Update in Anaesthesia

Anaesthesia for emergency paediatric general surgery

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Summary

Emergency surgery for bowel obstruction in children presents many challenges for the anaesthesia care provider. Delayed presentation and sepsis have a profound physiological impact on many organ systems. Hospital stays elongated by postoperative complications, and the lack of appropriate paediatric intensive care facilities also contribute to the high morbidity and mortality of this surgical population. Mortality in neonates is even higher.

Children have a great reserve and ability to heal but also the potential for sudden decompensation. Good outcomes rely on meticulous perioperative planning, proper training, equipment, and basic supplies. A team approach involving the nurses, laboratory technicians, paediatricians and surgeons is essential.

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INTRODUCTION

Paediatric emergency general surgery in Sub-Sahara Africa has a high morbidity and mortality with multiple contributing factors. Delayed presentation and diagnosis, hospital stays elongated by postoperative complications, and the lack of appropriate paediatric intensive care facilities all contribute to the overall mortality of this surgical population. The mortality in the neonates (less than 6 months) is even higher.

The following paediatric abdominal surgical emergencies were documented in a case series from a teaching hospital in southeastern Nigeria, and provide a description of the typical paediatric surgical practice in sub-Saharan Africa:[1]

	%workload
• Typhoid intestinal perforation (TIP)	19
• Intussusception	17
• Obstructed hernia	15
• Neonatal intestinal obstruction	10
• Appendicitis	10
• Trauma	7
• Ruptured omphalocele/ gastroschisis	7
• Hirschsprung's disease	6
• Adhesive bowel obstruction	6
• Malrotation	4

The incidence of typhoid perforation varies between regions; it follows infection with *Salmonella typhi*, the usual source of infection being contaminated water supplies.

Patients frequently present late, often with signs of severe illness, and careful preoperative assessment and resuscitation is essential. Severe pre-existing metabolic abnormalities, including acidosis and dehydration, will be a challenge for any anaesthesia care provider, but in an environment with limited anaesthesia, surgery and intensive care resources, the challenges are even greater.

This article will review the pathophysiology of intra-abdominal emergencies in children; how to construct an anaesthesia plan for such patients; intraoperative and postoperative problems; and typical case presentations. We hope to provide a greater understanding of general surgical emergencies in children, and to assist with the management of these challenging patients.

PATHOPHYSIOLOGY OF BOWEL OBSTRUCTION

The normal bowel contains gas and the sum of food and salivary, gastric, biliary, pancreatic, and intestinal secretions. Intrinsic or extrinsic blockage of the small bowel leads to accumulation of secretions that dilate the intestine proximal to the obstruction. Patients with delayed presentation may have a diminished oral intake for many hours, and perhaps even days or weeks, but intestinal secretions continue so that the bowel remains full of fluid. Vomiting is an important sign of obstructed bowel in children; the nature of the fluid vomited will suggest the level of the obstruction. Green coloured 'bilious' vomiting is characteristic of small bowel obstruction.

If the intraluminal pressure of the obstructed bowel exceeds the capillary and venous pressure in the bowel wall, intestinal absorption and lymphatic drainage decreases and the bowel may become ischaemic; this is a dangerous development that may lead to perforation, but it is difficult to predict when this will occur.

Bacterial translocation

Once the bowel becomes ischaemic, bacteria will pass into the peritoneum by a process known as bacterial translocation, even if the perforation cannot be visualized. The colonized fluid is then transported via the lymphatic channels into the thoracic duct, which drains into the central venous system. This allows bacteria to enter the circulation, which in turn causes septicaemia. Studies have shown that bacteria injected into the peritoneum can be cultivated from peripheral blood only six minutes after the injection into the peritoneum, confirming the extremely rapid flow from the peritoneum into the systemic circulation. Bacterial translocation will produce a cascade of events, which will impact multiple systems. Septicaemia is common in children with delayed presentation due to an abdominal emergency, and a child presenting for emergency paediatric surgery in this condition will provide many challenges to the anaesthetist.

DEFINITION OF PAEDIATRIC SEPSIS

The International Paediatric Sepsis Consensus Conference (2005) attempted to develop specific criteria for an international definition of sepsis. These experts determined that the presence of two of the following four criteria, one of which must be abnormal temperature or leukocyte (white blood cell) count, along with a suspected or proven infection, would constitute the definition of sepsis. The infection could be bacterial, viral, fungal or rickettsial in origin.[2] In most patients with a surgical abdomen, the infection would be a 'suspected' bacterial infection.

