***6 CE Credits**

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5

AANA Journal Course: Update for nurse anesthetists – Intraoperative fluid management for the pediatric surgical patient

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Intraoperative fluid management for the pediatric surgical patient is a critical element of the anesthetic care plan. In contrast with adult patients, the fluid management is systematized by the use of established protocols that calculate fluid on a per kilogram basis. Children are relatively volume sensitive, and mismanagement of fluid and electrolytes can contribute to morbidity and mortality in infants and young children undergoing even the simplest procedures. Failure to correct volume deficiencies can lead to multisystem failure and death. Inappropriate overhydration can result in pulmonary edema and respiratory problems that can prove fatal. Regardless of the fluid management plan, perioperative fluid management must be flexible and take into account the physiologic development and age of the pediatric patient. The goals of intraoperative fluid management are to restore intravascular volume, maintain cardiac output, and, ultimately, ensure provision of oxygen to the tissues.

Key words: Blood loss, fluid management, fluid translocation, hypovolemia, pediatric anesthesia.

Objectives

Upon completion of this course, the reader should be able to:

1. **Discuss the developmental changes in the extracellular fluid compartment of the pediatric patient.**
2. **Determine at what age the renal function of the infant is completely mature.**
3. **Recall the amount of clear fluid per kilogram**

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of body weight that can be administered preoperatively and maintain an acceptable level of risk for aspiration.

4. Calculate the following fluid management parameters: hourly fluid requirement, estimated fluid deficit, fluid replacement plan, third-space loss, estimated blood volume, and allowable blood loss.

5. Formulate a blood replacement plan based on 1 of 4 formulas.

Introduction

Perioperative fluid management must be adapted to the physiologic development and age of the pediatric patient. Fluid requirements and maturation of the renal and cardiovascular systems set limits on the type and quantity of perioperative fluids administered. Basal or maintenance fluid needs are based on the energy needs or caloric requirements, which are twice as great as those of the adult patient. Very small amounts of fluid and electrolytes are required for growth; however, fluid homeostasis can be dangerously affected by prolonged fasting. Replacement fluid needs are based on losses secondary to trauma, bleeding, and translocation of body fluids and anesthetic agents. Improper fluid management for infants and children can cause life-threatening consequences. The inadvertent administration of 100 mL to a full-term neonate is similar to a 1 to 2 L excess in the adult. Likewise, 3 tablespoons of blood (45 mL) in a 1,000-g premature infant is 50% of the entire circulating volume.[1]

The goals of intraoperative fluid and electrolyte management are to prevent the kidney from having to conserve or excrete large amounts of fluid or electrolytes and to attenuate the cardiovascular changes induced by anesthetic agents. Individual responses to trauma and illness and to healing and health mandate a customized approach to fluid management.

Developmental considerations

■ *Changes in body fluid compartments.* Changes in body compartments affect the fluid balance in pediatric patients. Those changes are as follows: (1) size and composition of extracellular fluid (ECF), intracellular fluid, and interstitial fluid compartments; (2) membrane integrity; and (3) percentage of body fat. Water constitutes 75% of a full-term neonate's body weight, 65% of a 12-month-old child's body weight, and 50% to 55% of an adult's body weight.[2] Forty percent of the infant's body water is ECF. The extracellular water is divided into 2 compartments: plasma and interstitial fluid. This large ECF volume and its high percentage relative to other compartments cause a high turnover of water and electrolytes, especially sodium. As maturation occurs, ECF becomes a smaller percentage of the total body water and, consequently, a smaller portion of the total body weight.[3]

The integrity of the capillary membrane prevents the movement of proteins in plasma into the interstitial fluid. A damaged or immature capillary membrane, as in the premature infant, can result in excessive loss of circulating volume due to proteins passing into the interstitial fluid.

