B7.B. WHEN NOT TO INTUBATE IN A PEDIATRIC EMERGENCY CASE?PROTOCOLS IMPLEMENTATION

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Introduction

Intubation for airway management and for other indications to reduce secondary insults is a cornerstone therapy in critically ill pediatric patients. Inevitably, once the patient is intubated, is admitted in the PICU and put in Mechanical Ventilation (MV) under sedation. However, despite its life saving effect, MV complications can arise such as barotrauma due to air leak from the development of uncontrolled positive pressures and/or gas-trapping, and severe nosocomial infections such as Ventilator-Associated Pneumonia (VAP). Moreover, there are some critical situations such as Diabetic Ketoacidosis (DKA), where early intubation and institution of MV are not only of no benefit for the patient, but might lead to harm. The scope of this lecture is to put under consideration the indication for and/or the right time of intubation for the Anesthetist/PICU intensivist on call to take part on the evaluation and management of three common pediatric emergencies.

Bronchiolitis/Bronchial Asthma (BA), Status Epilepticus (SE), and Diabetic Ketoacidosis (DKA) are three common pediatric emergency situations; they are typical examples where the strict implementation of protocols is the best patient management that could lead to the best patient outcome. International guidelines could serve as a key basis for the development of national and institutional protocols, tailored to regional needs. Intubation should be preserved in these cases, only for situations that are not responding to protocols, after sufficient time has elapsed.

Brochiolitis/Bronchial Asthma

The two common causes of wheezing due to lower respiratory obstruction in children are Bronchiolitis and Acute Severe Asthma; almost without exception, bronchiolitis is confined to the under one year olds and asthma is much more commonly diagnosed in the over ones. The chest radiograph, if present, shows hyperinflation with downward displacement and flattening of the diaphragm due to small airways obstruction and gas-trapping. In one third of infants there is also evidence of collapse or consolidation, particularly in the upper lobes. Respiratory syncytial virus and other viruses can be cultured or identified with a fluorescent antibody technique on nasopharyngeal secretions. Blood gas analysis, which is required in only the most severe cases, shows lowered oxygen and raised carbon dioxide levels. Bronchiolitis can be difficult to differentiate from heart failure, or may trigger it in an infant with a previously undiagnosed cardiac lesion. The management below is based to Advanced Paediatric Life Support (APLS) guidelines, 6th Edition, 2016[1].

Bronchiolitis Emergency Treatment

Management is usually supportive; fluid replacement, gentle sunctioning of nasal secretions, prone position (if in hospital), oxygen therapy and respiratory support if necessary.

- Assess ABC.

- Infants are nasal breathers; ensure that the airway is patent and clear: use of a soft suction catheter of the suitable size (8CH, blue, in young – 10CH, black in older infants) applied to the nares can help to ensure that the nose and nasopharynx are cleared, which can have a significant impact on an infant's respiratory distress.
- Give a high concentration of oxygen via mask with reservoir bag. Monitor SpO_2 and keep at 94-98%. Milder and improving cases may use oxygen via nasal cannulae at <2 litres/min.
- Consider using humidity, prone positioning and high-flow, humidified systems (HFNC flows of 1-2/lit/kg/min).
- Maintain hydration and nutrition. In infants with significant respiratory distress, maintain hydration by feeding via nasogastric tube, or intravenously at two thirds the usual maintainance. Remember, nasogastric tubes may partially occlude the airway. Breastfeeding may be too stressful in which case breast milk should be expressed and given via gastric tube.

Monitor for apnoea / hypoventilation in those <2 months old:

- SpO_2
- Respiratory frequency / apnoea monitor
- PCO_2 – transcutaneous, capillary or end-tidal

- Heated, humidified, high-flow nasal cannulae $(HFNC)^2$ therapy and continuous positive airway pressure (CPAP) are both delivered to improve the work of breathing by preventing dynamic airway collapse during the expiration thereby reducing air trapping and improving gas exchange. HFNC/CPAP results in decreased respiratory rate and $PaCO_2$, and clinical practice suggests that HFNC/CPAC decrease the need for mechanical ventilation with greatest benefit if instituted early. Indications for HFNC/CPAP include severe respiratory distress, a requirement for FiO_2 > 0.5 or infants with apnoeas.
- Mechanical ventilation is required in 2% of infants admitted to hospital. All intubated infants must have continuous SpO_2 and CO_2 monitoring.

