REVIEW ARTICLE

Fluid resuscitation in burned child

Reparação volêmica na criança queimada

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ABSTRACT

Burns are the most frequent accidents in Pediatrics, with high mortality rates. The most frequent complications are a hypovolemic shock, progressive malnutrition, and infections. This article is a review of the hypovolemic shock approach in the burned child in relation to his pathophysiology and the various treatment modalities, discussing their advantages and disadvantages.

Key words: Shock; Burns; Burns/therapy; Pediatrics; Rehydration Solutions.

RESUMO

A queimadura é dos acidentes mais frequentes em Pediatria, com altas taxas de mortalidade. As complicações mais frequentes são o choque hipovolêmico, a desnutrição progressiva e as infecções. Este artigo faz uma revisão sobre a abordagem do choque hipovolêmico na criança queimada em relação à sua fisiopatologia e as diversas modalidades de tratamento, discutindo as suas vantagens e desvantagens.

Palavras-chave: *Choque; Queimaduras; Queimaduras/terapia; Pediatria; Soluções para Reidratação.*

INTRODUCTION

Burns are serious accidents that affect all age groups and are accompanied by significant distress to the patient either by lesions or the given treatment, represented by baths and daily dressings, surgical debridement, skin grafting, venous punctures, blood collection for laboratory tests, and physiotherapy. Clinical complications are frequent, especially the hypovolemic and hyponatremic shock, progressive malnutrition due to the increasing energy expenditure, and infections, both in wounds and systemic. Survivors carry on traumatic marks for life, both physical and emotional. Scars, deformities with physical limitations and difficulties of social adaptation are common.

Its annual rate lies around 1.200.000.[1] In the João XXIII Hospital of the Hospital Foundation of Minas Gerais, a reference institution in the management of burns for the entire state of Minas Gerais, approximately 1,200 children are served per year, and 200 more severe cases, need to be admitted to Burn Treatment Unit.[2]

Approximately 85% of burns in children occur at home, mostly in the kitchen. Scalding is the most important agent, followed by lesions of thermal nature from contact with chemicals and solar radiation. Accidents by electricity, although infrequent, cause

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major muscle vascular damage, with consequent mutilation. About 60% of burned children are males.[2,3]

This article discusses the different types of volemic repair in burned hospitalized children with the prevention of hypovolemic and hyponatremic shock as the main objective.

PATHOPHYSIOLOGY

Burns affect not only the skin but the whole individual, physically and psychologically, with high mortality rates and a number of complications such as[4-11] hypovolemic shock; decreased immune defense, predisposition to infectious complications; increased protein-caloric catabolism with depletion of energy reserves, progressive muscle mass consumption, and development of severe hypoalbuminemia; progressive anemia due to hemolysis, decreased average life of red blood cells, bleeding, debridement and skin grafting, blood collections, stress ulcer, infectious complications and anemia prior to burning; physical and emotional consequences, and difficulty in social adjustment.

The shock associated with the burn is the hypovolemic and hyponatremic type. Cell destruction caused by burning releases large amounts of systemic and cellular mediators (kinins, anaphylatoxins, histamine, serotonin, arachidonic acid metabolites, O_2 free radicals, prostaglandins, etc.) that lead to increased capillary permeability, maximally around eight hours. Clinically, almost complete capillary regeneration is already observed from the second day; however, the damage evidenced by electron microscopy extends until the fourth week. Normal capillaries usually allow the free flow of water and electrolytes from the intravascular and interstitial space prevent the passage of albumin, whose molecular weight is 60,000 KD. However, vasodilation accompanying burning allows substances with molecular weight over 250,000 Kd to reach the interstitium. The consequence is the occurrence of a massive movement of proteins, water, and electrolytes from the vascular into the extravascular space with reduced intravascular fluid volume and dehydration, hypovolemic shock, acute renal failure, and severe hypoproteinemia. Albumin given in that stage enters the extravascular space. After the restoration of capillary perfusion, the albumin retained in the extravascular space contributed to the formation of edema and increased risk of pulmonary complications.[6,7,12-13]

There is a decrease in cardiac output and urine in burned patients. The excessive extravascular fluid compresses blood vessels, already suffering the hypovolemia and increased viscosity, which may cause the increase of necrotic areas. The edema caused by capillary vasodilation is usually limited to the burned area and its proximity. However, in burns that affect more than 40% of the body surface, it appears anasarca. This is caused by the increase in intracellular sodium and potassium due to decreased action of ATP-ase and compounded by hipoalbuminemia.[5-7,10-12,14-16]

