OUR EXPERIENCE IN THE TREATMENT OF BURN SHOCK BY HYPERTONIC LACTATED SALINE SOLUTION

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SUMMARY. Hypertonic salt solutions have for many years been known to be effective in the treatment of burn shock. Rapid infusion of a high concentration of sodium (250 mEq/l) produces positive effects by reducing fluid shifts, decreasing tissue oedema, and causing fewer attendant complications. This study presents data on 20 patients with severe burns who were resuscitated with hypertonic lactated saline (HLS) solution. The resuscitation regime used was that proposed in the USA and subsequently also in Europe. The fluid formula is based only on calculating fluid requirements for the first hour of therapy. Further adjustments of fluid requirements are based mainly on urine output. During the first hour of fluid therapy the amount of HLS given (ml) is 0.5 x percentage TBSA x kg body weight. This regime is recommended for resuscitation both of children, taking into consideration that urine output should be 1 ml/kg body weight/h, and of adults and the elderly, in whom an amount of 35 ml of urine per h is considered optimal and reflects sufficient vital organ perfusion. In order to control the administration of fluid volumes, we calculated fluid and sodium balances. Fluid load was 2.3 ml/kg/%; sodium load, 0.6 mEq/kg/%; net fluid accumulation, 20-30 ml/kg; and sodium retention, 56 %, associated with high natriuresis. We observed a high volume load in the first hour and in the first four hours of therapy, which regressed after lower fluid loads. During resuscitation the clinical and laboratory criteria were maintained within acceptable limits. Our clinical experience indicates that during burn shock resuscitation with HLS solution, the amount of fluid can be reduced, compared to conventional formula. Early administration of high sodium and fluid loads in the first four hours may decrease the total fluid load in the first 24 hours post-burn. A hypertonic regime requires careful observation and calculations. Resuscitation with HLS solution is a valuable regime in the treatment of severe burn patients that is also applicable in other similar clinical conditions.

Introduction

Burn shock consists of hypovolaemia and cellular shock. Its characteristic features are specific haemodynamic changes such as a reduction in cardiac output, extracellular fluid, and the presence of oliguria. Hypertonic solutions have long been known to be effective in the treatment of burn shock. Resuscitation with hypertonic lactate saline (HLS) with a sodium concentration of 250 mEq/l was first practised by Monafo in 1970, 1973, and 1984, by Moylan in 1973, by Shuji in 1977, and by Caldwell and Bowser in 1979, 1983, and 1985. These were followed by Carlson in 1986, Crum in 1988, and Boeckx in 1990.1-12 In recent years experimental studies have concentrated on hyperosmolar resuscitation using small volumes of hypertonic saline dextran (HSD) in which the concentration of sodium is 1280 mEq/l.13,14 Hypertonic fluids (205-310 mEq/l Na+ or 410-620 mOsm) have been used successfully in burn injury to replenish and maintain plasma volume without having to infuse excessive quantities of water.14 Resuscitation with hypertonic salt solutions involves the administration of higher concentrations of sodium than in isotonic resuscitation. Rapid infusion produces serum hyperosmolarity and hypernatraemia. The hypertonic serum reduces the shift into the extracellular space of intravascular water, and the added sodium replaces the sodium loss in the burn eschar and the cells, with minimal fluid load. This should minimize general and wound oedema, reduce the need for colloid replacement, diminish post-burn ileus, and achieve optimal fluid therapy, maintaining good urine flow. Decreased tissue oedema leads to fewer pulmonary complications due to overload, improves tolerance of enteral feeding, and stabilizes arterio-venous circulation, particularly in the extremities. It also maintains wound oxygen tension, contributing to wound healing.

Material and methods

During the period January 2003-January 2004, 20 patients with severe burns hospitalized in the Burns Service Intensive Care Unit of Tirana University Hospital Centre in Albania were resuscitated with HLS solution. Our study concentrates on the first 24 h of treatment.

The protocol used during rehydration was devised by Boeckx.13 This is based on the calculation of fluid needs in the first hour of therapy. It does not take into consideration the time of the burn or the amount of fluid administered during transportation or in regional hospitals. The amount of HLS solution given in the first hour is as follows: 0.5 x percentage TBSA x body weight (kg) = ml HLS solution.

The critical moment of resuscitation is the monitoring of fluid therapy in relation to diuresis (ml/h). If the hourly
diuresis is adequate, the same fluid rate is given the following hour. If the diuresis differs from the value of 0.5 ml/kg/h in adults and 1 ml/kg/h in children, with the same percentage we change the fluid infusion of HLS solution. A decrease of 10% in diuresis requires the addition of 10% of the fluid volume infused in the following hour, and vice versa.

