

Volume replacement in trauma

Travmada volüm replasmanı

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We aimed to compare different fluids indicated in volume replacement in multiple trauma patients, enlightening the indications, mechanisms of action and side effects. An extensive review of references (indexed journals) between 1997 and 2008 was performed. There is not yet a consensus about which fluids should be used in trauma patients. The systematic reviews available did not show a benefit of colloid solutions over crystalloid fluids. Crystalloids intensify physiological internal dilution, furthered by water migration from interstitial and intracellular spaces into intravascular space due to hypovolemia. The most recent hypertonic solutions used in resuscitation have a large role in expanding blood volume and making blood pressure rise. The hyperoncotic effect of dextran solution produces an initial expansion of intravascular volume that is bigger than the administered volume. Gelatins are no longer used in developed countries due to their insignificant ability regarding volume expansion when compared to crystalloids and the potential risks of anaphylactic reactions. The crystalloids are used more in trauma, even if some authors prefer the use of colloids, which can produce a quicker restoration of the intravascular volume. No convincing evidence shows a clear superiority of colloids over crystalloids for restoration of the volume depletion.

Key Words: Colloids; hemorrhagic shock; plasma substitutes; traumatic shock.

Çoklu travma hastalarındaki volüm replasmanında kullanılma endikasyonu bulunan değişik sıvıları, endikasyonlarını, etki mekanizmalarını ve yan etkilerini aydınlatmak suretiyle karşılaştırdık. 1997 ve 2008 yılları arasındaki yayınlar (dizin dergileri) kapsamlı olarak incelendi. Travma hastalarında hangi sıvıların kullanılması gerektiği konusunda halen bir fikir birliği bulunmamaktadır. Mevcut sistematik gözden geçirmeler, kolloid sıvıların kristaloid sıvılara karşı herhangi bir üstünlüğünü ortaya koymamıştır. Kristaloidler, hipovolemiye bağlı olarak interstisiyel ve intraselüler alanlardan intravasküler alana sıvı geçişi ile kolaylaşan fizyolojik internal dilüsyonu artırır. Resüsitasyonda kullanılan en yeni hipertonic solüsyonlar, kan hacmini genişletmekte ve kan basıncını yükseltmekte büyük bir kaliteye sahiptirler. Dekstran solüsyonunun hiperonkotik etkisi, intravasküler volümde, uygulanan hacimden daha fazla bir başlangıç genişlemesi oluşturur. Kristaloidlere kıyasla önemsiz volüm genişletme yetenekleri ve potansiyel anafilaktik reaksiyon riskleri nedeniyle, jelatinler, gelişmiş ülkelerde artık kullanılmamaktadır. Bazı uzmanlar daha hızlı intravasküler volüm restorasyonu oluşturabilen koloidleri kullanmayı tercih etse bile, travmada kristaloidler daha fazla kullanılmaktadır. Bu arada, volüm açığının restorasyonu ile ilgili olarak kristaloidlere göre açık bir koloid üstünlüğünü gösteren inandırıcı hiçbir kanıt bulunmamaktadır.

Anahtar Sözcükler: Koloidler; hemorajik şok; plazma yedeği; travmatik şok.

In the last few years, the high rate of trauma with serious blood loss has emerged as the first cause in death among youth. Car accidents represent the major cause of such traumas followed by stab and gunshot wounds.

The hemorrhagic shock caused by trauma is an important cause of Emergency Department admissions.^[1] In general, surgical intervention is necessary to control the bleeding. Anesthetic induction can enhance the hemodynamic instability due to vasodi-

lation and myocardial depression. In these patients, administration of large volumes using either isotonic or hypertonic solutions is performed for initial volume replacement before surgical intervention, aiming at hemodynamic stability.^[2]

The first approach in shock is to acknowledge its existence via clinical findings, which can be demonstrated through signs of tissue hypoperfusion/oxygenation. The second step consists in identifying its probable cause. The majority of traumatized patients during shock present with hypovolemia. Hemorrhage is its main etiology. However, they might suffer from septic, neurogenic or cardiogenic shock.

