PERIOPERATIVE FLUIDS IN CHILDREN

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Starvation, surgery and anaesthesia cause stress and alter physiology. Intravenous fluids are administered perioperatively to maintain homeostasis during this period. Water and electrolytes are required to correct deficits and ensure adequate intravascular volume, cardiac output and ultimately tissue oxygen delivery. Calories in the form of dextrose may be needed to prevent hypoglycaemia.

The majority of fit paediatric patients undergoing minor surgery (circumcision, hernia repair) will re-establish oral intake in the early postoperative phase and will not need routine intravenous fluids. Fasting times should be observed so that children are not left without fluid intake for longer that necessary. In elective surgery clear fluids should be allowed up to 2 hours preoperatively but food should not be taken within 6 hours. Breast or formula milk may be given within 4 hours.

Patients undergoing longer or more major procedures, or anyone compromised by underlying problems, will need intravenous fluids. Fluids are given for three reasons:

- **Resuscitation** - to correct pre-existing hypovolaemia or dehydration
- **Maintenance** - to provide water, electrolytes and glucose during the starvation period.
- **Replacement** of ongoing losses due to evaporation from an open wound or via the humidification of dry inspired gases, bleeding, pyrexia, gastrointestinal and third space losses (fluid leak into tissues) during surgery and into the post-operative period.

Resuscitation

The dehydrated or hypovolaemic child should be resuscitated prior to surgery unless the nature of the illness and operation preclude this. In this case rapid correction of hypovolaemia should commence to maintain circulating volume and cerebral perfusion.

Hypovolaemia (losses from the intravascular space) should be replaced initially with boluses of isotonic (0.9%) saline or colloid 20 ml/kg. Blood should be considered if the haemoglobin is low and more than 40 ml/kg of fluid is required.[1]

Dehydration (total body water loss) should be corrected more slowly, preferably, by the oral route if tolerated and time allows, but otherwise intravenously. The rapid rehydration technique advocated by Assadi and Copelovitch[2] describes an initial rapid (1-2 hours) infusion of isotonic saline to correct hypovolaemia. This is followed by a slower correction of dehydration over 24-72 hours with 0.9%, 0.45% or 0.2% saline depending on measured plasma sodium. Too rapid correction of dehydration with hypotonic fluid will result in cerebral oedema secondary to hyponatraemia.

An otherwise healthy child starved preoperatively will have a fluid deficit. This may be calculated by multiplying the hourly maintenance requirement (see table) by the number of hours starved. The deficit can be replaced 50% in the first hour of surgery, and 25% in each of the subsequent two hours.[3] If maintenance fluids are also given, deficits should be corrected using isotonic saline or Hartmanns (Ringers Lactate) solution. This will avoid giving hypotonic fluids at greater than maintenance rates.

Maintenance

Maintenance fluid requirements have been calculated a number of ways including by caloric expenditure and body surface area. The simplest and most commonly used formula was devised by Holliday and Sega[4] and modified by Oh.[5] It relates energy (caloric) expenditure, and therefore volume of fluid required to weight in kg (table 1).

For example a child of

- 9kg requires 4x9 = 36ml/hour
- 18kg requires 40+ (2x8) = 56ml/hour
- 36kg requires 60 + 16 = 76ml/ hour

Electrolyte and glucose requirements were also calculated on a weight basis and an "ideal" solution proposed containing 0.22% NaCl in 5% dextrose (0.18% NaCl in 4% dextrose in the UK) with KCl 20mmol/l. This solution has become the mainstay of maintenance intravenous fluid therapy ever since. However, its use has recently been questioned and the use of isotonic fluid or possibly smaller volumes of hypotonic fluid advocated instead.

Table 1

	Holliday and Segar	Oh
Body weight		
1-10kg	4ml/kg/hour	4ml/kg/hour
10-20kg	40ml/hour + 2ml/kg/hour above 10 kg	20 + (2 x weight in kg) ml/kg/h
>20kg	60ml/hour + 1ml/kg/hour above 20 kg	40 + weight in kg ml/kg/h

Table 2. Paediatric Surgical Unit Guidelines, Sheffield Children's Hospital.				
Weight / age	**< 1.0 kg**	**1.0 - 1.5 kg**	**1.5 - 2.0 kg**	**> 2.0 kg**
	Fluid requirement	**ml/kg/day**		
Day 1	100 - 120	80 - 100	60 - 80	40 - 60
Day 2	120 - 150	110 - 130	90 - 110	60 - 90
Day 3	150 - 170	140 - 160	120 - 140	80 - 100
Day 4	180 - 200	160 - 180	140 - 160	100 - 120
Day 5	180 - 200	170 - 200	150 - 180	120 - 150

Neonates (up to 44 weeks post-conceptual age) have a slightly different fluid requirement. They are born physiologically "waterlogged" but then lose up to 10% of their body weight in the first week of life. Initially much smaller maintenance volumes are needed which increase over the next few days. Premature or low birth weight babies have a greater surface area to weight ratio, lose more water by evaporation and consequently require more replacement fluid (table 2). The fluid is usually given as 10% dextrose with or without saline.

An isotonic fluid contains the same concentration of solutes as plasma, and therefore exerts an equal osmotic force. Dextrose is metabolised in blood, so although 5% dextrose solution is isosmolar to plasma, and isotonic in vivo, once metabolised it becomes effectively free water. Dextrose solutions, unless they contain solutes of an equivalent amount to plasma are therefore hypotonic fluids.