The criteria for the definition of sepsis in children are as follows:

- Core (rectal, oral) temperature of >38.5°C or <36°C.
- Tachycardia in the absence of external stimulus, chronic drugs or painful stimuli, or otherwise unexplained elevation, for over a 30 minute to 4 hour period, OR, for children <1 year, bradycardia in absence of drugs, vagal stimulation or congenital heart disease, or otherwise unexplained bradycardia, for over a 30 minute time period (see Table 1).
- High respiratory rate or mechanical ventilation for an acute problem not related to a neuromuscular disease or for just receiving general anaesthesia (see Table 1).
- Leukocyte count elevated or depressed for age, not related to chemotherapy.

The criteria for definition of severe sepsis in children is 'sepsis' PLUS one of the following:[2]

- Cardiovascular dysfunction,
- Acute respiratory distress syndrome (proven need for >50% inspired oxygen (FiO_2 >0.5), to maintain arterial saturation >91%),
- Two or more organ dysfunction (respiratory, renal, neurologic, hematologic, or hepatic),

The presence of organ dysfunction can be determined clinically or with basic lab tests such as platelet count, creatinine level, or bilirubin level. This allows the clinician at the bedside to diagnose sepsis without sophisticated tests, and prompts the appropriate interventions. It is important to understand that the paediatric surgical patients who require emergency surgery could have an assortment of organs that are functioning abnormally; this information will help you to plan the perioperative care for these very ill patients.

Cardiovascular dysfunction

Children compensate for a decrease in circulating volume and may not become hypotensive until long after septic shock develops, unlike in adult shock patients where hypotension is commonly seen.

Some investigators have defined the cardiovascular symptoms of septic shock as tachycardia with signs of decreased perfusion including:[2]

- Decreased peripheral pulses compared to central pulses
- Altered alertness

Table 1. *Criteria for definition of sepsis in children of different ages*

Age Group	Heart Rate, Beats/Min Tachycardia	Heart Rate, Beats/Min Bradycardia	Respiratory Rate, Breaths/Min	Leukocyte Count, Leukocytes x 103.mm-3	Systolic Blood Pressure, mmHg
0 days to 1 wk	>180	<100	>50	>34	<65
1 wk to 1 mo	>180	<100	>40	>19.5 or < 5	<75
1 mo to 1 yr	>180	<90	>34	>17.5 or < 5	<100
2-5 yrs	>140	N/A	>22	>15.5 or < 6	<94
6-12 yrs	>130	N/A	>18	>13.5 or < 4.5	<105
13 to <18 yrs	>130	N/A	>14	>11 or < 4.5	<117

- Capillary refill >2 seconds
- Cool extremities
- Decreased urine output.

If a child presents with signs above and with hypotension and tachycardia, this indicates that they have lost a significant amount of blood (e.g. from trauma), or they are severely volume depleted (e.g. due to intra-abdominal pathology). A child presenting for surgery with this picture requires significant fluid resuscitation prior to induction of anaesthesia.

Blood volumes in children are small in absolute terms (75-80 $ml.kg^{-1}$). Every paediatric patient will need to be weighed accurately prior to starting fluid resuscitation. There are many references that discuss assessment of percentage of deficit, but in general, if a patient is dehydrated, a fluid bolus of $10ml.kg^{-1}$ normal saline (0.9% saline) or a balanced salt solution such as lactated Ringer's, should be given and repeated as required. A child with a 'surgical' abdomen may typically require repeated IV boluses up to $30\text{-}50ml.kg^{-1}$ preoperatively to restore adequate intravascular volume. If repeated crystalloid boluses are required, greater than $30ml.kg^{-1}$, consider blood transfusion.

Renal system and fluid and electrolyte management

Decreased circulating volume and hypotension also trigger sodium and water conservation by the kidneys through decreased urinary output. Remember that the developing child does not have the same anatomical and functional renal capacity as the adult patient, thus maximum concentrating capacity may not be demonstrated. Increase in sympathetic tone in shock causes constriction of the renal arteries, which reduces blood flow to the kidneys and decreases filtration and urine output. This low flow state causes the kidney to release vasopressin (antidiuretic hormone, ADH), a potent vasoconstrictor, and activates the renin-angiotensin-aldosterone hormone pathway which results in further decrease of blood flow to the kidneys, as well as generalized vasoconstriction. All of these actions are focused on improving systemic blood pressure, blood flow, and maintaining tissue perfusion. Note the above mechanism describes the normal mechanisms that will occur in all patients with fluid loss into the gut; some may have the abnormal 'syndrome of inappropriate anti-diuteric hormone' secretion; SIADH - see below.

