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Review Article:

Fluid Replacement Therapy in Different Medical Conditions in Children

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ABSTRACT

Vascular access and Intravenous Fluid (IVF) administration are essential issues in children who are admitted to the emergency wards. Despite the common use of maintenance IVF, there are a lot of variations in fluid administration methods and no definite guidelines for IVF and electrolyte monitoring. Because hypotonic fluids cause hyponatremia in many children, isotonic fluids are indicated, according to recent studies, as an accepted method in pediatric IVF therapy to prevent hyponatremia. This narrative review aims to provide an evidence-based approach for selecting the most appropriate IVFs in patients aged 1 day to 18 years. Data showed that the basis of fluid therapy in children varies according to the type of disease and the underlying conditions of children. Depending on each case, the clinicians should decide on what and how fluid and electrolytes be used.

Keywords: Rehydration solutions, Child, Fluid Therapy

Introduction

Vascular access and Intravenous Fluid (IVF) administration are essential issues in children who are admitted to the emergency wards [1]. Choosing appropriate fluid types and the appropriate method and location of IV access is mandatory in various emergency conditions [2] and even rare metabolic diseases [3]. Despite the common use of maintenance IVFs, there is a great deal of variation in fluid administration methods and no definite guidelines for IVF and electrolyte monitoring. As the usage of hypotonic fluids might lead to hyponatremia in children, according to recent studies, administration of isotonic fluids is indicated as an accepted method in pediatric IVF therapy. This narrative review aims to provide an evidence-based approach for selecting the most appropriate IVFs in patients aged 1 day to 18 years [3].

Evidence Acquisition

This narrative study was conducted through a literature search with the keywords of “intravenous fluids”, “IVFs”, “pediatric”, “isotonic fluid”, “hypotonic fluid”, and “serum therapy”. In this study, the authors summarized the proper fluid replacement therapies in the following conditions: neonatal need, burns, metabolic

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disorders, shock, renal failure, tumor lysis syndrome, malnutrition, gastroenteritis, and perioperative setting.

Results

Fluid replacement therapy in neonates

Fluid therapy in the neonatal ward is guided using three clinical factors of changes in body weight, serum sodium concentration, and urine output. The frequency of weight, fluid, and electrolyte assessments depend on the gestational and postnatal ages. For infants under 26 weeks of gestation, the neonate's weight is often checked every 12 hours, serum electrolytes daily, and intake/output every 6-8 hours. The hemodynamic status is evaluated through parameters, such as heart rate, capillary filling (<3 s is considered normal), skin turgor, and edema. In neonates, urine output of 1-3 mL/kg/h and urine specific gravity of 1008-1012 are acceptable. The frequency of these assessments will reduce as the infant reaches a steady state following initial diuresis and skin cornification. For infants 27-32 weeks of gestation, a twice-daily assessment should initially suffice, and for more mature neonates, daily assessment [4, 5]. After the initial diuresis, 2-4 mEq/kg/d of sodium and 2-3 mEq/kg/d of potassium intake are recommended. An approximate weight loss of 5% in term neonates and 15% in very low birth weight infants within a few days after birth is considered normal. Fluid requirements during the first month of life are listed in Table 1 [6].

Fluid replacement therapy in burn injury

Fluid resuscitation should begin at the early phase of burn injury in children. Delay in fluid resuscitation can increase the risks of acute kidney injury, multi-organ failure, prolonged stay in the hospital, and mortality. Any pediatric burn with greater than 10% of the Total Body Surface Area (TBSA) requires IV fluid replacement. Patients with a burn percentage of >15% Body Surface Area (BSA) should not receive anything per oral. Ringer is the preferred fluid during the first phase of resuscitation. The volume of administered fluid in the first 24 hours after burn injury is calculated based on the Parkland formula (4 mL× weight [kg] × TBSA [%] of burned area). Moreover, the maintenance serum should be added to the aforementioned resuscitation fluid. The preferred serum is lactated ringer (if the child is under 5 years of age, 5% dextrose should be added). Colloids are inappropriate fluids in burn settings because of increased capillary permeability during the first hours after injury. Moreover, the maintenance serum should be added to the aforementioned resuscitation fluid. Half of the estimated volume is administered in the first 8 hours and the rest in the next 16 hours [7]. Adequacy of fluid therapy should be assessed by monitoring vital signs, urinary output, level of consciousness, acid-base status, and serum electrolytes. In cases with burns above 30% TBSA, the patient should be transferred to pediatric ICU, and a central venous line catheter should be installed. In a study, it is recommended to use 2 mL/kg ×TBSA % burns (named as modified Brooke formula) over the same period instead of the Parkland formula [8].