The main purpose of volume replacement in traumatized patients is to reestablish tissue perfusion. There are a vast number of intravenous solutions used to treat hypovolemic shock. These solutions can vary from crystalloid and colloid fluids to blood transfusions.^[2]

The infusion of large volumes in the trauma patient using isotonic or hypertonic solutions has been used for initial volume replacement in the emergency room before surgical intervention.^[2] Clinical and experimental studies have shown that hypertonic NaCl solution is effective in restoring hemodynamic stability after hemorrhagic shock. However, the isotonic NaCl solution continues to be the most frequently used fluid in initial recovery of hemorrhagic shock.^[3]

Review of the Current Literature and Discussion

Pathophysiology of Blood Loss

Hemodynamic responses prior to blood loss are compensatory mechanisms. The responses depend on body reply, which is highly selective: heart and brain flux are maintained, whereas skin, bowel and muscle flux are diminished. When severe shock occurs, inadequate perfusion to the brain and heart also occurs, leading to imminent death.^[4]

Tachycardia is the most precocious and measurable clinical manifestation in the majority of cases. The release of catecholamines increases peripheral vascular resistance. Consequently, there is a rise in diastolic blood pressure and a decrease in pulse pressure.^[4] The most effective way of restoring cardiac output and driving pressure is to reestablish venous return back to normal through volume replacement.

The traditional treatment of trauma patients with hemorrhagic shock consists in prompt volume adjustment, in order to improve tissue perfusion and oxygenation. Interventions for its adjustment are hemorrhagic management and general measures involving volume replacement.

There is not yet a consensus about which fluids should be used in trauma patients. The options available include the use of isotonic or hypertonic crystalloids, colloids (especially gelatins and starches), blood transfusions, and hemoderivatives.^[5]

Hemorrhage Effects

Due to liquid transferences between different compartments of the body, the response of a trauma patient to blood loss is actually more complex. Blood volume in adults corresponds to approximately 7% of their body weight, whereas in children, this amount can vary from 8 to 9%.

The different categories of hemorrhage are based on the percentage of acute blood loss (Table 1). Due to liquid transferences between different compartments of the body, the response of a trauma patient to blood loss is actually more complex (Table 2).

Fluid Selection for Volume Replacement

There is no consensus regarding which fluid to administer in trauma victims. In prehospital settings, crystalloids and colloids can be given. Once inside the hospital, blood transfusion is done if necessary.

Isotonic solutions are used during initial approach. This type of fluid promotes transient intravascular expansion and contributes to vascular volume stabilization. The initial choice falls upon crystalloid fluids. Systematic reviews available on colloid solutions did not support any real benefits over crystalloid solutions.^[6]

Crystalloids

Since the great wars, lactated Ringer has been the first choice to treat hypovolemic shock. Crystalloid solutions improve the internal/physiological dilution acquired by the migration of water from the interstitial and intracellular space to intravascular areas, due to hypovolemia. Lactated Ringer solution has been selected preferentially when the infusion of large volumes is necessary for specific reasons: first, because it contains less chlorine/sodium ions when compared to saline solution, and in view of its similarity to plasma since it contains calcium and potassium.

Table 1. Estimated fluid and blood losses

	Class I	Class II	Class III	Class IV
Blood Loss (ml)	Up to 750	750 - 1500	1500 - 2000	>2000
Blood Loss (% Blood Volume)	Up to 15%	15 - 30%	30 - 40%	>40%
Pulse Rate	<100	>100	>120	>140
Blood Pressure	Normal	Normal	Decreased	Decreased
Pulse Pressure (mmHg)	Normal or increased	Decreased	Decreased	Decreased
Respiratory Rate	14 - 20	20 - 30	30 - 40	>35
Urinary Output (ml/hr)	>30	20 - 30	5 - 15	Negligible
CNS/Mental status	Slightly anxious	Mildly anxious	Anxious, confused	Confused, lethargy
Fluid Replacement (3:1 rule)	Crystalloid	Crystalloid	Crystalloid and blood	Crystalloid and blood

Table 2. Therapeutic decisions based on patient response^[4]

	Fast Response	Transitory Response	No Response
Vital signs	Back to normal	Transitory improvement, recurrence of \uparrow PA \downarrow FC	Continue abnormal
Estimated blood loss	Minimal (10-20%)	Moderate (20-40%)	Severe (>40%)
Need for more crystalloids	Low	High	High
Need for blood	Low	Moderate/High	Immediate
Blood preparation	Crossmatched and type-specific	Type-specific	Released when emergency verified
Need for surgery	Possible	Probable	Highly probable
Early presence of surgeon	Yes	Yes	Yes

Due to their effective extravasation into the extravascular space, the maximum hemodynamic effects of crystalloids occur immediately after infusion and last only for a short period. Because of their brief duration, they do not promote lasting effects upon the cardiovascular system.^[7] Consequently, in order for the body to maintain the initial hemodynamic effect, new infusions of crystalloids are required, the main concern of which is the excess infiltration of the fluid back into the interstice, attacking especially the lungs. Their advantages, just like with saline solution, are their inexpensiveness and ease of handling.

