Update in Anaesthesia

# Paediatric intensive care in resource-limited countries

Rola Hallam, Mohammod Jobayer Chisti, Saraswati Kache and Jonathan Smith*
*Correspondence Email: drjonathansmith@me.com

**SUMMARY**

This article provides guidance on setting up a PICU in a low-income country, based on the personal experience of the authors. We also describe clinical management of specific conditions.

***Rola Hallam***
Research Fellow, Great Ormond Street Hospital, London

***Mohammod Jobayer Chisti***
Scientist and Clinical Lead, Paediatric Intensive Care Unit, Dhaka Hospital, International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B)

***Saraswati Kache***
Clinical Associate Professor, Lucile Packard Children's Hospital, Stanford University School of Medicine, USA

***Jonathan Smith***
Consultant Paediatric Anaesthetist, Great Ormond Street Hospital, London

The leading causes of death in the under-five age group are pneumonia, diarrhoea, malaria, complications of prematurity and birth asphyxia. Acute febrile illness is the most common cause of hospital admission, and the largest proportion of admissions are due to malaria and/or invasive bacterial disease. Malnutrition contributes to approximately one third of all childhood deaths. The demand for intensive care services for children and the global burden of critical illness is hard to estimate, but 10 to 20% of children who present to primary care are severely ill and need referral for hospital care. Mortality rates of severely ill children admitted to hospital vary between 10% and 30%.

Critical care is defined as care given in hospital to patients with sudden and reversible critical illness. Paediatric critical care is often thought of as a luxury, but the underlying principles of rapid recognition and targeted interventions using a simple ABC approach, appropriate fluid resuscitation, oxygen and antibiotic therapy are not expensive and do not depend on complex equipment. Younger patients with reversible processes represent the majority of critical illness in low income countries; therefore, simple timely intervention can save lives.

This article provides guidance on setting up a PICU in a low-income country, based on the personal experience of the authors from working in Bangladesh, Nepal and Uganda. We will also consider clinical management of children presenting with shock, convulsions, fever, gastroenteritis and malnutrition; the management of children with pneumonia is considered in detail on page 251.

## PAEDIATRIC CRITICAL CARE IN LOW-INCOME COUNTRIES

The World Bank defines low-income countries (LIC) as those having a per capita gross national income of US $1,025 or less. This describes the situation in 36 countries, mainly in sub-Saharan Africa.

The WHO recommends that every hospital performing surgery and anaesthesia should have an ICU, but a survey from Zambia showed that only 7% of hospitals do.[1] Where an ICU does exist, many admissions are for children under five years old (nearly 30% of admissions to an urban ICU in Uganda (RH personal experience)).

The challenges to provision of intensive care for children are similar in many LIC. There are few trained staff, and few trained in care of the critically ill child; in one study, 73% of doctors and 91% of nursing staff displayed insufficient knowledge in at least one of the medical conditions assessed.[1] Nurses provide most of the care, but there are often few nurses on duty overnight. Basic resources to support intensive care may not always be available; the majority of hospitals have access to supplies of water and electricity, but power surges and intermittent water shortages are common. In a study of 21 hospitals in Bangladesh, Dominican Republic, Ethiopia, Indonesia, Philippines, Tanzania and Uganda, supplementary oxygen was present in 87% of city teaching hospitals but only in 47% of district hospitals.[1] Compressed air, pressurized oxygen or basic monitors such as pulse oximeters may not be available, and there are few biomedical engineers to maintain sophisticated equipment. Mechanical ventilation is not a viable option for children in these situations, and alternative approaches to respiratory support must be used.

## SETTING UP A PICU

Children requiring intensive monitoring and support include those with a 'medical' diagnosis, such as severe pneumonia, acute dehydration or

sepsis, or after traumatic injury or burns, or after major surgery such as laparotomy.

Much can be achieved through structured education and training of existing staff and reorganization of available resources. Substantial financial input is not required and setting up a PICU is thus a realistic goal. Establishing an intensive care unit may also motivate professional development more widely, and help to foster a culture of education, training and clinical improvement in a hospital.

An initial needs assessment is essential to identify and prioritize key issues; these depend on the institution, the patient volume, rates and causes of mortality, and available resources. The WHO has developed a useful tool for assessing the quality of hospital care for children that scores various aspects of hospital care against a standard applicable to LIC.[1]

The following are useful questions to consider:

*Why do you want to establish a PICU?*
- What are your rates of admission of children?
- What are the leading causes of mortality and morbidity amongst children in your hospital?

*What physical space do you have available?*
- How many bed spaces?
- Do you have the actual beds?
- Are isolation rooms available?

*Is the infrastructure reliable?*
- Is the water supply reliable? Do you need a water purification system?
- Is the electricity supply reliable? Do you need an upstream voltage stabiliser to protect your equipment?
- Is there a temporary automatic emergency power supply in case of power failure?

*What equipment is available?*
There are many pieces of equipment to consider, but we think these are the most important:

- Patient cardio-respiratory monitors, including pulse oximeters, one per patient bed space
- Patient charts to record observations
- An Ambu bag (self-inflating bag), adult, child and infant sizes
- Airway equipment, including facemasks, oral airways, tracheal tubes
- A reliable oxygen source. Oxygen concentrators cost up to $1200, but are reliable, cheap to maintain, and can provide oxygen up to four patients simultaneously using a flow splitter. Oxygen cylinders are cheap to buy but expensive and cumbersome to maintain. A supply of compressed air and oxygen will be needed for invasive ventilation, but this is by no means an essential part of setting up a PICU
- Further equipment is needed for an advanced PICU such as patient ventilators, a blood gas machine, and IV infusion pumps
- Is this equipment available from a local vendor or agent?