Patients with septic shock typically present with acute changes in their fluid status including:

- Decreased oral intake
- Fever
- Fluid shift into the gastrointestinal system
- Electrolyte disturbances
- Pronounced reduction in intravascular volume.

A detailed history will help determine the period of decreased fluid intake and also the type of fluid used for resuscitation by the caregivers or the medical care provider prior to arriving at your institution. A question to the patient's mother (or caregiver) regarding frequency of a wet diaper/nappy in the last 24 hours will help one assess intravascular status and renal function.

'Inappropriate' ADH (vasopressin) secretion is common in the 'sick' child, and children presenting with abdominal pathology are at particular risk of perioperative hyponatraemia. It is important to avoid intravenous fluids with a low sodium content at all times in these patients, especially if they are requiring fluid at more than normal maintenance rate.

Unfortunately, iatrogenic harm is common in paediatric fluid management, particularly if low sodium containing fluids such as 4% dextrose 0.18% saline are used for resuscitation. This may lead to symptomatic hyponatraemia (low plasma sodium), which may complicate diagnosis and delay surgical intervention. For example, if hypotonic fluids are used for fluid resuscitation in a child with an acute abdomen, the plasma sodium may fall to extremely low levels ($<125mmol.l^{-1}$), and the child may have seizures. This causes diagnostic confusion if the child is investigated for a seizure disorder when in fact the child has dehydration secondary to bowel obstruction. Severe hyponatraemia may lead to irreversible brain damage in children, but can be avoided by using isotonic fluids for resuscitation.

Early symptoms of hyponatraemia include nausea and headache. Later symptoms can include confusion, seizures and even respiratory arrest. A seizure caused by hyponatraemia is very difficult to control with benzodiazepines and barbiturates until the sodium level reaches $120mmol.l^{-1}$. This scenario may be extremely dangerous without adequate critical care facilities to manage ventilation and cardiac monitoring since the tendency is overaggressive treatment of the seizures with long-acting benzodiazepines causing respiratory depression. A bolus of hypertonic saline (3% sodium chloride) $1ml.kg^{-1}$ should be given, and may be repeated if the seizures continue. Over correction must be avoided; the rate of correction of plasma sodium should not exceed $8mmol.kg.d^{-1}$.

The renal system in children is immature, which affects the ability to compensate during periods of decreased oral intake, emesis, and bowel obstruction. For example, in the first year of life, the renal plasma flow and the GFR are approximately one half that of the adult patient. Additionally, the fractional excretion of sodium does not reach adult levels until 6 months of age. Hyponatraemia is common at presentation in children with an acute abdomen, again reinforcing the importance of only using isotonic fluids (0.9% saline, Ringer's) to expand the circulating blood volume in the dehydrated patient.

Large extracellular fluid deficits due to poor intake, excessive losses and poor renal capability to compensate may require aggressive fluid resuscitation with close monitoring of fluid input, urine output and pulmonary status. An indwelling bladder catheter may be necessary, and the respiratory rate and oxygen saturation (if available) should be monitored closely. Even if a patient receives 50-70ml.kg^{-1} of intravenous fluids, pulmonary oedema is rare in this patient population with previously normal cardiovascular function.

Haematologic system

Altered production and function of white blood cells (WBC), red blood cells (RBC), and platelets is common in children with bowel obstruction and sepsis. Sepsis may be associated with anaemia, or the haemoglobin level may be artificially high due to severe dehydration. Anaemia in sepsis may develop from haemodilution due to early fluid resuscitation and also anaemia of inflammation (decreased erythropoietin production, decreased bone marrow response to the erythropoietin, and decreased RBC survival).[3] Chronic anaemia is also common in this patient population. The platelet count may be reduced in sepsis, or the function may be abnormal, which may lead to excessive bleeding. Coagulation abnormalities frequently occur in sepsis. The more delayed the presentation of bowel obstruction, the greater the chance of disseminated intravascular coagulation (DIC). DIC is characterized by intravascular thrombosis and secondary tissue ischaemia, which leads to abnormal bleeding.[4]