Recommended serum in the second 24 hours is lactated ringer equal to half of the calculated volume in the first day. Colloid fluid is prescribed at 8-24 hours after burn if the burnt surface area exceeds 85% (infants are exceptions). In electrical injuries, serum alkalization is recommended to prevent acute tubular necrosis. Serum albumin level below 2 g/dL should be corrected. For burned TBSA> 30%, 5% albumin infusion (0.3-0.5 mL/kg/BSA%/24 h) is recommended. After 48 hours, fluids through an oral or nasogastric tube should be started and the volume of serum gradually titrated [9].

Fluid replacement therapy in metabolic disorders

The goal of treatment in metabolic disorders is to prevent the accumulation of harmful substances and toxic metabolites. In the emergency room, clinicians do not require to know the nature of the metabolic disease. In patients with a decreased level of consciousness and vomiting, oral intake must be discontinued. At first, airway, breathing, and circulation must be checked and established in these patients, similar to other emergent conditions. Secondly, hypoglycemia, acidosis, and hyperammonemia must be corrected. Antibiotics in an unstable child should be considered. To prevent long-term neurologic morbidity and mortality, good management and treatment are required. Due to the risk of cerebral edema, lactated ringer solution and hypotonic fluids should be avoided, especially in hyperammonemia.

For maintenance, 10% dextrose in normal saline should be administered. However, if the patient is hypoglycemic, dextrose as a bolus dose (10% dextrose IV for neonates and 10%-25% [0.25-1 g/kg/dose, not to exceed 25 g/dose] after the neonatal period) should be given at first. To promote urinary excretion of toxic metabolites, 1-1.5 folds of maintenance in the form of 10% dextrose (7-8 mg/kg/min) in normal saline is given to keep glucose level at 120-150 mg/dL and prevent catabolism. Insulin (0.2-0.3 IU/kg) might be indicated to maintain normoglycemia. Correction of metabolic acidosis, electrolyte abnormalities, and reducing the ammonia level

Table 1. Maintenance fluid requirements during the first month of life

Birth Weight (g)	Insensible Water Loss (mL/kg/d)	Total Water Requirements by Age (mL/kg/d)		
		Day 1-2	Day 3-7	Day 8-30
<750	100	100-200	120-200	120-180
750-1000	60-70	80-150	100-150	120-180
1001-1500	30-65	60-100	80-150	120-180
>1500	15-30	60-80	100-150	120-180

should be considered as well. Sodium bicarbonate (0.25-0.5 mEq/kg/h, up to 1-2 mEq/kg/h) or in hypokalemic patients, potassium acetate at pH <7-7.2 should be administered to compensate acidosis. It is noteworthy that rapid correction or overcorrection may have paradoxical effects on the central nervous system. For intractable acidosis, hemodialysis should be taken into consideration. It is recommended to add electrolytes at the maintenance concentrations with appropriate adjustments [10, 11].

Fluid resuscitation in shock

Initial resuscitation of hypovolemic or septic shock starts with infusion of isotonic crystalloid as a bolus dose of 20 mL/kg over 10 min in hypotensive children (if there are no findings associated with cardiogenic shock). Vital signs including pulse, respiratory rate, capillary refill, and urine output should be recorded every 10 minutes. If there are no signs of improvement and no evidence of lung crackle and hepatomegaly (attributable to cardiac involvement or cardiogenic shock), repeated doses of 20 mL/kg isotonic crystalloid up to a total of 60 mL/kg over the first 30 to 60 minutes are acceptable. For children with signs of cardiogenic shock who are hypovolemic, fluid bolus (5 to 10 mL/kg over 15 to 30 min) should be given cautiously, with frequent reevaluation. Inotropic agents or vasopressors are indicated if fluid resuscitation by crystalloid alone is ineffective. Norepinephrine is the preferred drug in septic shock, and if there is no increase in blood pressure, vasopressin might be added. If the patient is hypotensive and the cardiac output is low, a vasodilator in addition to inotrope or an indicator could be administered. Albumin is given in cases that require substantial amounts of crystalloids. In severe hemolytic anemia, a blood transfusion would be considered as the priority [12-14].

