Intraoperative Fluids and Fluid Management for Ambulatory Dental Sedation and General Anesthesia

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Intravenous fluids are administered in virtually every parenteral sedation and general anesthetic. The purpose of this article is to review the physiology of body-water distribution and fluid dynamics at the vascular endothelium, evaluation of fluid status, calculation of fluid requirements, and the clinical rationale for the use of various crystalloid and colloid solutions. In the setting of elective dental outpatient procedures with minor blood loss, isotonic balanced crystalloid solutions are the fluids of choice. Colloids, on the other hand, have no use in outpatient sedation or general anesthesia for dental or minor oral surgery procedures but may have several desirable properties in long and invasive maxillofacial surgical procedures where advanced hemodynamic monitoring may assess the adequacy of intravascular volume.

Key Words: Intravenous fluids; Ambulatory; Sedation; General anesthesia; Dentistry; Crystalloids; Colloids.

Intravenous fluids are administered in almost every parenteral sedation and general anesthetic.¹ Historically, sedative medications were administered using a variety of methods that included barbotage, intramuscular injection, or inhalation of volatile agents. The goal of intravenous fluid therapy in anesthetic practice is to maintain adequate tissue perfusion and oxygen delivery,¹⁻³ and, in most cases, provide a fluid vehicle for drug administration. Decisions regarding the type and amount of fluids administered intraoperatively may affect post-operative outcomes.¹ This article reviews the physiology of body-water distribution and fluid dynamics at the vascular endothelium, evaluation of volume status, calculation of fluid requirements, and the clinical rationale for the use of various crystalloid and colloid solutions.

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BODY-WATER DISTRIBUTION

Total body water is distributed in various compartments. The total volume of water in the body is 60% of lean body mass in males and 55% in females with a distribution of two thirds intracellularly and one third extracellularly.⁴ For instance, in a 75-kg male, there is an approximate total body-water volume of 45 L, with 30 L intracellular and 15 L extracellular. The extracellular compartment is comprised of interstitial space and plasma volume. In the same 75-kg male, this extracellular volume (15 L) consists of interstitial space (10 L) and intravascular space (5 L). Within the intravascular space, the various blood cells and platelets account for 2 L and the plasma is the remaining 3 L. The plasma volume accounts for only 20% of the extracellular volume. There is a minor amount of transcellular fluid, such as the cerebrospinal fluid or intraocular fluid, that is not available for redistribution with the compartments.^{1,2,4}

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FLUID DYNAMICS AT THE VASCULAR ENDOTHELIUM

Diffusion and transport of substances across membranes depend on several factors. Cell membranes are selectively permeable; small, nonpolar, uncharged molecules and water molecules may pass through the membrane, whereas large and/or polar/charged molecules require a membrane channel or carrier protein. Specialized channels called aquaporins allow for rapid intracellular movement of water bypassing the lipid bilayer of cells. Energy is not required for a substance traveling along its electrochemical gradient (from high to low), and this is termed diffusion, facilitated transport, or passive transport. Active transport, on the other hand, requires energy for the active transport of a substance against a gradient.⁵

The diffusion of water across a semipermeable membrane towards equilibrium is termed osmosis. Tonicity describes the relationship of the concentrations of solutes separated by a membrane. An isotonic solution is one where the solution has the same concentration of solutes on either side of a membrane. Assuming a membrane is impermeable to solute but permeable to water, with an isotonic solution there will be osmosis of water across both sides of a membrane, but the net movement of water into the different compartments will be zero. A hypertonic solution contains a higher concentration of solute. Because the membrane is not permeable to the solute, the movement of water will go from the area of higher water concentration (and lower solute concentration) to the area of lower water concentration (and higher solute concentration). The net effect will be that the hypertonic compartment will gain water until the solute concentrations are equal on both sides. If a hypertonic solution is administered to a patient intravascularly, then water from the interstitial and intracellular spaces will diffuse into the vasculature. Conversely, a hypotonic solution has a lower solute concentration, and if it is administered intravenously, water will diffuse into the interstitial and intracellular spaces to maintain an isotonic state.⁵