*Are essential and emergency drugs available?*
- Antibiotics, fluids, resuscitation drugs, inotropic agents, anti-epileptic agents, bronchodilators, anaesthetic agents, analgesics and sedatives should be available in the PICU
- Drugs should be stored in a locked drug cupboard, but must be easily accessible when needed
- Access to blood and blood products

*Is there access to basic laboratory studies and diagnostics?*
- A laboratory that can run a basic chemistry panel, a complete blood count, cultures, and check for malaria should be available
- Diagnostics capabilities such as X-ray should also be available within the institution. Although a CT-scan is not essential, it will be of benefit in a location with multiple trauma patients

*Personnel*
- Who will be responsible for the management of children in the PICU?
- How many nurses do you have available to work on the PICU?
- Are they local staff? Are they trained? Do you have links with any other institutions to assist with training?
- Are the staff dedicated to the PICU, or are they required to cross cover for another area? A nurse is required to look after the child at the bedside, and another is required as a 'runner'

*Management*
- Does your hospital management support this initiative?
- Who will be the key people in the hospital/community/country that are going to move this project forward?

*Finances*

- How much money is available for this PICU to be established?
- Will this be adequate to make changes to the physical space and buy the equipment that is required?
- Is someone assigned to take care of the finances?
- Is there a plan to maintain the PICU once opened, for instance to support on-going costs of staff, maintenance of equipment, drugs and supplies of disposable equipment?

*Time-line*

- When do you expect to open the PICU?
- Is this realistic?

*Hurdles*

- What are the main hurdles you and other key personnel see?
- This process is useful to identify other issues that may not have been considered previously

It is possible to start small, with a few 'high dependency' beds identified on the children's ward or in the adult intensive care unit. The ideal is to have specific areas identified for children's critical care, both for neonates and for infants and older children.

## GENERAL PRINCIPLES OF PICU MANAGEMENT

The WHO 'Pocket book for hospital care of children'[1] is a valuable resource, which should be available to all clinicians caring for children in these settings. The WHO Emergency Triage Assessment and Treatment (ETAT) course has been developed by the WHO and is planned for widespread implementation in LIC. Staff retention and training and a change in culture are often the key to sustain improvements.

### Triage

'Triage' is the process of rapid screening of children on arrival to hospital in order to identify those with emergency signs who require immediate life-saving treatment to avert death, and those with priority signs who need to be treated before those deemed non-urgent. It is an essential part of care for the critically ill child, and is described in detail on page 223. Initial management of the critically ill child is also described there.

In practice, we have found that triage is frequently not present, or is of variable quality. Parents queue with their children at the hospital or clinic, and do not undergo medical evaluation until they reach the front of the line, which may be hours later. Children who are 'marginal' may decompensate while waiting to be seen. In one study, triage in 14 of 21 hospitals was judged to be 'poor' due to avoidable delays, poor organization of the facilities or inadequate assessment of patients.[1]

An estimated 50 to 87% of children who die in hospital do so in the first 24 hours.[1] Effective triage and emergency care can lead to impressive reductions in in-patient mortality, and should be an early focus of training when setting up a paediatric critical care unit.

### Diagnostic considerations

Precise diagnosis of the cause of severe illness, in particular, differentiation between severe malaria, sepsis, pneumonia, and meningitis, is often not possible at the time of admission as most sick children present with signs and symptoms related to more than one of these conditions. Striving to make a single diagnosis may not be possible or appropriate, and may lead to incorrect or delayed management.

The initial management of critically ill children should therefore be largely independent of the underlying diagnosis, and should focus on addressing life threatening conditions such as hypoxia, hypovolaemia, hypoglycaemia, and convulsions. The WHO advocates the use of integrated management of childhood illnesses (IMCI) approach whereby children are treated according to clinical symptoms rather than focusing on a specific diagnosis. This approach is illustrated in the following case study and has been described in detail on page 224.

### Case study

Adebola is a 16-month-old girl in Nigeria. She weighs 10 kg. Her temperature is 38°C. Her mother says "Adebola has been coughing for 6 days, and she is having trouble breathing." The health worker checks Adebola for general danger signs. The mother says that Adebola is able to drink. She has not been vomiting. She has not had convulsions during this illness. The health worker asks, "Does Adebola seem unusually sleepy?" The mother says, "Yes." The health worker claps his hands. He asks the mother to shake the child. Adebola opens her eyes, but does not look around. The health worker talks to Adebola, but she does not watch his face. She stares blankly and appears not to notice what is going on around her.

The health worker asks the mother to lift Adebola's shirt. He then counts the number of breaths the child takes in a minute. He counts 60 breaths per minute. The health worker sees lower chest wall in-drawing, but does not hear stridor.

The health worker asks, "Does the child have diarrhoea?" The mother says, "No".

Due to presence of danger signs, the child is admitted. Oxygen and anti-pyretics are given. IV antibiotics are given due to presence of a clinical condition requiring antibiotics (pneumonia). It is high season for malaria so IV anti-malarials are also given.

Adebola makes good progress and is discharged 5 days later.

## Treatment of hypoxaemia

Hypoxaemia is common in children with pneumonia, and is associated with high mortality.