In many hospital settings, the ability to perform a bleeding study in a patient with suspected DIC is impossible, and a clinical diagnosis must be attempted. The clinician should have a low index of suspicion for coagulopathy in a patient with sepsis, particularly if there is prolonged bleeding with simple interventions such as insertion of IV lines. Whole fresh blood, less than 48 hours old, is available in the blood bank in most rural hospitals, which is a good option for children who undergo emergency abdominal surgery as it will improve haemoglobin, platelet count and coagulation factors. A dose of 20ml.kg^{-1} blood in divided doses is a good starting point for children requiring blood transfusion. The heart rate, blood pressure and respiratory status should be monitored. Blood that is needed for surgery should be given immediately (less than one hour) before the surgery starts, to maximize the function of coagulation factors and platelets. If blood is donated immediately prior to surgery, it can be given without refrigeration, as the warmth of the recently donated blood will assist in keeping the temperature normal during surgery, for instance during an exploratory laparotomy. If possible, blood should not be warmed by placing into a bath of warm water; water that is too hot may cause haemolysis of the red blood cells, which would produce a massive release of potassium. The hyperkalaemia could result in sudden cardiac arrest immediately after the blood is transfused. Water that is too hot to submerge your hand in for over 5 seconds will be too hot to warm IV fluids and should not be used.

CLINICAL APPLICATION - CASE EXAMPLE

A previously healthy 10-month-old male infant presents to the clinic with a five day history of sudden crying, irritability, and sweating but with periods where the child seems to be acting normally. The child has been able to take fluids during the times where he appears normal but the frequency of pain and sweatiness has increased in the last two days and the intake has significantly decreased. The mother denies any fever until yesterday but over the last 4 days the child has had loose stools described as some blood and mucus with a frequency of 4-6 stools per day.

The mother took the child to a local dispensary where he was given IM antibiotics and some intravenous fluids while being monitored. After 12 hours of fluids and no improvement, the child was transported to the referral hospital (6 hours by taxi) where he presented with abdominal tenderness and distention, decreased peripheral perfusion, and breathing difficulties. Vital signs: HR= 200bpm; RR= 40min^{-1}; BP 50/30 (very weak pulses); oxygen saturation (no monitor available) but patient appears pale. Initial labs: Na^{+}= 126mmol.l^{-1}; creatinine

Figure 1. *Intussusception. Upright abdominal Xray: note loops of bowel, flattened diaphragm, and rounded abdomen. The child will be at risk of aspiration on induction of anaesthesia*

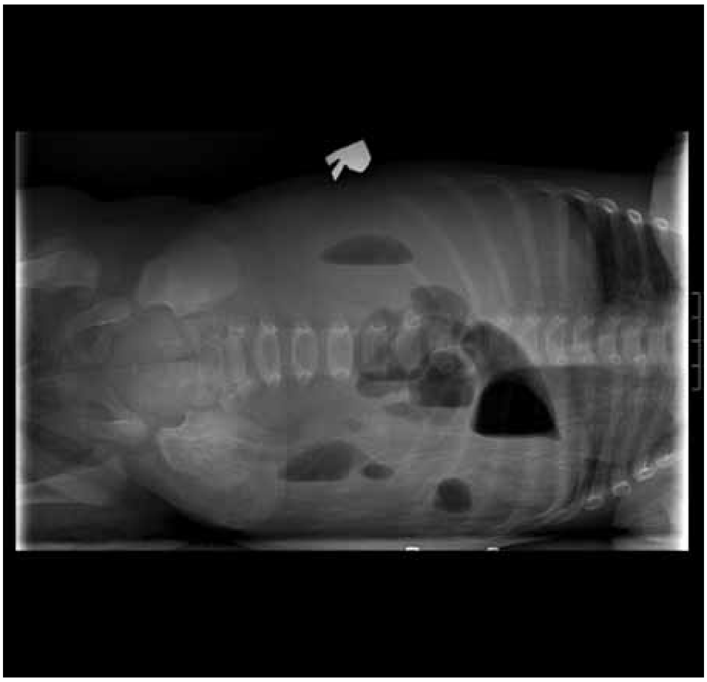

Figure 2. *Intussusception. Lateral abdominal Xray: air-fluid levels (intravascular volume status impacted) and no obvious perforation (non-specific)*

= 1.1mg.dl^{-1} (97mcmol.l^{-1}); K^+= 3.0mmol.l^{-1}; haemoglobin = 8g.dl^{-1}. Weight = 6kg. The surgery team has decided that this patient needs an exploratory laparotomy for bowel obstruction.

In most centres, intussussception is the most common cause of intestinal obstruction in the age group 3 months to 3 years. Delayed presentation is common due to the nature of the disease, partly as the obstruction is intermittent initially, partly due to the lack of appropriate centres for paediatric surgery and anaesthesia. Typically, upper intestinal obstruction causes emesis as the primary symptom and lower intestinal obstruction results in diarrhoea, unless the obstruction is prolonged in which case you will see emesis with diarrhoea. Once the obstruction has become fixed, the pain will get progressively worse and will become constant, which typically causes the care givers to seek urgent surgical care.