Starling's forces describe the movement of fluids at the vascular endothelium. Starling described 4 forces: (a) the capillary hydrostatic pressure, (b) the capillary oncotic pressure, (c) the interstitial hydrostatic pressure, and (d) the interstitial oncotic pressure. Hydrostatic pressure pushes fluid across a permeable membrane away from its respective compartment. Large, impermeable proteins and high-molecular-weight glucose polymers can generate an oncotic force. It is said that oncotic pressure "pulls" fluid into its respective compartment. Because large compounds in the intravascular space cannot diffuse across the vascular endothelium, water will diffuse

into the vasculature to maintain an isotonic state. The capillary hydrostatic pressure favors fluid movement into the interstitial space and the capillary oncotic pressure favors the retention of water in the intravascular space. The capillary hydrostatic and capillary oncotic pressures vary in the arterial and venous systems. (See Figure.) Thus, the sum of the four forces results in the net movement of small amounts of fluid across the vascular endothelium into the interstitial space. Normally, the lymphatic system returns this fluid to the circulation to prevent interstitial edema. Interstitial edema may form because of pathological changes such as inflammation or infection, surgical trauma to the vascular barrier, or iatrogenic fluid administration.¹

The distribution of intravenously administered fluids depends on its composition. An infusion of 5% dextrose in water (D5W) redistributes in the intracellular, interstitial, and intravascular space. D5W is technically an isotonic fluid. However, the dextrose is rapidly utilized by the liver and other tissues, leaving essentially free water, and thus, on a practical level, it is a hypotonic solution of water. As previously described, plasma accounts for 3 of the 42 L of total body water in a 75-kg male. This is roughly 7% of the total body water. Therefore, only 7% of the infused D5W, only 70 mL, remains in the intravascular compartment. Normal saline (0.9% NS) or lactated Ringer's (LR) infusions contain ions. These infusions are restricted to the extravascular space (interstitial and intravascular spaces) because the ions cannot freely cross the cellular membranes but may cross the vascular endothelium. Because the plasma is 20% of the extracellular volume, only 200 mL of a 1-L infusion of NS will remain in the intravascular space. Colloids, on the other hand, contain either protein or high-molecular-weight glucose polymers, which cannot leave the intravascular space. They will generate an oncotic pressure and most of the volume of infused colloid solution will remain in the intravascular space. Slightly less than the entire infusion may remain in the intravascular space as there may be capillary leakage due to inflammation, infection, or surgery.^{1,4}

EVALUATION OF PREOPERATIVE VOLUME STATUS

Preoperative direct measurement of a patient's fluid compartments is not routinely performed.⁷ Therefore, estimation of the patient's preoperative fluid status relies on the summation of several indirect techniques and indicators. Invasive monitors, such as central venous catheters and pulmonary artery catheters, have their limitations in ambulatory settings for assessing volume status and they pose their own risks and morbidities.^{3,7}

Pressure gradients in the arterial and venous systems.⁶

Preoperative evaluation begins with a thorough history and physical examination. The patient's preoperative fasting or non per os (NPO) status, history of recent illness, skin turgor, mucosal hydration, fullness of palpated peripheral pulses, and urine output offer insights into the patient's overall fluid status.^{3,4,7} Preexisting deficits can be attributed to fasting, bowel preparations, burns, diaphoresis, diarrhea, hemorrhage, and vomiting.³ Patients with significant hypovolemia present with dried mucosa, decreased urine output, increased heart rate, and decreased blood pressure.⁷ In most ambulatory ASA I and II patients without acute illness, NPO duration is likely the critical factor in determining fluid status. Physical findings of hypovolemia may include changes in lowering of blood pressure

and narrowing of pulse pressure, but more noticeably increases in heart rate.^{3,7} Orthostatic changes are present in hypovolemic patients: an increase in heart rate and a decrease in blood pressure when changing positions from supine to standing. Orthostatic changes may not become manifest in healthy, young patients until they have lost at least 20% of their blood volume, whereas 20–30% of elderly patients with normal blood volume may exhibit orthostatic changes.^{7,8} Hypervolemic patients with normal organ function may demonstrate pitting edema.⁷ Signs of severe hypervolemia include cyanosis, tachycardia, pink and frothy pulmonary secretions, and wheezing and/or crackles on pulmonary auscultation.^{4,7}