- Hypoxaemia is defined as peripheral arterial oxygen saturation <90% in room air at sea level as recorded by pulse oximetry
- The treatment target $SpO_2$ is >92%

Severity of hypoxaemia is defined as follows

- Mild: $SpO_2$ 85-90%
- Moderate: $SpO_2$ 80-85%
- Severe: $SpO_2$<80%

Indications for oxygen therapy:

- $SpO_2$ <90%

In the absence of pulse oximetry:

- Central cyanosis
- Severe lower chest-wall in-drawing
- Grunting respiration
- Restlessness (due to hypoxaemia)
- Inability to drink or feed
- Respiratory rate >70 breaths.min$^{-1}$
- Head nodding.

*Bubble CPAP*

Continuous Positive Airway Pressure (CPAP) is commonly used to provide non-invasive mechanical support for children in ICU, either using conventional mechanical ventilators or increasingly using specifically designed CPAP devices.[2,3]

CPAP may be given by facemask or nasal cannulae. Advantages of nasal CPAP (nCPAP) are as follows:

- Effective treatment for hypoxaemia
- Reduces the number of children requiring endo-tracheal intubation and mechanical ventilation
- Helps stent airways open and decreases the work of breathing, often with minimal oxygen requirement; particularly effective as children are prone to small airway disease.

Bubble-CPAP is a low cost, but effective method of providing continuous positive airway pressure (CPAP) oxygenation in neonates, infants and children and is widely used in LIC for conditions such as pneumonia and respiratory distress of the newborn. The following are required (see figure 1 and 2):

- Source of gas flow (typically 5–10L.minute$^{-1}$; start at low flow rates in neonates)
- An air-oxygen blender
- A humidifier
- 'T-piece' connector, for instance nasal prongs with inspiratory and expiratory limbs (see Figure 1).

The long expiratory limb of the T-piece breathing tube is inserted into a bottle of water: the level of CPAP delivered is equivalent to the length of the expiratory tubing that remains under water. Modern equipment is now available at a fraction of the cost of mechanical ventilators.

Bubble CPAP has been proposed as an inexpensive method of delivering CPAP in developing countries. Bubble CPAP is used as a 'step up' treatment from facemask or nasal prong oxygen.

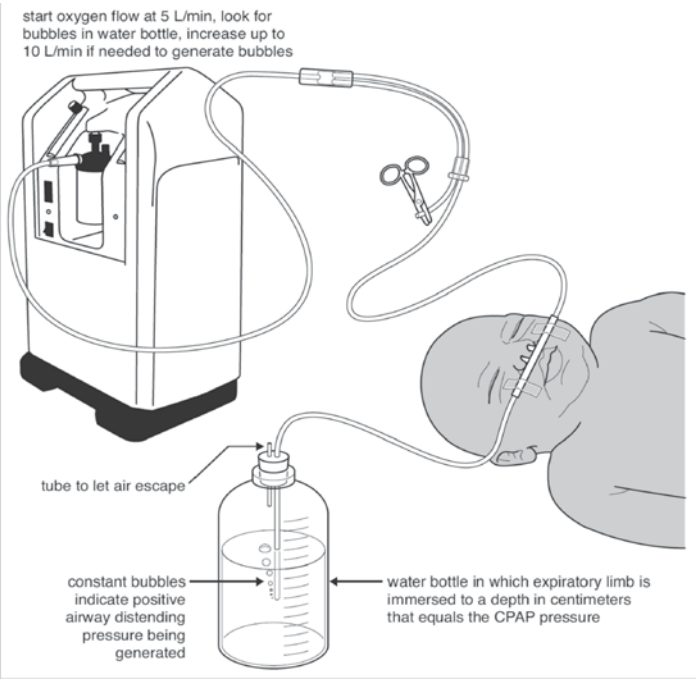


**Figure 1.** *Figure of bubble CPAP. Reproduced, with permission of the publisher, from The clinical use of oxygen. Geneva, World Health Organisation, 2011 (Fig 6.1, page 38)*[2]

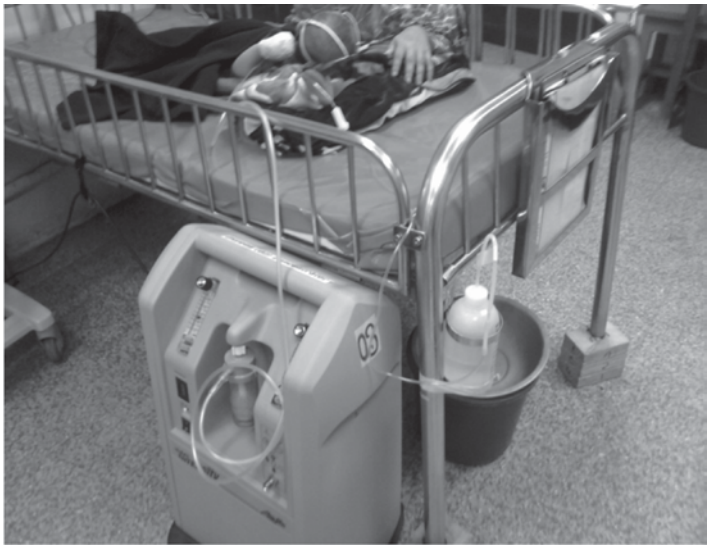

**Figure 2.** *Bubble CPAP in the ICU of the Dhaka Hospital of ICDDR,B*

The advantages of Bubble-CPAP over invasive mechanical ventilation are as follows:

- Low cost
- Easy to use, minimal training required
- Sedation not required to tolerate treatment
- No need for a physician to intubate the patient
- No need for respiratory therapist to operate/maintain a ventilator
- Lower risk of complications e.g. pneumothorax
- Greater hemodynamic stability.