Fluid management in renal failure

In cases with oliguria or anuria, maintenance fluid administration may lead to volume overload, so limitation in fluid replacement must be considered. Initially, the child should be carefully assessed for volume status and accurate measurement of urine output. Administration of 10-20 mL/kg of crystalloid IV bolus over 30 minutes is necessary for children with a history or physical findings consistent with hypovolemia to prevent more severe intrinsic Acute Kidney Injury (AKI). The bolus can be repeated two times until the establishment of adequate urine output. Bolus fluid administration is contraindicated in patients with obvious volume overload (heart failure or edema). In some cases, even restriction in maintenance fluid is required. If the child is euvolemic, insensible water loss (300 to 500 mL/m^2/d or 25%-40% of the maintenance) as 5% dextrose in half saline should be given. Replacement of ongoing losses, including exact urine volume or gastrointestinal losses by 5% dextrose in half saline, is mandatory. Since the kidney is the main site of potassium excretion, in these cases and depending on the patient's condition, potassium of the maintenance fluid should be restricted or removed [15].

Fluid management in tumor lysis syndrome

Tumor Lysis Syndrome (TLS) is an oncologic emergency caused by massive tumor cell lysis and the release of large amounts of potassium, uric acid, and phosphate into the bloodstream. TLS occurs within 12-48 hours of the initiation of chemotherapy in patients with Burkitt lymphoma and T-cell Acute Lymphoblastic Leukemia (ALL) or other tumor types with a high rate of proliferation such as Hodgkin lymphoma, neuroblastoma, and hepatoblastoma. Aggressive fluid therapy and IV hydration are the mainstays of prevention and treatment of TLS. Preventing uric acid crystallization and calcium phosphate deposition in the renal tubules can be accomplished by induction of high urine output before chemotherapy in high-risk patients. Urine output should be measured at least hourly, and a formal assessment of fluid balance should be undertaken at least every 6 hours. There is no consensus on the particular fluid infusion rate. Still, according to recent reports in adults,

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Table 2. The volume of deficit fluid during the first hour of surgery

Weight (kg)	Volume of Deficit (mL/kg/h)
1-10	4
10-20	2
>20	1

it is reasonable to give 2-3 L/m² fluid every 24 hours (equal to 200 mL/kg/d in children weighing ≤10 kg) to establish > 4 mL/kg/h urine output in infants and 100 mL/m²/h in older patients [16]. Care should be taken to record all fluid losses such as vomiting or diarrhea. Infants, elderlies, and those with pre-existing cardiac and renal diseases are at particular risk of fluid overload. Daily weighing can be guided as a helpful marker in assessing fluid balance. Infants may need to be weighed twice daily to assess their fluid status better. Due to the risk of sodium retention and hypertension, the expert panel suggests the initial use of 5% dextrose one-quarter normal saline in patients with ALL who receive steroids during induction of remission. However, monitoring sodium is necessary for the prevention of the syndrome of inappropriate antidiuretic hormone secretion. In patients with hyponatremia or volume depletion, isotonic saline should be the initial hydrating fluid. Potassium should be removed from the hydration fluids due to the risk of hyperkalemia. A reduction in urine output needs prompt reassessment of fluid balance and laboratory parameters. The probability of urinary obstruction must be considered in the case of oliguria or anuria, which may require urgent intervention. Otherwise, volume overload due to AKI may occur. Diuretics such as Lasix (0.5 mg/kg) could be useful in this setting while remembering its lower efficacy and the risks of renal tubular obstruction due to uric acid deposition. Based on recent TLS guidelines, urine alkalinization is no longer recommended due to the increased risk of calcium phosphate precipitation in the setting of decreased urine xanthine solubility [16]. As administering acetazolamide and bicarbonate may not increase urine uric acid solubility, their usage is under consideration [17].