Composition of Selected Intravenous Crystalloid Solutions*

Solution	Osmolality† (mOsm/L)	Sodium (mEq/L)	Chloride (mEq/L)	Potassium (mEq/L)	Calcium (mEq/L)	Magnesium (mEq/L)	Dextrose (g/L)	Buffers (mEq/L)	pH‡
Plasma	Isotonic (290)	140	103	4	5	2	—	Bicarbonate (25)	7.4
Plasmalyte§	Isotonic (295)	140	98	5	—	3	—	Acetate (27) Gluconate (23)	7.4
LR	Isotonic (273)	130	109	4	3	—	—	Lactate (28)	6.4
0.9% NS	Isotonic (308)	154	154	—	—	—	—	—	5.7
D5W	Isotonic (285)	—	—	—	—	—	50	—	4.5

* LR indicates lactated Ringer's solution; NS, normal saline; and D5W, 5% dextrose in water.

† Plasma osmolality is 290 mOsm/L. A solution is isotonic if it is within ± 50 mOsm/L, hypertonic if the difference in osmolality exceeds +50 mOsm/L, and hypotonic if the difference in osmolality exceeds –50 mOsm/L.

‡ Most intravenous fluids are relatively acidic to maintain a stable fluid product.

§ Other brands: Normosol and Isolyte may have lower pH.

| | D5W is functionally hypotonic as dextrose utilized is quickly.

Laboratory tests can serve as indirect indicators of volume status and include arterial blood gas with base deficit, serial hematocrit, serum sodium, serum blood urea nitrogen to creatinine ratio, and urine specific gravity or osmolality.^{4,7} The base deficit is derived using measured serum bicarbonate and pH from the arterial blood gas. The base deficit may facilitate the interpretation as to the cause of the patient's acid-base status and is directly related to blood loss in trauma patients.⁹ Also, an increase in base deficit and decrease in urine output become apparent with moderate to severe tissue hypoperfusion.^{3,7} The serial hematocrit and urine specific gravity or osmolality are inversely related to volume status.⁷ Serum sodium values can vary with respect to volume status; the patient may be hyponatremic while hypovolemic, euvoletic, or hypervolemic. Similarly, a hypernatremic patient may have increased sodium, water loss, or both.^{4,7} An elevated blood urea nitrogen : creatinine ratio, greater than 10 : 1, frequently indicates a hypovolemic state.⁷

INTRAOPERATIVE FLUIDS: CRYSTALLOIDS AND COLLOIDS

Intravenous fluid solutions are classified as either crystalloids or colloids, where the size of the crystals in solution denotes its classification (see Table).¹⁰ Crystalloids are aqueous solutions, consisting of inorganic ions, such as sodium, chloride, and sometimes potassium, calcium, and magnesium, as well as in some cases small organic molecules such as dextrose, lactate, acetate, or gluconate.^{2,3,7} Crystalloids are available as isotonic, hypotonic, and hypertonic solutions.³ Physiologic solutions contain ions such as potassium and more closely resemble the intravascular composition.⁴ Colloids are defined as homogenous, noncrystalline substances with

large molecules (high-molecular-weight glucose polymers or proteins) dissolved in a crystalline solution.^{3,7,11} Colloids are most commonly dissolved in an isotonic saline solution; however, isotonic physiologic, isotonic glucose, and hypertonic saline solutions are also available.^{2,3}