Lack of body insulation due to limited body fat and an increased body surface area–weight ratio make infants particularly susceptible to heat loss in a cold environment. The cold stress increases the metabolic rate in an attempt to increase body temperature, and the increased metabolic response results in increased fluid requirements.[4]

■ *Renal electrolyte and fluid physiology.* At term, renal function is not completely mature. Glomerular filtration rate is 25% to 30% that of the adult, and renal tubular function is not as efficient, especially for sodium.[5] It reaches approximately 90% of maturity by 44 weeks postconceptual age. By 1 year after birth it is completely mature. The renal handling of water is related to glomerular filtration and tubular function. However, when challenged with moderate fluid loading for short periods, neonates can increase urine volume because the negative effect exerted by the low glomerular filtration rate is counteracted by the positive effect of the low concentrating capacity of the neonatal kidney. Volume depletion can lead to more serious problems than volume loading.[6]

Because neonates and infants are obligate sodium losers and have decreased ability to conserve in situations of sodium depletion, the administration of sodium-free fluids may lead to hyponatremia more readily than in older patients. Therefore, the amount of sodium necessary to maintain sodium balance is directly related to sodium intake. The amount of sodium necessary to maintain balance is inversely related to gestational age.[2] By 4 to 5 days after delivery, there is marked improvement in renal function and the ability to conserve fluid and excrete an overload.

■ *Cardiovascular physiology.* In the presence of normal cardiovascular function, most infants can tolerate moderate overhydration for short periods; however, in the neonate, overhydration may be fatal. In the pediatric patient with delayed closure of the ductus arteriosus, maintaining fluid balance can be a complex task. Due to the transitional state of the circulatory system, overhydration may result in pulmonary edema, congestive failure, or both.[7] If the normal transition from intrauterine to extrauterine circulation does not occur, precise management of fluid is mandatory.

■ *Caloric requirements.* Infants require more calories to provide the fuel for body systems. Holliday and Segar[8] determined a measure of caloric expenditure in the patients restricted to bed or hospitalized. A generally accepted measurement of calories used during bed rest is 100 cal/kg per day in infants weighing more than 10 kg but less than 20 kg. As infants grow and mature, their caloric needs increase at a slower pace. For example, a 6-month-old 8-kg infant will require 800 calories per day, whereas the caloric requirements of a child weighing more than 20 kg drops to 50 cal/kg per day. Daily fluid requirements can be calculated by determining fluid lost based on caloric expenditure. For every 100 calories expended, 100 mL of water will be lost. Anesthesia will impose caloric requirements close to that of basal requirements (32 cal/kg per day). Up to 25 kg, the following formulas can be used to calculate hourly calorie, fluid, and electrolyte requirements[9]:

Caloric requirements = 1.5 × kg + 5 = maintenance calories per hour

Fluid requirements = 2.5 × kg + 10 = maintenance fluid per hour

Sodium requirements = 0.045 × kg + 0.16 = maintenance Na^+ per hour

Potassium requirements = 0.03 × kg + 0.10 = maintenance K^+ per hour

The goal of fluid management is to maintain circulating volume to prevent activation of the body's homeostatic mechanisms. These mechanisms, such as peripheral vasoconstriction, impair peripheral tissue oxygenation so that blood flow is provided to the major organs.

Fasting

Preventing pulmonary aspiration, maintaining fluid balance, and decreasing the risk of dehydration or hypoglycemia from prolonged fasting are important concerns facing anesthesia providers. Historically, prolonged fasting has been recommended to decrease the amount of gastric fluid and, in turn, decrease the risk of aspiration on induction of anesthesia. The risk of aspiration in the pediatric patient undergoing general anesthesia has been reported as between 1 and 9 per 10,000 patients. The majority of those patients had known risk factors, eg, gastroesophageal reflux, difficult airway, impaired cough, emergency surgery, and obesity.[10]

Gastric emptying time has been shown to be slower for solids and milk than for clear liquids.[11] Clear fluids are defined as any liquid that you can see through. It is a matter of current debate as to the status of breast milk, but more often it is categorized as a clear liquid due to its rapid gastric emptying time.

The gastric volume and pH in healthy children who fasted for 2 hours preoperatively did not demonstrate significant difference from those in children who fasted 6 to 8 hours.[12] Allowing 3 mL/kg of clear liquid until 2 hours before induction is acceptable in the reduction of risk for regurgitation and aspiration.[13] Generalized fasting guidelines for patients without known risk factors for aspiration are presented in Table 1.