Indications for intubation and mechanical ventilation, especially when severity risk factors (premature birth, age under 6 weeks, congenital heart disease, chronic lung disease and immunodeficiency) are present:

- Recurrent apnoea
- Exhaustion
- Severe hypercapnia and hypoxia

- Both nebulised 3% saline and nebulised adrenaline with corticosteroids have been subjected to trials, but without showing substantial benefit.
- Bronchodilators, steroids and antibiotics and physiotherapy are of not useful. However, a trial of nebulised salboutamol and/or ipratropium bromide could be given and the response evaluated for further use.

Acute Severe Asthma

Two degrees of severity are described to indicate the appearance of asthmatic children; these are acute severe and life-threatening asthma. Arterial oxygen saturation by a pulse oximeter (SpO_2) is useful in assessing severity, monitoring progress and predicting outcome in acute asthma. More intensive in-patient treatment is likely to be needed for children with SpO_2 <92% on air after initial bronchodilator

treatment. The peak expiratory flow rate (PEFR) can be a valuable measure of severity, but children under 6 years old and those who are very dyspnoic are usually unable to produce reliable readings. Examination features that are poor signs of severity include the degree of wheeze, respiratory rate, and pulsus paradoxus. A chest radiograph is indicated only if there is severe dyspnoea, uncertainty about the diagnosis, asymmetry of chest signs or signs of severe infection.

Asthma Emergency Treatment

- Assess ABC.
- Give high flow oxygen via a face mask with reservoir bag.
- Attach pulse oximeter; always aim to keep SpO_2 at 94-98%.

Give a beta-2 agonist, such as salbutamol every 20 – 30 minutes:

- In those with mild to moderate asthma and maintaining SpO_2 > 92% in air, use pressurised aerosol 1000 microgram (10 sprays) via a valved holding chamber (spacer) with/without facemask. Children with mild to moderate asthma are less likely to have tachycardia and hypoxia if given beta-2-agonists via a pressurised aerosol and spacer. Children aged <3 years are likely to require a face mask connected to the mouthpiece of a spacer for successful drug delivery. Inhalers should be actuated into the spacer in individual puffs and inhaled immediately by tidal breathing.
- In those with acute severe or life-threatening asthma, or when oxygen is needed, use nebulised salbutamol 2.5 mg (<5years) or 5 mg (>5 years) with oxygen at a flow of 4-6 litres per minute in order to provide small enough particle sizes. Higher flows may be used, but more of the nebulised drug may be lost from the face mask.
- Give oral prednisolone 0.5 - 1.0 mg/kg, or if vomiting, IV hydrocortisone 4mg/kg.
- If receiving nebulised salbutamol, add ipratropium bromide 250 micrograms (125 mcg in < 2 years) driven with oxygen. This may be given every 20-30 minutes initially, reducing as improvement occurs. In severe asthma the nebulizers can be continuous as breaks between them can lead to a rebound of symptoms.
- If an infant or child is clearly in respiratory failure with poor respiratory effort, depressed conscious level and poor saturation despite maximum oxygen therapy, attempt to support ventilation with bag-valve-mask and arrange for urgent intubation. Give an intravenous salbutamol infusion if provided (give a loading dose of 15 micrograms/kg; 5 mg/kg in < 2 years).

  Reassess ABC and monitor the response to treatment carefully. Assessment is based on physical signs and oxygen saturation measurements performed immediately before and 15–30 minutes after inhaled treatment. This should be accompanied by improved peak flow measurement when feasible.

If not responding, or deteriorating condition:

- For acute severe or life-threatening asthma, intravenous bronchodilators are effective: consider IV aminophylline, magnesium sulfate or salbutamol. There is no clear evidence that one intravenous therapy is superior to another.
- Give magnesium sulphate 40 mg/kg (max 2 gr) over 20 minutes.
- Give IV salbutamol 15 micrograms/kg over 10 minutes in patients aged 2years and older (5 mg/kg in < 2 years). The latter may be followed by IV infusion of 1-5 mcg /kg/min, whilst monitoring ECG and serum potassium regularly to allow for the

detection and treatment of hypokalemia. Note the loading dose is equivalent to 1.5 mcg/kg/min.

