Perioperative Fluid Therapy in the Pediatric Patient: Recommendations

Néstor Busto-Aguirreurreta* and Juan José Jiménez Suarez

Departament of Pediatric Anesthesia, Complejo Hospitalario de Navarra, Pamplona, Spain

*Corresponding author: Néstor Busto-Aguirreurreta, Departament of Pediatric Anesthesia, Complejo Hospitalario de Navarra, Pamplona, Spain, Tel: 0034619524680;
E-mail: nbustoag@gmail.com

Introduction

The goal of perioperative fluid therapy is to maintain body homeostasis administering intravenous solutions to provide adequate intravascular volume, cardiac output and therefore oxygen to tissues when physiological functions are altered by surgical stress and anaesthetic agents.

Caloric and water requirements for basal metabolism in the hospitalized, not anesthetized children were calculated by Holliday and Segar in 1957 [1]. They developed an empirical equation estimating maintenance requirements: 100 mL/kg/day for the first 10 kg, 50 mL/kg /day for the second 10 kg and 20 ml/kg/day for the remaining kg with hypotonic solutions (saline 0.2%) containing 2-3 mEq/100 kcal/day and 3 mEq/100 kcal/day of sodium and potassium respectively (protocol 4/2/1). This requirements became a standard that made hypotonic solutions the maintenance solutions for most of the hospitalized children (also of anesthetized). However, in sick children, there are many non-osmotic stimuli that increase levels of antidiuretic hormone (ADH) that determine the loss of renal ability to remove free water and thus an increased risk of dilutional hyponatremia mainly if associated with perfusions with hypotonics fluids.

Hyponatremia (serum sodium <135 mEq/L) is the most common electrolyte disturbance in children, affecting approximately 25% of hospitalized children and 30% in the postoperative time [2]. Mortality by hyponatremic encephalopathy in children with lower serum sodium than 129 mEq/L is about 8% and although it is not known what the real incidence is, it appears that a serum sodium to 125 mEq/L is associated with encephalopathy in 50% of patients [3-6]. At least half of the cases documented in children have occurred during the postoperative period, many of them following not complicated surgery [7,8]. It is estimated that there are over 600 deaths in the US and one death per year in France by this reason [8,9]. In Australia it is estimated that hyponatremia is involved in 10% of hospital-acquired emergencies [10].

Given the lack of scientific evidence on the subject (mainly because it becomes very difficult and sometimes unethical to make a well-designed clinical trial) we have tried to collect the necessary information to establish useful recommendations to administer an adequate fluid therapy for paediatric patients in the perioperative period. We are talking about infants and children older than one month and for a period covering up to 24 h after surgery.

Recommendations [11]

1. It is recommended a non-restrictive preoperative fasting protocol [12-17]

a. Water and clear liquids: 2 h

b. Breast milk: 4 h

c. Light formula milk and meals: 6 h

2. Intraoperatively [18]

a. The Holliday´s and Segar´s1 protocol (see before) remains the most commonly formula used for calculating the volume of perioperative fluid maintenance (the main objective is to cover the basal water and electrolyte needs, equal to the losses produced in the body of a healthy child) in paediatrics [19-21].

b. Solutions (Table 1) must be isotonic or "near isotonic" (tonicity similar to plasma) for perioperative maintenance fluids except in special situation [22].

c. It is recommended to abolish perioperative hypotonic fluids because of the high risk of hyponatremic morbidity and mortality except in situations where there is an increased loss of free water [8,22,23].

d. In the intraoperative period it is recommend the administration of maintenance solutions (with glucose concentrations not exceeding 2% [24-28]).

e. The glucose solutions should not be administered as a replacement solution, that is to replace extraordinary losses (bleeding, third space, vomiting…) because they are hypotonic solutions that produce hypergycemia and hyponatremia [20,29-31].

f. Intraoperative initial fluid replacement should be performed with isotonic crystalloids. There is no evidence of superiority among different isotonic crystalloid solutions [22,32-35].

g. In rapid and considerable volume replacements it seems reasonable to employ an isotonic balanced crystalloid (with physiological pH and with a pattern similar to plasma electrolytes) to prevent hyperchloremic acidosis that may occur with NaCl 0.9% [27,36,37].

h. Colloids are an option for a massive and acute replacement (albumin, gelatines or hidroxietilherstach).

i. It's no clear if there is a role for colloids in non-emergent volume replacement and which colloid is better to protect for the shift of fluids to the interstitial space and the subsequent complications, even in non pediatric patients. Probably the best goal is to avoid hypervolemia and hypovolemia [38-40].