PECULIARITIES OF CHILDREN

Children present certain peculiarities that make them more hydro labile than adults, favoring the earlier onset of dehydration. The first is a great amount of total body water: 80% in newborns, 60% at the age of one year, and 58% in adults. Another feature is the percentage of the distribution of fluids in the extracellular compartment, immediately available for losses: 40% in newborns, 25% to the age of one year, and 18% in adults. Children have greater body surface to weight ratio, this being 1.5 times higher in newborns than in 10-year-old, and three times higher than in adults. The calculation of body surface in children varies according to age as presented in the Lound & Browder table.[3]

Table 1 - Calculation of Body Surface – Lund & Browder modified

Segment	% of segments that varies with age					
	<1	1 to 4	5 to 9	10 to 14	15	≥ 15
Head	19 %	17 %	13 %	11 %	9 %	7 %
Thigh	5.5 %	6.5 %	8.0 %	8.5 %	9 %	9.5 %
Leg	5 %	5 %	5.5 %	6 %	6.5 %	7 %
Neck	2 %					
Upper body	26 %					
Arm	4 %					
Forearm	3 %					
Hand	2.5 %					
Buttock	2.5 %					
Foot	3.5 %					
Genitals	1.0 %					

VOLEMIC REPAIR

The first care for the burnt child, as in every trauma patient, follows the basic rules of Advanced Life Support Trauma (ATLS®). The volemic repair should not be delayed because shock can be installed quickly. It must be initiated on the first visit, if possible in the place where the accident occurred. There is no consensus on a single formula for the compensation of electrolyte disturbances; however, all have some peculiarities in common: the urgent need to replenish sequestered fluid and losses in order to restore blood volemia; maintenance of tissue perfusion and cardiac and urinary debts. It is recommended to monitor closely prescriptions and exam results to make the necessary individual adjustments. The correct volemic replacement contributes to the best prognosis, whereas if it is inadequate, it is associated with shock, acute renal failure, acidosis, edema, tissue ischemia, and predisposition to infectious complications. There is no advantage in administering volumes higher than needed because the edema leads to capillaries compression, ischemia, infection, and deepening of lesions.[3,6,12,13,16-18]

PROPOSED VOLEMIC REPAIR SCHEME

In children with burns that are 15% less than the body surface length (10% if less than one-year-old) use just oral hydration based on physiological losses and needs; while, in those with more extensive burns, hydration is used by percutaneous venipuncture. Venous dissection should be avoided, except in cases of hemodynamic instability.

Urine output is the main parameter to evaluate volemia and tissue perfusion because the massive release of catecholamines keeps a full pulse, elevated heart rate, and normal or high blood pressure. In burns accompanied by inhalation lesions, there is a 50% increase in the needs of fluid intake. The urine volume should be kept at around 1.5 mL/kg/h, and in electrical burns, 2 mL/kg/h due to the additional risk of acute renal failure by hemoglobinuria and myoglobinuria resulting from intense rhabdomyolysis. In some of these patients, it may be necessary to prescribe $NaHCO_3$ (33 ml per liter of administered solution, replacing NaCl) while maintaining the urinary pH above 6.5. In these cases, it is also necessary to monitor the pH and K^+ in the blood due to the risk of hypokalemia and metabolic alkalosis. The fluid therapy path scheme should not be rigid but adapted to each patient's particular response.[5,19]

Intravenous hydration in the first 24 hours

- **repair formula (Parkland modified):** 3 mL x weight x % SCQ. Consider 50% as the maximum SCQ;
- **maintenance solution** (physiological needs): 100 mL x weight up to 10 kg; 1,000 mL + 50 mL/kg between 10 and 20 kg; 1,500 mL + 20 mL/kg for children weighing over 20 kg.

Pure 0.9% NaCl is administered on day 1 (310 mOsm/L, 154 mEq/L Na^+; 154 mEq/L Cl).

- administration mode: ½ volume of the repair formula + ⅓ of physiological necessities is administered in the first eight hours. Time is counted from the time of the burn and not from the moment when the child has reached the hospital. In the next 16 hours, it is administered: ½ of the repair formula + the remaining ⅔ of physiological needs. The oral or enteral intake volume taken through an infusion pump should be considered in the administered volume. Although the potassium and calcium pool is reduced, they should not be administered on the first day because potassemia and calcemia are normal due to the plasmatic release of these elements by injured cells. Example: a child with 30 kg of weight and burn reaching 40% of the body surface should be given on the first day, 0.9% NaCl: 3,600 mL (3 x 30 kg x 40%) for repair and 1,700 mL for maintenance. In the first eight hours: 1,800 mL (½ for repair) + 566 mL (⅓ for maintenance). The remaining solution should be administered in the remaining 16 hours.

There may be advantages in reducing the first solution infusion time to four hours instead of eight hours.[20]

Intravenous hydration on the second day

- **repair formula:** 2 mL x Weight x% SCQ + maintenance solution. The 0.9% NaCl solution is diluted with isotonic glucose solution (SGI) at 5% in the ratio of 1: SGI/1: 0.9 % NaCl and equally administered over 24 hours. Add 10% KCl and 10% calcium gluconate, 2 mL and 1 mL, respectively, for each 100 mL of the maintenance solution. Consider the volume administered by the oral or enteral intake infusion pump.