When fasting times can be kept to a minimum, there is a demonstrated decrease in the stress level of the patient and the parents. There is less risk of hypotension on induction and perhaps less hypoglycemia.[11]

Table 1. Fasting guidelines*

	Hours of fasting before anesthesia	
Age group	Milk and solid food	Clear liquids
Neonate	4-6	2
1-6 mo	4-6	2
6-36 mo	6-8	2-4
>36 mo	8	2-4

* From Children's Hospital of Alabama, Birmingham

Intraoperative fluid management

■ *Requirements.* Compared with adults and older children, neonates and infants have greater fluid needs because of higher rates of metabolism and growth. Neonates who drink nothing for a day may lose 10% of their body weight.[3] They have a surface area–weight ratio approximately 3 times greater than the adult, resulting in greater insensible loss and greater excretion of sodium. This obligatory loss of sodium combined with decreased tubular concentrating ability increases fluid loss, making neonates more susceptible to dehydration.

Fundamental to any system of fluid management is an accurate determination of the current volume and hydration status of the patient. Following a review of the child's medical history, a physical examination should be performed and pertinent laboratory test results evaluated. A child's state of hydration can be estimated by determining how much weight the child has gained or lost since the onset of the illness. For each kilogram of weight lost, 1 L of fluid is required to rehydrate the child. In young infants, a 5% volume deficit could be indicated by depressed fontanelles, sunken eyes, dry mucous membranes, and a small tongue. Table 2 provides guidelines for estimating the patient's state of hydration. Special attention should be directed to the patient's cardiovascular and renal status as it relates to the state of hydration. Tachycardia, hypotension, or both may signify that the child is hypovolemic, whereas the presence of pulmonary edema in a healthy child may indicate fluid overload. Although decreased urine output may be due to renal failure or cardiovascular dysfunction, in a healthy child this is generally an indication of abnormalities of fluid balance. Corrections in fluid balance, as reflected by a reduction in hematocrit, should be implemented, if at all possible, before the administration of anesthesia.

■ *Fluid replacement.* Many systems have been developed for the administration of fluids and electrolytes to the pediatric surgical patient. Fluid replacement can be calculated by giving a predetermined amount of fluid per square meter of body surface area, per kilogram of body weight, or per calorie expended. Body surface area calculations require an accurate height and weight measure of the patient. The information is applied to a nomogram to determine fluid requirements. This method is logistically difficult, and the results are too variable, due to an average error rate of 15%.[14]

One approach is to divide the fluid therapy into 3 phases: replacement of fluid deficit, maintenance fluid administration, and administration of replacement fluids. The initial step in initiating any type of fluid therapy is to calculate the patients' hourly fluid requirements. This calculation can be done in several ways; however, the most common and expedient one is based on patient weight. Hourly fluid requirements calculated with this method, in its simplicity, do not consider metabolic rate, caloric intake, core temperature, body surface area–weight ratio, and ongoing fluid losses (eg, nasogastric suction).

The formula based on patient weight often is referred to as the "4-2-1 rule." Table 3 provides another method for calculating hourly fluid requirements based on body weight. It is the "Rule of 10s." The 4-2-1 rule calculates the patient's hourly fluid requirements, and the Rule of 10s calculates the patient's fluid requirements for a 24-hour period.

■ *Fluid deficit.* Fluid deficit (losses of fluid and electrolytes that occurred before the patient's admission to the surgical service) must be calculated and managed. Primarily, the severity of dehydration is estimated from the patient's history and physical condition at the time of admission to the surgical service. The fluid deficit of a healthy child who is not being fed parenterally may be estimated by multiplying the child's hourly maintenance requirement for fluid by the number of hours

Table 2. Clinical signs of hydration status[2]

Deficit/ clinical findings	Deficit/ clinical findings
5%—Poor tissue turgor, dry mouth, depressed fontanelles	5%—Cold "sock" feet
Or	
10%—Oliguria, tachycardia	10%—Cold up to knees
15%—Hypotension, sunken eyes	15%—Entire extremity cold
20%—Unconscious	

Table 3. Formulas for hourly maintenance fluid requirements[2]

Rule of 10s	
0-10 kg	100 mL/kg for 24 h
10-20 kg	(1,000 mL + 50 mL/kg >10 kg)/24 h
20 kg or more	(1,500 mL + 20 mL/kg >20 kg)/24 h
Body weight (4-2-1 rule)	
0-10 kg	4 mL/kg per h
10-20 kg	40 mL + 2 mL/kg per h >10 kg
20 kg or more	60 mL + 1 mL/kg per h >20 kg

Table 4. **Replacement regimen for fasting deficit**[22]

50% deficit + maintenance, first hour
25% deficit + maintenance, second hour
25% deficit + maintenance, third hour

*No more than 20 mL/kg per hour unless clinical situation dictates

since the child's last oral intake. This calculation is based on the assumption that the patient was in water balance at the time oral intake was discontinued. If a patient is actively bleeding or vomiting or has a draining nasogastric tube in place, these and other abnormal fluid losses should be added to the fluid deficit.

