

Perioperative and postoperative fluid management in pediatric cardiac surgery

Abstract

The fluid management plays a vital role in establishing and maintaining cellular homeostasis in pediatric cardiac surgery. Goals of optimizing fluid therapy to manage tissue perfusion, heart rate, hemoglobin, and oxygen saturation in this patients during perioperatively and postoperatively.

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Introduction

Perioperative and postoperative fluid management in pediatric cardiac surgery vary according to operation type, fluid needs and the condition of each patient adaptation. The gold standard of the fluid therapy is to use the correct fluid, to maintain the electrolyte balance, and to provide cardiovascular stability, adequate organ perfusion and tissue oxygenation.¹

Pediatric patients were sorted according to their ages in seven different groups: premature newborns (<38 weeks gestational age), term newborns (> 38 weeks gestational age), neonate (0-30 days), infant (1 month - 2 years), young child (2-6 years), child (6 - 12 years), and (g) adolescent (12 - 18 years). Newborn 75-80 % of your body is water, fat and muscle content increase with age and this ratio decreases up to 60 %. The extracellular fluid in newborn is 45 % of their body weight. This ratio becomes 30% by the age of 1 year, and 20% when they reach adolescent period.² Newborns who have a large surface-to-weight ratio, higher total water content, limited renal ability to concentrate, greater insensible water loss, thin skin, and high blood flow can dehydrate quicker;³ therefore, the fluid management is very important for pediatric patients.

Holliday and Segar first identified the 4/2/1 rule based on calories and water consumption in intravenous (IV) fluid therapy in children (Table 1).⁴ Newborn (3-10 kg) spends 100 kcal/kg calories, whereas, children (10-20 kg) 1000 kcal + 50 kcal per/kg and 20 kg and over children 1500 kcal+20 kcal/kg. It is determined that daily energy requirement for potassium and chloride is 2 mEq/100 kcal/day, for sodium 3mEq/100 kcal/day. These electrolytes are found in 5% dextrose and 0.45 % normal saline, which is a hypotonic solution. However, in the perioperative period the use of hypotonic fluids increases the antidiuretic hormone secretion and may lead to hyponatremic encephalopathy, and temporary neurological damage.⁵

It is important to know the preoperative fluid deficit. Initially, preoperative fluid deficit was calculated by multiplying the hours of fasting by the fluid need calculated as per 4/2/1 rule and it was suggested that the half of the calculated volume should be given during the first hour of surgery, and the remaining half over the next 2 hours.⁶ Later this method was revised and the new practice was to give 25 ml/kg of fluid to children age of 3 and under during the first hour of surgery and 15 ml/ kg to children 4 years and older.⁷

In 1999, American Society of Anaesthesiologists prepared guideline allowing clear fluid intake until 2 hours before anesthesia for patients undergoing elective surgery taking into consideration of the dehydrated children during secondary preoperative period (Table 2).⁸ There are protocols suggesting fasting period which is more than 2 hours (APA). However, the amount of fluid deficit after normal fasting cannot be exactly determined⁹ and there is no conclusive clinical findings indicating the degree of preoperative dehydration. In acute conditions, the child's weight loss may usually show the total water loss. Additionally, because renal function is the most important indicator of showing normal hydration, monitoring of urine output guides us in the evaluation and treatment of the fluid deficits.³ Decrease in blood pressure in pediatric patients is seen as a late finding of hypovolemia. If there is no finding of hypovolemia, dehydration should be corrected slowly with 0.9 % NaCl / Ringer Lactate. Depending on the severity of dehydration, hypovolemia should be treated with 10-20 ml / kg isotonic/ colloid in order to protect cardiac output and perfusion of organs.¹⁰

Table 1 Holliday and Segar' formula (4/2/1 rule)

Weight (kg)	Hourly fluid requirements	Daily fluid requirements
0-10 kg	4 ml/kg/h	100 ml/kg
10-20 kg	40 ml/saat + 2 ml/kg/h (above 10 kg)	1000 ml/kg + 50 ml/kg (above 10 kg)
>20 kg	60 ml/saat + 1 ml/kg/h (above 20 kg)	1500 ml/kg+ 25 ml/kg (above 20 kg)

Table 2 Preoperative Fasting guidelines for elective surgery as American Society of Anaesthesiologists

Ingested material	Minimum fasting period (h)
Clear liquids	2
Breast milk	4
Infant formula	4 (< 3 months), 6 (> 3 months)
Nonhuman milk	6
Light meal	6

Perioperative fluid management

In major surgical cases such as cardiac surgery, fluid passage to third space is 15-20 ml/kg/h, in premature infants it is 50 ml/kg/h.¹

As young children and small infants have more extracellular volume compared to older children and adults, this translates into relatively more perioperative water loss. To protect homeostasis during the fluid resuscitation, crystalloid compound should be isotonic. Hyperchloremic metabolic acidosis may occur as a result of excess crystalloid compound. When ringer lactate is given, this is not seen.¹¹ In fluid management towards the individual target, besides the use of crystalloid or colloid determining the optimum fluid deficit with monitoring is very important. In infants older than 1 month and children, fluid management should be made with isotonic fluids.