### Use of antibiotics in PICU

There is an emerging problem with antibiotic resistance, and 'antimicrobial stewardship' is being encouraged to assure that antibiotics are used appropriately, and for the correct length of time. The basic tenet of antimicrobial stewardship is 'Start smart, then focus':

*'Start smart' is:*

- Do not start antibiotics in the absence of clinical evidence of bacterial infection
- If there is evidence/suspicion of bacterial infection, use local guidelines to initiate prompt effective antibiotic treatment
- Document on a drug chart and in the medical notes: clinical indication, duration or review date, route and dose of antibiotics
- Obtain cultures first wherever possible.

*'Then Focus' is:*

- Review the clinical diagnosis and the continuing need for antibiotics by 48 hours and make a clear plan of action - the "Antimicrobial Prescribing Decision"
- The four Antimicrobial Prescribing Decision options are:
    1. Stop
    2. Switch IV to Oral
    3. Change
    4. Continue and Outpatient Parenteral Antibiotic Therapy (OPAT)
- It is essential that the review and subsequent decision is clearly documented in the medical notes.

## MANAGEMENT OF SPECIFIC CONDITIONS

Management of children presenting with shock, convulsions, fever, gastroenteritis and malnutrition will be considered below. Detailed management of children presenting with respiratory infections is considered on page 251.

### Child presenting with shock

The WHO definition of shock is as follows[1]:

- Cold peripheries
- Capillary refill time greater than 3 seconds
- Weak pulse with tachycardia.
- Narrow pulse pressure.

Blood pressure is not commonly recorded in low resource settings and a fall in blood pressure is a very late sign. Hypotension is associated with poor outcomes (See Table 1).

Types of shock:

- Haemorrhagic shock
- Cardiac shock
- Septic shock
- Hypovolemic shock
- Specific infectious outbreak: e.g. Dengue shock syndrome
- A combination of several of the above.

A careful history, examination and investigations should be performed (see Table 2).

**Table 1.** *Cardiorespiratory parameters of shock in children*

| | <2 months | 2- 12 months | 1-5 years | >5 years |
|---|---|---|---|---|
| **Blood pressure (mmHg)** | <50 | <50 | <60 | <70 |
| **Heart rate (beats.min$^{-1}$)** | >180 | >180 | >160 | >140 |
| **Respiratory rate (breaths.min$^{-1}$)** | 60 | 50 | 40 | 30 |

## Septic shock in children in LIC

Septic shock is common in LIC, and treatment guidelines formulated for high-income countries should be adopted with care.

*Pathophysiology*

Septic shock occurs when a severe infection in any anatomic location within the body leads to Systemic Inflammatory Response Syndrome (SIRS). When uncontrolled, this leads to hypotension, multi-system organ dysfunction, failure, and eventual death. SIRS triggers both pro- and anti-inflammatory mediators; the vascular endothelium is the primary culprit in being both a source and a target of injury to multiple organs. The three basic changes that occur are vasodilation, 'third spacing' due to capillary leak, and myocardial dysfunction.

*Diagnosis*

The following may be present:

- High fever
- Hypothermia, particularly neonates and malnourished patients
- Hypotension (late finding)
- Prolonged capillary refill time of >3 seconds (cold shock)
- Flash capillary refill (warm shock)
- Altered mental status
- Decreased urine output.

Children with concerning findings on physical examination should receive an IM dose of antibiotics immediately, and should be referred to the hospital if in a clinic setting. Concerning signs include convulsions, lethargy or unconscious, tachypnea, severe chest indrawing, nasal flaring or grunting, bulging fontanelle, umbilical redness, fever or hypothermia, severe skin pustules.

2007 American College of Critical Care Medicine algorithm for management of septic shock in children is as follows[4]:

**Table 2.** *Shock in children*

| History | Examination | Investigation |
|---|---|---|
| Nature of onset? | As per rapid initial assessment plus: | Haemoglobin |
| Any trauma? | Fever? | |
| Bleeding? | Any bruises or bleeding? | Malaria blood smear |
| History of congenital or rheumatic heart disease? | Heart murmur? | |
| History of diarrhoea? | Distended neck veins? | Blood cultures if fever |
| Any febrile illness? | Enlarged liver? | |
| Any known regional outbreaks of infectious diseases eg: meningitis/dengue fever? | Petechiae? | Microscopy of CSF and urine |
| Are they able to feed? | Purpura? | |
| | Level of consciousness? | HIV testing |

- Prompt recognition
- Initial resuscitation
- Diagnosis
- Appropriate antibiotics
- Source identification and control
- Early access to critical care if available, but delays in access to a critical care bed should not delay these interventions
- Institution of inotropic support
- Management of metabolic derangements
- Frequent, repeated assessment of the response to therapy

### Early aggressive fluid therapy should be used with caution in LIC

- The recent FEAST trial results[5] suggest the traditional recommendations of aggressive fluid resuscitation for patients with septic shock may not be applicable in the LIC environment (see page 81). Use IV fluids with caution when resuscitating patients in septic shock in LIC, particularly if there is concern that the patient has a malarial infection. Start with isotonic fluids (Ringer's) at normal maintenance rate initially. 5% dextrose must NOT be used in this setting
- Malnourished children require slower rehydration and careful observation (every 5-10 minutes) as they are at greater risk of congestive heart failure from over-hydration
- Anaemia is common in LIC; consider blood transfusion early

