



**CONSENSUS GUIDELINE  
ON  
PERIOPERATIVE  
FLUID MANAGEMENT IN  
CHILDREN  
2007**

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## EXECUTIVE SUMMARY

1. Children can safely be allowed clear fluids 2 hours before surgery without increasing the risk of aspiration.
2. Food should normally be withheld for 6 hours prior to surgery in children aged 6 months or older.
3. In children under 6 months of age it is probably safe to allow a breast milk feed up to 4 hours before surgery
4. Dehydration without signs of hypovolaemia should be corrected slowly.
5. Hypovolaemia should be corrected rapidly to maintain cardiac output and organ perfusion.
6. In the child, a fall in blood pressure is a late sign of hypovolaemia.
7. Maintenance fluid requirements should be calculated using the formula of Holliday and Segar

Body weight	Daily fluid requirement
0-10kg	4ml/kg/hr
10-20kg	40ml/hr + 2ml/kg/hr above 10kg
>20kg	60ml/hr + 1ml/kg/hr above 20kg
8. A fluid management plan for any child should address 3 key issues
  - i. any fluid deficit which is present
  - ii. maintenance fluid requirements
  - iii. any losses due to surgery e.g. blood loss, 3<sup>rd</sup> space losses
9. During surgery all of these requirements should be managed by giving isotonic fluid in all children over 1 month of age
10. The majority of children over 1 month of age will maintain a normal blood sugar if given non-dextrose containing fluid during surgery
11. Children at risk of hypoglycaemia if non-dextrose containing fluid is given are those on parenteral nutrition or a dextrose containing solution prior to theatre, children of low body weight (<3<sup>rd</sup> centile) or having surgery of more than 3 hours duration and children having extensive regional anaesthesia. These children at risk should be given dextrose containing solutions or have their blood glucose monitored during surgery.
12. Blood loss during surgery should be replaced initially with crystalloid or colloid, and then with blood once the haematocrit has fallen to 25%. Children with cyanotic congenital heart disease and neonates may need a higher haematocrit to maintain oxygenation.
13. Fluid therapy should be monitored by daily electrolyte estimation, use of a fluid input/output chart and daily weighing if feasible.
14. Acute dilutional hyponatraemia is a medical emergency and should be managed in PICU.

## **INTRODUCTION**

This guideline was developed for the Association of Paediatric Anaesthetists of Great Britain and Ireland. The guideline covers intravenous fluid management of children undergoing surgery. It was intended that this guideline would be written using the methodology of the Scottish Intercollegiate Guideline Network (SIGN). A multidisciplinary group was enlisted to assess the evidence and write the guideline. Following extensive searching of PubMed and EMBASE it became apparent that there was very little evidence from systematic reviews or randomised controlled trials on peri-operative fluid management in children. This required us to alter direction and construct a guideline using a modified Delphi technique, which required the recruiting of further members to join the group. Search terms used are contained in appendix 1.

## **METHODS**

The Delphi technique is described by Jones and Hunter (1995), and entails the development of a list of statements which are distributed to the rest of the group in a series of rounds (Jones et al 1995). Each member is invited to mark on a scale of 1 to 9 their level of agreement with each statement and to provide any additional comments. These responses are collated and added to the statements for recirculation, giving members the opportunity to change their responses in view of the group's response. The process is repeated until an acceptable level of consensus is achieved. The statements were generated from guidelines and articles contained in appendix 2.

Statements were circulated on 3 occasions. For the second and third rounds, the proportion of respondents selecting each rating, the median and interquartile range for the ratings and any comments were re-circulated with the statements. Statements which gained consensus, defined here as all ratings excluding one extreme high and one extreme low rating falling within pre-determined three points (1-3, 4-6, 7-9) were removed from subsequent rounds. A small number of statements were removed after round 1 as these were felt to be too complicated or outside the scope of the guideline. Some statements were altered between rounds for clarification.

After 3 rounds the guideline was constructed and distributed for comments.

Statements in normal case letters denote those for which consensus was obtained within the group. Statements in italics are those for which consensus was not achieved, or additional statements to qualify consensus made by one or more members of the group.

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## 1.1 STATEMENT OF INTENT

It is the aim of this guideline

- To provide clinicians with recommendations for oral fluid management before elective surgery in children of all ages.
- To provide recommendations for intravenous fluid management during and after surgery in children of all ages.
- To provide recommendations for the management of electrolyte imbalance in the peri-operative period.

It is important to remember that guidelines provide guidance and that clinical acumen and judgement are also important factors in patient care.

Recommendations are based on a multidisciplinary consensus opinion to provide guidance in clinical care.

