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Emergency Medicine

Indications for treatment of hospitalized patients with blood volume replacement fluids in the perioperative period

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Summary:

The goal of this paper is to present indications for intravenous fluid therapy in patients subjected to surgical procedures, principles of selection and application of blood volume replacement products, associated complications as well as to identify indications for therapeutic use of blood derivatives.

Key words: fluid therapy, blood substitute.

The aim of therapeutic administration of blood volume replacement products is to replenish the lost blood and body fluids, to fill the vascular bed in order to prevent the consequences of tissue ischemia, provide proper organ perfusion, preserve excretory function of the kidneys, maintain electrolyte balance for sustaining proper blood pressure as well as intra- and zextracellular pH.

1. Systemic water distribution

Principles and indications for application of blood volume replacement products require understanding of the mechanisms of fluid distribution in human organism, which is divided into separate fluid compartments. We distinguish two basic body fluid compartments divided by a semipermeable membrane:

- intracellular space,
- extracellular (interstitial) space.

In a human body, depending on age and sex, water comprises from 80% of total body mass in a neonate to 45% in a 60-year-old woman. Intracellular water constitutes 60% of body mass (in a 35-year old, 70-kg male it corresponds to about 42 L of fluid). As oncotic pressure exerted on the cellular membrane from the inside is equaled by the oncotic pressure of the extracellular space and water diffusion from the inside to the outside of a cell is very limited even in extreme situations, we may concede that by application of blood replacement fluids we will be mainly influencing the volume and quality of fluid that fills the extracellular space.

Physiologically, water filling the extracellular space of a properly hydrated person comprises 20% of body mass (for a 35-year old, 70-kg male it constitutes about 14 L of extracellular fluid) and is distributed between intrerstitial and intravascular spaces in a 4:1 ratio.

Relatively undisrupted flow of water between interstitial and intravascular spaces together with slow diffusion of osmotically active fluids through an intact vascular endothelium are the theoretical bases for the choice of blood substitutes.

2. Types of blood replacement fluids

Preparations administered intravenously in order to expand the volume of circulating blood may be divided into:

- isotonic crystalloid solutions,
- hypertonic solutions,
- blood substitutes.

Crystalloid solutions
The following solutions belong to the group of isotonic crystalloids:

- 0.9% NaCl solution,
- Ringer's solution,
- Multi-electrolyte fluid.

Osmolalities of these fluids are between 300 and 310 mOsm/l, which corresponds to the osmolality of plasma. Differences in ionic compositions of above mentioned fluids allow for optimizing supplementation of specific electrolytes depending on the needs of an individual patient (with the exception of potassium and bivalent ions, which are present in those solutions in insufficient amounts and their deficiencies must be supplemented with solutions in higher concentrations).

Due to their easy application, wide therapeutic safety window and low costs, isotonic crystalloid solutions are fundamental for management of blood loss without symptoms of hypovolemic shock and they are used as adjuvants to colloid therapy of shock patients. In case of massive bleeding, crystalloid use as sole means of replacement of lost fluid volume is insufficient as they are distributed to the entire interstitial space.

Therefore, only 20% of administered fluids contribute to filling of the vascular bed. Every one liter of administered fluid replaces only 200ml of lost blood volume. The remaining portion of fluid diffuses to the interstitial space, which may lead to peripheral swelling or even pulmonary edema. Hemodynamic effect of crystalloids is short-lasting.

Hypertonic solutions

Administration of a small volume of hypertonic solution to a patient with hypovolemia leads to osmotic movement of water from interstitial space into the lumen of a vessel and an increase of circulating blood volume exceeding the volume of the administered solution.

Blood replacement solutions
Blood replacement solutions may be divided into plasma volume replacement fluids, i.e. colloid solutions that increase the volume of circulating blood, or so-called true blood substitute products with oxygen-carrying capacity.

Colloid fluids
The basic feature of active colloid solutions is a polymer molecule with high molecular mass and reduced ability to pass from the vascular bed into the extravascular space. While remaining in a vessel, it binds water molecules and increases circulating blood volume. Hemodynamic effect of colloid solutions persists much longer than in case of crystalloids (HES 450/0.7 half-life is 48 h).

The following fluids belong to the colloid group:

- dextran,
- hydroxyethyl starch,
- gelatin solutions,
- albumins.