Unless the child's fluid deficit is very large, the fluid generally is replaced during the first 3 hours of anesthesia. Table 4 illustrates the regimen for fluid deficit replacement. One half of the deficit is replaced during the first hour, along with the maintenance fluid for that hour. The remaining half of the deficit is divided in half and administered during the next 2 hours, along with the maintenance fluid requirements.[15] If the child is seriously dehydrated, hydration should begin as soon as the dehydration is noted. Anesthesia should not be induced until the patient is in fluid balance unless the surgery is extremely urgent, easy intravenous access is anticipated, or the surgery is such that oral feeding will be allowed immediately after anesthesia.

■ *Maintenance fluids.* The purpose of maintenance fluids is to replace water and electrolytes that are lost under ordinary conditions. Maintenance fluids are required for 4 reasons: (1) evaporation from the skin, an essential part of thermoregulation; (2) excretion of waste products via the kidney and stool; (3) water losses from the respiratory tract; and (4) growth. Maintenance fluids are designed to maintain water and electrolyte homeostasis with minimal renal compensation. Maintenance fluid requirements vary depending on the metabolic requirements of the infant or child. These losses frequently can be replaced by a solution of 5% dextrose in quarter-strength saline. This solution may be used during very short surgical procedures involving minimal tissue trauma, such as bronchoscopy or excision of skin lesions. During procedures associated with more tissue trauma, balanced salt solutions are more appropriate. Maintenance fluids should not be used intraoperatively or postoperatively until the need for replacement fluids has passed.

■ *Hypoglycemia.* Managing the patient's glucose requirements is important. Anesthesia lowers glucose requirements by decreasing metabolic rate; however, the stress response to surgery and anesthesia causes an increase in serum glucose levels. This increase is due to increased glucose production and a decrease in glucose storage. Healthy pediatric patients rarely develop intraoperative hypoglycemia. Historically, glucose was given to prevent intraoperative hypoglycemia, provide free water, conserve protein, and prevent ketosis. Today, glucose solutions are not used routinely for intraoperative fluid replacement. A 5% glucose solution, given intraoperatively, consistently has produced hyperglycemia and osmotic diuresis. Dextrose content needs to be high enough to prevent protein breakdown and avoid ketosis while avoiding hypoglycemia. A 2.5% dextrose solution has demonstrated consistent normal glucose levels when given introperatively.[16] While hypoglycemia is rare, certain subsets of patients require glucose infusions: neonates during the first few days of life, premature infants with low glycogen stores, critically ill neonates, and those receiving parenteral nutrition before surgery. Patients who are receiving glucose-based parenteral nutrition are at risk for rebound hypoglycemia when their nutrition is abruptly discontinued. Frequent monitoring of glucose levels should be performed for patients at risk for hypoglycemia.[11]

■ *Replacement fluids.* In response to the surgical procedure, children move more fluid from the intravascular to the interstitial space. The amount of fluid lost can be substantial and depends on the amount of tissue exposed and the degree of surgical manipulation. Fluid loss can vary from 1 to 2 mL/kg per hour for a minor procedure to as much as 10 to 25 mL/kg per hour for a major abdominal procedure, such as a bowel resection for necrotizing enterocolitis. In patients in whom a significant volume shift is likely, a sizable portion of the estimate of the fluid requirement is open to error, inasmuch as an approximation can result in a correct or an incorrect amount. Table 5 provides guidelines for replacement of third-space fluid losses. This additional fluid loss should be added to the hourly maintenance rate. The total hourly requirement for the patient could be composed of the following: (1) fluid deficit, (2) maintenance, (3) third-space loss, and (4) blood loss. It is essential that careful hourly monitoring assess the results of the volume restoration. An