Intravenous hydration on the third day

- **repair formula:** 1 mL x Weight x % SCQ + maintenance solution. The 0.9% NaCl solution is diluted with SGI 5%, in the ratio 2: SGI/1: 0.9% NaCl and equally administered over 24 hours. Add KCl and calcium gluconate. In calculating the volume administered, consider the oral or enteral intake through the infusion pump.

HYPERTONIC SOLUTIONS

In critically ill patients, only 20% of the delivered liquid volume remain in the circulation after one to two hours after infusion, thus, one should replenish lost liquid in treating shock and vascular deficit. The large volume of necessary repair fluid in the treatment of burned patients can come to constitute an additional problem, i.e. more edema compressing the capillaries and tissues suffering, leading to the extension of necrotic areas. The use of hypertonic solutions aims at the fastest restoration of blood volume, reducing the edema caused by over hydration. Furthermore, hyperhydration is associated with pulmonary injury. There is water accumulation in the cellular space when there is a shock.

Hypertonic solutions promote a rapid expansion of vascular and interstitial spaces by the diversion of intracellular water to the extracellular space with increased intracellular osmolality.[5,15]

Key characteristics of hypertonic solutions

The hyperosmolarity in these solutions allows a rapid increase in plasma volume and cardiac output with quick recovery from shock and urine output. There is also a reduction in the peripheral and pulmonary vascular resistance and decrease in cardiac work. Additionally, the intracranial pressure decreases and causes systemic and pulmonary vasodilation. The recovery of the intestinal flow contributes to decrease bacterial translocation.[15]

The administration of hypertonic solutions allows to decrease the water flow to the burned tissue.[21,22] It is assumed that there is 40% reduction of the liquid delivered volume. Another advantage in the lower volume of hypertonic solutions is reaching body temperature faster than with isotonic solutions, whose volumes are much larger, protecting patients with major burn against the serious effects of hypothermia. Although there is no consensus on the adoption of hypertonic rehydration, it is at least as beneficial as isotonic hydration.[5,17,18,21,22]

Main indications of hypertonic solutions

- **critical major burn:** burns that affect 30% or more of the body surface;
- **delay in the first care:** the patient is admitted in shock or evolving to shock. The hypertonic solution allows a quick recovery from the shock and speedy recovery of cardiac and urinary debts;
- circular burns can tourniquet limbs and compromise blood flow to the extremities, and they can cause difficulty breathing when located on the trunk;
- extensive lesions of the face and neck leading to the risk of respiratory failure due to edema. Hypertonic solutions reduce the size of secondary edema in response to water repair;
- burns with inhalation injuries.

Types of hypertonic solutions

There are different types of hypertonic solutions for the treatment of large burned patients. The most commonly used contains 1.5 or 7.5% NaCl.

1.5% solution

It contains 250 mEq/L Na^+ and 500 mOsm/L osmolarity. In preparing 500 mL of this solution, 16 mL 20% NaCl + 484 mL of 0.9% NaCl are used. A bolus of 10 mL/kg body weight is administered to restore the capillary perfusion and blood volume, measured mainly by the measurement of urinary flow at around 1 mL/kg of body weight/hour. Subsequently, 0.9% NaCl is administered as predicted and for the 16 hours following the intravenous hydration during the first 24 hours.

7.5% solution

Contains 1,250 mEq/L of Na^+ and 2400 mOsm/L osmolarity. In preparing 100 mL of this solution, use 35 mL of 20% NaCl + 65 mL of 0.9% NaCl. 4mL/kg of weight should be infused in 30 minutes, followed by the administration of 0.9% NaCl, as recommended for the 16 hours following the intravenous hydration during the first 24 hours.

Complications of hypertonic solutions

Hypertonic solutions do not carry high risks when managed properly; they can cause hypernatremia (above 160 mEq/L), pontine myelinolysis, and risk of cerebral hemorrhage in children less than three years of age when infused quickly. Hyperchloremic acidosis is another possible complication when hypertonic solutions are administering quickly. These solutions are not recommended in the hydration of newborns. Peripheral venous access can be used for its administration.

PREVENTION

Burns are the leading cause of fatal accidents in the home in the first nine years of life; they leave a scar forever and treatment outcomes, no matter how good they are, are accompanied by varying degrees of sequelae. Accidents are not due to chance, i.e., they are predictable and should be avoided. Burn prevention programs should include educational aspects aiming at behavior change; legislative aspects ensuring the preventive measures proposed; and technological aspects to modify the environment or product that leads to the trauma.

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