- If respiratory effort is poor or deteriorating, or conscious level is depressed, or SaO_2 is low and falling despite maximum oxygen therapy, attempt to support ventilation with bag-valve-mask, or with a mask, T-piece and bag with high flow oxygen.
- Contact the PICU or the retrieval service and senior anesthetic support.
- Consider intubation for mechanical ventilation; either rapid sequence induction with IV ketamine or inhalational anesthesia may help bronchodilation.
- If the child is not on oral theophylline or other methylxanthines, give a loading dose of IV aminophylline 5mg/kg over 20 minutes, monitoring the ECG for arrhythmias, followed by an infusion of 1mg/kg/h.
- If respiratory effort is poor or deteriorating, or conscious level is depressed, or SPO_2 is low and falling, despite maximum oxygen therapy, attempt to support ventilation with a bag-valve-mask, T-piece and bag with high flow oxygen, whilst arranging for urgent intubation. Use a slow inflation rate (< 12 inflations/min) as marked hyperinflation prolongs exhalation.

Indications for intubation:

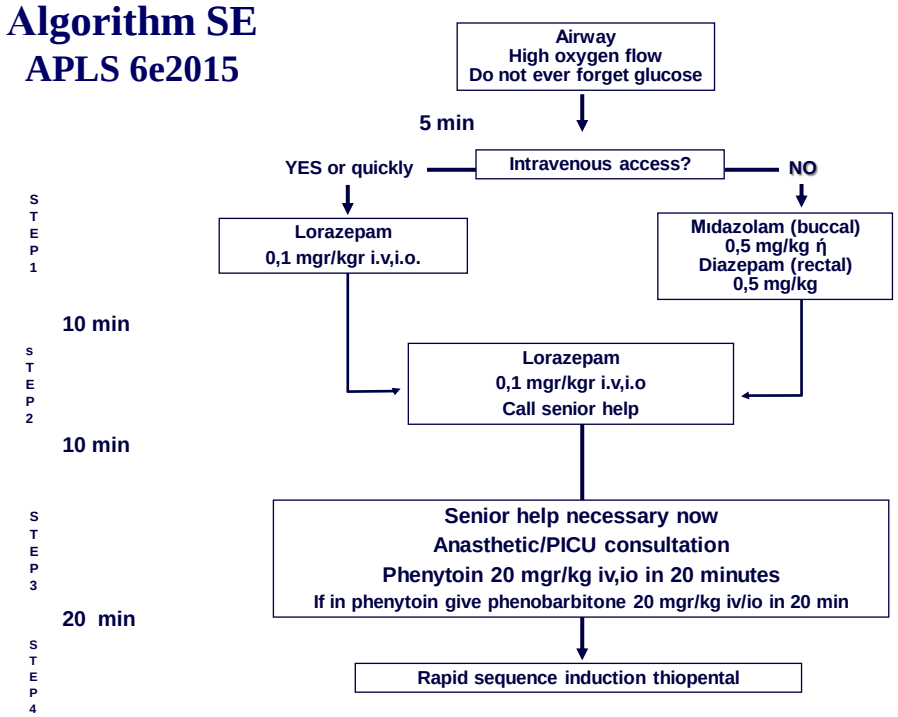
- Increasing exhaustion
- Progressive deterioration in
  - Clinical condition
  - SpO_2 - decreasing and/or oxygen requirement increasing
  - $PaCO_2$ increasing

Mechanical ventilation is rarely required. There are no absolute criteria, as the decision to intubate is usually based on the clinical condition of the child, and response to previous treatment. In cases of acute severe asthma that respond to treatment, there is usually little value to be gained from routine blood gas measurement. However, in those responding poorly, repeated blood gases with raised CO_2 that is not improving should expedite the decision to intubate. For example, ventilation should be considered if there is a PCO_2 of > 8 kPa (> 60 mmHg), persistent hypoxia with PO_2 < 8 kPa (<60 mmHg) in an inspired oxygen of 60%, particularly if there is increasing exhaustion, despite intensive drug therapy. Children with acute asthma who require mechanical ventilation need transfer to PICU. The prognosis is good but complications such as air leak, and lobar collapse are common. All intubated children must have frequent or continuous CO_2 monitoring.