Crystalloids

There are several advantages and disadvantages to intraoperative crystalloids. Crystalloids are generally safe, are inexpensive, and do not share the same concerns as colloids, which include anaphylaxis and coagulopathy. Crystalloids remain in the intravascular component for a shorter amount of time as compared to colloid solutions. Isotonic fluids redistribute along the various fluid compartments and therefore larger volumes of crystalloid are needed to replace blood loss. As mentioned earlier, only approximately 20–30% of an isotonic crystalloid solution remains in the intravascular space. Consequently, tissue edema is a potential side effect of administering high volumes of crystalloid, such as 4–5 L, rapidly.^{3,7}

Isotonic crystalloids are the most commonly used fluids for intraoperative volume replacement.^{3,7,12} Hypotonic fluids are not appropriate for the replacement of isotonic losses: they may cause hyponatremia and have a short intravascular half-life.^{3,8,12} Hypotonic fluids include D5W or half normal saline.⁷ Hypertonic saline, on the hand, has several indications: 3% saline for the treatment of severe hyponatremia and 3–7.5% saline as a resuscitative fluid in severe hypovolemic shock.⁷ In theory, a hypertonic fluid should result in the diffusion of water into the intravascular space, acting as an effective volume expander.² However, this volume expansion is short-lived.¹² Hypertonic saline is an

irritant. It is recommended that it be injected through a central venous catheter or a large vein to reduce peripheral vessel irritation, endothelial damage, or thrombosis. Studies suggest that 1.8% saline may be tolerated if injected peripherally.² Slow infusion is recommended in the setting of hyponatremia to prevent central pontine myelinolysis or central pontine demyelination.^{7,8,12} Also, 11.7% saline is used clinically as a sclerosing agent for cosmetic treatment of varicose and spider veins.¹³

Isotonic crystalloids are administered to replace isotonic losses such as blood loss. Normal saline, LR, and Plasmalyte are commonly administered crystalloids. (Plasmalyte is a brand name product. Similar products include Normosol and Isolyte, which have the same ion and other components but may have lower pH. This article will refer to Plasmalyte but the other solutions are similar.) Normal saline contains sodium and chloride only whereas LR and Plasmalyte are termed balanced or physiologic solutions. Both LR and Plasmalyte contain potassium. LR contains calcium, magnesium, and lactate. Plasmalyte contains magnesium, acetate, and gluconate. Plasmalyte is more isotonic than LR. Its sodium content is also intermediate between that of NS and LR, but it has less chloride than both.^{4,14} (See Table.¹⁰)

For patients with significant medical illnesses, assessment of the electrolyte status will help determine whether NS or either of the physiologic solutions is more appropriate. Physiologic solutions contain potassium; this can be problematic in patients with hyperkalemia, end-stage renal disease, and dialysis. LR should not be used for the administration of blood products as it contains calcium. Blood products contain a citrate preservative, which chelates calcium and prevents clotting. Therefore, NS and Plasmalyte can be coadministered with blood products.^{2-4,7,14}

Another parameter for consideration when choosing a crystalloid solution is the potential effects on the patient's acid-base status. If administered in high volumes, NS can produce a hyperchloremic metabolic acidosis associated with a normal anion gap. On the other hand, LR and Plasmalyte may produce a metabolic alkalosis. LR contains lactate and Plasmalyte contains acetate; these compounds are converted to bicarbonate.^{2-4,14}

It was previously thought that infusions with dextrose would prevent hypoglycemia and consequently protein catabolism.⁸ Both LR and saline are available with dextrose.³ Hypoglycemia is a risk for diabetic patients, particularly those on insulin therapy, as well as younger pediatric patients, who are at risk for hypoglycemia with NPO times as short as 4–8 hours. Blood glucose evaluation is recommended to guide the need for dextrose administration in these patients. Hyperglycemia

from dextrose infusions, on the other hand, can result in osmotic diuresis, which limits the efficacy of fluid resuscitation. Additionally, there is evidence that hyperglycemia can worsen outcome in critically ill patients and patients with brain injuries.^{7,8,12} In general, dextrose-containing solutions are administered only when there is a noted indication.

