REVIEW

Controversies in fluid resuscitation for burn management: Literature review and our experience

Lucian Fodor a, Adriana Fodor b, Ytzhack Ramon a, Oren Shoshani a, Yaron Rissin a, Yehuda Ullmann a, *

a Department of Plastic and Reconstructive Surgery, Rambam Medical Centre & Bruce Rapaport Faculty of Medicine, Ha’Aliya St. 8, Haifa 31096, Israel
b Institute of Endocrinology and Metabolism, Rambam Medical Centre & Bruce Rapaport Faculty of Medicine, Haifa, Israel

Accepted 20 June 2005

Keywords
Burns;
Fluid resuscitation;
Colloids;
Crystalloids

Summary
The purpose of this review is to summarise the commonly used formulae for fluid resuscitation in major burns and to discuss the controversy surrounding the use of protein-based colloids as a component of these types of formulae. Fluid resuscitation in major burns is one of the most critical steps in managing this type of injury. In practice, a wide variety of formulae for fluid resuscitation has been suggested. Some propose only the use of crystalloids, while others combine the colloids together with crystalloids. A review was performed of the literature addressing fluid resuscitation formulae and our experience using our formula is presented.

At the authors’ burn centre a unique formula is in use, which combines plasma and crystalloids. Our experience using this specific formula extends over a period of 15 years and 356 patients with major burns have been resuscitated using this protocol. At our centre, 27 deaths were recorded, 19 of which had third degree burns of more than 80% total body surface area (TBSA).

The protein-based colloids are included in most of the formulae and the beneficial effect is considered to be higher than the potential side effects. We are in favour of administering colloids during the resuscitation period for major burns, starting in the early period after injury.

© 2005 Elsevier Ltd. All rights reserved.
Introduction

Despite the vast experience worldwide in the management of burn victims, there are still significant controversies regarding the best type of fluid resuscitation during the early phase following a major burn. The purpose of this study is to analyse and discuss the controversy around fluid resuscitation in burn patients. Following this literature review, we will describe our experience in this specific subject matter.

Fluid management in patients with major burns plays a fundamental role during the early period following the burn, when many pathophysiological changes take place. Release of mediators such as histamine, prostaglandins and leukotrienes, together with complement activation, seems to play an important role in permeability changes causing hypovolaemia and shock.11,12,38,47,49 According to Leape,31 histamine plays the most important role in the acute phase.

Intravascular components leak into the extravascular space and contribute to fluid depletion.21 Changes in capillary permeability, in both burned and unburned tissues, have been demonstrated by Arturson,2 using an experimental canine model. Cellular membrane permeability disturbances also produce electrolytic alteration, with intracellular sodium (Na) accumulation and consequent cellular swelling.48 According to Demling et al.,16 in major burns involving more than 50% TBSA, half of the fluid requirement can be due to extravasation into the unburned areas.

Burn patients having more than 20% TBSA involved, may suffer hypovolaemic shock if not treated properly. Tissue oedema develops quickly within a few hours. According to Pitt,18 the intravascular pressure is the most important factor in oedema formation during the first 3—5 h. Leakage and accumulation of plasma proteins outside the vascular compartment contributes substantially to the oedema formation. The time at which the protein leakage stops has been described differently in the literature.38 Carvajal, as reported by Cocks et al.,14 found that albumin extravasation stops 8 h after injury. According to Demling,17 capillary leakage of protein ceases significantly about 12 h following the burn.

There is a wide agreement that patients with burns involving less than 20% TBSA for adults and 10—15% for children, can be treated successfully by using only oral fluids.27,48

Some authors believe that only crystalloids should be used during the resuscitation period. The starting time of treatment is important and Barrow et al.3 emphasised the importance of early fluid resuscitation, preferably from thermal injury time. Several resuscitation formulae for calculation of the fluid requirement are used worldwide. The best known formulae are: Evans, Brooke, modified Brooke, Monafo, Parkland and modified Parkland.4—8,18,30,34—37,39,42,43 Generally, these formulae take into account the body weight and the burn surface area.

Evans formula (1952)

(a) First 24 h: crystalloids in the amount of 1 ml/kg/%burn, plus colloids at 1 ml/kg/%burn, plus 2000 ml glucose in water.
(b) Next 24 h: crystalloids at 0.5 ml/kg/%burn, colloids at 0.5 ml/kg/%burn, and the same amount of glucose in water as in the first 24 h.