Preoperative considerations

Haemodynamic assessment and initial management

This child has low blood pressure, tachycardia, and poor peripheral perfusion and demonstrates the most common form of cardiovascular instability, namely hypovolaemia. The history describes a period of low intake, diarrhoea, bowel obstruction, fever, and possibly sepsis. Each of these factors contributes to an overall picture, that results in low circulating blood volume in a child where the total body water represents 60-70% of body weight. Delayed presentation further amplifies the negative impact of the pathological state on the loss of intravascular volume. This child is demonstrating clinical signs of over 15% deficit which will require a significant amount of fluid in the form of normal saline. Bloody diarrhoea in this patient may cause anaemia, protein loss, and electrolyte disturbances; a normal haemoglobin in a patient with this clinical picture may be misleading as it may be due to haemoconcentration and severe dehydration with a RBC mass which is actually low. Be aware that significant volume resuscitation may then reveal the true anaemia and low haemoglobin.

This child needs urgent intravenous or intra-osseous access and resuscitation with a normal saline (isotonic) fluid bolus. IV access should not be delayed; the patient is near complete cardiac collapse, and his sympathetic nervous system is working at maximum capacity to maintain mean arterial blood pressure with vasoconstriction and tachycardia. Children at this age can have a significant reduction in the intravascular volume without demonstrating a large drop in blood pressure, but then suddenly have a cardiac arrest due to low intravascular volume as their compensatory mechanisms are overwhelmed. The mother may be able to inform you of the last time the child had any urine output which will help estimate deficit. The normal urine output is 0.5 to 1ml.kg-1.hr^{-1} but many patients with this clinical picture may be severely dehydrated with present with no urine output and no wet diapers for 24 hours.

This patient should have 20ml.kg^{-1} IV (IO) 0.9% saline bolus push, repeated until there are clinical signs of improved perfusion and the HR falls; the mental status will also improve as perfusion improves. Don't forget – blood should be considered if 30-50ml.kg^{-1} volume resuscitation is required, particularly if there is a history of bleeding. The patient may require up to 100ml.kg^{-1} IV volume resuscitation, ideally a combination of isotonic saline and blood prior to surgery. The fluids need to be warmed to avoid causing hypothermia. Do not give potassium to any volume depleted patient until urine output is established and renal function can be assessed. Place a bladder catheter to help determine fluid status in this situation. The specific gravity (SG) of the urine has been shown to be a rough indicator of intravascular dehydration and sensitivity to the negative inotropic effects of anaesthetic agents. If the SG is less than 1009, i.e. the urine is not very concentrated, then the risk of hypotension with halothane is lower compared to when the SG is greater than 1009. A urine specific gravity can be obtained in most basic laboratories. Note that the patient with decreased level of consciousness will improve after volume resuscitation. The serum glucose level must be measured in any patient with reduced level of consciousness to rule out hypoglycaemia. At times, when the intravascular volume is replaced but due to hypoglycaemia, the child remains in a less responsive state. When in this clinical situation an intravascular glucose bolus may be required while still attempting to maintain normal serum glucose levels.

Respiratory assessment and initial management
A patient who presents with tachypnoea and/or hypoxia (or low oxygen saturation documented with pulse oximetry) must be assessed carefully prior to the induction of anaesthesia. High respiratory rate may be a secondary compensation to metabolic acidosis due to decreased perfusion. Oxygen delivery to the cells may be inadequate in conditions of poor perfusion for instance due to septic shock, which results in acidosis and excess hydrogen ion production. The body is attempting to remove carbon dioxide to correct the acidosis. Subtle changes in the respiratory system may precede frank respiratory failure if the child becomes exhausted and compensation is overwhelmed. The lungs are not the primary organ of failure but merely required to overwork to balance the metabolic derangement. As with the cardiovascular system, the respiratory reserve is immense but can suddenly fail, resulting in respiratory arrest. Any sudden slowing of the respiratory rate should prompt immediate airway assistance such as tracheal intubation. The treatment of this metabolic process is not bicarbonate but resuscitation fluids (normal saline), titrated as described. When the patient's fluid status improves, the patient will become more alert, the perfusion will improve and the respiratory rate will become more normal. Note that fever will also elevate the respiratory rate and could confuse the clinical picture. Metabolic acidosis should be primarily treated in this scenario with isotonic fluids.