## 1.2 SCOPE OF THE GUIDELINE

Key areas covered:

- Oral fluid management prior to elective surgery
- Assessment and correction of any fluid deficit
- Calculation of maintenance fluid requirement in children of all ages
- Use of glucose containing intravenous fluids during surgery
- Fluids used to replace losses during surgery
- Fluids used to replace losses after surgery
- Monitoring of fluid therapy
- Diagnosis and management of hyponatraemia and hypernatraemia
- Diagnosis and management of hypokalaemia and hyperkalaemia
- Diagnosis and management of hypocalcaemia

## 2 ORAL FLUID MANAGEMENT PRIOR TO SURGERY

- i. **Whenever possible the enteral route should be used for fluid administration. Children having minor surgery such as circumcision or hernia repair can be managed with oral fluids alone.** *Although most of the group agreed with these statements, there was opinion that intravenous fluids given during surgery would reduce the need for early drinking and reduce the incidence of PONV.*
- ii. **Allowing clear fluids up to 2 hours before surgery does not increase the risk of aspiration and helps to prevent dehydration, keeping the period of starvation short.**
- iii. *Consensus was not obtained on the safe starvation time in infants given formula or breast milk. Some felt it safe to anaesthetise an infant 3 hours after finishing breast milk or 4 hours after formula. Some felt that this was only valid in infants under 6 months of age. Others would allow 4 hours after breast milk and 6 hours after formula.*
- iv. The Royal College of Nursing guideline on fasting in children recommends 4 hours after breast milk and 6 hours after formula for all infants.
- v. **Older children should be fasted of solids and milk for 6 hours prior to surgery.**



### 3 ASSESSMENT AND CORRECTION OF ANY FLUID DEFICIT

- i. Fluid management should be divided into 3 parts – replacement of any fluid deficit, administration of maintenance fluid and replacement of any losses.**
- ii. The child coming for minor elective surgery usually has only a minor fluid deficit, which it is not necessary to correct.**
- iii. Consensus was not obtained on management of fluid deficit in children undergoing major surgery. Whilst it was felt that in elective cases the fluid deficit should be no greater than that of children having minor surgery, many would give an initial bolus of 10ml/kg in the first hour to correct it.*
- iv. The fluid used to replace this deficit should be isotonic – such as 0.9% sodium chloride or Ringer lactate/Hartmann's solution.**
- v. Hypovolaemia should be corrected with an initial fluid bolus of 10-20ml/kg of an isotonic fluid or colloid, repeated as necessary as per APLS guideline. In severe blood loss transfusion will be required.**
- vi. Precise calculation of water deficit due to dehydration using clinical signs is usually inaccurate. The best method relies on the difference between the current body weight and the immediate pre-morbid body weight, which is often unavailable.**
- vii. A child's water deficit in mls can be calculated following an estimation of the degree of dehydration expressed as a percentage of body weight (eg a 10kg child who is 5% dehydrated has a water deficit of 500ml).**
- viii. Clinical signs give only an approximation of the deficit. In mild dehydration the useful clinical signs/symptoms are increased thirst and dry mucous membranes.**
- ix. In moderate dehydration the useful additional clinical signs/symptoms are tachypnoea, cool, pale peripheries with prolonged capillary refill time, decreased skin turgor and sunken eyes.**
- x. In severe dehydration the useful additional clinical signs/symptoms are irritability, lethargy, deep (acidotic) breathing, sunken fontanelle.**
- xi. In severe dehydration in addition to multiple physical signs present, the child may also be acidotic and hypotensive, which is a late premonitory sign.**
- xii. Consensus was not obtained on the management of the dehydrated child who requires urgent surgery. It was felt that any hypovolaemia should be corrected with an isotonic fluid or colloid, followed by a slower correction of residual dehydration with an*

*isotonic fluid, taking into account ongoing losses, serum electrolytes and urine output.*

## 4 MAINTENANCE FLUID REQUIREMENTS IN CHILDREN

- i. **Maintenance fluid requirements should be calculated according to the recommendations of Holliday and Segar for children and infants older than 4 weeks of age, using body weight. It is important to remember that all formulae should be used as a starting point only and the individual child's response to fluid therapy should always be monitored and appropriate adjustments made.**
- ii. *Consensus was not achieved on recommending a maximum volume of maintenance fluid within a 24 hour period depending on gender in line with adult practice. This would give a maximum daily volume of 2,000ml to females and 2,500ml to males. It was felt that there was no evidence base for this statement. Some of those who agreed with the statement commented that menstruant females are more prone to water retention and hyponatraemia.*
- iii. **In term neonates (>36 week gestational age) maintenance fluid requirements are reduced in the first few days after birth. The normal infant will lose up to 10-15% of its body weight in water during this time.**
- iv. **In term neonates during the first 48 hours of life 10% dextrose should be given at a rate of 2-3ml/kg/hr or 40-80ml/kg/day.** *Not all members of the group answered this question. Some felt that there should be some provisos to this statement. One member felt that there should be a qualifying statement attached which said '...unless there is a clinical indication for increased or decreased fluid administration.'*
- v. *Consensus was not obtained on what type and volume of fluid to give a term neonate from day 3 of life. Neonatal input recommended that the maintenance fluid should be 0.18% saline in 10% dextrose given at a rate of 4ml/kg/hr or 100-120ml/kg/day.*
- vi. *Consensus was not obtained on fluid management of the preterm infant with a weight <2kg. Again our neonatal input recommended that maintenance requirements are at least 100ml/kg/day and should be assessed at least daily by assessment of weight and electrolytes.*
- vii. **Maintenance fluid requirements may need to be increased in children with pyrexia, excess sweating, hypermetabolic states such as burns or when radiant heaters or phototherapy is used.**
- viii. *Consensus was not obtained as to whether maintenance fluid requirements should be reduced in children in PICU who were sedated and ventilated with humidified gases. Many felt that maintenance requirements would be unaffected by either of these factors.*
- ix. *Consensus was not obtained on what should be the routine maintenance fluid used after surgery in the majority of children. Many would prefer to use Ringer lactate or Hartmann's with dextrose. The NPSA guideline states that in post-operative patients,*

