Current consensus on crystalloids and colloids in the perioperative period in children

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Fluid & electrolyte disturbances are extremely common in the peri-operative period. Large amounts of intravenous fluids are frequently required to correct fluid deficits and compensate for blood loss during surgery. Major disturbances in fluid and electrolyte balance can rapidly alter cardiovascular, neurologic and neuromuscular functions. Anesthesiologists must, therefore, have a thorough understanding of the current consensus on crystalloids and colloids in the perioperative period. It is important to remember that guidelines provide guidance and that clinical insight and judgment are also important factors in patient care.

ORAL FLUID MANAGEMENT PRIOR TO SURGERY

- 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. However intravenous fluids given during surgery would reduce the need for early drinking and reduce the incidence of PONV.
- It is safe to anaesthetize an infant 3 hours after finishing breast milk or 4 hours after formula.
- In children under 6 months of age it is probably safe to allow breast milk feed up to 4 hours before surgery. Children can safely be allowed clear fluids 2 hours before surgery without increasing the risk of aspiration and helps to prevent dehydration, keeping the period of starvation short.
- In children above 6 months and older children should be fasted of solids and milk for 6 hours prior to surgery.

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FLUID MANAGEMENT SHOULD BE DIVIDED INTO 3 PARTS

1. Replacement of any fluid deficit
2. Administration of maintenance fluid
3. Replacement any losses due to surgery e.g. blood loss, 3rd space losses

1. Assessment and correction of any fluid deficit

- Child coming for minor elective surgery

  The child coming for minor elective surgery usually has only a minor fluid deficit, which it is not necessary to correct.

- Elective cases

  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. The fluid used to replace this deficit should be isotonic – such as 0.9% sodium chloride or Ringer lactate solution. Hypovolaemia should be corrected with an initial fluid bolus of 10-20 ml/kg of an isotonic fluid or colloid, repeated as necessary as per APLS guideline. In severe blood loss transfusion will be required.

  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.

How to calculate degree of dehydration

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 (e.g. a 10kg child who is 5% dehydrated has a water deficit of 500ml). Clinical signs give only an approximation of the deficit.

- Mild dehydration

  In mild dehydration the useful clinical signs/ symptoms are increased thirst and dry mucous membranes.

- Moderate dehydration

  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.

- Severe dehydration

  In severe dehydration the useful additional clinical signs/symptoms are irritability, lethargy, deep (acidotic) breathing, sunken fontanelle. In severe dehydration in addition to multiple physical signs present, the child may also be acidotic and hypotensive, which is a late premorbid sign.

The management of the dehydrated child who requires urgent surgery, 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.

2. Maintenance fluid requirements in children

- Term neonates (>36 week gestational age)

  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. 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.

- Term neonate from day 3 of life

  Maintenance fluid should be 0.18% saline in10% dextrose, given at a rate of 4ml/kg/hr or 100-120ml/kg/day.

- Preterm infant with a weight < 2kg

  Maintenance requirements are at least 100 ml/kg/day and should be assessed at least daily by assessment of weight and electrolytes.

- Children and infants older than 4 weeks of age, using body weight

  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.

  Routine maintenance fluids are calculated by Holliday and Segar formula which was introduced in 1957.

0-10 kg	4 ml/kg/hr
Above 10 – 20 kg	40 ml/hr + 2 ml/kg/hr
Above 20 kg	60 ml/hr + 1 ml/kg/hr

  4-2-1 Rule, for crystalloid delivery has been challenged more recently. The focus of this challenge is on reduction of free water administration because of increased postoperative hyponatremia related to increased secretion of ADH. An alternative concept is for much lower glucose administration and isotonic sodium-containing solutions to avoid the rare problem of hyponatremic seizure and brain damage (which is seen mainly in children)[1].

  Isolyte P was used as maintenance fluid in paediatric patient in the past; however, consensus guidelines on perioperative fluid management in children: 2007 clearly states that the maintenance fluid used during surgery in children should be isotonic solutions such as 0.9% sodium chloride or Ringer's lactate[2].

- Children in PICU

  Maintenance fluid requirements should be reduced in children in PICU who were sedated and ventilated with humidified gases.

Following conditions maintenance fluid requirements is increased

Maintenance fluid requirements need to be increased in children with pyrexia, excess sweating, hypermetabolic states such as burns or when radiant heaters since higher amount of water is lost.

- *Pyrexia*

  Moderate sweating gives rise to fluid loss about 500 ml, but severe sweating can give rise to losses up to 3 liter in adults. If patient is having history of high-grade fever in the ward but comes to the theatre for operative procedure with normal temperature it means patient must have been treated with antipyretics and cooling measures in the ward. When patient is having normal temperature after pyrexia, it means patient must had sweating (insensible losses of water) which may be moderate or severe. Insensible losses should be replaced to maintain normal blood volume and normal composition of the ECF. In this patient, if ECF volume is not replaced, then after induction of anaesthesia, patient can have cardiovascular collapse due to unmasking of the fluid deficit.