Hypertonic NaCl Solutions (7.5%)

The recently known hypertonic solutions are considered to have a greater ability to expand blood volume and thus elevate blood pressure, and they can be administered as a small volume infusion over a short time period. In addition to improving blood pressure, they can also reduce tissue edema and hemodilution, altering the activation of inflammatory cells.^[8]

Colloid Solutions

Human serum albumin is responsible for 60 to

80% of oncotic, plasmatic and normal pressure. It is expensive because of its source: human plasma. Their levels are far more related to prognostic factors than with the need of keeping them in adequate levels through exogenous albumin infusions. It can be used in 5 and 25% and is especially indicated when there are risks of coagulation disorders. The use of colloids can unleash coagulopathies and it has a 24-hour action on blood pressure. Due to its high cost, the solution is not popular in the treatment of hypovolemic shock.

Dextrans are a mixture of variable sizes of glucose polymers and molecular weights produced by bacteria in a sucrose environment. The molecular weight can certainly vary. However, most of the dextrans used present an average molecular weight of 40,000 daltons, commercially available in a solution of 10%, or of 70,000 daltons, available in a 6% solution.^[7]

The expansion and effect periods of dextrans vary according to the average molecular weight and speed of plasma elimination. Smaller molecules are quickly filtered by the glomerulus and can determine a

stimulus to diuresis. The biggest molecules are stored inside hepatocytes and cells of the reticuloendothelial tissue, without suffering any toxicity, and then are finally metabolized to carbonic gas and water.

Solutions such as 6 or 10% hydroxyethyl starch (HES 200/0.5) are indicated for severe hypovolemias, at dosages of 33 ml/kg and 20 ml/kg, respectively, with a half-life of 8 hours. Its anaphylaxis index is comparable to that of human 5% serum albumin, around 0.1%.^[8]

Gelatins

Gelatins are no longer used in developed coun-

tries due to their insignificant ability for volume expansion when compared to crystalloids and to the potential risks of anaphylactic reactions.

Crystalloids Versus Colloids

There is a more effective expansion in the circulatory system when colloids are used because they are kept inside the vascular bed longer than the crystalloids (Table 3). These are freely permeable to the vascular membrane and therefore distributed mainly in the interstitial and/or intercellular compartment. Only 25% of the infused crystalloid solution remains in the intravascular space, whereas 75% extravasates into the interstitium. Nevertheless, there is no evi-

Table 3. Crystalloids versus colloids

	Sodium mEq/L	Mechanism of action	Advantages	Disadvantages
0.9% Saline Solution	154	Improves the internal/ physiological dilution acquired by the migration of water from the interstitial and intracellular space to intravascular areas, due to hypovolemia	Balanced with electrolytes, buffer capacity	Need for large amounts, reduction of osmotic pressure, risk of hyperhydration
Lactated Ringer	130	Improves the internal/ physiological dilution acquired by the migration of water from the interstitial and intracellular space to intravascular areas, due to hypovolemia	Contains less chlorine/sodium ions when compared to 0.9% saline solution and calcium + potassium, which it is similar to plasma	Edema and hyponatremia
Albumin 5%	130-160	Plasmatic volume expander	Therapeutic advantages in oncotic deficits or in long duration shock when treatment is late	High cost, anaphylactic reactions, risk of infections
Dextran 40 (10%)	154	Hyperoncotic effect produces initial expansion of intravascular volume, which is bigger than infused volume	Improvement in microvascular circulation	↑ fibrinolysis, ↓ platelet aggregation, risk of acute renal failure
Hypertonic Saline Solution (7.5%)	1250	Initial expansion of intravascular volume → which is bigger than infused volume	Low cost, resuscitation with little volume, improvement in hemodynamic and tissular perfusion, inflammation and intracranial pressure decrease	Anaphylactic reactions
Gelatin	274		–	Anaphylactic reactions

dence that the use of colloids, instead of crystalloids, reduces the risk of death in patients with trauma, burns or following surgery.^[9,10]

The advantage of using crystalloids is greater since they do not induce anaphylactic reactions, do not interfere with the coagulation system and have low cost. Some starches and red blood cell units might be harmful to renal function. Virus transmission, infectious diseases and anaphylactic shock may occur with blood/ hemoderivative transfusions.