Status Epilepticus

Generalised convulsive (tonic-clonic) status epilepticus (CSE) is currently defined as a generalised convulsion lasting 30 minutes or longer or when successive convulsions occur so frequently over a 30-minute period that the patient does not recover consciousness between them. Although the outcome of CSE is mainly determined by its cause, the duration of the convulsion is also relevant. In addition, the longer the duration of the episode, the more difficult it is to terminate it. In general, convulsions that persist beyond five minutes may not stop spontaneously so it is usual practice to institute anti-convulsive treatment when the episode has lasted five or more minutes (algorithm). Time keeping is crucial[1].

Unfortunately, the time sequence is not kept universally, and there are instances that there is an urge to intubation before enough time e.g., 45 min have elapsed. Typically, after the SE there is a post ictal critical phase where the child is asleep but can be aroused to painful stimulations with vocalizations and purposeful movements, e.g., GCS $\geq$ 8, which under other circumstances could had been the threshold to intubation, but in SE further recovery is expected in a short time. Pupils are dilated but reacted to light. The patient should be kept in the upright position under oxygen administration and close observation. Alternatively, the recovery position could be used. Frequent reassessment of ABC is mandatory as therapy may cause depression of ventilation or hypotension. This particularly applies after treatment with benzodiazepines used to control the fit. Assessing breathing efficacy solely by SpO_2 is not enough, as this cannot reveal hypoventilation. Checking SpO_2 breathing room air periodically may unmask hypoventilation; alternatively monitor carbon dioxide levels. Under oxygen administration PaO_2 and SpO_2 values are normal, but mild respiratory acidosis due to hypercapnia ($PaCO_2$ > 45 mmHg) is a common finding. In this case ventilation with a bag-valve-mask should be supported until ventilation becomes adequate. From our experience full uneventful recovery happened even with high $PaCO_2$ values up to 120 mmHg in the emergency room/ward (usually between 60-80 mmHg), with adequate bag-valve-mask ventilation support for some time, without intubation.



Diabetic Ketoacidosis

The typical respiratory pattern of a child with severe DKA is intense hyperventilation with extremely low $PaCO_2$ levels (even less than 10 mm Hg sometimes) in response to severe metabolic acidosis. There is often a fear of the attending pediatrician that the patient is at increased risk of exhaustion and respiratory failure due to the increased work of breathing. Anesthetists on call are often involved in the evaluation of children with severe DKA, when a drop in the level of consciousness is observed and a question on airway protection is arisen.

DKA guidelines are reviewed regularly; the following changes in BSPED 2015 DKA guidelines have been made since the last version of BSPED 2009 which generally represents a more strict fluid policy and an adherence to the importance of sodium levels which should rise as long as the child emerges from DKA. This protocol aims to minimize the risk of cerebral edema by producing a slow correction of the metabolic abnormalities[3,4].

- Change in the degree of dehydration to be used to calculate fluids; 5% for mild to moderate DKA and 10% for severe DKA, based on pH.
- De-emphasize sodium chloride bolus at the start of treatment apart from the sickest children.
- No more than one 10ml/kg fluid bolus to be given without discussion with a senior doctor.
- Further reduction in maintenance fluid rates, and simpler calculation of fluid rates.
- No longer to subtract any boluses given up to 20 ml/kg from the fluid calculation (as the rate is already reduced significantly from previous guidelines).
- Continuation of 0.9% sodium chloride (instead of changing to 0.45% sodium chloride) for the full duration of rehydration.
- Option for using an intravenous insulin infusion rate of 0.05 Units/kg/hour OR 0.1 Units/kg/hour.
- Continue to emphasize the importance of near to patient blood ketones monitoring

MANAGEMENT (see algorithm)

WEIGH THE CHILD. If this is not possible because of the clinical condition, use the most recent clinic weight as a baseline, or an estimated weight from centile charts. Use current weight for calculations.

1. FLUIDS: It is essential that all fluids given are documented carefully, particularly the fluid which is given in the accident and emergency department and on the way to the ward, as this is where most mistakes occur.