Colloids

As compared to crystalloids, colloids have different properties. One advantage of colloids is that they remain in the intravascular space for longer periods of time with less risk of peripheral and pulmonary edema.³ Commonly used colloids include albumin, hydroxyethyl starch, and dextran. Disadvantages include increased cost and risks for hypersensitivity reactions, coagulopathy, and renal failure.^{2,4,11,12} Colloids expand the volume of the intravascular space, resulting in dilution of blood cells, platelets, and coagulation factors.^{2,15} This hemodilution effect as well as interactions with clotting factors can inhibit coagulation. Dextran, in particular, affect coagulation.² Serious allergic or anaphylactoid reactions are another disadvantage associated with colloid administration. Severe, life-threatening reactions have been reported with the following incidence: dextrans (<0.28%), albumin (<0.1%), and hydroxyethyl starch (<0.06%). Although these may appear to be small and inconsequential numbers, the incidence of severe reactions to penicillin is <0.05%.²

Albumin. Albumin (5 or 25%) is a human plasma product. Compared to crystalloids, it has a longer (16-hour) half-life in the intravascular space. Albumin is pasteurized, so there is no risk of transmission of blood-borne pathogens (such as hepatitis B, hepatitis C, and HIV). However, patients with certain religious beliefs or restrictions, such as Christian Scientists or Jehovah's Witnesses, may object to receiving albumin as it is a blood product.⁷

Hydroxyethyl Starch. Hydroxyethyl starch is a semisynthetic colloid. It contains a branching D-glucose polymer with an average molecular weight of 450 kd. It is available as a 6% solution in saline (Hespan) and in a physiologic solution (Hextend).⁷ There are different types of hydroxyethyl starch solutions available. The solutions with higher molecular weight and hydroxyethyl substations are more resistant to hydrolysis by nonspecific amylases in the circulation. These solutions will expand volume over longer durations but will also have more pronounced adverse effects.

Dextran. Dextrans are semisynthetic colloids produced by bacteria (*Leuconostoc mesenteroides*) using

sucrose as a substrate. Dextran is available at 2 molecular weights: dextran 40 (40 kd) and dextran 70 (70 kd). Dextran 70 is a more effective volume expander than dextran 40. Dextrans smaller than 55 kd are excreted renally.¹² Therefore, low-molecular-weight dextrans may induce an osmotic diuresis.⁸ Dextran 40 has an intravascular half-life of 3–4 hours, as compared to 5–6 hours for dextran 70.¹² Dextran 70, when administered in a 6% solution, will expand intravascular volume similarly to 6% hydroxyethyl starch. Additionally, if 1 L of dextran 70 is infused, 80% will remain in the intravascular compartment at the end of the infusion.^{2,3}

Dextrans have several disadvantages. Renal failure has been reported, with higher incidence if there is renal ischemia or compromised renal function preoperatively. Dextrans, by coating erythrocytes, interfere with cross-match testing to assess compatibility for blood transfusions.¹¹ Dextrans have antiplatelet effects and dextran 40 may be infused in vascular and plastic/reconstructive surgery, such as head and neck cancer and reconstructive surgery, to help maintain the patency of, and ensure blood flow through, microvascular anastomoses.^{2,3}

Allergic reactions to dextrans have been reported. Dextran 1 (Promit) is administered prior to dextran 40 or dextran 70 infusions to prevent severe allergic reactions by the mechanism of hapten inhibition. Dextran 1 is a hapten; it binds dextran antibodies and prevents an immune response.³ Treatment with dextran 1 has reduced the incidence of severe allergic reactions to <0.0015%.²

CALCULATING FLUID REQUIREMENTS

Calculating patient fluid requirements requires an assessment of preoperative deficits, intraoperative maintenance requirements, and replacement of surgical blood loss, third spacing, and insensible losses.^{3,7} Preoperative deficits are not only due to fasting, but also attributed to urine formation, blood loss, gastrointestinal secretions, third spacing, and insensible losses. Third spacing is described as the internal redistribution of fluids, or a fluid shift from the vascular compartment into the interstitial space. Vascular membrane permeability may be altered by inflammation, infection, and trauma (especially during major surgery).² Insensible losses due to evaporation may occur through the skin, lungs, or large open wounds, and may be increased in patients who are diaphoretic, febrile, or mechanically ventilated with dehumidified gases. These deficits continue during the maintenance period in addition to surgical blood loss.^{3,7}