*only isotonic fluids should be administered such as sodium chloride 0.9% with dextrose 5%, sodium chloride 0.9% or Hartmann's solution/RingerLactate solution. It further states that solution choice should be tailored to the patient's needs.*

- x. *It was felt that in neonates following surgery it was difficult to be prescriptive as to which maintenance fluid to choose as many factors will affect this choice.*

## **5 FLUID AND DEXTROSE MANAGEMENT DURING SURGERY**

- i. During surgery the majority of children may be given fluids without dextrose. Blood glucose should be monitored if no dextrose is given.**
- ii. The maintenance fluid used during surgery should be isotonic such as 0.9% sodium chloride or Ringer lactate/Hartmann's solution.**
- iii. Neonates in the first 48 hours of life should be given dextrose during surgery.**
- iv. Preterm and term infants already receiving dextrose containing solutions should continue with them during surgery.**
- v. Infants and children on parenteral nutrition preoperatively should continue to receive parenteral nutrition during surgery or change to a dextrose containing maintenance fluid and blood glucose monitored during surgery.**
- vi. Children of low body weight (less than 3<sup>rd</sup> centile) or having prolonged surgery should receive a dextrose containing maintenance fluid (1-2.5% dextrose) or have their blood glucose monitored during surgery.**
- vii. Children having extensive regional anaesthesia with a reduced stress response should receive a dextrose containing maintenance fluid (1-2.5% dextrose) or have their blood glucose monitored during surgery.**

## 6 MANAGEMENT OF OTHER LOSSES DURING SURGERY

- i. **All losses during surgery should be replaced with an isotonic fluid such as 0.9% sodium chloride, Ringer lactate/Hartmann's solution, a colloid or a blood product, depending on the child's haematocrit.**
- ii. **There is no evidence that the use of human albumin solution is better than use of an artificial colloid to replace blood loss.**
- iii. **In children over 3 months of age the haematocrit may be allowed to fall to 25%. Children with cyanotic congenital heart disease may need a higher haematocrit to maintain oxygenation.** A recent article (Laroix J, Hebert P et al – Canadian Critical Care Trials Group: Pediatric Acute Ling Injury and Sepsis Investigators Network (2007) looking at transfusion policy within PICU has concluded that in stable, critically ill children a haemoglobin threshold of 7g/dl for red cell transfusion can decrease transfusion requirements without increasing adverse outcomes.
- iv. *Consensus was not achieved on how low the haematocrit could be allowed to fall in infants less than 3 months of age. It was felt that gestational age was important and a low Hb/Hct may be acceptable in small, older preterm infants.*
- v. **During surgery third space loss due to sequestration of fluid from the vascular space into tissues around the site of surgery occurs and should be replaced with an isotonic fluid.**
- vi. **Third space loss is difficult to quantify and normally an estimate is made with 1-2ml/kg/hr given for superficial surgery, 4-7ml/kg/hr given for thoracotomy and 5-10ml/kg/hr given for abdominal surgery. It is important to assess clinical signs – HR, BP and capillary refill time – to ensure adequate replacement. Third space loss will be less if procedures are performed laparoscopically.**

## 7 POST OPERATIVE FLUID MANAGEMENT

- i. Surgery, pain, nausea and vomiting are all potent causes of ADH release. A recent NPSA alert has recommended that hypotonic fluids should not be used for postoperative maintenance as this may cause hyponatraemia due to retention of free water released after metabolism of dextrose from the solution. Consensus was not agreed on what the ideal fluid for postoperative maintenance is. Many felt that Ringer lactate/Hartmann's solution with added dextrose was the most appropriate, but currently this formulation does not exist in the UK. 0.9% sodium chloride with 5% dextrose is the only available isotonic fluid containing dextrose within the UK at present.*
- ii. Consensus was not agreed on the maintenance fluid rate in the postoperative period. Some would use the full rate as calculated using Holliday and Segar's formula, while others would fluid restrict to 60-70% of full maintenance and additional boluses of isotonic fluid given as required.*
- iii. In the postoperative period ongoing losses from drains or nasogastric tubes should be replaced with an isotonic fluid such as 0.9% sodium chloride with or without added KCl.**
- iv. Losses should be measured hourly and replaced every 2 to 4 hours depending on the amount.*
- v. Consensus was not achieved on when oral fluids should be recommenced after surgery and intravenous fluids discontinued. There needs to be a matching of increasing oral intake with a reduction of intravenous administration of fluid.*
- vi. When oral intake approximates hourly maintenance rate then IV fluids may be discontinued. All fluid intake should be recorded on a fluid balance sheet.**

## **8 MONITORING OF FLUID THERAPY**

- i. Serum electrolytes do not need to be measured pre-operatively in healthy children prior to elective surgery where IV fluids are to be given.**
- ii. Serum electrolytes need to be measured pre-operatively in all children presenting for elective or emergency surgery who require IV fluid to be administered prior to surgery.**
- iii. Children should be weighed prior to fluids being prescribed and given.**
- iv. Serum electrolytes should be measured every 24 hours in all children on IV fluids or more frequently if abnormal.**
- v. Although ideally children should be weighed daily while on IV fluids, practically this is difficult in older children, or those who have undergone major surgery. Use of a fluid input/output chart will help with fluid management.**