Volume of fluid

By this stage, the circulating volume should have been restored and the child no longer in shock after a maximum of one bolus of 10 ml/kg 0.9% sodium chloride. If not, **discuss with a consultant whether a second bolus should be given.**

Otherwise, once circulating blood volume has been restored, calculate fluid requirements as follows

Requirement = Deficit + Maintenance

Deficit

It is not possible to accurately clinically assess the degree of dehydration to work out the deficit. Therefore assume a

- **5% fluid deficit in in mild or moderate DKA (pH $\geq$ 7.1)**
- **10% fluid deficit in severe DKA (pH below 7.1)**

Maintenance

Calculate maintenance fluid requirement using the following 'reduced volume' rules:

- Body Weight < 10 kg, give 2 ml/kg/hour

- Body Weight between 10 - 40 kg, give 1 ml/kg/hour
- Body Weight > 40 kg, give a fixed volume of 40 ml/hour.

These are lower than standard fluid maintenance volumes because large fluid volumes are associated with an increased risk of cerebral oedema. Do not use other methods of calculating maintenance fluids, for example APLS, or the standard Holiday-Segar 4-2-1 rule, as these over-estimate fluid requirement.
N.B. Neonatal DKA will require special consideration and larger volumes of fluid than those quoted may be required, usually 100-150 ml/kg/24 hours.

Resuscitation fluid: for boluses up 20 ml/kg 0.9% NS do not subtract from fluids requirements; subtract any additional bolus volumes from the total fluid calculation for the 48-hour period i.e., if 30 ml/kg has been given subtract 10 ml/kg from the calculations.

Fluid Calculation

Calculated the fluid deficit (either 5% or 10% dehydration depending on severity of acidosis), divide over 48 hours and add to the hourly rate of maintenance deficit, giving the total volume **evenly** over the next 48 hours. i.e.,

Hourly rate = (deficit / 48hr) + maintenance per hour

Use 0.9% sodium chloride with 20 mmol potassium chloride in 500 ml (40 mmol per litre) until blood glucose levels are less than 14 mmol/L (252 mg%)

Examples:

A 20 kg 6 year old boy who has a pH of 7.15, who did not have a sodium chloride bolus, will require

- Deficit 5 % x 20 kg = 1000 mls
- Divide over 48 hours = 21 ml/hr
- Plus maintenance 1ml/kg/hr = 20 ml/hr

Total = 41 ml/hour

A 60 kg 16 year old girl with a pH of 6.9, and who was given 30 ml/kg 0.9% sodium chloride for circulatory collapse will require

- Deficit 10 % x 60 kg = 6000 mls
- Minus 10ml/kg resuscitation fluid = - 600 ml
- Divide over 48 hours = 113 ml/hr
- Plus maintenance fixed rate = 40 ml/hr

Total = 153 ml/hour

Do not give additional intravenous fluid to replace urinary losses. Urinary catheterization should be avoided but may be useful in the child with impaired consciousness.

Type of fluid

Corrected sodium levels should rise as blood glucose levels fall during treatment. Some have suggested that Corrected Sodium levels give an indication of the risk of cerebral oedema. If you wish to calculate this go to:

http://www.strs.nhs.uk/resources/pdf/guidelines/correctedNA.pdf.

If corrected sodium levels do not rise during treatment, discuss with the consultant on call.

If the child is becoming hypernatraemic, this is not generally a problem, and is protective against cerebral oedema. Please discuss with the consultant on call.

Special considerations once the patient is intubated

Mechanical Ventilation

In an excellent review on mechanical ventilation in DKA patients, Dr R. Tasker et coworkers in 2005 pointed out the following key points[5]:

- pH CSF or the extracellular fluid in the blood-brain barrier determines CBF. When considering the PCO_2-HCO_3 buffering system in the brain, [HCO_3] CSF changes slowly (over hours), whereas CSF PCO_2 changes rapidly in response to changes in $PaCO_2$ (as PCO_2 readily crosses the blood-brain barrier). Changes in CSF PCO_2 will thus cause changes in pH CSF that are fundamentally related to [HCO_3] CSF.
- In the context of metabolic acidosis that has developed over days, there is likely low [HCO_3] CSF, and a low $PaCO_2$ will be required to maintain normal pH CSF.
- It may be possible to explain the development of cerebral edema in some patients with DKA by the development of low pH CSF due to abruptly developed increased $PaCO_2$ levels, leading to cerebral hyperemia and vasogenic cerebral edema.
- In the context of DKA, it is theoretically possible to calculate the limits of what $PaCO_2$ levels patients could maintain before decompensating (figure 1).