For office-based dental and oral surgery, fluid deficits can be calculated using the classical 4 : 2 : 1 rule for

maintenance rate and deficit. The 4 : 2 : 1 rule calculates crystalloid fluid requirements based on body weight. The first 10 kg body weight is at a rate of 4 mL/kg/h, the next 10 kg is at 2 mL/kg/h, and the remainder of the body weight is calculated at 1 mL/kg/h. The total volume is the maintenance rate per hour. The deficit due to fasting is the maintenance rate multiplied by the number of hours the patient has fasted. Classically, the deficit is replaced in the following fashion: half of the deficit in the first hour, one quarter in the second hour, and the last one quarter in the third hour.^{3,7,8,12} For many office-based dental and oral surgeries, full deficit replacement may not be necessary and slow infusion of intravenous fluid over the course of a 30–120-minute case with negligible blood loss is generally satisfactory. Calculating the deficit using the 4 : 2 : 1 rule for calculating deficits assumes 6–8 hours of preoperative fasting.¹² However, ASA guidelines permit ingestion of clear liquids up to 2 hours prior to sedation or anesthesia, so this can be taken into consideration when determining fluid deficit.¹⁶ Patients fast for varying amounts of time, some in excess of NPO guidelines. In patients with normal renal function, these deficits may be less than calculated.^{7,12}

Deficits due to surgical blood loss, third spacing, and insensible losses must also be calculated for more invasive surgeries. Surgical blood loss can be difficult to estimate but is based on blood volume in suction canisters, soaked gauzes and laparotomy pads.³ Surgical blood loss is replaced in a 3 : 1 ratio of crystalloid to blood loss, and a 1 : 1 ratio if colloid is administered.³ Depending on the procedure, losses due to third spacing and evaporation are replaced at the following rates depending on the degree of anticipated tissue trauma: minimal (such as hernia repair), 0–2 mL/kg/h; moderate (such as cholecystectomy), 2–4 mL/kg/h; and severe (such as bowel resection), 4–8 mL/kg/h.⁷ Third spacing is not a major factor in most oral procedures except for major maxillofacial, head and neck cancer, or facial reconstructive procedures.

Measurement of urine output can serve as a valuable indicator of volume status and perfusion of vital organs. Urine output at a rate of 0.5–1.0 mL/kg/h is acceptable.^{1,3,17} Monitoring urine output is especially useful in procedures where intentional hypotension is employed to reduce blood loss, such as during maxillary orthognathic surgery. Placement of a urinary catheter is generally necessary in the setting of invasive and/or lengthy procedures where blood loss and fluid replacement are anticipated, such as in maxillofacial trauma, maxillary orthognathic surgery, radical neck dissection, and head and neck microvascular flap surgery.

FLUID CHOICE FOR DENTAL, ORAL, AND MAXILLOFACIAL PROCEDURES

The ideal fluid would possess the following properties: safe, efficient intravascular volume expander, isotonic to plasma, with a similar distribution of electrolytes without altering the acid-base balance. The ideal fluid would not cause allergic reactions, electrolyte imbalances, peripheral or pulmonary edema, coagulopathies, or renal dysfunction. No single fluid product has all these properties. Calculations of weight-based volume deficits and maintenance requirements provide a quantitative and tangible answer for how much fluid is required, despite the understanding that such “cookbooks” have their shortcomings.

Isotonic balanced crystalloids are considered the fluid of choice for outpatient procedures involving sedation/general anesthesia where only minor blood loss is anticipated, such as in most dental and oral surgery. Crystalloids contain only smaller molecules, do not generally maintain the oncotic pressure, and equilibrate with the interstitial space when isotonic fluid is administered, with an intravascular half-life of 20–30 min.⁷ Most patients presenting for surgery will have not only an intravascular fluid deficit but also a deficit in the interstitial space. Fortunately, crystalloid will replace losses in both compartments.^{7,11,12} For most office-based dental and oral surgery, insensible and urinary losses are negligible.