During resuscitation we monitored the vital parameters of cardiac rate, respiratory rate, and temperature, as also systolic, diastolic, and mean blood pressure. Blood tests and urine analysis were performed every 8-12 h. The blood tests included haematocrit, haemoglobin, blood urea nitrogen, and glycaemia, as well as proteins and pH. Electrolytes and osmolarity were measured both in blood and in urine in the 24 h. On the basis of these data we calculated water and sodium balances, as follows:

- water load (ml/kg/%)
- sodium load (mEq/kg/%)
- net fluid accumulation (ml/kg)
- sodium retention (difference between sodium excreted and sodium given (mEq/kg))

We also monitored the distribution of fluids in the three 8-h periods (in percentage and in ml/kg/%/h). We did not perform invasive monitoring with a Swan-Ganz catheter. During resuscitation we took into consideration the acceptable limits of haematocrit, haemoglobin, plasma sodium, and osmolarity in plasma and urine in order to decide whether HLS solution therapy was changing to isotonic or not. Acceptable limits were:

- Ht not above 45%
- Hb not above 18 g/%
- plasma sodium not above 155 mmol/l
- plasma osmolality not above 320 mOsm/kg
- urine osmolality not above 900 mOsm/kg

**Technical note**

A comparison of HLS solution with Ringer’s lactate solution is presented in Table I. To prepare the solution we collaborated with our pharmaceutical colleagues, who produced it using modern Profarma technology. The solution was packed in 500-cc flacons.

<table>
<thead>
<tr>
<th>Solution compounds</th>
<th>Ringer’s lactate (in 1000 ml)</th>
<th>Hypertonic lactated saline (in 1000 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>6.00 g</td>
<td>7.5 g</td>
</tr>
<tr>
<td>Na lactate</td>
<td>3.12 g</td>
<td>13.4 g</td>
</tr>
<tr>
<td>KCl</td>
<td>0.4 g</td>
<td>0.4 g</td>
</tr>
<tr>
<td>CaCl₂ 2H₂O</td>
<td>0.27 g</td>
<td>0.27 g</td>
</tr>
<tr>
<td>Na⁺</td>
<td>131 mmol/l</td>
<td>250 mmol/l</td>
</tr>
<tr>
<td>Lactate</td>
<td>29 mmol/l</td>
<td>120 mmol/l</td>
</tr>
<tr>
<td>K⁺</td>
<td>5 mmol/l</td>
<td>5 mmol/l</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>2 mmol/l</td>
<td>2 mmol/l</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>111 mmol/l</td>
<td>138 mmol/l</td>
</tr>
</tbody>
</table>

**Statistical analysis**

The statistical process was done from two aspects: an analytic view and a descriptive view. The data are presented as numbers of cases or as percentages. For comparison of the results we used the t-test. The results are reported as mean ± SD.

**Results**

**Epidemiological data**

The group of patients consisted of 20 cases. The HLS group comprised 14 children and 6 adults, respectively 70% and 30%. The mean age in the HLS group was 16.1 ± 2.9 yr (SD). The burns covered approximately 25% TBSA, with a prevalence of second degree. The most frequent aetiological cause was scalding.

**Water and sodium balance**

*Table II* presents the fluid load and sodium load during resuscitation, expressed in ml/kg/% and mEq/kg/%. The patients were rehydrated with 2.3 ml/kg/% and with a sodium load of 0.6 mEq/kg%. The t-test demonstrated a statistical difference for fluid load (p = 0.001) compared with theoretical values.

**Table II** - Sodium and fluid loads

<table>
<thead>
<tr>
<th>Group</th>
<th>Volume (ml/kg/%)</th>
<th>Sodium (mEq/kg/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLS</td>
<td>2.3</td>
<td>0.6</td>
</tr>
</tbody>
</table>

*Fig. 1* presents net fluid accumulation expressed in ml/kg. The HLS group showed constant values, especially in the second and third period of resuscitation.

**Fig. 1** - Net fluid accumulation.

Sodium retention expressed in mEq/kg is presented in *Fig. 2*. Sodium retention was 56%.

The distribution of fluids in the first 24 h post-burn is presented in *Fig. 3*. During the first hour and the first four hours of the therapy we administered higher amounts of

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**Table I** - Comparison of resuscitation fluids (Ringer’s lactate vs hypertonic lactated saline)
fluids - in the first hour we administered 19% of the total fluid load. The distribution in the other hours of the day was similar to that of isotonic resuscitation.