*Other interventions in septic shock are as follows*

- Within the first hour (ideally within the first 15 minutes), give the first dose of antibiotics
- Correct any abnormalities in calcium and glucose
- If venous access is difficult, place an intraosseous line to administer fluids, antibiotics, blood products and inotropes if required
- If available, place a central venous catheter with central venous pressure (CVP) monitoring if more than 60ml.kg$^{-1}$ fluid boluses are required
- Consider starting inotropes if a patient continues in shock despite fluid resuscitation: use dopamine (5-9mcg.kg$^{-1}$.min$^{-1}$) or adrenaline (0.05-0.3mcg.kg$^{-1}$.min$^{-1}$) for cold shock and norepinephrine (0.05-0.3mcg.kg$^{-1}$.min$^{-1}$) for warm shock
- If the patient shows signs of respiratory distress and non-invasive or invasive mechanical support is available, use it. Otherwise, give facemask oxygen
- If an infusion pump is not available to administer inotropes, a solution of dopamine can be made by placing 200mg dopamine into 100ml normal saline in the burette of a paediatric microdrop IV set. Titrate this infusion to maintain the blood pressure in the normal range. Similarly, adrenaline or noradrenaline 1mg can be added to 100ml saline and titrated to effect in a microdrop burette
- Inotropes are always best administered through an infusion pump when available.

## Child presenting with convulsions

The differential diagnosis for a child presenting with convulsions is as follows:

*Age less than 2 months*

- Birth asphyxia/birth trauma
- Hypoxic ischaemic encephalopathy
- Intracranial haemorrhage
- Haemolytic disease of the newborn
- Neonatal tetanus
- Meningitis
- Sepsis.

*Age more than 2 months*

- Meningitis
- Encephalitis
- Cerebral or severe malaria
- Febrile convulsion
- Hypoglycaemia
- Head injury (including Non Accidental Injury)
- Poisoning
- Shock (not likely to cause convulsions)
- Diabetic ketoacidosis
- Acute glomerulonephritis with encephalopathy.

A careful history, examination and special investigations is required (see Table 3).

**Table 3.** *Convulsions in children*

| History | Examination | Investigations |
|---|---|---|
| Fever<br>Head injury<br>Drug overdose or toxins<br>History of convulsions: how many, how long did they last?<br>Known epilepsy?<br>If < 1 week: birth asphyxia or trauma | General: (as per rapid initial assessment +)<br>Fever<br>Jaundice<br>Palmar pallor<br>Peripheral oedema<br>Level of consciousness (AVPU)<br>Petechial rash<br>Deep breathing (sign of acidosis)<br><br>Head/neck:<br>Stiff neck<br>Signs of trauma<br>Pupil size and reaction to light<br>Tense or bulging fontanelle<br>Abnormal posture | Malaria blood smear<br>Glucose<br>Lumbar puncture and CSF microscopy if no signs of raised intracranial pressure (unequal pupils, paralysis, irregular breathing, rigid posturing) |

## Child presenting with fever

A febrile illness is the commonest cause of children presenting to hospital in LICs. Some causes are only found in particular regions (e.g. dengue fever); some are seasonal or occur in epidemics.

There are three main diagnostic categories:

- *Fever without localizing signs*
  - Malaria
  - Septicaemia
  - Typhoid
  - Urine tract infection
  - HIV related.
- *Fever with localizing signs*
  - Meningitis
  - Pneumonia
  - Otitis/mastoiditis/sinusitis
  - Septic arthritis
  - Skin/soft tissue infection
  - Viral URTI
  - Throat abscess
  - Dengue fever.
- *Fever with a rash*
  - Measles
  - Viral infection
  - Meningococcal infection
  - Relapsing fever
  - Typhus
  - Dengue haemorrhagic fever.

A careful history, examination and special investigations are required (see Table 4).

## Child with gastroenteritis

Gastroenteritis is a common problem in developing countries, presenting with diarrhoea and vomiting. Pre-existing malnutrition can cause the diarrhoea to be more

**Table 4.** *A child with a fever*

| History | Examination | Investigation |
|---|---|---|
| Duration of fever | As for rapid initial assessment + | Malaria blood smear |
| Are they in a malarious region? | Stiff neck? | LP if suggestion of meningitis |
| Skin rash? Headache? | Bulging fontanelle | |
| Pain on passing urine | Mastoid region tenderness | Urine microscopy |
| Cough or difficulty breathing? | Rash? | Blood culture |
| Ear ache | Skin sepsis: pustules, purpura, petaechiae | |
| | Discharge/redness in ear | |
| | Refusal to move joint or limb | |
| | Tachypnoea | |

severe, prolonged and frequent compared to diarrhoea in the non-malnourished child. Close monitoring in PICU may be necessary to treat life-threatening consequences of gastroenteritis such as severe dehydration and electrolyte abnormalities, especially in children with severe acute malnutrition (SAM).

Differential diagnosis of children who present severely unwell with diarrhoea:

Acute watery diarrhoea:

- Cholera
- Dysentery e.g. shigella.

Persistent diarrhoea >14 days.

- Diarrhoea with severe malnutrition
- Diarrhoea secondary to recent antibiotic use
- Intussusception.

Take a careful history, including the frequency and number of days of diarrhoea, the presence of blood, and any relevant infectious history. Assessment and management of dehydration is described in Table 5.

### Pneumonia in children with dehydrating diarrhoea

The clinical classification of pneumonia based on the diagnostic criteria according to WHO[1] should be carefully evaluated in children presenting with dehydrating diarrhoea caused by Vibrio cholerae, Enterotoxigenic E Coli (ETEC) or rotavirus.