Table 5. **Guidelines for replacement of third-space fluid loss**

Estimating third-space loss	
Major intra-abdominal surgery	Up to 25 mL/kg per hour
Moderately invasive surgery	4-7 mL/kg per hour
Superficial surgery	1-2 mL/kg per hour
Replacement of third-space intraoperative losses	
Short procedure—minimal to moderate third-space loss	D_5LR, maintenance LR 0.9% NS
Long procedures—moderate to extensive third-space loss	$D_5$0.25 NS, maintenance LR 0.9% NS
Procedures with massive third-space loss	Colloid to restore one third to one fourth of loss LR

D indicates dextrose; LR, lactated Ringer's solution; and NS, normal saline.

adequate urine output is one measure of adequate volume restoration in the patient. Vital signs, laboratory test results, and clinical signs, ie, capillary refill, skin temperature, and skin color, should be used to ascertain the need for large-volume infusions in each case. Consideration should be given to the postoperative course when the capillary membranes recover and shift fluid back into the intravascular space.

■ *Fluid selection.* The choice of the appropriate fluid is a very important aspect of fluid management. Errors in pediatric fluid management usually occur in 2 areas: errors calculating fluid requirements or the choice of the fluid administered.[17] The indiscriminate use of sodium-free fluids, such as 5% dextrose and water can lead to hyponatremia. Due to the immaturity of the neonatal kidney, this problem is more likely to occur in this youngest age group. Sodium loss continues even when these infants are hyponatremic. Therefore, maintenance fluids always should contain sodium. The solution used also should contain a reasonable quantity of electrolytes to avoid excretion or conservation of large quantities of other electrolytes by the immature renal system in order to maintain balance.

Short-term fluid therapy also needs to involve the replacement of caloric expenditures. This cannot be done with glucose alone. To fully replace caloric expenditures with glucose, a 25% glucose solution would be required to avoid overhydrating the patient. This very concentrated solution is very irritating to the endothelium of the peripheral blood vessels. Fortunately, it is not necessary to replace caloric expenditure completely in most patients. Enough calories should be replaced, however, to avoid ketosis and protein breakdown, resulting in a catabolic state. This amounts to 20 to 25 cal or 5 to 6 g of glucose for every 100 cal burned. Each gram of glucose provides approximately 4 cal.[2] Six to 10 mg/kg per minute of glucose helps prevent protein catabolism. One liter of dextrose solution contains 50 g of carbohydrate, or 200 cal. The clinical rule of thumb for glucose in infants is 0.5 to 1 g/kg or 2 to 4 cal/kg. As a point of reference, administration of 10 mL/kg of 5% dextrose and lactated Ringer's solution equals approximately 0.5 g/kg or 2 cal/kg of glucose; administration of 20 mL/kg of 5% dextrose and lactated Ringer's solution equals approximately 1 g/kg or 4 cal/kg of glucose. Maintenance fluid losses can be replaced with 5% dextrose and quarter-strength saline for short procedures with minimal tissue trauma. In procedures associated with more tissue trauma, balanced salt solutions are more appropriate, since the electrolyte composition is closer to that of plasma.

In situations involving minimal blood loss, fluid and electrolyte balance can be maintained with lactated Ringer's solution. Maintenance losses may be replaced with 5% dextrose and lactated Ringer's solution; however, because it is hypertonic, excessive amounts should be avoided to prevent development of a hyperosmolar state. In most circumstances, if the initial intravenous solution is 5% dextrose in lactated Ringer's solution followed by solutions of plain lactated Ringer's, most children will spontaneously maintain fluid and electrolyte balance.

■ *Postoperative considerations.* The goal of fluid management is euvolemia at the end of the surgical procedure. A key principle to remember is that children not only have basal needs to be met, but there is also a requirement to support growth and development. In most short noncritical procedures in healthy children, a balanced salt solution with 20 mEq/L potassium added and the patient's own fat stores will prevent ketosis and tissue catabolism.[18] The renal threshold for glucose is low, and if a hypotonic saline or glucose solution is used postoperatively, osmotic diuresis may occur and dilutional hyponatremia could result. Vomiting, a common postoperative complication, could result in high losses of sodium. In addition, blood loss, interstitial losses, and release of antidiuretic hormone to maintain volume may exacerbate dilutional hyponatremia. Hyponatremia pulls water from the extracellular to the intracellular space, possibly resulting in cerebral edema. Administration of glucose to fulfill approximately 20% of the total caloric needs is suggested.[1]

In the postoperative period, significant fluid losses can continue because of draining nasogastric tubes, ongoing blood loss, peritoneal drains, chest tubes, and other surgical requirements. In neurosurgical and certain cardiovascular procedures, fluid and sodium restriction may be indicated. The volume and type of fluid necessary to maintain fluid balance during this period must be tailored to each individual patient.