SOLUTION	pH	Na+ mEq/l	Cl- mEq/l	K+ mEq/l	Ca++ total mEq/l	Mg++ mosm/l mEq/l	Buffer mEq/l	Tonicity	osmolarity mosm/l	cost	Glucose
PLASMA	7,4	140	98	4	4,5-6	1,5-3	Bicarbonate 24	Isotonic	290-310	++++	
PLASMA-LYTE (RINGER ACETATO)	7,4	140	98	5		1,5-3	ACETATE 27	Isotonic	294 Iso-osmolar	++	
PLASMA-LYTE (RINGER ACETATO) Glucose al 1%	¿	140	98	5			ACETATE 27	Near-Isotonic	294+278/5=349 Hyperosmolar	++	1%
LACTATED RINGER	05-Jul	132	112	4	1,85		LACTATE 29	Near-Isotonic	273 Iso-osmolar	+	
LACTATED RINGER + Glucose 1%	¿	132	112	4	1,85		LACTATE 29	Near-Isotonic	273+278/5=328 Hyperosmolar	++	1%
LACTATED RINGER + Glucose 5%	4-6,5	131	111	4			LACTATE 29	Isotonic	555 Hyperosmolar		5%
STEROFUNDIN ISO [1]	5,1-5,9	145	127	4	2.5	1	ACETATE 24 MALATE 5	Isotonic	309 iso-osmolar	++	
PLASMA-LYTE (RINGER ACETATO) + Glucose a 5%		140	98	5		3	GLUCONATE: 23	Isotonic	547 Hyperosmolar		5%
SODIUM CHLORIDE 0,9%	5,5	154	154					Isotonic	308 iso-osmolar	+	
GLUCOSALINE 5%-0,18%	5,5	154	154					hypotonic	320 Iso-osmolar	+	5%
GLUCOSALINE 3,3%-0,3%	3,2-6,5	51,3	51,3					hypotonic	285 Iso-osmolar	+	3,3%
GLUCOSALINE 2,5%-0,45%		77	77					hypotonic	290 Iso-osmolar		2,5%
GLUCOSE 5%	4,2							hypotonic	278 Iso-osmolar	+	5%
HIDROXYETYL STARCH 6%	4-5,5	154	154					Isotonic	308 Iso-osmolar	+++	

Table 1: 1. Solutions are made with multiple different formulations available worldwide according to regional clinical practices and preferences. These are real and theoretical solutions. 2. According to the country, the names of the solutions may be different.

3. Fluids within the first 24 h postoperatively [41-44]

a. In not complicated surgery or minor surgery with intraoperative adequate replacement, postoperative fluid administration is not necessary unless there is an inability to tolerate oral fluids [4,28,42,43].

c. It is recommended to administer isotonic fluids with glucose 5% especially in children under 6 years as maintenance fluid, over 6 years it`s enough with 2% glucose [7,43,44].

d. If hypovolemic status is suspected during the postoperative course, it is recommended to replace blood volume with isotonic crystalloid solutions (10-30 ml/kg) or colloids (10 ml/kg) avoiding the use of hypotonic solutions [19,28,45].

4. Monitoring of postoperative fluid volumes, electrolytes and postoperative glycaemia

a. You should perform a clinical assessment of the patient´s hydration status [28].

b. It is recommended daily monitoring with ionogram and glucose levels in patients who require intravenous fluid therapy for a period longer than 24 h [28].

c. It is recommend perioperative glucose monitoring in clinical situations that can lead to hypoglycemia or hyperglycemia [20,29,42].

d. Suspect hyponatremia at the onset of headache, nausea, vomiting, irritability, altered level of consciousness, seizures, neurogenic pulmonary edema and apnea. In this case it is necessary an urgent determination of natremia [20,46].

e. A remaining challenge is to find a reliable non-invasive monitoring of vascular volume in paediatrics patients to administer the optimal volume of fluids [47].

5. Treatment of acute dilutional hyponatremia (symptomatic hyponatremia) [4,22,48]

Hyponatremia is defined as plasma sodium levels under 135 mEq/L. It is considered mild hyponatremia when sodium levels are between 130 and 135 mEq/L, moderate between 130 mEq/L and 125 mEq/L. Plasma sodium levels under 125 mEq/L or any symptomatic hyponatremia is considered severe hyponatremia.

Hyponatremic encephalopathy can be difficult to recognize, as the presenting symptoms are variable and can be nonspecific (headache, nausea and vomiting, confusion and disorientation, irritability, lethargy, reduced consciousness, convulsions, coma, apnoea). It

requires a high index of clinical suspicion and should be confirmed by measuring plasma sodium levels [49,50]. Computed tomography doesn't help to the diagnosis.