Colloids have no place in office-based dental and minor oral procedures and may have utility only in the setting of long and/or invasive maxillofacial surgical procedures where significant blood loss is anticipated and advanced monitoring of blood pressure and/or urinary output is available.

FLUID THERAPY AND ANESTHETIC AGENTS

Perioperative fluid therapy can be influenced by hemodynamic effects of anesthetics.³ Anesthetic induction with intravenous agents may be accompanied by hemodynamic changes. Propofol's principal cardiovascular effect is hypotension; this is achieved by reducing systemic vascular resistance, preload, and myocardial contractility.^{3,7} On the other hand, ketamine has sympathomimetic effects, resulting in increased heart rate, blood pressure, and cardiac output. These effects are mediated indirectly by central sympathetic nervous system stimulation and norepinephrine reuptake inhibition.^{3,7} This is a useful property for an induction agent in acute hypovolemic shock. However, ketamine also possesses direct myocardial depressant effects that can become apparent in a catecholamine-depleted state,

such as severe end-stage renal disease and congestive heart failure, in critically ill or nursing home patients as well as those with sympathetic blockade (such as in high spinal cord transection).^{3,7} Etomidate is an induction agent with minimal hemodynamic effects; this is a desirable induction agent for patients who may present with hypovolemia and blood loss due to trauma. Etomidate does not release histamine, nor does it have an effect on cardiac output or myocardial contractility. There may be a small decrease in blood pressure due to a decrease in peripheral vascular resistance.⁷ Benzodiazepines and opioids should not produce significant hemodynamic changes, particularly if titrated carefully for an intended depth of moderate sedation.⁷

Inhalational agents, when used for induction and maintenance of anesthesia, have hemodynamic effects. Sevoflurane, isoflurane, and desflurane are the volatile anesthetics used for induction (sevoflurane) and maintenance of anesthesia. All 3 volatile agents reduce systemic vascular resistance, causing vasodilation and a decrease in blood pressure. Cardiac output is generally maintained at doses of 1 minimum alveolar concentration (MAC) with isoflurane and desflurane with reductions at higher concentrations; it is not as well maintained with sevoflurane.^{3,7} These depressant effects may become apparent in severe hypovolemia and coronary artery disease, potentially leading to hypotension, which may result in myocardial ischemia.⁷ Nitrous oxide usually has minimal effects on heart rate, systemic vascular resistance, blood pressure, and cardiac output. High concentrations can lead to mild increases in heart rate, however. Additionally, positive pressure ventilation in hypovolemic patients will reduce preload and blood pressure.³

Fortunately, healthy patients have relatively normal intravascular volumes despite prolonged fasting. Studies have demonstrated that hypotension on induction is most appropriately treated by vasopressor therapy rather than administration of intravenous fluids.¹ Moreover, routine administration of large volumes of crystalloid has not been shown to affect hypotension due to anesthesia. Judicious use of crystalloid solutions (eg, 200–300-mL bolus in adults) is, however, frequently appropriate for managing hypotension for office-based dental or oral surgery, realizing that large fluid volumes will not be tolerated by patients without placement of a urinary catheter.