Colloid fluids, despite many advantages such as smaller infusion volume, long-lasting hemodynamic effect, less pronounced tendency for causing peripheral edema, are used less often than crystalloids due to the possibility of inducing pulmonary edema, especially in the presence of vascular endothelial damage (also in the course of ARDS). They also elevate the risk of coagulopathy and anaphylactic reaction and their costs greatly exceed the costs of treatment with crystalloids.

True blood substitute fluids
True blood substitutes should simultaneously act as plasma volume replacement and oxygen carriers. Currently two types of blood substitution products are in an experimental phase of development:

- hemoglobin-based oxygen carriers (HBOC) devoid of cellular matrix,
- perfluorocarbon-based compounds.

Regrettably, despite many years of research the results are still unsatisfactory. The only fluid available for use is Fluosol DA. It serves as an oxygen-dissolving medium and since oxygen solubility depends on pressure, the patient must stay in a hyperbaric chamber in order to increase the effectiveness of "artificial blood."

3. Indications for administration of blood replacement fluids

Indications for administration of colloid solutions:

- acute hypovolemia regardless of the cause (hypovolemic, traumatic or toxic shock, burns),
- prevention of shock,
- prophylaxis of thromboembolic complications in immobilized patients with elevated risk of vascular thrombosis (dextran-70),
- treatment of an early phase of deep vein and arterial thrombosis (dextran-70),
- vascular procedures,
- acute intravascular hemolysis, especially in the course of paroxysmal nocturnal hemoglobinuria,
- disorders of microcirculation – late phase of shock, organ transplantation, extracorporeal circulation, acute coronary syndromes – myocardial infarction (dextran-40).

Indications for albumin administration:

- following allogenic organ transplantation (kidney and/or liver),
- plasmapheresis, repeated paracentesis > 5l,
- hypoalbuminemia < 15-20 g/l (lower limit of tissue edema) in specific disorders of the gastrointestinal tract, liver, pancreas, kidneys,
- correction of intravascular volume in overloaded patients or those with intolerance of other colloids.

Indications for use of true blood substitute products:

- shortage of blood supply of an appropriate type for transfusion,
- acute autoimmune hemolytic anemia diagnosed before surgery,
- patients refusing blood transfusion due to religious reasons.

Fluid replacement therapy in shock patients

Regardless of the cause of shock (trauma, gastrointestinal bleeding, rupturing aneurysm, septic shock, anaphylactic shock, etc.) fluid treatment is the fundamental method of sustaining proper tissue perfusion required for restoration of organ functions after removal of the causative factor. One should set specific goals during administration of fluid therapy in a patient in shock (an adult):

- attaining central venous pressure of >10-15mmHg,
- attaining pulmonary capillary wedge pressure of 10-12mmHg,
- cardiac index >3 l/min/m2,
- serum lactic acid level < 4mmol/l,
- base deficit -3 > BE > 3 mmol/l.

The first step toward attaining these goals should be rapid intavenous infusion (6 ml/kg BM/min) of crystalloid solutions (2000 ml). If patient's condition improves, crystalloid administration should be continued until above mentioned goals are accomplished. In case of failure, one should start administration of colloid fluids until clinical effects are apparent. If patient's condition is not improving despite appropriate blood volume, one should suspect a reduction in blood oxygen-carrying capacity caused by dilution with blood replacement fluids and begin transfusion of packed red blood cells. Whole blood should be used if patient has symptoms of coagulopathy.

Indications for transfusion of packed red blood cells

Packed red blood cells should not be used for expanding circulating blood volume, but only if there is a need for increasing blood oxygen-carrying capacity. The following are clinical symptoms of disrupted tissue oxygenation in a patient with proper volume of circulating blood:

- brain or heart ischemia,
- lactic acidosis >4 mmol/l,
- decreased oxygen consumption $VO2 < 100$ ml/min/m^2,
- oxygen extraction increased > 0.5, with normal cardiac output.

While making a decision regarding blood transfusion one should take into consideration:

- hemoglobin concentration,
- existing intravascular volume,
- anticipated blood loss,
- extent of surgery,
- comorbidities.

Summary

Understanding water-electrolyte balance physiology, familiarity with existing types of blood volume replacement fluids as well as indications and principles of fluid replacement therapy allow for an effective, safe and cost-effective prophylaxis of intravascular volume disturbances in patients exposed to the risk of fluid loss during surgical procedures and treatment of shock. Proper consideration of indications for blood volume replacement fluids can protect the patient against dangers associated with transfusions of blood derivatives. Despite the development of modern fluid therapy, blood and blood-derived products remain the ideal and often irreplaceable substitutes of patient's own blood.

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