- Exposed wound surfaces, burns and exposed intestines

  Exposed wound surfaces, burns and exposed intestines can cause severe third space fluid losses. Evaporation of fluid from exposed viscera is entirely water. The amount of evaporation is directly proportional to relative humidity.

  During laparotomy (exposed intestine if not covered with wet pack), insensible loss can be

approximately calculated as 750 ml to1lit/hr in adult. The loss can be replaced by balanced salt solutions or 0.9 % NaCl. Bowel wall oedema may be lessened by using colloids rather than crystalloids. The composition of third space losses is equivalent to the ECF electrolyte concentration and smaller amount of protein. Balanced salt solution is the most appropriate replacement fluid in the above condition[3].

3. Replacement of third space loss

Third space loss is also called redistribution of fluid. During surgery third space loss is due to sequestration of fluid from the vascular space into tissues around the site of surgery and should be replaced with an isotonic fluid.

Functionally, this fluid is not available to the vascular space. The volume redistributed correlates roughly with the degree of manipulation. It is important to assess clinical signs e.g. heart rate, blood pressure and capillary refill time – to ensure adequate replacement. Third space loss will be less if procedures are performed laparoscopically.

Intra-abdominal procedures with small incisions may require an additional 2 ml/kg/hr whereas a major bowel resection requires an additional 4-6 ml/kg/hr[2].

Type of surgery	Rate of fluid	Type of fluid
Superficial surgery	1-2 ml/kg/hr	Isotonic fluid
Moderate surgery	4-7 ml/kg/hr	
Abdominal surgery	5-10 ml/kg/hr	

Blood loss is replaced initially with 3 ml of balanced salt solutions or 0.9% NaCl for each 1 ml of blood loss. For each 1 ml of blood lost, 1 ml of colloid solution should be administered to provide improvement of filling pressure, arterial blood pressure, and heart rate.

Ascites and pleural effusions have same electrolyte composition as that of the ECF volume, but they also contain protein at concentrations 30% to 100% of the plasma value. Balanced salt solutions are the most appropriate for replacement. However, colloids should be administered when there is decrease in colloid osmotic pressure (<15to17 mm Hg). The electrolyte composition of gastrointestinal tract losses depends on the site. The most gastrointestinal losses removed at the time of surgery entered the bowel lumen preoperatively and should be considered to be part of the deficit.

Replacement fluid - Management of other losses during surgery

All losses during surgery should be replaced with an isotonic fluid such as 0.9% sodium chloride, Ringer lactate, a colloid or a blood product, depending on the child's haematocrit. There is no evidence that the use of human albumin solution is better than use of an artificial colloid to replace blood loss.

- 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 PRet 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.

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.

HOW TO CORRECT HYPOVOLAEMIA?

1. **First priority is to rapidly and efficiently correct hypovolaemia**

   Whenever there is loss, the first priority is to rapidly and efficiently correct hypovolaemia. Hypovolaemia should be corrected rapidly to maintain cardiac output and organ perfusion. In children, fall in blood pressure is a late sign of hypovolaemia. Dehydration without signs of hypovolaemia may be corrected slowly. The intraoperative choice of fluid is always crystalloid which is least expensive, reaction-free and readily available[4].

2. **Less urgently, water losses from the intracellular space (ICS) and interstitial space**

   Less urgently, water losses from the intracellular space (ICS) and interstitial space (ISS) should be replaced. The major problem in shock is hypovolaemia; not salt and water depletion. As colloids and crystalloid solutions contain fixed amount of Na, additional amounts are rarely necessary. Simultaneously, electrolyte losses such as K, PO_4, Ca, and Mg should be replaced according to regular measurement. The rate of replacement of water loss depends on the rate at which it occurred. If it occurred over minutes or hours (e.g. result of vomiting) then it can be rapidly replaced. If the losses occur over days or weeks, it should be corrected slowly.

Dextrose management during surgery

Though guidelines provide guidance, clinical assessment and judgment are equally important factors in patient care.

1. Preterm and term infants already receiving dextrose containing solutions

   Preterm and term infants already receiving dextrose containing solutions should continue with them during surgery.

2. Neonates in the first 48 hours

   Neonates in the first 48 hours of life should be given dextrose during surgery.

3. Infants and children on parenteral nutrition preoperatively

   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.

4. Children of low body weight or having prolonged surgery

   Children of low body weight (less than 3rd centile) or having prolonged surgery (more than 3 hours duration) should receive a dextrose-containing maintenance fluid (1-2.5% dextrose) or have their blood glucose monitored during surgery.

5. Children over 1 month of age

   The majority of children over 1 month of age will maintain a normal blood sugar if given non-dextrose-containing fluids during surgery. Blood glucose should be monitored if no dextrose is given[2]. The maintenance fluid used during surgery should be isotonic such as 0.9% sodium chloride or Ringer lactate solution.