Fig. 4 shows the curve of fluid therapy expressed in ml/kg/% in two cases hospitalized at different times post-burn. The fluid therapy curve had a comparable degree of regression in fluid therapy. In the first hour and in the first four hours there was an evident higher fluid load, which regressed in the more horizontal part of the curve between 8 and 24 h post-burn.

Laboratory data during the first 24 h post-burn

Figs. 5 and 6 present the haematocrit and haemoglobin values. The curves present acceptable values during resuscitation.

Fig. 5 - Laboratory values of haematocrit in first 24 h.

Fig. 6 - Laboratory values of haemoglobin in first 24 h.

Figs. 7 and 8 present values of plasma osmolarity and plasma sodium in the first hour of therapy, in the 12th hour, and in the 24th hour. The curves are similar - plasma osmolarity was higher in the first analysis, corresponding to the effects of burn trauma, while during resuscitation and at the 24th hour of therapy the values were similar. We did not see any patient with plasma osmolarity above 320 mOsm/kg. There were three cases with a respective osmolarity of 318, 312, and 312, but without
higher values of plasma sodium, which is another cause of higher osmolarity.

Figs. 9-11 show the values of urinary osmolarity and electrolytes in the urine collected over 24 h (sodium and potassium). Urinary osmolarity was at acceptable limits. The values of urinary sodium in the hypertonic group corresponded with osmolarity, while urinary potassium did not show any significant increase.

Discussion

In 1981 Pruitt wrote, “The goal of burned patient fluid resuscitation is the maintenance of vital organ functions at the least immediate or delayed physiological cost. The volume necessary to achieve this end is dependent on injury severity, age, physiological status, and associated injuries, and the actual volume of fluids used for resuscitation should be modified according to the individual patient’s response to the injury and therapy.”

Pruitt’s words remain true. During resuscitation the primary goal is to replace the fluid sequestered as a result of thermal injury. The critical concept is that in burn shock massive fluid shifts can occur even though total body water remains unchanged. It is now recognized that burn shock is a complex of circulatory and microcirculatory dysfunction, not easily or fully repaired by fluid resuscitation. Haemodynamic changes of hypovolaemia, myocardial depression despite adequate preload and control of volume, and also the beginning of the systemic inflammatory response lead to a vicious circle with a probability of organ dysfunction.
Resuscitation formulae are based on the percentage body surface area of cutaneous burn and importance should be given to accurate estimation of burn size, careful monitoring, and the choice of rehydration fluid, which together have a real potential for improving outcome.

Various formulae are based on calculation of sodium deficit in the extracellular space. According Baxter this amount is estimated by the formula 0.5-0.6mEq Na/kg/% TBSA. Adults and children are resuscitated with four main groups of formula, of which three are applied in the Burns Service in Tirana, Albania. These are:

- the colloid resuscitation group (Evans, Brooke, Slater, Shriner Galvestone)
- the crystalloidal resuscitation group (Parkland and modified Brooke)
- the hypertonic resuscitation group (Monafo, Boeckx, modified Warden)
- the dextran group (Demling)

Our discussion is based on our own data, observed during resuscitation with HLS solution, and on consideration of the data in the literature.

1. Small amount of rehydration fluid

As sodium appears to be the key element in crystalloidal infusion, with water being primarily a solvent, solutions with increased sodium concentration have a theoretical advantage inasmuch as less water is infused. Hypertonic salt solutions generating osmotic pressures of several thousand mm Hg in excess of normal have been known for many years to be effective in treating shock states by borrowing intracellular water to fill the extracellular space deficit because sodium does not cross into the cells. Resuscitation is directed towards minimal positive fluid while providing adequate sodium loads compared to isotonic resuscitation. In our data resuscitation is achieved with 2.3 ml/kg/% or 50% of theoretical values, while the sodium load is similar.

2. Controlled fluid infusion rate

Infusion rates in the first 24 h are based on the same principles as for isotonic solutions, with 50% of the total amount of fluids given in the first 8 h, 25% in the second 8 h, and 25% in the third 8 h. One characteristic of the protocol recommended by Boeckx is that early administration of the high sodium load, especially in the first hour of therapy, will diminish total fluid loads during the 24 h period because of hyperosmolarity.

Our data show that in the first h we gave 19.3% of the fluid volume and 32% in the first 4 h, which is similar to the data of Boeckx. In the first 8 h we gave 50% of the total amount of fluids.

