that can impact the morbidity and mortality of children in these regions is possible.

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