Children given hypotonic fluid may become hyponatraemic 6. Ordinarily the kidneys will rapidly excrete a free water load, and homeostasis is maintained. When the body is subjected to stress such as surgery, pain, nausea or hypovolaemia, antidiuretic hormone (ADH) levels rise. Even the relatively mild hypovolaemia of preoperative starvation causes a greater rise in ADH than if supplemental intravenous fluid is given.[7] ADH blocks the renal excretion of water which is therefore conserved, diluting and lowering plasma sodium levels. A rapid or profound drop in sodium results in water moving into cells causing swelling and oedema. This can manifest as raised intracranial pressure, brain stem herniation, coning and death. Prepubertal children in particular are susceptible to brain damage associated with postoperative hyponatraemic encephalopathy. A retrospective analysis of patients with symptomatic hyponatraemia showed a mortality of 8.4%.[8]

Arguments for and against using isotonic fluids for maintenance are laid out by Taylor, Durward and Hatherill.[9, 10] The Royal College of Anaesthetists in conjunction with the Royal College of Paediatrics and Child Health recently issued a statement advising caution in the use of 0.18% saline in 4% dextrose.[11] For these reasons maintenance fluids should be given as at least 0.45% saline, if not always 0.9% saline or Hartmanns solution. Hypotonic fluids should not be administered if the plasma sodium is less than 140mmol/l, although pre-operative measurement may not always be either appropriate or feasible. When the plasma electrolytes are not known it is probably safer (in the short term at least) to give 0.9% saline to a patient with an elevated plasma sodium, than it is to give hypotonic fluids to a hyponatraemic patient.

Dextrose may be required to prevent hypoglycaemia while the child is starved, although this appears to be less of a problem than was previously thought.

The diurnal variation in cortisol levels effects blood glucose levels. These are higher in the morning than the afternoon. Children starved overnight have a higher blood glucose than those starved during the day[12]. The stress response to surgery and starvation results in hyperglycaemia in children as young as 2 weeks of age. This occurs even if no dextrose containing fluids are given.[13] Administration of dextrose will exacerbate this even further.

Recent studies have shown that the per-operative hypoglycaemia is rare in most children. Exceptions to this are neonates less than 48 hours old[14], neonates in whom a pre-operative glucose infusion is interrupted[14] and children below the 3rd centile in weight.[15] These groups of children should be maintained on dextrose infusions without prolonged interruption. The majority of children can be given dextrose free maintenance fluids. An elevated base excess due to lipid mobilisation and ketosis was shown in children given dextrose free Hartmanns solution. This did not occur when dextrose (2% or 5%) in Hartmanns solution was used.[16]

If dextrose is given in theatre, Welborn[17] recommends a 2.5% dextrose infusion as 5% dextrose invariably resulted in moderate to marked hyperglycaemia. Alternatively, glucose requirement may be calculated on a mg/kg/hour basis. Glucose 120mg/kg/hour maintains blood suger within a normal range, and prevents lipid mobilisation.[16] If solutions containing less than 5% dextrose are unavailable, dextrose may be given as a separate infusion or added to a bag of saline or Hartmanns.

Any child perceived to be at risk of hypoglycaemia or hyperglycaemia should have their blood glucose monitored at regular intervals.

Ongoing losses

Measured losses should be replaced with an isotonic fluid e.g normal saline, a colloid, or blood to replace haemorrhage resulting in unacceptably low haemoglobin levels.

Fluid evaporation from an open wound or 3rd space losses vary depending on the operation and may range from 5 up to 20ml/kg/hour.[18] Loss of fluid via the respiratory tract due to humidification of inspired gas may be reduced by using a circle system or HME (heat and moisture exchange filter) in the breathing circuit.

Blood or other fluid loss is often difficult to measure especially when irrigation fluids are used. For this reason the child's clinical state should be monitored continuously looking at heart rate, capillary refill time and blood pressure. In longer or more complicated cases core-peripheral temperature gradient, urine output (volume and osmolarity) invasive blood pressure and central venous pressure should be measured. In a warm and otherwise stable child with good analgesia a rise in heart rate and prolonged capillary refill time are reliable indicators of fluid loss, while hypotension occurs relatively later when due to hypovolaemia.

Monitoring of vital signs should continue in the post-operative period and fluid loss from the urinary catheter, naso-gastric tube or wound drains measured and replaced promptly. Symptoms of raised intracranial pressure include nausea, vomiting, reduced level of consciousness, respiratory depression and seizures. Nausea, vomiting and drowsiness may be attributed to the side effects of surgery, anaesthesia and analgesia but by the onset of seizures and respiratory depression due to hyponatraemic encephalopathy, it may be too late.

Suggested fluid regime

- Maintenance infusion calculated on weight basis using 0.9% or 0.45% saline.
- Additional fluid to correct deficits, measured or suspected ongoing losses: 0.9% saline, colloid or blood.
- Dextrose if neonate, or measured blood sugar is low at 120mg/kg/hour.

Conclusions

- The majority of fit paediatric patients undergoing minor surgery will re-establish oral intake in the early postoperative phase and will not need routine intravenous fluids.
- Hypotonic fluids should be used with care and must not be infused in large volumes or at greater than maintenance rates.
- Hypovolaemia should be corrected with rapid infusion of isotonic saline, while dehydration is corrected more slowly over 14-72 hours as appropriate.
- Ongoing losses should be measured and replaced.
- Plasma electrolytes and glucose should be measured regularly in any child requiring large volumes of fluid or who remains on intravenous fluids for more than 24 hours.

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Erratum

In Update in Anaesthesia Number 18, the authors of the "The Emergency Management of Poisoning" should have read: Appelboam R and Appelboam A. The editor apologises from this error.