## 9 MANAGEMENT OF HYPONATRAEMIA

- i. Hyponatraemia (serum Na<135mmol/l) may occur following surgery with any fluid regime, but more so if hypotonic maintenance fluids are given.**
- ii. The early signs of hyponatraemia are non-specific and often the first presenting feature is a seizure or respiratory arrest. Headache is a consistent early sign of hyponatraemia and is found in the majority of cases reported in the literature. Young children may be unable to complain of headaches.**
- iii. Children with hyponatraemic encephalopathy should be managed as a medical emergency and transferred to PICU.**
- iv. Hyponatraemic seizures respond poorly to anticonvulsants and initial management is to give an infusion of 3% sodium chloride solution. One ml/kg of 3% sodium chloride will normally raise the serum sodium by 1mmol/l. Serum Na should be raised quickly until the child has regained consciousness and has stopped fitting or the serum Na is above 125mmol/l. The amount of Na required can be calculated according to the following formula:**  
$$\text{mmol of Na required} = (130 - \text{present serum Na}) \times 0.6 \times \text{Weight (kg)}$$
- v. One panel member who had extensive experience in treating children with hyponatraemia felt strongly that in acute symptomatic hyponatraemia (presumably due to the inappropriate administration of hypotonic fluids) the time limit on raising the serum Na was about 1 hour and if you correct at a slower rate then an adverse outcome was inevitable.**
- vi. Consensus was not achieved on how further to correct hyponatraemia. Once seizures have stopped a slower Na correction should take place. It was agreed that 0.9% sodium chloride solution should be used. The addition of dextrose to this solution was controversial as producing hyperglycaemia may worsen brain injury. Monitoring of the child's progress would require frequent estimation of serum Na and glucose.**
- vii. The child with asymptomatic hyponatraemia will not require active correction with 3% sodium chloride solution. The dehydrated child may be treated with enteral fluids or if not tolerated, with intravenous 0.9% sodium chloride solution.**
- viii. The child with asymptomatic hyponatraemia and normal or increased volume status, if taking oral fluids should be volume restricted or if on IV fluids should have fluid administered at 50% of maintenance rate.**

## 10 MANAGEMENT OF HYPERNATRAEMIA

- i. In hospitalised children, hypernatraemia (serum Na > 150mmol/l) commonly occurs as a result of excessive water loss, restricted water intake or an inability to respond to thirst. *It may also occur in infants given incorrectly made feeds.*
- ii. Signs of hypernatraemia are more severe when it develops rapidly or when the serum Na > 160mmol/l. Chronic hypernatraemia is often well tolerated because of cerebral compensation.
- iii. The true degree of dehydration is often underestimated if clinical signs alone are used compared to loss of weight. Intravascular volume is often well preserved during the initial stages.
- iv. Management of hypernatraemic dehydration consists of initial volume replacement with 0.9% sodium chloride given in boluses of 20ml/kg to restore normovolaemia. Complete correction should be done very slowly over at least 48 hours to prevent cerebral oedema, seizures and brain injury. The serum Na should be corrected at a rate of no more than 12mmol/kg/day with 0.45% sodium chloride or 0.9% sodium chloride in dextrose. Potassium should only be added to maintenance fluids once urine output is established.
- v. In hypernatraemic dehydration it is important to give maintenance fluid alongside fluid to correct dehydration.

## **11 MANAGEMENT OF POTASSIUM IMBALANCE**

- i. Hypokalaemia (serum K < 3.5mmol/l) produces symptoms of cramp, arrhythmias, reduced cardiac contractility and paralytic ileus. Management is to give oral supplements of 3-5mmol/kg/day.**
- ii. In severe hypokalaemia (serum K < 3mmol/l), intravenous correction should be no faster than 0.25mmol/kg/hr using a maximum peripheral concentration of 40mmol/l KCl (as per BNFC). For a more rapid correction, the patient should be in PICU or HDU and the infusion be administered via a central line.**
- iii. Hyperkalaemia (serum K > 5.5mmol/l) causes skeletal muscle weakness and ECG changes when serum K > 7mmol/l.**
- iv. Immediate treatment of hyperkalaemia is to antagonise membrane effects by giving 100 micrograms/kg of 10% Calcium gluconate. This equates to 0.5ml/kg of 10% solution (1ml 10% calcium gluconate contains 0.22mmol calcium). (APLS recommendation)**
- v. Alongside this it is important to increase intracellular shift of potassium by giving 1 to 2mmol/kg of sodium bicarbonate, an infusion of 0.3-0.5g/kg/hr of glucose with 1 unit of insulin for every 5g of glucose or to give 2.5 to 5mg nebulised salbutamol (5micrograms/kg in neonates IV).**
- vi. Removal of potassium from the body is by giving 125-250mg/kg calcium resonium rectally or orally, by use of furosemide 1mg/kg or by dialysis or haemofiltration.**