A child who presents with dehydration is likely to be acidotic, which can cause tachypnoea. Under these circumstances, it can be difficult to differentiate increased respiratory rate due to pneumonia, or acidosis, or both. The following approach is suggested:

- Rehydrate the child in the first 4-6 hours using IV/oral fluids according to the type of dehydration present
- Then continue respiratory rate monitoring according to the standard WHO pneumonia guidelines[1]
- Perform a chest radiograph after full hydration to confirm/exclude the diagnosis of pneumonia
- Note: Do not delay antibiotics during the rehydration process in a child with suspected sepsis.

### Pneumonia in children with severe acute malnutrition (SAM)

Severe malnutrition significantly increases the risk of death from pneumonia. Clinical signs are relatively poor predictors of pneumonia in malnourished children, so you may fail to diagnose pneumonia if using standard WHO criteria.

- Common bacterial pathogens: S. aureus, enteric Gram negative bacilli, particularly K. pneumoniae and E. coli; Gram positive bacteria such as S. pneumoniae and H. influenza
- Give routine broad-spectrum antibiotics in children with severe malnutrition.

**Table 5.** *Recognition and management of dehydration in children*

| Level of dehydration | Examination | Management |
|---|---|---|
| *Severe dehydration*<br>*> 10%* | ≥2 of the following:<br>lethargy/unconscious,<br>sunken eyes,<br>unable to drink,<br>skin pinch returns very slowly (≥2 seconds). | WHO treatment plan C<br>Admit to hospital<br>Rapid IV hydration* (100ml.kg$^{-1}$ Ringers lactate**)<br>Frequent reassessment (every 15-30 minutes)<br>Switch to ORS when able to drink<br>Give antibiotics if appropriate<br>Note: 5% dextrose is NOT effective and must never be used for IV rehydration. |
| *Some dehydration*<br>*5-10%* | ≥2 of the following:<br>restless/irritable,<br>sunken eyes,<br>thirsty,<br>skin pinch returns slowly. | WHO treatment plan B<br>Give food and fluid<br>Then as for no dehydration |
| *No dehydration*<br>*0-4%* | Not enough of the above signs | WHO treatment plan A<br>Treat at home<br>Oral rehydration solution (ORS)<br>Advice mother when to return<br>Follow up in 5 days if not improved |

*<12 month old: 30ml.kg$^{-1}$ in first 1 hour, then 70 ml.kg$^{-1}$ over next 5 hours

*>12 months old: 30ml.kg$^{-1}$ in first 30mins, then 70 ml.kg$^{-1}$ over next 2.5 hours

**If Ringer's lactate/Hartmann's is not available, normal saline (0.9% NaCl) can be used.

## Electrolyte abnormalities in children with gastroenteritis

### *Sodium*

Children with gastroenteritis may present with dehydration associated with hyponatraemia (Na<135mmol.l$^{-1}$) or hypernatraemia (Na > 150mmol.l$^{-1}$); it is important to measure plasma electrolytes so that these children can be managed appropriately. This is a particular challenge in situations where measurement of electrolytes is not routine. Hyponatraemia is more common in older children, and in patients with malnutrition, whereas hypernatraemia is more common in younger children. The case fatality rate from gastroenteritis is 2.5 times greater in children with hyponatraemia compared to those with normal plasma sodium.

### *Hyponatraemic dehydration*

The following signs and symptoms are suggestive of acute hyponatraemic dehydration in a child with diarrhoea:

- Reduced activity
- Lethargy
- Hypotonia
- Convulsion and coma

- History of invasive diarrhoea
- Diminished deep tendon reflexes.

*Treatment of hyponatraemic dehydration*
Correct hyponatremia slowly to prevent osmotic demyelination syndrome:

If serum sodium <120mmol.l$^{-1}$, child asymptomatic:

- Add sodium to the diet
- If the child needs IV fluid for other indications (such as paralytic ileus, dehydration with persistent vomiting), give 0.9% NaCl

If serum sodium <120mmol.l$^{-1}$, child symptomatic (i.e. convulsions):

- Give 3% NaCl (12ml.kg$^{-1}$ over 4 hours IV, maximum 500ml)

If serum sodium < 110mmol.L$^{-1}$, irrespective of presence or absence of symptoms:

- Give 3% NaCl (12ml.kg$^{-1}$ over 4 hours IV, maximum 500ml)

*Hypernatraemic dehydration*
The following signs and symptoms are suggestive of acute hypernatraemia in children with diarrhoea:

- Irritability
- Excess thirst
- Presentation during winter months (association with rotavirus diarrhoea)
- History of intake of several packets of ORS or of inappropriately concentrated ORS
- Exaggerated deep tendon reflexes
- Fever.

*Treatment of hypernatraemic dehydration*
The serum sodium concentration should be reduced slowly at a rate of 0.5mmol.l$^{-1}$ per hour to prevent cerebral oedema and convulsions. Estimate the fluid deficit and correct the deficit using reduced osmolarity Oral Rehydration Solution (i.e. WHO recommended ORS, Na+ 75mmol.l$^{-1}$):

- Give ORS PO to replace the fluid deficit over 24-48 hours
- If the child cannot take ORS by mouth, then rehydrate via the nasogastric route
- Give fluids IV in the following circumstances only:
  - Circulatory collapse (hypovolaemic or septic shock)
  - Persistent vomiting (3 or more episodes per hour)
  - High purging (stool output > 15ml.kg$^{-1}$.hour$^{-1}$)
  - Paralytic ileus

If IV fluids are required for above conditions, give 0.9% saline 20ml.kg$^{-1}$ IV over 2 hours, then continue with ORS.