An alternative cause of tachypnoea in this patient may be primary respiratory pathology, such as pneumonia caused by the aspiration of gastric contents. Gastro-oesophageal reflux is common in the child less than 1 year and when a child has a distended abdomen, reflux of gastric contents occurs readily. Gentle insertion of a nasogastric tube should be considered to drain some gastric fluid, although this procedure can prompt emesis and aspiration in the child with a decreased mental status. The nasogastric tube (size 10-12 French) should be softened in warm water prior to placement to help avoid trauma and the patient should be placed in the lateral position to avoid aspiration in case they vomit. Auscultation of chest sounds will help to differentiate between metabolic acidosis (non-pulmonary) and aspiration pneumonia. If the chest sounds are clear the chance of aspiration pneumonia is lowered but if you hear crackles or wheezing particularly on the right side of the chest, this could help diagnose pneumonia. Pneumonia in this setting should not delay surgery in a child with compromised gut perfusion, but will indicate that the child is at greater risk postoperatively.

Electrolytes
A child presenting late with bowel obstruction may have significant electrolyte abnormalities. In patients with altered mental status, the sodium and glucose levels must be measured and corrected. Hypoglycemia can be a result of decreased intake over many days, especially in paediatric patients who are at baseline malnourished and then get sepsis. If the blood glucose level is low, give a bolus of 50% dextrose $2ml.kg^{-1}$ and recheck with a glucometer before starting surgery. If the surgery lasts longer than 1 hour, recheck the blood sugar again as undetected hypoglycaemia under anaesthesia can have serious neurological implications.

Hyponatremia (low sodium) is common in the surgical paediatric patient and could be caused by diarrhoea, vomiting, low salt oral fluids, and use of incorrect fluids such as 4% dextrose 0.18% saline for resuscitation at a medical care facility. Paediatric patients who have been resuscitated using 5% dextrose (without added sodium) due to concerns about blood glucose levels can present with an altered mental status and even seizure activity due to iatrogenic hyponatremia. Hyponatraemic seizures are very difficult to manage with anti-seizure medications such as diazepam, and even phenobarbital, if the sodium level is below $120mmol.l^{-1}$. These patients should be resuscitated with 0.9% saline; their seizure activity and alertness will improve as the plasma sodium rises. The anaesthesia care provider should not delay emergency surgery until the plasma sodium level is normal if the intravascular fluid status has been corrected. A documented rise in plasma sodium towards normal is reassuring, and shows that resuscitation measures are having a positive impact.

When can you start the surgery?
The case described is a surgical emergency, particularly if there is vascular compromise to the intestines. Bowel ischaemia, necrosis then perforation (with ensuing sepsis) increases the morbidity and mortality of surgery dramatically. If the patient continues to demonstrate metabolic acidosis after resuscitation with isotonic fluids, removal of a necrotic section of intestine may be the only intervention that improves the clinical condition of this child. With the history of delayed presentation, the child does not need to go to theatre in a few minutes, rather in a period of less than 2 hours after IV fluid resuscitation has commenced. The heart rate, respiratory rate and peripheral perfusion should begin to normalize prior to the induction of anaesthesia. Establishing some urine output is a useful sign and indicates improved renal preload following resuscitation efforts.

The following laboratory measurements need to be obtained if possible, but do not delay surgery for the results to normalize:

- Full blood count

- Type and cross match for one unit of blood (typically 400ml of whole blood in a rural hospital).
- Plasma sodium
- Glucose

If you are working in a hospital that cannot measure electrolytes, do not attempt to get a plasma sodium level at another hospital, but rather give volume resuscitation with 0.9% saline as indicated, and proceed with the surgery.

Prepare the theatre with a warmer if the environment is cool, as the child will have extensive exposure and opportunity for heat loss. Prepare all the equipment required to anaesthetise a child. Do not attempt to give the anaesthetic alone but find an assistant. Explain about airway management, the aspiration risk, and the need for cricoid pressure.

Consider the plans for postoperative care well in advance:

- Staffing level on the ward
- Oxygen
- Suction
- Monitoring
- Location on the ward relative to the nursing station
- Light.