## 12 MANAGEMENT OF CALCIUM IMBALANCE

- i. **Hypocalcaemia (corrected total  $\text{Ca} < 2\text{mmol/l}$  or  $< 1.5\text{mmol/l}$  in neonates) may produce symptoms of twitching and jitteriness, perioral, finger and toe paraesthesia, masseter and carpopedal spasm, prolonged QT interval and reduced cardiac contractility. Immediate treatment is with 10% calcium gluconate  $0.5\text{ml/kg}$  to a maximum of  $20\text{ml}$  over  $10\text{mins}$  or 10% calcium chloride  $0.2\text{ml/kg}$  to a maximum of  $10\text{ml}$  over  $10\text{mins}$ . Warning: danger of extravasation causing tissue injury. *Other comments made were that the central venous route should be considered for injection. Use of continuous ECG monitoring during injection. It may be more important to look at ionised treatment level (treat when  $< 1.0\text{mmol/l}$ ) rather than total level.***
- ii. **Calcium levels appear low in the newborn because of low albumin levels. There is a normal physiological fall in calcium concentration after birth which rises after the second day. Causes of hypocalcaemia in the newborn are encephalopathy, renal failure, Di George syndrome, disordered maternal metabolism or maternal diabetes mellitus.**

## ***Clinical Scenarios***

### **Clinical Scenario 1: Peri-operative hyponatraemia**

#### **Case History**

A four year old girl weighing 16kg was admitted to hospital for an elective tonsillectomy. During the procedure intravenous fluids were commenced using sodium chloride 0.18% with glucose 4% at a rate of 80 ml/kg/day. She was discharged to the ward in the late afternoon and intravenous fluids were continued at the same rate.

At 0430 the child suffered a 3 minute generalised tonic-clonic seizure, which was terminated with lorazepam 1.6mg given intravenously. At this time the serum biochemistry was performed and the results were as follows; sodium 120 mmol/L, potassium 3.9 mmol/L, glucose 6.3 mmol/L, urea 2.7 mmol/L, creatinine 27 µmol/L. After the termination of the seizure the child was able to maintain her airway and was breathing regularly in 10 L/min of supplementary face mask Oxygen. She was cardiovascularly stable but neurological examination revealed that she opened her eyes only to painful stimuli, displayed an abnormal flexion response to pain and was capable only of incomprehensible sounds; giving her a Glasgow Coma Score of 7/15. Her pupils were equal and responsive to light.

The intravenous fluid infusion was immediately discontinued and a hypertonic sodium chloride solution was used to rapidly correct the serum sodium concentration. The amount of sodium required to correct the serum sodium concentration to 130 mmol/L was calculated as 96mmol according to the following formula:

$$\text{mmol of Na required} = (\text{Desired serum Na} - \text{Present serum Na}) \times 0.6 \times \text{Weight (kg)}$$

A total of 187ml of 3% sodium chloride solution (513 mmol/L) was infused intravenously over 30 minutes.

Following the hypertonic sodium chloride infusion, the child's neurological status improved to the point that she opened her eyes to speech, withdrew from painful stimuli and verbalised inappropriate words; giving her a Glasgow Coma Score of 10/15. A repeat set of serum electrolytes were performed and the results were as follows; sodium 131 mmol/L, potassium 3.7 mmol/L, glucose 7.4 mmol/L, urea 2.6 mmol/L, creatinine 25 µmol/L.

Intravenous fluids were recommenced using sodium chloride 0.9% with glucose 5% at a rate of 53 ml/kg/day and the child was transferred to the Paediatric High Dependency Unit where she made a full recovery.

## **Clinical Scenario 2: Per-operative management of diabetes insipidus.**

### **Case history:**

An 8 year old girl presented with symptoms of raised intra-cranial pressure and visual disturbance. She was diagnosed with craniopharyngioma on MRI and has been listed for frontal craniotomy.

At the pre-operative visit you note her short stature and recent rapid weight gain (now 30kg). She is well hydrated and has normal cardiovascular/respiratory systems examination. Her FBC and U+E's are within normal limits.

### **Question:**

What else would you want to have done pre-operatively and how would you manage this child's fluid balance pre- and post-operatively?

### **Answer:**

#### **Pre-operatively:**

- The endocrinology team should be involved early – the patient is at risk of developing pan-hypopituitarism and DI before or during as well as after the operation. Have a plan discussed and ready for when this happens (an example is given below).
- The patient should have had growth hormone, thyroid and adrenal studies done and be on hydrocortisone pre-operatively. Adrenal studies are the most important as failure to replace steroids adequately may be fatal.
- Ensure HDU/ITU bed available and warn the patient that they may be there for days until their fluid balance is under control.

#### **Per/post-operatively:**

- Monitor CVP, and urine output (via urinary catheter) continuously, along with regular U+E's and arterial blood gases.
- 6 hourly parenteral hydrocortisone is essential.
- Hypothalamic vasopressin release may reduce urine output initially (SIADH). Surgery around the hypothalamus may also cause cerebral salt wasting with a high urine output which may be confused with DI.
- Urine sodium and specific gravity measurements may be required if urine output increases to distinguish between DI (hypernatraemia, low urine sodium and specific gravity) and cerebral salt wasting (hyponatraemia, high urine sodium and SG).
- Paired urine and plasma U+E's should be measured 4 hourly once DI is diagnosed.
- 80-100% patients will develop DI post-operatively.

### **Fluid balance can be complicated!**

#### **In theatre:**

- Maintenance fluids and replacement of surgical losses should be with an isotonic fluid (Hartmanns, normal saline, colloid or blood) as appropriate and standard for craniotomy.