According to Boeckx the amount of fluids given in the first h (0.5 x body weight (kg) x percentage TBSA) should be equal to the amount recommended by Parkland in the first 4 h. If the patient presents 2 or 3 h post-burn, comparing the two formulae, we may give the same amount of fluid in the first hour but the infusion rates should differ for the next 4 hours. The infusion rates in isotonic resuscitation should therefore be higher for a longer period, while in hypertonic resuscitation the infusion rates are lower after 4 h, which corresponds to thermal physiopathology.

Again with reference to Boeckx’s data, the HLS solution curve expressed in ml/kg/%/h is similar in all cases, apart from the time of the beginning of therapy. Also, patients with larger burns, in whom therapy begins at the same time, need a higher value in the first hour of therapy. We present two cases of patients with severe burns with different times of beginning of therapy with HLS solution. The regression of the fluid load is evident, especially 8 h post-burn.

3. Decreased net fluid accumulation

Carlson et al. showed that in burn patients net fluid retention is a better predictor of mortality than burn area, age, sex, or the presence or absence of inhalation injury. The increased osmotic pressure in the resuscitation fluid may help to counteract this in burned tissue, thereby decreasing net fluid flux into the burn. The added sodium also replaces the sodium loss into the burn eschar, restoring the extracellular sodium content and, in turn, its water content.

In our study the differences in accumulation of fluids were visible. They are explainable by the smaller fluid loads and the increased diuresis in the HLS group compared to the control group.

4. The important role of diuresis and natriuresis

During resuscitation with hypertonic salt solutions, diuresis and net fluid retention are very important parameters. Titrating fluid infusion to urine output does not jeopardize other important physiological variables. The algorithm for setting the HLS solution infusion rate based on urine output is efficacious.

According to Crum, diuresis and natriuresis increase in resuscitation with HLS solution. Our data show that an increase in diuresis decreased net fluid accumulation in the HLS group. Natriuresis was higher (172.6 ± 3.4, SD). Meanwhile urinary potassium showed lower values. Fig. 2, showing sodium retention, indicates lower sodium retention, which suggests a lesser level of oedema. The increase of urinary sodium in urine collected over 24 h was accompanied by an increase in urine osmolality, which remained however within normal values.

5. Monitoring of clinical and laboratory parameters and the possibility of complications

In order to verify the possibility of administering the
volume of fluids according to formulae, apart from calculating sodium and fluid balances we also took into consideration cardiac rate, mean blood pressure, diuresis, Ht, Hb, plasma sodium, plasma osmolarity, and urinary osmolarity, provided acceptable limits were maintained, as mentioned above. The study would have been more complete if we had performed invasive monitoring to guide resuscitation. Hypertonic solutions have been reported to increase myocardial contractility, to produce precapillary dilatation, and to decrease vascular resistance by a direct effect on the capillary smooth muscle.\cite{21,22}

Our clinical observations were as follows:
- cardiac rate and blood pressure stabilized quickly
- pH stabilized in the first 8 h
- enteral feeding began in the first 24 h
- there were no early pulmonary complications
- there was no evident oedema
- the wound did not present exudation
- the use of NaHCO$_3$ in the first 24 h was avoided
- the haematocrit and haemoglobin values were almost the same as in the control group

Although studies have suggested that modest intracellular water depletion does not appear to be deleterious, the question still remains of how much of this solution can be used.\cite{23} For this purpose it is necessary to monitoring plasma sodium and osmolarity. Among our cases we distinguish two in particular (a child with 45% TBSA burns and an adult with 50%), in whom HLS solution was used during the first 8 h, followed after rehydration by completion with Ringer’s solution and colloids. In these two cases plasma osmolarity was within maximal normal values. Clinically, we observed a concentration of urine during the 8 h of resuscitation.

According to Warden,\cite{24} burn shock resuscitation still fails in certain patients despite the administration of controlled volumes of fluids, advances in emergency care and transport, resuscitation regimes, and physiological stabilization. He makes the following recommendations:
- most patients with burns < 40% TBSA and patients without pulmonary injury can be resuscitated with isotonic crystalloid fluid;
- in patients with burns > 40% TBSA and in patients with pulmonary injury, hypertonic saline can be utilized in the first 8 h post-burn, following which lactated Ringer’s can be infused to complete burn shock resuscitation;
- in children and the elderly, a lower but still hypertonic concentration of sodium (i.e. 180 mEq/L) should be used, in order to give the benefits of hypertonic resuscitation without the potential complications of excessive sodium retention and hypernatraemia;
- in patients with massive burns complicated by severe inhalation injury, a combination of fluids may be utilized to achieve the desired goal of tissue perfusion while minimizing oedema.