Intraoperative considerations

Induction concerns

This patient has a distended abdomen due to obstruction and is considered to have a "full-stomach" so must have a rapid sequence induction with cricoid pressure. The anaesthetist must have an able assistant. A child with intestinal obstruction will need full precautions to prevent aspiration on induction, irrespective of the length of time they have been starved, or the fact they have a nasogastric tube (NGT). Cricoid pressure needs to be applied so that it does not distort the airway, as this will make the intubation more difficult. Ask the assistant to direct the trachea backwards, upwards and gently to the right. Preoxygenation prior to intubation is extremely important in children with intestinal obstruction as the functional residual capacity (FRC) is reduced and the child will desaturate rapidly when apnoeic. However, preoxygenation may be difficult if the child is crying, but you can achieve some form of preoxygenation if you waft high flow oxygen through a mask directed towards the child's face. If the patient is obtunded and less responsive, a good mask fit may be achieved, which will allow preoxygenation with 100% oxygen, thus reducing the risk of desaturation during intubation. As you can see from figure 3, if the abdomen is very distended it has the potential to restrict diaphragmatic movement and lung volumes, particularly in the supine position. Both of these factors will cause a rapid drop in the oxygen saturation once the patient stops breathing spontaneously.

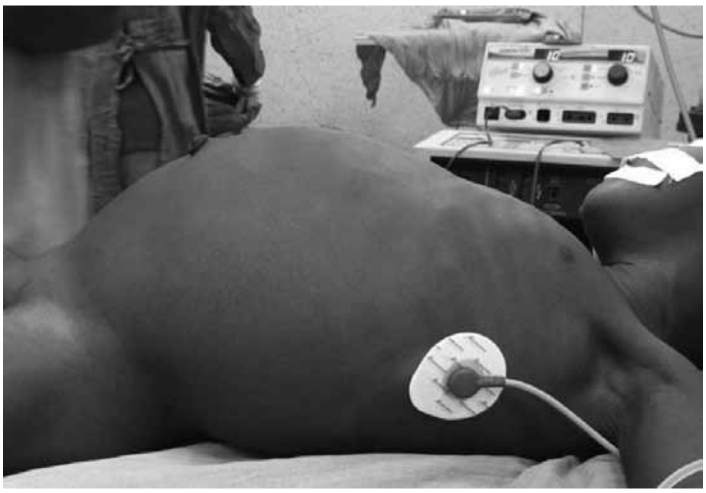

Figure 3. *Child with bowel obstruction. The high intraperitoneal pressure will decrease the lung capacity, FRC and oxygen reserve prompting a rapid drop in oxygen saturation during intubation*

Figure 4. *Intubation hand positioning: notice that the trachea is being displaced posterior and midline*

If the patient has an NGT to help drain the stomach, it should be suctioned prior to the induction of anaesthesia. Some suggest it should be removed immediately prior to induction to ensure a good seal with the facemask if you need to ventilate the patient with cricoid pressure, should more than one attempt at intubation be required. Check the position of the endotracheal tube by auscultation prior to removal of cricoid pressure. Early removal of the cricoid pressure can result in aspiration if the endotracheal tube is placed in the oesophagus. A cuffed tube of an appropriate size can be considered in children of all ages, but the cuff pressure should be measured and the cuff should not be overinflated. Uncuffed tubes are still routinely used in many institutions. Clinical evaluation of the position of the tube in the trachea is essential after intubation, ideally confirmed by capnography, if available.

The choice of induction agent includes thiopentone (2-4mg.kg^{-1}), propofol (1-2mg.kg^{-1}), or ketamine (1-2mg.kg^{-1}) IV. Ketamine is an ideal agent if the child is critically unwell. An even lower dose of induction agent should be used if the patient is in shock not responding to fluid. If the child has been sick for some time, the blood pressure may drop even with ketamine as the sympathetic nervous system is overwhelmed. Never perform an inhalation induction in these patients. Succinylcholine (2mg.kg^{-1} IV) should be used as the muscle relaxant. Rocuronium could be considered as an alternative, if available. Once the endotracheal tube position is confirmed, the NGT should be replaced if it has been removed to decompress the stomach during the remainder of the intraoperative and postoperative course.

Maintenance concerns

After induction of anaesthesia and intubation with succinylcholine, monitor the haemodynamic status closely. Induction may reveal hypovolaemia and cause the blood pressure to fall. If this happens, give a fluid bolus of normal saline or blood in 10ml.kg^{-1} increments. Two peripheral IV lines should be inserted (ideally 22G), with access to an injection port during surgery. Place a three-way stop-cock in line so that blood or normal saline can be pushed with a 20-60ml syringe. This helps to deliver fluids accurately, also rapidly if required. It is important that fluid balance is documented as accurately as possible; pulmonary oedema can be a complication of excessive fluid administration in the operative setting. Blood should be given based upon blood loss, with the goal of improving oxygen delivery dictated by cardiac output, oxygen saturation, and haemoglobin level. Studies have shown that in "stable sepsis" in the paediatric population that a haemoglobin level above 7g.dl^{-1} should be safe.[5] In a rural hospital setting, this figure may need to be higher due to the weak medical infrastructure and support systems.