Brooke formula

(a) First 24 h: Ringer Lactate (RL) in amount of 1.5 ml/kg/%burn, plus colloids at 0.5 ml/kg/%burn, plus 2000 ml glucose in water.
(b) Next 24 h: RL in amount of 0.5 ml/kg/%burn, colloids at 0.25 ml/kg/%burn and the same amount of glucose in water as in the first 24 h.
Modified Brooke

(a) First 24 h: no colloids. Crystalloids (RL) in amount of 2 ml/kg/%burn in the adult and 3 ml/kg/%burn in children.
(b) Next 24 h: colloids in amount of 0.3–0.5 ml/kg/%burn, and no crystalloids. Glucose in water is added in the amounts required to maintain good urinary output.

Monafo formula

He uses a solution containing 250 mEq Na, 150 mequiv. lactate and 100 mequiv. Cl. The amount is adjusted by urine output. In the following 24 h, the solution is titrated with 1/3rd N. Saline according to urinary output.

Parkland formula

This is probably the most widely used formula:

(a) First 24 h: no colloids. RL in amount of 4 ml/kg/%burn for adults and 3 ml/kg/%burn for children. Ringer Lactate solution is added as maintenance for children as following: for children weighting 0–10 kg the amount is 4 ml/kg/h; between 10 and 20 kg the amount is 40 ml/h + 2 ml/kg/h; for more than 20 kg, the amount is 60 ml/h + 1 ml/kg/h.
(b) Next 24 h: colloids in amount of 20–60% of calculated plasma volume. No crystalloids. Glucose in water is added in amounts required to maintain urinary output of 0.5–1 ml/kg/h in adults and 1 ml/kg/h in children.

Modified Parkland

(a) First 24 h: RL in amount of 4 ml/kg/%burn (adults).
(b) Next 24 h: begin colloid infusion of 5% albumin at the amount of (0.3–1 ml/kg/%burn)/16 per hour.

None of the proposed formulae fulfills all the requirements. It is for this reason that, over time, many formulae have been proposed and different centres use different calculations; i.e., in the UK, Muir and Barclay’s formula is the most widely used. Parkland’s formula, which is widely used, does not fulfill all the requirements for burn resuscitation, mainly due to the extensive loss of the fluid into the intercellular space causing oedema formation, which may disturb the function of vital organs.

In order to increase plasma osmolality, one must reduce the amount of the fluid that would be required to overcome the fluid loss into the extracellular space. This is the reason for adding hypertonic solutions, such as hypertonic saline, glucose 20%, 40%, or manitol 20%, to the crystalloids, in some of the protocols. In an animal model, initial resuscitation using a hypertonic solution during the first hour after burn proved to be useful, with significant fluid sparing. The second dose, which was administered in the same study at 12 h after burn, had no significant effect. A decrease of oedema in the gastrointestinal tract (GIT), liver, pancreas, muscles and unburned skin was found by Kinsky et al. in his experimental study on sheep treated with hypertonic dextran, as compared with those treated with RL.

The main controversy in fluid resuscitation focuses on the administration of protein-based colloids: whether to provide or not, which solutions to use, and when to begin. Colloids, as hyperosmotic solutions, are used to elevate the intravascular osmolality and to stop the extravasation of the crystalloids. Bert et al. compared the Parkland and Evans formulae in an animal model, starting the resuscitation 1 h postburn. He concluded that the large volume of fluids administered by Parkland’s formula resulted in dilution of the circulatory proteins and a decrease in colloid osmotic pressure. Using Evans’s formula, the total fluid volume needed was much less than when Parkland’s formula was used. In this study all the compartments had elevated levels of protein.

The main colloids used for this purpose are albumin, which is the most active oncotically and Fresh Frozen Plasma (FFP), which contains both clotting factors and heat fixed proteins that have lost part of their oncotic properties. Goodwin et al.’s study performed on 79 patients, who were either treated with Ringer Lactate solution, or 2.5% albumin–RL solution, found that the colloid group required less fluid (2.98 ml/kg/%burn), compared with the crystalloid group (3.82 ml/kg/%burn).

The Conchrane Injuries Group presented three studies of albumin administration in burns. The relative risk of death in these three studies was 2.4 (calculated by Mantel–Haenszel method) suggesting that human albumin might increase mortality. As the authors admitted, the study is limited and some data may be prone to bias. Wharton and Khanna found, in their survey of 22 Burn Units in the UK, that 18 units were routinely using albumin-based formulae. Fakhry, reported by Webb, found that 40 of 62 units
outside the UK gave colloids at some time during the resuscitation period, most of them during the second 24 h. Seventy eight percent of the units in the US change the fluid regimen after 24 h, 72% of them by adding colloids.  