■ *Urine output.* Urine output is a standard measurement of volume status in most pediatric patients, even in the face of technical difficulties in the smallest patients. An output of 1.5 to 2.0 mL/kg per hour reflects adequate volume restitution. When the patient reaches 25 to 30 kg, 50 to 60 mL/h is considered adequate.[17]

Blood product management

■ *Estimating blood volume.* Procedures that will involve substantial and rapid blood loss require plans for restoring blood volume before anesthesia. Two common approaches to managing blood loss in pediatric surgical patients are hematocrit measurements and percentage of blood volume lost. The lowest acceptable hematocrit and what percentage of the total estimated blood volume can be lost before transfusion should be determined in the preoperative period.

In the past, 30% was the lowest hematocrit value that was advocated. This was an arbitrary number that reflected the mean hematocrit of a population of children. In a neonate, a higher value was more rational, since fetal hemoglobin shifts the oxyhemoglobin dissociation curve to the left. This shift decreases oxygen unloading at the tissue level and can lead to tissue hypoxia if the hemoglobin falls too low. Presently, hematocrit values in the 25% to 27% range are being accepted as a result of the concurrent risks associated with the transfusion of blood and blood products.[19] After blood volume is determined, the patient's estimated red blood cell mass is calculated by multiplying the estimated blood volume by the preoperative hematocrit in volumes percent. Table 6 gives 2 methods used for calculating estimated blood volume and estimated red cell mass.

Table 6. Formulas for calculating blood volume and estimated red blood cell mass

Premature infant	90-100 mL/kg
Full-term infant	80-90 mL/kg
3 mo-1 y	75-80 mL/kg
>1 y	70-75 mL/kg
Or	
Hematocrit + 50 × weight (kg)	
Estimated red blood cell mass	
Estimated blood volume × hematocrit = estimated red blood cell mass	

■ *Estimating blood loss.* When caring for pediatric patients, one must think in terms of the percentage of blood volume lost and not in terms of units of blood lost. Most methods of estimating blood loss intraoperatively are inaccurate. A rough estimate can be made by measuring the volume of blood in suction bottles, weighing the blood accumulated on sponges, and estimating the amount of blood in the surgical field. In the smallest infants, weighing sponges is the most accurate. A dry Raytech sponge, when saturated with blood, weighs 10 g, which is equivalent to 10 mL of blood.[20] Another method is to calculate 15% of the patient's blood volume and transfuse when that plateau is reached and symptoms dictate. Serial hematocrit determinations are also valuable.[19]

■ *Allowable blood loss.* Allowable blood loss can be calculated by several formulas. The simplest, most expedient method is to estimate the maximum allowable blood loss (MABL) by simple proportion:

$$MABL = EBV \times [HCT_{PT} - HCT_{LA}] / [HCT_{PT}]$$

where EBV is the estimated blood volume, HCT_{PT}, the patients current hematocrit, and HCT_{LA}, the lowest acceptable hematocrit.[21]

Maximum allowable blood loss can be replaced by one of the following methods based on the patient's ongoing physiology.

1. Two to 3 mL of lactated Ringer's solution or normal saline for each milliliter of blood loss,
2. Blood loss that is less than the maximum allowable can be replaced with colloid (1 mL hydroxyethylstarch or 5% albumin) for each milliliter of loss,
3. Whole blood replacement of 1 mL for each milliliter of loss, or
4. Packed red blood cell replacement of 0.5 mL for each milliliter of loss.

Summary

The management of perioperative fluids in a pediatric patient can have numerous variables, and fluid loss can be calculated and replaced based on several methods. Appropriate fluid management must be monitored, as always, by hemodynamic variables, as well as by urine output. Healthy infants, children, and, especially, premature infants are very sensitive to changes in blood volume, so that hypotension in the absence of anesthetic overdose is frequently due to hypovolemia.

An understanding of the physiology of fluid requirements in surgical patients is essential for good management. Standard formulas for fluid therapy can be modified to account for the rapidly changing physiology of the pediatric surgical patient, and oral rehydration formulas may offer an alternative method of fluid support for these children.

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