- Should DI develop consider starting a vasopressin infusion. As long as urine output meticulously replaced vasopressin is not essential, however urine output can be torrential! Some units use DDAVP (desmopressin) rather than vasopressin. Vasopressin has a shorter half life and is therefore more flexible than DDAVP

### **Vasopressin Administration and Dosage**

- Vasopressin 1U in 500ml 5% dextrose or 0.9% saline (gives solution of 2 mU/ml)
- Dose is tailored to produce a slight diuresis every 24 hours to avoid water intoxication
- Commence vasopressin infusion at 50% of the previous hour's urine output (e.g. if 400mls passed, run at 200mls/hour)
- For the first 3 hours, reduce the infusion by 50% every 30 minutes (e.g. 200ml/hr, 100ml/hr, 50ml/hr, 25ml/hr etc).

Monitor urine output closely, aim for a urine output of 1 – 2 mls/kg/hour at the end of this 3 hour stabilisation phase.

Sliding Scale Regime: Implement only when urine output of 1 – 2 mls/kg/hour achieved

Urine output < 1ml/kg for the last hour	- Reduce infusion rate by 50% (Reduce to 0.1ml/hour, then for further reduction cease infusion for next hour)
Urine output 1 – 2ml/kg for the last hour	Continue with same infusion rate
Urine output 2 – 3ml/kg for the last hour	Increase infusion rate by 50%
Urine output > 3ml/kg for the last hour	Increase infusion rate by 100%

- The infusion rate in this regime rarely exceeds 5mls/hour
- Once urine output is stable check urine and plasma, urea, electrolytes and osmolality 8 hourly. Increase frequency if unstable.
- Reduce maintenance fluids to take into account the vasopressin infusion (and later, any oral intake).

Aim for:

- Urine output 1-2 ml/kg/hour
- Urine SG 1.010 – 1.020
- Serum sodium 140-145 mEq/l
- Total fluid input equal to previous hour's urine output plus replacement of surgical and insensible losses.

### **Post-operatively:**

- Continue the above fluid management regime initially.
- Meticulous fluid balance charts should be kept, with continuous monitoring of CVP, urine output and regular U+E's and ABG's. Paired urine and plasma U+E's should be measured 4 hourly.
- The endocrinology team will advise on how and when to change to DDAVP which is given IM/SC, orally or intranasally.
- Continue regular hydrocortisone. The endocrinologists will commence other hormone replacement as necessary post-operatively.

**If you need to use the above guideline, you should be talking to an endocrinologist!**

**Case history continued:**

3 hours into the operation her urine output increases to 130 ml/hour and the CVP starts to drop. ABG's show a sodium of 148 mEq/l.

You have been maintaining her fluids at 10 ml/kg/hour of Hartmanns solution. Surgical blood loss is minimal.

**Question:**

What fluids will you give now?

**Answer:**

- Continue maintenance fluids as routine for a craniotomy with replacement of blood/CSF/insensible losses as appropriate.
- Commence vasopressin infusion at 65 ml/hour (50% of previous hour's urine output) and continue to monitor/replace on an hour by hour basis according to the sliding scale.

References:

Diabetes Insipidus IV regime. Sheffield Children's Hospital.

<http://www.emedicine.com/ped/topic497.htm>



### Clinical Scenario 3: Pyloric stenosis

A 3 week old term baby, weighing 3.2kg is admitted with a history of projectile vomiting for 3 days. The baby is lethargic and dehydrated. His eyes are sunken and his skin feels cool and doughy, and when it is pinched it takes several seconds to return to its former position. The capillary refill time is more than 8 secs. Mother tells you that he has worn the same nappy all day because he has not soiled it. He is 10% below his birth weight. During examination an olive sized mass can be felt 3cm below the right costal margin and gastric peristalsis is observed. A diagnosis of pyloric stenosis is made following ultrasound.

Blood taken for electrolyte estimation and acid base status reveals

Na	128mmol/L
K	2.8mmol/L
Cl	86mmol/L
HCO <sub>3</sub>	32mmol/L
pH	7.55
BE	+10

This shows a typical hypochloraemic alkalosis with hypokalaemia. The fluid lost during vomiting is gastric acid (HCl). The clinical picture and electrolytes point to a moderate degree of dehydration with a fluid deficit of 100ml/kg or 320ml.

The initial resuscitation is with a bolus of 20ml/kg of 0.9% saline.

Fluid replacement should continue with 0.45% saline in 5% dextrose at 1.5 times normal maintenance rate – 19ml/hr. In addition any nasogastric loss should be replaced ml for ml with 0.9% saline,

Potassium chloride, 20mmol/L, is only added into fluid replacement once urine output is established.

Electrolytes should be checked every 6 to 12 hours initially until normal, and then every 24 hours for the duration of intravenous therapy.

Surgery should only take place when the dehydration is corrected and plasma Na and K are normal, Cl is >100mmol/L, HCO<sub>3</sub> is <28mmol/L and BE is <+2.

Intra-operative fluid management should be to continue with the maintenance fluid already running at normal maintenance rate – 13ml/hr. Surgery is relatively short and should not require any extra fluid to be given.