*Potassium*
The normal plasma potassium is 3.5-5.3mmol.l$^{-1}$. The symptoms of hypokalaemia and hyperkalemia are similar:

- Lethargy
- Abdominal distension with ileus
- Bradycardia.

They may be distinguished by ECG morphology:

- Hypokalaemia
  - Narrowing QRS complex
  - Flat T waves
  - Prolonged ST segment
  - U waves
- Hyperkalaemia
  - Tall, peaked T wave (mild hyperkalaemia)
  - Prolonged PR interval
  - ST segment depression
  - Loss of P wave
  - Widening QRS complex, gradually leading to `sine wave' in severe hyperkalaemia, then asystole

*Treatment of hypokalemia*
Hypokalemia is common in children with SAM, and fluid overload a great concern if hypokalemia is treated with IV fluids. Oral potassium supplementation is usually adequate:

- Give potassium 4mmol.kg$^{-1}$ per day in divided doses 8 hourly PO for 5 days.
- If a child requires IV fluids for severe dehydration, or has a large stool output that cannot be managed with ORS,

then add potassium to IV fluids as follows:

- If serum potassium is <2mmol.l$^{-1}$, increase potassium in IV fluids to 40 mmol.l$^{-1}$
- If serum potassium is between 2 and 2.5 mmol.l$^{-1}$, increase potassium in IV fluids to 30 mmol.l$^{-1}$

*Treatment of hyperkalemia*

- Check potassium not being given in IV fluids
- Rehydrate; may be sufficient to treat mild hyperkalemia (K+<6 mmol.l$^{-1}$)

If serum K+ is >6.0mmol.l$^{-1}$:

- **10% Calcium gluconate**: 0.5ml to 1.0ml.kg$^{-1}$ over 2 to 5 minutes IV
  - Reduces cardiac toxicity
  - Protective effect within minutes, but effective only for an hour
- **Salbutamol (nebulised or inhaler): 2.5 to 5mg inhaled:**
  - Increases potassium movement into the cells by increasing the activity of Na-K-ATPase
  - Very effective, for up to 2 to 4 hours
- **8.4% Sodium bicarbonate: 1 to 2mmol.kg$^{-1}$ over 3 - 5 minutes IV:**
  - Increases pH and shifts potassium into the cells
  - Effect begins in 5 - 15 minutes, lasts for 1 to 2 hours
  - Bicarbonate causes precipitation of calcium; flush the IV line between drugs
- **Insulin and glucose**: dextrose 0.5 g.kg$^{-1}$ IV + insulin 0.3 unit per gram of dextrose over 30 minutes. Be sure to check a blood sugar in 30 minutes to assure the patient does not develop hypoglycemia.
  - Use if other measures fail
  - E.g. for a 5.0kg child: 2.5g of glucose (25ml 10% or 10ml 25% dextrose) + 1.5 unit (5 x 0.3) insulin
- **Calcium resonium**: 1g.kg$^{-1}$ PO or PR
  - Binds potassium in the gut and permanently removes
  - Contraindicated in patients with diarrhoea, hypovolaemia or uraemia since it may precipitate colonic necrosis
- **Furosemide**: 1-2mg.kg$^{-1}$ – effective in only those patients that have renal function and native urine output
  - Increases potassium wasting in urine
- **Dialysis**: If available, when other measures fail.

## Typhoid fever

Typhoid fever affects more than 21 million people globally each year. It is due to ingestion of food or water contaminated with Salmonella typhi, and is most common in school-aged children or young adults in areas of over-crowding with poor sanitation. Transmission is usually from a chronic carrier and it is endemic in many low-income countries, most commonly in Central and South-East Asia.

The WHO recommendation is to consider typhoid if a child presents with fever lasting 7 or more days with the following signs (and malaria has been excluded):

- Constipation followed by diarrhoea ('pea soup')
- Vomiting
- Abdominal pain
- Headache
- Cough.

The main diagnostic features of typhoid are:

- Fever with no obvious focus of infection
- No features of meningitis
- Inability to feed
- Convulsions
- Lethargy and disorientation
- Persistent vomiting
- Rose spots on the abdominal wall
- Hepatosplenomegaly and a distended and tender abdomen.

*Complications*

- Mild hyponatremia and hypokalaemia are common
- Enteric encephalopathy is seen in 10-30% of cases of severe enteric fever, and presents with altered consciousness, disorientation, confusion and delirium, mainly in children and young adults. The case fatality from enteric encephalopathy is high. A positive Widal test for typhoid fever, leucopenia, and severe dehydration are predictors of encephalopathy

- Perforation of an ulcer in the small bowel. The child presents critically unwell in the second to third week of untreated illness.

*Treatment of Salmonella typhi*

- IV fluids (blood transfusion)
- Antibiotics (antibiotic resistance is common)
  - Ciprofloxacin IV (Africa)
  - Ceftriaxone or cefotaxime IV (Asia)
  - Add metronidazole and gentamicin in cases of bowel perforation
- Surgery for bowel perforation; high mortality. If there is general peritonitis the child will require a laparotomy for peritoneal washout and oversewing of the typhoid perforation. Bowel resection may be required for multiple perforations. A localised mass may be treated conservatively (as for an appendix mass)
- Dexamethasone 3 $mg.kg^{-1}$ loading dose then 1 $mg.kg^{-1}$ per dose IV 6 hourly for 48 hours – this is recommended mainly for enteric encephalopathy with or without multi drug resistant (MDR) enteric fever, and improves outcomes
- Exclude hypoglycaemia
- Treat electrolyte abnormalities.