Hyponatremic encephalopathy in a child should be treated as a medical emergency and must be treated by the most experienced team and in critical care units. The delay in diagnosis and treatment leads to catastrophic consequences as severe neurological sequelae (not reversible cerebral palsy) and even death. The goal of treatment with boluses is to correct the plasma sodium to safe levels (clinical improvement), which can be used safely anywhere in moderate or severe encephalopathy without having to appeal to complicated formulas or infusions, in the emergency department or in the patient's bed before to be transferred to a critical care unit to be monitored properly.

The approach to the treatment is as follows:

a. Bolus injection of 2 cc/kg of 3% NaCl slowly (over 10 min). Maximum 100 cc.

b. The bolus can be repeated one or two times as needed until symptoms improve.

c. The purpose of the correction is to eliminate the symptoms or raise the concentration of Na+ serum (SNa) 5-6 mEq/L in one or two hours. It is unlikely to be in hyponatremic encephalopathy if there is not clinical improvement after acute elevation of SNa 5-6 mEq/L.

d. Check plasma Na$^+$ after the second bolus and at least hourly.

e. Stop 3% NaCl therapy when the patient:

i. It is free of symptoms: Awake, alert, responds to commands, and resolution of headache or nausea.

ii. SNa sharp rise of 10 mEq/L in the first 5 h

f. After hyponatraemia symptoms have resolved, ensure that plasma sodium does not increase by more than 12 mmol/L in a 24 h period.

Algorithm for Deciding Fluid Therapy in Pediatric Perioperative Patients

Figure 1 represents an option that seems reasonable. This algorithm excludes decisions on special situations, such as diabetes, metabolic disease....In any case it is only a guide and always shall prevail the decision of the physician or nurse in charge and should be individualized for each patient [11].

Conclusion

We do not know what the ideal solution for fluid therapy is and there is probably no single one but we do know which the inadequate ones in the paediatric perioperative settings are: hypotonic solutions.

We believe that if we simplify our fluid management strategy, guided by the literature, based on clear ideas, we can help to lessen morbidity and mortality, specially the preventable cases.

We are aware of the potential adverse events that might appear with the use of this fluid therapy, including phlebitis due to increased osmolality administered, serum hypernatremia, hyperchloremic acidosis or water and fluid overload, but these concerns have not been yet documented in papers [51]. In any case we must be attentive to them and prepared for changes.

We believe, as expressed Jacob and cols in an editorial published in 2011 [52]: "It is currently impossible to formulate evidence based guidelines for optimal procedure-specific perioperative fixed-volume regimes. Lack of evidence, however, should not be misused as a justification for continuing current therapeutic arbitrariness. Rather, as long as evidence is not available, we must "get back to basics" and medical practice should be guided by physiologic principles and scientific facts".
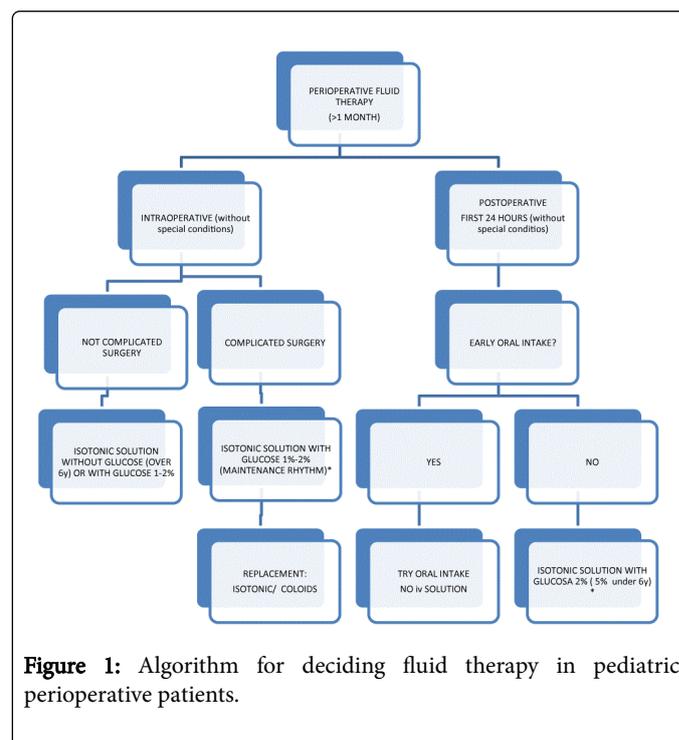

Figure 1: Algorithm for deciding fluid therapy in pediatric perioperative patients.

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