The issue of pulmonary extravascular water during the resuscitation period is also contradictory. Holm et al. 24 investigated 35 patients with burns involving more than 20% TBSA, with associated inhalation injury, and monitored the extravascular lung water and the pulmonary permeability index. Only crystalloids were administered in the first 24 h, then, in following 24 h, colloids (5% albumin + 6% HES) were added. The study confirmed that increases in lung water and capillary permeability are rare, even in the presence of an inhalation injury.

The beneficial effects of colloid resuscitation were also confirmed by Guha et al. 23 Aharoni et al. 1 showed that colloids might be protective against pulmonary complications, such as pneumonia and ARDS. Goodwin et al. 22 found that in patients treated with crystalloids, the lung water remained unchanged, but in the colloid group, over a period of 7 days, the extravascular water progressively increased. Tranbaugh et al. 45 reached the same conclusion and found that massive crystalloid infusion does not increase the pulmonary extravascular water.

The correct amount of protein-based colloids is not defined, and many centres 4,17,19,30,48 use different quantities, mostly varying between 0.5 and 1 ml/kg/%burn. The resuscitation formulae are only guidelines and most of the authors agree on the need to monitor closely and to adjust the amount of fluids according to the clinical and the laboratory parameter responses. Urine output 4,18,30,48 should be kept between 0.5 and 1 ml/kg/h for adults and 1—1.5 ml/kg/h for children.

To conclude, the advantages of protein-based formulae for fluid resuscitation are reduced oedema, thereby reducing the incidence of compartment syndrome 25,26,40,44 and the need for fasciotomy, reduced GIT oedema and incidence of ileus. On the other hand, the disadvantages are potentially higher costs, possible viral transmission with FFP, leakage from the vascular compartment, thereby elevating the extracellular osmolality, increased febrile incidence 13 with FFP, and possible anaphylactic reactions. 32,41

**Authors’ experience**

Resuscitating a burned patient is a fine balancing act, on the one hand treating the deficit of intravascular fluid and, on the other, the potential side effects of fluid overload, namely pulmonary oedema, increased central venous pressure, and compartment syndrome, even in the unburned areas. During the last 15 years, we have used our own protocol, according to which we administer regular plasma in addition to RL solution. The administration of colloids starts at 8 h from the injury time, as calculated by what we call the Haifa formula. 46 In the first 24 h we administer plasma in the amount of 1.5 ml/kg/%burn plus RL in the amount of 1 ml/kg/%burn. In burns involving more than 50% TBSA, the maximum administered plasma is calculated as for 50% TBSA. Half of the amount is given during the first 8 h and half in the next 16 h. In the subsequent 24 h, we give half of the amount estimated for the first day. The quantity is adjusted by clinical and laboratory parameters, mainly the urinary output. When that is less than 0.5 ml/kg/h, RL is added. In the last 15 years, we had only one case of viral transmission via plasma (hepatitis C). Today, with thorough blood screening, we believe that plasma has more beneficial, than detrimental, effects for burn resuscitation.

Over this period we have treated 356 patients with major burns. The total body burn surface was distributed as follows:

- Children (15—20% TBSA)—55 cases;
- Adults and children (20—29% TBSA)—122 cases;
- Adults and children (30—39% TBSA)—69 cases;
- Adults and children (40—49% TBSA)—43 cases;
- Adults and children (50—59% TBSA)—27 cases;
- Adults and children (60—69% TBSA)—10 cases;
- Adults and children (70—79% TBSA)—11 cases;
- Adults and children (80—89% TBSA)—seven cases;
- Adults and children (more than 90% TBSA)—12 cases.

Twenty-seven deaths were recorded over this period and 19 had third degree burns involving more than 80% TBSA.

In one of our recent studies, 46 we established the validity of our formula and reported that for the majority of our patients, the fluid administration, using this specific protocol, enabled our patients to overcome the resuscitation period without any harm to the kidneys, or other vital organs. We do not profess that our formula is necessarily superior, but we are happy with the audited fluid resuscitation results and shall continue using it for our burn patients. We remain persuaded that formulae used for calculating burn resuscitation fluids are merely guidelines, and the clinical and laboratory parameters are essential in adjusting to the patient’s needs.
References