## The child with malnutrition

Malnutrition is a major independent risk factor for death in children in developing countries, and increases the risk of mortality from other conditions such as septic shock, acute respiratory infection, diarrhoea, malaria, or measles.

Severe Acute malnutrition (SAM) is defined by the WHO as a weight-for length/height < 3SD below normal, a mid-upper arm circumference < 115mm, or oedema of both feet (sign of kwashiorkor).

The cause of the high mortality among malnourished children is unclear, but may relate to both changes in physiology and poor case management. All aspects of physiology are affected including cardiovascular, GI, renal, endocrine and immune function.

A standardised management protocol for severely malnourished children has been developed in the Dhaka hospital at the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), which has resulted in a 47% reduction in death rates among severely malnourished children. The management of diarrhoeal disease in children with malnutrition is divided into three phases:

*Acute phase*

- Identify and treat problems that endanger life e.g. hypoglycaemia and infection
- Initiate feeding according to standard feeding schedule
- Correct micronutrient deficiencies
- Give broad-spectrum antibiotics
- Vitamin and mineral supplementation
- Slow rehydration using oral rehydration therapy
- Early recognition of complications

Mortality is highest during this phase of management, the principal causes being hypoglycaemia, hypothermia, infection, and water-electrolyte imbalance.

*Nutritional rehabilitation phase*

- Recover lost weight - intensive feeding.
- Stimulate the child emotionally and physically
- Train the mother to continue care at home

*Follow up*

Follow up prevents relapse of severe malnutrition, and ensures proper physical growth and development of the child

A number of critical problems may be seen during the acute stage of treatment of malnutrition:

*Hypoglycaemia*

Children with severe malnutrition and hypoglycaemia may die within minutes. Test the child for hypoglycaemia on admission or whenever you find lethargy, convulsions or hypothermia. If blood glucose cannot be measured, suspect all children with SAM to have hypoglycaemia and treat accordingly. Hypoglycaemia can also be a sign of infection.

- If the child is conscious and blood glucose is <3$mmol.l^{-1}$ (54$mg.dl^{-1}$): give 50ml of 10% glucose or 10% sucrose solution PO or NG (1 rounded teaspoon of sugar in 3.5 tablespoons water). The 'starter diet' (F-75) is given every 30 minutes for two hours (giving one quarter of the two-hourly feed each time). Thereafter, two-hourly feeds are continued for first 24-48 hours
- If the child is unconscious, lethargic or convulsing, give 10% glucose 5$ml.kg^{-1}$ IV, followed by 50ml of 10% glucose or sucrose by NG tube. Then give the starter diet F-75 as above.

*Septic shock*

- Defined as weak or absent radial pulse, delayed CRT (> 3sec), cold peripheries, or hypoglycaemia
- Give fluid bolus 15ml.kg$^{-1}$ IV over one hour using 5% dextrose 0.9% saline
- 'Cholera saline' with 5% dextrose is preferred if there is a history of watery diarrhoea (Na+133 mmol.l$^{-1}$, K+ 13mmol.l$^{-1}$, Cl- 98mmol.l$^{-1}$, acetate 48mmol.l$^{-1}$)
- Repeat rescue therapy once if signs of shock remain
- Provide broad-spectrum antibiotics: IV ceftriaxone 100mg.kg$^{-1}$ once daily and gentamicin 5mg.kg$^{-1}$.day$^{-1}$ in divided doses 12 hourly
- Supportive measures include oxygen therapy, correction of hypoglycaemia, hypothermia or acidosis.

*Hypothermia*

- Wrap the child in blankets if axillary temperature is <35°C
- Place an electric lamp close to the body but sufficiently away to avoid burns
- Measure temperature every 30 minutes during re-warming with a lamp, as the child may become hyperthermic
- Measure rectal temperature with a rectal thermometer; never use an oral thermometer for this purpose
- Start feeding (hypothermia can co-exist with hypoglycaemia).

## SUMMARY

In summary, a basic PICU is an opportunity to focus and concentrate resources in terms of personnel, drugs and equipment such that the most critically unwell children have a better standard of medical and nursing care, are observed 24 hours a day and can have vital services available such as oxygen to maximize their chance of survival.

## REFERENCES


1. WHO pocket book of hospital care for children, 2nd edition. Geneva, World Health Organisation, 2013. Available from http://www.who.int/maternal_child_adolescent/documents/child_hospital_care/en/ (accessed 22/10/14).
2. The clinical use of oxygen. Geneva, World Health Organisation, 2011 (Fig 6.1, page 38, available from http://video.rch.org.au/cich/The_Clinical_Use_of_Oxygen_November_2011.pdf accessed 20/01/15).
3. Duke T. CPAP: a guide for clinicians in developing countries. *Paediatr Int Child Health* **34**(2014): 3-11.
4. Brierley J et al. Clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock: 2007 update from the American College of Critical Care Medicine. Crit Care Med. 2009 Feb;37(2):666-88. doi: 10.1097/CCM.0b013e31819323c6.
5. http://www.feast-trial.org/ (accessed 20/01/15). Now available as: Maitland K, Kiguli S, Opoka RO et al. Mortality after fluid bolus in African Children with severe infection. *NEJM* 2011; **364**: 2483-95