Blood glucose level should be controlled within normal limits when dextrose-free liquid is given during surgery. Before they are taken to the operating room, premature infants taking parenteral nutrition and fluids containing dextrose, low weight and high-risk newborns, and children having 3 hours longer duration of surgery such as cardiac surgery and receiving regional anesthesia carry high risk for hypoglycemia. Low concentration of (LRD 1 % or LR $\frac{1}{2}$ D 2.5 %) should be given to these patients in perioperative period.¹² Giving routine dextrose is not required except this group of children. However, hyponatremia, hyperchloremic acidosis, hyperglycemia and hypoglycemia (blood glucose <45 mg / dL) should be avoided and glucose monitoring should be performed. Hypoglycemia, if not treated, causes temporary neurological disorders. Hyperglycemia with anaerobic metabolism causes accumulation of lactate, ischemia and hypoxia, decrease in intracellular pH and cell death. In addition, hyperglycemia causes dehydration, electrolyte abnormalities and osmotic diuresis.¹²

Choice of crystalloid or colloid should be assessed by the type of fluid deficit, coagulation cascade and its contribution to the microcirculation.¹³ Today, crystalloid is firstly preferred due to low cost and the lack of coagulation, anaphylactic and infection risk. After administration of a total of 30–50 ml/kg of crystalloid solution or colloid solutions, it is important to observe intravascular osmotic pressure.¹⁴ There are comparably fewer data to confirm the safety use of synthetic colloids (hydroxyethyl starches; HESs, gelatins and dextrans) in children than the data in adults. Due to their high molecular weight and their degree of molar substitution, synthetic colloids have long term volume expander effect. Among colloids the natural one is albumin gold standard. The 5% albumin solution is osmotically equivalent to plasma.¹⁵ Recently, HES (130/0:42/6:1) has been used for volume replacement in neonates and small infants in cardiac surgery.^{14,15} However, colloids have adverse effects on coagulation in children with bleeding problems and in some studies it is stated that they disrupt capillary leakage in septic newborns.¹⁵

Prime solution used during cardiopulmonary bypass (CPB) should be physiological. The CPB process itself leads to significant changes in erythrocytes, platelets and coagulation factors, dilution in plasma proteins and drug levels, in electrolyte. Therefore, the content and preparation of prime solution is important. Blood (erythrocytes), crystalloid and colloid solutions should be used as the prime CPB solution. Sufficient quantity is typically 200–300 ml volume, while it is 240 ml for the newborn. Factors such as the age of blood transfused in pediatric patients, the target hematocrit level according to the patient's pathology, the use of reduced-volume assembly line in CPB affect the duration of intraoperative and postoperative period.

The use of fresh blood during cardiac surgery in neonatal reduces the drainage in the ICU, systemic inflammatory markers, pulmonary and renal complications and shorten the duration of mechanical ventilation, inotropic support rate for 24-hour and the length of hospital stay.^{16,17} Because the use of old blood as the prime solution (12 days >) rises the lactate levels and causes tissue hypoxia development.¹⁸

Also, to reduce perioperative inflammation, leukocyte-free blood transfusion is recommended.¹⁹

Studies show that in recent years, in the new generated CPB machine, optimal Hgb 7g/dl levels are protected by miniature oxygenator and arterial filter systems in newborn patients without perioperative blood transfusion.²⁰

Postoperative fluid therapy

Fluid therapy should compensate the basic metabolic requirements, gastrointestinal losses, and additional losses such as fever. Postoperative hyponatremia is the most common electrolyte disorder during this period, when hypotonic solutions are avoided; it can be prevented.⁶ The hematocrit level is important in newborn children with cyanotic congenital heart disease. If hematocrit level is < 25 %, blood should be transfused. Pediatric patients compared to adults have much higher oxygen consumption and cardiac output to blood volume ratio. During hemoglobin decrease, neonatal myocardium cannot compensate the reduced O₂ carrying capacity by increasing cardiac output. Normal term neonatal hemoglobin levels (14–20g %), respectively, begin to fall in subsequent months.²¹

Premature infants have higher ratio of fetal hemoglobin (HbF) than term infants. HbF production decreases in a few months. In pediatric blood transfusions, possible complications are similar to adult patients'. Also, metabolic complications such as hypocalcemia, hyperkalemia and hypothermia can be developed most often.²²

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Conflicts of interest

Author declare that there is no conflict of interest.

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