For initial fluid replacement with isotonic solutions, lactated Ringer is the first choice. Saline solution is the second choice because of its potential to cause hyperchloremic acidosis in patients with compromised renal function. The initial volume is administered as fast as possible: 1 to 2 L in adults and 20 ml/kg in children.^[4]

Hypothermia must be avoided and rectified when the patient arrives at the hospital in such condition. The most efficient way of preventing hypothermia in patients who receive a massive volume of crystalloids is to heat the fluid to 39°C before its use. This can be done via a stove or microwave. However, it is important to point out that the hemoderivatives cannot be heated in the microwave and must instead be administered through endovenous fluid heaters.^[4]

The response of the patient to fluid replacement can be observed through urinary output, which is the most sensitive indicator. Adequate replacement should establish an output of 0.5 ml/kg/hour in adults, 1 ml/kg/hour in children and 2 ml/kg/hour in children under one year old.

Blood Replacement

The main target of blood transfusions is to restore the capacity of intravascular volume for oxygen transport. The best option is that all of the bloods have appropriate cross-match. A specific blood type can be provided in 10 minutes and matches a patient in systems ABO and Rh. When a specific blood type is not available, a red cell concentrate type O negative is indicated.^[5]

The red cell concentrate is stocked at 1 and 6°C. In small transfusions, this temperature has no important effects, but in the case of massive transfusions in patients with hemorrhagic shock, hypothermia is a problem that must be addressed.

Hypothermia can induce ventricular arrhythmia, which powered by hypocalcemia can lead to a weak-

ness in left ventricular function. This arrhythmia occurs frequently when this red cell concentrate is applied through a central line, placed near to the cardiac conducting system.

There are various ways to by avoid these effects, such as by moving the central line away from the atrium, lowering the infusion or employing blood heaters, which cannot increase the temperature over 42°C to avoid hemolysis of the concentrate. Another possible procedure is the addition of saline previously heated with the blood cells before infusion.^[10]

Special Situations in the Trauma Patient

1. Severe burns:^[4]

In this situation, the blood volume circulation is usually difficult to estimate. A burn patient needs from 2 to 4 ml/kg by percentage of body area with second and third degree burns within the first 24 hours to keep an adequate circulating blood volume and produce a satisfactory urine output.^[4]

Half of the total estimated volume is administered in the first 8 hours after the burn and the rest in the next 16 hours.

As the second and third degree burns and pulmonary lesions require greater volumes at early stage, it is best to administer the larger volume dose of resuscitation, 4 ml/kg, and evaluate the patient's response.

2. Traumatic brain injury

The hypovolemia in these patients is harmful and the application of hypotonic solutions is not indicated. The employment of solutions that contain glucose can lead to hyperglycemia, which was shown to be harmful to the damaged brain.

Application of saline isotonic solution is indicated or Ringer's lactate with concomitant serum sodium levels.^[4]

3. Spinal cord injuries

If spinal cord injury is suspected, intravenous solutions are infused in the same manner as done during resuscitation of multiple trauma patients. If active hemorrhage is not detected, persistent hypotension after 2 L or more of volume replacement must be interpreted as being a result of cardiogenic shock. Patients usually present bradycardia.

Aggressive volume replacement in cardiogenic shock may result in pulmonary edema. When in doubt about the volume conditions, invasive moni-

toring might be useful, as well as the use of a vesical probe to monitor urinary output.

Aggressive Volume Replacement

One must be careful with aggressive volume replacement, since it can lead to hemorrhage with the release of a clot due to the increase in blood vessel wall tension and increase in flux.

Isotonic crystalloid solutions drop the oncotic pressure of the vascular bed, facilitating tissue edema, worsen oxygenation and predispose to a compartmental syndrome, which can lead to multiple organ dysfunction.^[11]

Coagulopathy is rare in a trauma patient at the beginning of the treatment. However, a massive transfusion with dilution of platelets and coagulation factors and adverse effects of the hypothermia in platelet aggregation are the usual causes of coagulopathy in a trauma patient.

Measuring prothrombin and partial activated thromboplastin time is important at first, mainly if the patient has reports of coagulopathy or is on platelet anti-aggregation. Based on this coagulation rate, a transfusion of platelets, fresh frozen plasma and cryoprecipitate may be prescribed.

Patients with severe head trauma are prone to coagulopathy due to release of active substances by damaged nervous tissue. Coagulation parameters in these patients should be carefully followed.^[4]

In conclusion, the crystalloids are more frequently used in trauma, even if some authors prefer the use of colloids, which can produce a quicker restoration of the intravascular volume. At present, there is no convincing evidence showing a clear superiority

of colloids over crystalloids for restoration of the volume depletion.

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