Inotropes will need to be started if blood pressure remains low despite fluid administration. Opening the abdominal fascia may reduce venous return if the abdomen is tense, for instance where there is bowel ischaemia and necrosis, which will cause a fall in the cardiac output (BP). In addition, movement of bacteria from the obstructed, and possibly necrotic intestines to the blood stream may release mediators and hydrogen ions (producing acidosis), resulting in more cardiovascular instability during surgical manipulation and repair of the damaged intestines. A bolus of adrenaline 1 mcg.kg^{-1} IV may be useful whilst an infusion of adrenaline is prepared (dilute 1 mg adrenaline in 1000ml saline to give a solution of 1mcg.ml^{-1} adrenaline).

To prepare a solution of dopamine for use without a syringe infusion pump, place 200mg dopamine into 100ml of normal saline in a paediatric microdrop giving set. Titrate this infusion to maintain the blood pressure in the normal range. The infusion may be required for a few days in severe cases. Monitor urine output as an indirect measurements to assess adequate organ perfusion and keep the patient warm in the perioperative period with the means which you have available to you in your hospital setting.

The use of inhalation agents, ketamine, opioids or any combination will be determined by the patient's response to induction and surgery. Inhalation agents will all cause some degree of vasodilation and cardiac depression, which may not be tolerated in the seriously ill patient, thus prompting the use of a ketamine infusion. You will need to control the ventilation, either by manual ventilation or using a ventilator with settings for a paediatric patient. If the patient is acidotic (determined clinically or by measurement of the venous or arterial blood gas), they will not tolerate spontaneous ventilation with low tidal volumes, particularly if the abdomen is compressed by the surgical team during laparotomy. Consider using a non-depolarising muscle relaxant to assist the surgeon and expedite the procedure, but the child must be fully reversed at the end of the operation. Beware sudden cardiac arrest in theatre due to hypovolaemia, myocardial depression, or associated with CO_2 in the absence of end-tidal CO_2 monitoring. If the monitors stop recording, do not automatically consider monitor malfunction but immediately evaluate the patient for cardiovascular collapse.

At the end of surgery, consider the options for extubation carefully. If a stoma is placed, the surgeon may manually decompress the bowel and the abdominal compartment may not be too tight. Alternatively, if there is a primary anastomosis, abdominal distension may persist postoperatively. In severe cases of obstruction and sepsis, primary anastomosis would not be the primary option due to potential failure and leakage. In either case, the child needs to be fully awake, breathing well and adequately reversed, indicated clinically by flexion of the legs.

Postoperative considerations

The two most important factors for safe postoperative care are the location in the hospital and the nurse: patient ratio. The ideal location should have oxygen, suction, good lighting, be close to the nursing station; the room should be warm, the head of the bed elevated, and there should be, one paediatric nurse assigned to 1-2 children. In many hospitals the nurse: patient ratio is 1:15 , with very ill children, and this will not be safe for this child for the 72 hour period when the risk of morbidity and mortality will be greatest. The location of postoperative care must be considered early so that the child has the best chance of survival.

Regular paracetamol 20-30mg.kg^{-1} PR should be given every 6-8 hours around the clock for 3 days, with very small doses of opioids titrated as required. Good nursing care is essential. Many of these patients will have an oxygen requirement for a few days while the sepsis and any pneumonia resolves. The respiratory status, respiratory rate, should be monitored carefully, particularly if opioids are given to a child receiving oxygen. A fall in saturation is a late finding and narcotics should only be used in the setting of a 1:2 nurse:patient ratio. Diligent monitoring of the vital signs is essential, and the surgical or ICU team must respond rapidly to concerns raised by the nursing team.

CONCLUSION

Emergency surgery for bowel obstruction in children presents many challenges for the anaesthesia care provider. Delayed presentation and sepsis have a profound physiological impact on many organ systems. Children have a great reserve and ability to heal but may also hide the seriousness of their illness, and have the potential for sudden decompensation. Good outcomes rely on meticulous perioperative planning, proper training, equipment, and basic supplies. A team approach involving the nurses, laboratory technicians, paediatricians and surgeons is essential. The anaesthesia care provider faced with this challenge needs to be cautious, ask for assistance, and be extremely diligent in monitoring the patient during the entire perioperative course.

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