Fluid management in malnutrition

Fluid management is complicated in children with malnutrition. Although oral fluid therapy is the preferred method even in patients with severe malnutrition, some patients should be managed through IV fluid therapy. It is mandatory in patients with severe acute malnutrition (mid-arm circumference <115 mm or height-for-age < -3) who is in shock or in patients with severe dehydration who cannot tolerate oral or nasogastric tube feeding. IV replacement therapy has the following steps:

1. Rehydration with lactated ringer in 5% dextrose or 5% dextrose in ½ saline or 5% dextrose in normal saline at 15 mL/kg in an hour. Ringer's lactate can be an alternative fluid.

2. Monitoring pulse and respiratory rates at the initiation and every 10 minutes.

3. If there are signs of improvement, repeat IV drip, 15 mL/kg in 1 hour, and the treatment could be switched to oral or nasogastric rehydration protocols.

4. In case of no signs of improvement, the septic shock must be considered: 4 mL/kg/h maintenance IV fluid is needed.

5. In the presence of heart failure, transfusion of 5-7 mL/kg packed cells is needed. However, in the absence of heart failure, 10 mL/kg fresh whole blood should be transfused slowly over 3 hours. During the transfusion, 1 mg/kg furosemide should be administered [18].

Fluid management in gastroenteritis

Intravenous fluids are needed for managing severe dehydration in patients with gastroenteritis until the restoration of patients' circulatory volume. Rehydration starts with 20-30 mL/kg of isotonic crystalloid (normal saline or lactated ringer solution) over 10 to 15 minutes. The bolus doses should be repeated if necessary, with monitoring the patient's pulse strength, capillary refill time, mental status, and urine output. Stabilization often requires up to 60 mL/kg of fluid within an hour. This volume is followed by 70 mL/kg D5W in normal saline over 2.5-5 hours (slower rates in infants). Electrolyte monitoring should be performed in all children with severe dehydration. Frequent reassessment of the patient is necessary. After completing the resuscitation phase, if signs are compatible with some dehydration (restlessness, sunken eyes, drinking eagerly, slightly increase in skin turgor), the fluid should be switched to maintenance with D5W in normal saline. This type of fluid not only protects the child from hyponatremia but also is a preferred one because it acts as an extracellular volume expander while rapidly correcting volume deficit [19]. In case of normal mental status, adequate perfusion, and ability to drink, the patient would be switched to oral feeding by oral rehydration solution or breast milk. Ongoing loss (through diarrhea or vomiting) should be replaced by half saline in D5W5 (10 mL/kg with 20 mEq/L potassium chloride) [20].

Perioperative fluid management

During anesthesia, cardiac preload decreases due to vasodilation and increased venous capacity. Errors in perioperative fluid management may lead to serious complications in children. To protect children from hyponatremia, isotonic solutions are safer than hypotonic ones. The perioperative fasting times should be as short as possible to prevent patients' discomfort, dehydration, and ketoacidosis. Bleeding during surgery and insensible fluid loss due to third space accumulation make the patient more prone to fluid depletion. Crystalloid fluid (normal saline or ringer plus dextrose in infants regarding the risk of hypoglycemia) is necessary to maintain cardiac output and organ perfusion. These fluids need to be replaced during surgery:

1. Deficit fluid during preoperative fasting
2. Maintenance fluid
3. Blood loss
4. Insensible water loss

Recommended volumes of deficit fluid during the first hour of surgery are presented in Table 2.

For longer procedures, the fluid deficit should be replaced with isotonic fluid calculated as the number of hours of child fasting. The third space fluid loss should be replaced by isotonic fluids at the rate of 3-5 mL/kg for minor surgeries (pyloromyotomy, herniorrhaphy, etc.) or 8-10 mL/kg for major surgeries (thoracic or abdominal). Blood loss during surgery should be replaced by blood products. Albumin administration decreases the volume of crystalloid fluid needed for a patient with blood loss [21].

Ethical Considerations

Compliance with ethical guidelines

This article is a review article with no human or animal sample.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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