## **Clinical Scenario 4: The day case with prolonged starvation period**

James is an 18 month old boy weighing 10kg is scheduled for orchidopexy as a day case on an afternoon list. On seeing him pre-operatively his mother tells you that she has not given him anything to eat or drink since last night, 'just to be on the safe side'. Closer questioning reveals that he has not had any oral intake for 15hrs.

What action, if any, would you take?

An ideal fluid management plan for a day case may vary between those patients on a morning list and those on an afternoon list.

### Patient on a morning list

We would normally assume that a child scheduled for a morning day case procedure is adequately hydrated up to their going to bed the night before.

A 10kg child would have a theoretical deficit of  $40 \times 12$  or 480ml if their last intake was at 21.00 and their surgery was scheduled for 09.00.

Ideal management would have the child being given a clear fluid drink of 200ml between 06.30 and 07.00, which leaves a residual deficit of 280ml or 5% of total body water (assuming a total body water in this child of 6,000ml)

### Patient on an afternoon list

This child should have been given breakfast at 08.00 and ideally a clear fluid drink at 11.00. This child should have a fluid deficit of only

$$(40 \times 6) - 200 = 40\text{ml}$$

Our child has a fluid deficit of  $40 \times 15 = 600\text{ml}$  or 10% of total body water.

It is important to note that even the gross error of a 15hr fast as opposed to a 2hr fast for clear fluid is unlikely to make a physiologically significant impact on the cardiovascular status of the child, or necessitate a different anaesthetic technique for an otherwise fit child. However it may give you a very unhappy and unco-operative child!

It is now 11.00 and the child is third on the list, expected to go to theatre at 15.00.

### What are the options?

If nothing is done and the child is left starved – the additional deficit incurred is  $40 \times 4 = 160\text{ml}$ , giving a total deficit now of 760ml or 12% total body water.

If the child is moved to be the first case on the list the additional deficit is  $40 \times 2.5 = 100\text{ml}$ , giving a total deficit of 700ml or 11% total body water.

If the child is given a drink of clear fluid (150ml) leaving the position on the list unchanged, the additional deficit is now  $160 - 150 = 10\text{ml}$ , giving a total deficit of 610ml or 9.5% of total body water.

If the child is given a drink now (150ml) and moved to the start of the list the additional deficit is now only  $(100 + 600) - 150 = 550\text{ml}$  or approx 9.3% total body water.

All of the above options only have a marginal effect on the child's physiology, although they may make a difference to the tempers of all concerned.

It's important to also consider post-operative events. Orchidopexy can be strongly emetogenic and there may be a case for giving prophylactic anti-emetic therapy.

It's important to also consider giving an intravenous fluid bolus during surgery of 20ml/kg of isotonic fluid such as Hartmann's. This could be carried on into the post-operative period at a rate of 40ml/hr (normal maintenance rate) or at twice this which gives us a rate of 80ml/hr. This would reduce our child's fluid deficit down to half what it was at the beginning of surgery.

## SUMMARY

When confronted with a child who has been given an over prolonged pre-operative fast –

1. it is rarely necessary to take any pre-operative action beyond giving the child a small drink to alleviate thirst (particularly on a morning list), and if a clear fluid is used it is safe to do this up to 2 hours before induction.
2. if the situation arises on the afternoon list and particularly if it is judged that the situation will be compounded by a delay in returning to oral fluids post-operatively, then it may be prudent to give an intravenous bolus during surgery.

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## Appendix 1 – SEARCH TERMS

Search history:

No.	Database	Search term	Info added since	Results		
1	MEDLINE - 1951 to date	INTRAVENOUS ADJ FLUID\$	unrestricted	1973	<a href="#">show titles</a>	<a href="#">rank</a>
2	MEDLINE - 1951 to date	IV ADJ FLUID\$	unrestricted	269	<a href="#">show titles</a>	<a href="#">rank</a>
3	MEDLINE - 1951 to date	NASOGASTRIC ADJ FLUID\$	unrestricted	4	<a href="#">show titles</a>	<a href="#">rank</a>
4	MEDLINE - 1951 to date	NG ADJ FLUID\$	unrestricted	1	<a href="#">show titles</a>	<a href="#">rank</a>
5	MEDLINE - 1951 to date	FLUID ADJ MANAGE\$	unrestricted	472	<a href="#">show titles</a>	<a href="#">rank</a>
6	MEDLINE - 1951 to date	FLUID ADJ INPUT	unrestricted	47	<a href="#">show titles</a>	<a href="#">rank</a>
7	MEDLINE - 1951 to date	FLUID ADJ ADMINISTRATION	unrestricted	730	<a href="#">show titles</a>	<a href="#">rank</a>
8	MEDLINE - 1951 to date	FLUID ADJ REPLACEMENT	unrestricted	880	<a href="#">show titles</a>	<a href="#">rank</a>
9	MEDLINE - 1951 to date	ENTERAL ADJ FLUID\$	unrestricted	9	<a href="#">show titles</a>	<a href="#">rank</a>
10	MEDLINE - 1951 to date	RESTRICTED ADJ WATER ADJ INTAKE	unrestricted	20	<a href="#">show titles</a>	<a href="#">rank</a>
11	MEDLINE - 1951 to date	MAINTENANCE ADJ FLUID\$	unrestricted	205	<a href="#">show titles</a>	<a href="#">rank</a>
12	MEDLINE - 1951 to date	ORAL ADJ REHYDRAT\$	unrestricted	2036	<a href="#">show titles</a>	<a href="#">rank</a>
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15	MEDLINE - 1951 to date	ELECTROLYTE ADJ REQUIREMENT\$	unrestricted	43	<a href="#">show titles</a>	<a href="#">rank</a>
16	MEDLINE - 1951 to date	FLUID ADJ REQUIREMENT\$	unrestricted	341	<a href="#">show titles</a>	<a href="#">rank</a>
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18	MEDLINE - 1951 to date	SODIUM ADJ INPUT	unrestricted	14	<a href="#">show titles</a>	<a href="#">rank</a>
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20	MEDLINE - 1951 to date	CHLORIDE	unrestricted	154095	<a href="#">show titles</a>	<a href="#">rank</a>
21	MEDLINE - 1951 to date	MAGNESIUM	unrestricted	70238	<a href="#">show titles</a>	<a href="#">rank</a>