6. Children having extensive regional anaesthesia

   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.

POST OPERATIVE FLUID MANAGEMENT

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 Ringer Lactate solution. It further states that solution choice should be tailored to the patient's needs. 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.

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. 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.

- 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.
- Losses should be measured hourly and replaced every 2 to 4 hours depending on the amount.
- There needs to be a matching of increasing oral intake with a reduction of intravenous administration of fluid.
- When oral intake approximates hourly maintenance rate then IV fluids may be discontinued. All fluid intake should be recorded on a fluid balance sheet.

MONITORING OF FLUID THERAPY IN CHILDREN

Serum electrolytes do not need to be measured pre-operatively in healthy children prior to elective surgery where IV fluids are to be given.

- 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.
- Children should be weighed prior to fluids being prescribed and given.
- Serum electrolytes should be measured every 24 hours in all children on IV fluids or more frequently if abnormal.
- 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.

IDEAL FLUID FOR TRAUMA

The lungs are moderately permeable relative to other organs, and during pathophysiological processes such as surgical trauma, the reflection coefficient may change further to alter capillary permeability, resulting in increased capillary permeability or leak. In this setting, colloids move more easily into the interstitial space and increase interstitial oedema. With leakage of colloid molecules into the interstitial space, further swelling of tissues occurs because of the unfavorable oncotic pressure gradient, and these molecules are removed by the lymphatic system. However removal of colloids requires longer period than for crystalloids and can be a significant problem in burns patients and patients undergoing major surgery[1].

A well known meta analysis by Velanovich published in 1989 concluded from eight studies of mortality that trauma patients should be resuscitated with crystalloid solutions, whereas colloids were more effective in nonseptic, nontraumatic, elective surgical patients. Current data seem to support the concept that blood composition should be maintained as close to normal as possible in terms of directed transfusion of red cells and coagulation factors[5].

Another factor that must be considered is the overall effect of resuscitation fluid on the

coagulation cascade. It is a well known phenomenon that after trauma, patients may have low levels of circulating coagulation factors. This deficiency may lead to transfusion of fresh frozen plasma to restore deficient factors. The clotting cascade is an extremely complex chain of events with many factors affecting the string to clot. Studies have shown that trauma patients are hypercoagulable. Definitive studies are still needed, however to clarify the true impact that resuscitation fluids take part in the coagulation cascade[6].

CRYSTALLOID VERSUS COLLOIDS

Much of the controversy surrounding the so-called colloid versus crystalloid is based on the mistaken basis that they are different fluids designed for same purposes.

- Theories favoring colloid

  If resuscitation with crystalloid is done, solution dilutes the plasma proteins with a subsequent reduction of plasma oncotic pressure resulting in fluid filtration from the intravascular to the interstitial compartment and thereby development of interstitial oedema; even pulmonary edema.

- Theories favoring crystalloid

  Colloid molecules normally enter the pulmonary interstitial compartment freely and then are cleared through the lymphatic system returning to the systemic circulation. Additional colloid should merely increase the colloid pool cleared by the lymphatics.

A review of literature by Moss conformed that all unlawful clinical and experimental studies showed that isotonic solutions are effective plasma expanders for resuscitation without the addition of a variety of colloids. The additional cost and potential risk of colloids compared with crystalloids is another argument against colloid administration.

Summary of recent protocol of fluid management in children

- During surgery all of these requirements should be managed by giving isotonic fluid in all children over 1 month of age
- The majority of children over 1 month of age will maintain a normal blood sugar if given non-dextrose containing fluid during surgery
- 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, of children low body weight (<3rd 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.
- 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.
- Fluid therapy should be monitored by daily electrolyte estimation, use of a fluid input/output chart and daily weighing if feasible.
- Acute dilutional hyponatraemia is a medical emergency and should be managed in PICU.

References

1. Ronald Miller, Miller's anesthesia, Seventh edition, Churchill Livingstone 2007, Chapter No.54, 1725 - 1728
2. Consensus guidelines on perioperative fluid management in children: 2007
3. Shires T. William J, Brown F: Acute change in extracellular fluids associated with major surgical procedures. Ann Surg 154:803, 1961
4. Paut O, Lacroix F (2006). Recent developments in the perioperative fluid management for the paediatric patient. Current Opinion in Anaesthesiology 19(3):268-77.
5. Velanovich V: Crystalloid versus colloid fluid resuscitation: A meta-analysis of mortality. Surgery 105:65,1989
6. Martin G, Bennett E, Wakeling H, et al: A prospective, randomized comparison of thromboelastographic coagulation profile in patients receving lactated Ringer's solution, 6% Hetastarch in abalanced saline vehicleor 6%Hetastarch in saline during major surgery. J Cardiothoracic Vasc anaesthesia 16;441,2002