Complications in the use of this solution are primarily related to the hyperosmolar state, which exists if too much salt is given. Marked hyperosmolarity should be avoided since it would never have favourable effects on tissue metabolism or renal circulation. It would appear that adequate urine output is difficult to obtain with a serum sodium concentration above 160 mEq/L.\cite{25}

Another problem to be taken into consideration is that in massive burns the cell membrane sodium pump mechanism can be impaired in the burned tissue, and that the sodium administered, contained in the HLS, can move freely in the impaired cells. In such cases the reduction of cellular volume may occur only in the unburned tissue and the response is alternated.

Another possible problem is the delayed onset of fluid retention that is likely to occur with the institution of hypotonic solutions beginning day 2 post-burn, at least until there is isotonicity. This problem may be less serious than that seen during the immediate resuscitation period.

At present there is little doubt that less fluid is required for initial resuscitation using HLS solution. The maintenance of clinical and laboratory parameters within acceptable limits during the first 24 h, when the main physiopathological changes occur, is mandatory. According to Boeckx, the parameters should not normalize quickly as there exists the possibility of “minimal” resuscitation, taking into consideration the vital functions of the body. According to Kirby, hypertonic solutions are beneficial in resuscitation from shock and trauma, and especially from haemorrhagic shock. Hypertonic solutions are confirmed as being efficacious in aortic reconstructive surgery.\cite{21,24,26}

Conclusions

Resuscitation with HLS solution is a method of optimal fluid therapy directed towards effecting minimal positive fluid and sodium loads while providing adequate resuscitation.

The most efficacious methods are sodium and fluid loads (in the first hours), the faster ones with decreased infusion rates, enabling the patient to adapt to the trauma.

The protocol recommended by Boeckx needs rigorous observation and precise mathematical calculations.

Resuscitation with HLS is an alternative fluid therapy that is valuable in the treatment of severe burn patients and is also applicable in similar clinical situations.
RÉSUMÉ. On sait depuis longtemps que les solutions salines hypertoniques sont efficaces dans le traitement du choc de brûlure. L’infusion rapide d’une concentration élevée de sodium (250 mEq/l) produit des effets positifs en réduisant les déplacements des liquides, diminuant l’œdème tissulaire et causant un numéro mineur de complications concomitantes. Les Auteurs de cette étude présentent les données de 20 patients atteints de graves brûlures réanimés moyennant le traitement avec la solution saline lactée hypertonique (SLH). Le régime de réanimation utilisé était celui proposé aux États-Unis et ensuite aussi en Europe. La formule des liquides se base uniquement sur le calcul des exigences de fluides pendant la première heure de la thérapie. Les modifications ultérieures des exigences de liquides se basent principalement sur la diurèse. Pendant la première heure de la thérapie la quantité de SLH administrée (ml) est 0,5 x pourcentage surface totale corporelle brûlée x kg poids corporel. Ce régime est recommandé pour la réanimation soit des enfants, prenant en considération que la production urinaire doit être de 1 ml/kg poids corporel/h, soit des adultes et des personnes âgées, où l’on considère optimale une quantité de 35 ml d’urine par h, qui reflète une perfusion organique vitale suffisante. Pour contrôler l’administration des volumes des liquides, les Auteurs ont calculé les bilans des liquides et du sodium. La charge des liquides était 2,3 ml/kg/%; la charge de sodium, 0,6 mEq/kg/%; l’accumulation nette des liquides, 20-30 ml/kg; et la rétention de sodium, 56 %, associée à une natriurèse élevé. Ils ont observé une charge élevée de volume pendant la première heure et pendant les quatre premières heures de thérapie qui diminuait après une réduction des charges de liquides. Pendant la réanimation les critères cliniques et de laboratoire sont restés entre les limites acceptables. L’expérience des Auteurs indique que pendant la réanimation pour le choc de brûlure utilisant la solution SLH, la quantité de liquides peut être diminuée, par rapport à la formule conventionnelle. L’administration précoce de charges élevées de sodium et de liquides pendant les 4 premières heures peut diminuer la charge totale de liquides pendant les 24 premières heures après la brûlure. Un régime hypertonique impose une observation et des calculs méteuriques. La réanimation avec la solution SLH est une méthode de grande valeur dans le traitement des grands brûlés utilisable aussi dans d’autres conditions cliniques similaires.

**BIBLIOGRAPHY**