22	MEDLINE - 1951 to date	<b>CALCIUM</b>	unrestricted	324554	<a href="#">show titles</a>	rank
23	MEDLINE - 1951 to date	<b>NORMAL ADJ SALINE</b>	unrestricted	7449	<a href="#">show titles</a>	rank
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28	MEDLINE - 1951 to date	<b>PEDIALYTE</b>	unrestricted	14	<a href="#">show titles</a>	rank
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91	MEDLINE - 1951 to date	61 OR 62 OR 63 OR 64 OR 65 OR 66 OR 67 OR 68 OR 69	unrestricted	459643	<a href="#">show titles</a>	<a href="#">rank</a>

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<b>92</b>	MEDLINE - 1951 to date	<b>70 OR 71 OR 72 OR 73 OR 74 OR 75 OR 76 OR 77 OR 78</b>	unrestricted	<b>401131</b>	<a href="#">show titles</a>	
<b>93</b>	MEDLINE - 1951 to date	<b>79 OR 80 OR 81 OR 82 OR 83 OR 84 OR 85 OR 86 OR 87 OR 88</b>	unrestricted	<b>356110</b>	<a href="#">show titles</a>	
<b>94</b>	MEDLINE - 1951 to date	<b>89 OR 90 OR 91 OR 92 OR 93</b>	unrestricted	<b>1083798</b>	<a href="#">show titles</a>	
<b>95</b>	MEDLINE - 1951 to date	<b>42 AND 94</b>	unrestricted	<b>664871</b>	<a href="#">show titles</a>	
<b>96</b>	MEDLINE - 1951 to date	<b>CHILD# OR ADOLESCENT.DE. OR INFANT#</b>	unrestricted	<b>1901460</b>	<a href="#">show titles</a>	
<b>97</b>	MEDLINE - 1951 to date	<b>SURGICAL OR MEDICAL</b>	unrestricted	<b>2623899</b>	<a href="#">show titles</a>	
<b>98</b>	MEDLINE - 1951 to date	<b>SURGICAL</b>	unrestricted	<b>591577</b>	<a href="#">show titles</a>	
<b>99</b>	MEDLINE - 1951 to date	<b>MEDICAL</b>	unrestricted	<b>2156865</b>	<a href="#">show titles</a>	
<b>100</b>	MEDLINE - 1951 to date	<b>96 AND 97</b>	unrestricted	<b>402679</b>	<a href="#">show titles</a>	
<b>101</b>	MEDLINE - 1951 to date	<b>96 AND 97</b>	unrestricted	<b>402679</b>	<a href="#">show titles</a>	
<b>102</b>	MEDLINE - 1951 to date	<b>95 AND 101</b>	unrestricted	<b>8507</b>	<a href="#">show titles</a>	

## **Appendix 2 – SOURCE DOCUMENTS**

**1. Royal Children’s Hospital Melbourne Clinical Practice Guidelines**

- a. Intravenous fluids**
- b. Neonatal intravenous fluid requirements**
- c. Hyponatraemia**
- d. Hypernatraemia**
- e. Diabetes mellitus**

**2. Paut O, Lacroix F (2006). Recent developments in the perioperative fluid management for the paediatric patient. Current Opinion in Anaesthesiology 19(3):268-77.**

**3. Advanced Paediatric Life Support Group. Advanced Paediatric Life Support: the practical approach. London: BMJ Publishing Group.**

**4. British National Formulary for Children. BMJ Publishing Group and RPS Publishing.**

**5. Plant R, Shorten G (2002). Renal function, acid base and electrolyte homeostasis. In Pediatric Anesthesia Principles and Practice Eds B. Bissonnette and B. Dalens, McGraw Hill, New York.**

**6. Camboulives J (2002). Fluid, transfusion and blood sparing techniques. In Pediatric Anesthesia Principles and Practice Eds B. Bissonnette and B. Dalens, McGraw Hill, New York.**

**7. Wilson CM (2005). Perioperative fluids in children. Update in Anaesthesia Issue 19.**

**8. Perioperative fasting in adults and children. Clinical Practice Guidelines. Royal College of Nursing 2005**

**9. Brady M, Kinn S, O’Rourke K, Randhawa N, Stuart P (2005). Preoperative fasting for preventing perioperative complications in children. Cochrane Database of Systematic Reviews, Issue 2, Art No: CD005285, DOI: 10.1002/14651858.CD005285.**