  Their recommendation in DKA is, where possible, to avoid endotracheal intubation and ventilation unless they are for exhaustion; it is better not to interfere with adaptive physiology. However, if intubation and ventilation are undertaken, consider a target level of $PaCO_2$ appropriate for estimated [HCO3]CSF, and treat with great caution those presenting with pH ART < 7.00.

  As shown in figure 1, accumulated data from DKA patients studying in parallel blood and CSF parameters, indicate that the average CSF pH is around 7.23. Given the iso-molar lines of different blood HCO_3 levels, the intersection of these lines with the iso-acidity line of CSF pH of 7.23 indicate the safe tolerated $PaCO_2$ level that is allowed to prevent cerebral edema; e.g., for HCO_3 of 6 to 10 mmol/L the safety $PaCO_2$ window lies between 18 - 27 mmHg. Open square denotes Kety et. al data, filled circle denotes the Pediatric Emergency Medicine Collaborative Research Committee of the American Academy of Pediatrics data and filled triangle denotes Glaser et al. data.

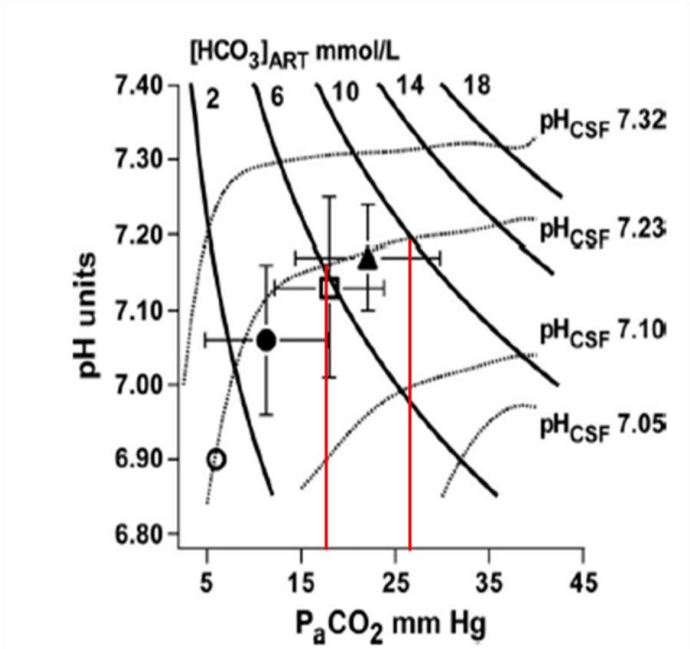


Figure 1. $PaCO_2$ safety limits according to blood pH and Iso-molar and iso-acidity CSF lines.

Fluid administration

Once the patient is intubated and put in mechanical ventilation under sedation fluid requirements may change, reflecting the effect of sedation and mechanical ventilation on DKA. Typically, conditions of relative hypovolemia are cumulatively developed, and there is an increase need for fluids due to

- Increase in vessel capacitance from sedation vasorelaxation
- Decrease in cardiac preload due to reduced venous return developed from the positive pressure ventilation

It is prudent to adapt the above guidelines to the patient condition guided by the close observation of the trends of clinical examination and the monitoring; placement of a central venous catheter to monitor central venous pressure is of paramount importance. Moreover, CVC will also be needed for administration of the high amounts of K which are usually needed. Patient requirements should be planned under the guidelines, and extra fluids could be given as extra replacements of 10 ml/Kg of crystalloids 0.9% N/S or R/L given in 1 to 4 hours. Human Albumin 20% at a dose of 1 mg/kg could follow in cases of hypoalbuminemia (<3 mg%). Our recent experience with DKA patients treated under the relatively strict 2009 -2015 guidelines while on mechanical ventilation under sedation, showed an extra need for fluids when the patient is intubated, according to clinical status.

Suggested References

1. Advanced Pediatric Life Support, 6th Edition, 2015.

2. Elizabeth Kepreotes, Bruce Whitehead, John Attia, et al. High-flow warm humidified oxygen versus standard low-flow nasal cannula for moderate bronchiolitis (HFWHO RCT): an open, phase 4, randomized controlled trial. JAMA, February 1, 2017. http://dx.doi.org/10.10116/S0140-6736(17)30061-2.

3. BSPED Recommended DKA Guidelines 2009.

4. BSPED Recommended DKA Guidelines 2015.