FLUID THERAPY FOR DENTAL AND ORAL SURGERY

Although formulas are useful to determine fluid needs, the appropriate volume to be administered to a patient is

influenced by several variables: the patient's preoperative medical and fluid status, surgical procedure, and anesthetic technique. Medical conditions such as hypertension commonly result in a decreased intravascular volume that is unmasked under the vasodilating effects of anesthetic agents. This is particularly true for patients taking angiotensin-converting enzyme inhibitors and angiotensin receptor blockers where loss of sympathetic tone in combination with loss of renin-angiotensin control can lead to treatment-resistant hypotension, frequently managed only with vasopressin. For the hypertensive patient, judicious intravascular volume expansion may be appropriate. The surgical procedure directly affects blood loss and may induce inflammatory changes that alter membrane permeability. The anesthetic medications have hemodynamic effects, as discussed above.²

In most ASA I and II patients presenting for routine dental or oral surgery, an isotonic solution is recommended. Normal saline, LR, or Plasmalyte are all acceptable. In general, especially for short procedures, 1000 mL or less of isotonic fluid is commonly administered. Rehydrating the patient based on the 4 : 2 : 1 rule has been shown to improve quality of recovery following oral surgery procedures.¹⁷ For a 70-kg person with a 10-hour NPO time, this calculates to a fluid deficit of 1100 mL. For older patients, replacing lost volume may improve symptoms of orthostatic hypotension, which is common in the elderly.

Use of functionally hypotonic solutions, such as D5W, was common in oral surgery offices in the past. This may be acceptable in typical volumes less than 500 mL in adults. They do provide a source of carbohydrate for the fasting patient who may be unable to resume eating for several hours because of local anesthesia of the oral cavity. Generally, however, sugar-containing liquids can be ingested even by these patients. The 25 g of dextrose in 500 mL of D5W increases blood glucose approximately 75 mg/dL (4.1 mmol/L) in the adult. This may provide excessive glucose for young children. The lactate in LR or acetate in Plasmalyte is metabolized to smaller amounts of glucose if this is a consideration in fluid selection. Patients with diabetes mellitus should only be administered dextrose-containing solutions based on blood glucose determinations.

The patient's fluid needs become increasingly complex with the invasiveness of the surgery. Again, the goal is to maintain sufficient intravascular volume to achieve tissue perfusion and to do so in the face of increased surgical blood loss and inflammatory changes leading to third spacing, while avoiding pulmonary and peripheral edema. A more accurate assessment of intravascular volume may be performed using direct invasive monitoring. It has been shown, however, that there is a poor

relationship between central venous pressure and blood volume as there is in predicting the hemodynamic effect of a fluid challenge. The routine use of pulmonary artery catheters may impose excessive risks and thus they are not routinely used.¹ Intraoperative transesophageal echocardiography may provide an assessment of preload and whether additional fluid administration will improve cardiac output in major surgery.^{1,2,8}

Fluid management is a part of every intravenous sedation and general anesthetic. Understanding the science of human fluid dynamics and the types of intravenous fluid options available allows us to optimize our treatment of the dental anesthesia patient.

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CONTINUING EDUCATION QUESTIONS

This continuing education (CE) program is designed for dentists who desire to advance their understanding of pain and anxiety control in clinical practice. After reading the designated article, the participant should be able to evaluate and utilize the information appropriately in providing patient care.

The American Dental Society of Anesthesiology (ADSA) is accredited by the American Dental Association and Academy of General Dentistry to sponsor CE for dentists and will award CE credit for each article completed. You must answer 3 of the 4 questions correctly to receive credit. Articles are eligible for CE credit for one year following the date of publication.

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1. Which of the fluids listed below is an appropriate isotonic fluid for procedural dental sedation in ASA I and II patients?
 - A. Albumin
 - B. 5% dextrose in water (D5W)/0.45% saline
 - C. Lactated Ringer's solution (LR)
 - D. D5W
2. What is the crystalloid volume requirement to replace the deficit for a 50-kg patient who has fasted 10 hours?
 - A. 900 mL
 - B. 90 mL
 - C. 450 mL
 - D. 1800 mL
3. Which of the following fluids is indicated for administration to patients with end-stage renal disease or dialysis?
 - A. Plasmalyte
 - B. LR
 - C. 0.9% normal saline
 - D. All of the above are appropriate choices for fluid therapy
4. Which of the following are indications for the administration of dextrose-containing solutions such as D5W?
 - A. Critically ill patients
 - B. Patients with brain injuries
 - C. Insulin-dependent diabetics
 - D. All of the above