

# Fluid resuscitation in treatment of burn shock

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## Summary

Treatment of burns can be divided into 3 phases. During first 36 hours fluid resuscitation and securing airways are the most important aspects of therapy. The fluid resuscitation is complex, and protocols are used to increase the consistency and success of treatment. The adequacy of the protocols should be continuously monitored and adjusted to the patients response. Current studies are exploring the use of antioxidants to minimize the oxidant stress during the burn shock phase. The aim of this thesis is to review current strategies in fluid resuscitation during the first 36 hours after burns.

## Introduction

According to Neely the post-burn care can be divided into three phases according time after burn (Diver, 2008):

- 0-36h – early resuscitation period
- 2-6 days – early post-resuscitation period
- 7 days-wound closure – inflammation-infection period

In the early resuscitation phase life threatening airway and breathing problems and hypovolemia are the major points of concern. The burn itself is assessed for size and depth, but apart from super-early necrectomy (within 24 hours), wound management is more important in the later phases.

During the mid-20<sup>th</sup> century there was a revolution in the treatment in the early resuscitation period. The concept of the “third space loss” was introduced and relations between total body

surface area (TBSA) and amount of fluid resuscitation recommended were explored. (Diver, 2008) In the 60s, the “Parkland formula” was introduced by Baxter and Shires, and it continues to be the most commonly used protocol (Greenhalgh, 2010; Tricklebank, 2009). However, even though most burn centers use a protocol, most make modifications in the final protocol they use. In Greenhalgh’s review of the ISBI/ABA study he suggests “that caregivers feel that their resuscitation “protocol” works well but the actual “formula” is less accurate for resuscitation volume” and that “in other words, the burn team resuscitates patients based on the patient's physiologic needs and less on the actual formula.” (Greenhalgh, 2010).

### **Basic pathophysiology of burns**

A burn is a thermal, electrical or chemical injury to the skin or underlying tissues. The initial injury then activates a cascade of inflammatory mediators. Locally, substance P, serotonin, prostaglandins E2 and F2, histamine, platelet-activating factor, nitric oxide, bradykinin, and leukotrienes B4 and D4 play a role in the increased local capillary permeability and initiation of the systemic inflammatory cascade. Systemically, levels of interleukin-2, -4, -6, and interferon-gamma (IFN-) are elevated in proportion to the severity of the burn injury, perhaps as part of a generalized systemic release of inflammatory mediators and generalized macrophage dysfunction. There is often an altered CD4/CD8 (T helper/T suppressor) cell ratio. In addition, in the first 24 hours following a significant burn, there is production of tumor necrosis factor and IFN-, which in turn stimulate production of the enzyme nitric oxide synthetase in hepatocytes. After 24 hours, lipopolysaccharide plays a dominant role in its production. Nitric oxide has been proposed as a mediator of the acute inflammation. Transforming growth factor beta and IL-10 and a markedly elevated level of IL-6 serve as

harbingers of a declining clinical course in severely burned patients. (McPhee & Papadakis, 2009)

## **Burn shock**

Burn shock is a hypovolemic, distributional shock. The thermal injury first lead to local changes at the burn site, if the injury is very extensive there can be a systemic response with general edema. The critical limit for developing general edema changes with age. From 0-2 years it is over 5%, up to 10 years it increases to 10%, and in adults it is 20%. In elderly it decreases to 15%. The development of burn shock is a result of a vicious cycle. Albumin leaks into the interstitial compartment because of increased capillary permeability. The increased oncotic pressure in the interstitial fluid increase edema through osmotic forces. The edema leads to hypoxia, and hypoxia decreases ATP production and disturbs cell membrane control of the ion concentrations. This maintains the intracellular edema. Loss of intravascular fluid to the interstitium naturally causes intravascular hypovolemia with a dramatically increased hematocrit. The increased hematocrit increases the viscosity of the blood and there is microinfarcts further preventing satisfactory oxygen delivery to the tissues thus increasing the cell death, cytokine release and edema, in a vicious cycle. In addition the red blood cells, damaged by the cytokine storm, are being destroyed. The decreased blood flow also damages the heart and leads to a circulatory shock in addition to the hypovolemic shock.

The general edema reaches its maximum after 24 hours. The goal of treatment during this period is not to treat the burn shock itself as this will resolve by itself, but to maintain the patients intravascular volume during this critical phase.

As the ATP levels are reaching normal levels and the cell membranes start to function again the edema is mobilized and the urine output spontaneously increases by 2-3.

Tabell 1: Classification of burns (Wikipedia - The free encyclopedia)

Nomenclature	Traditional nomenclature	Depth	Clinical findings	Example
<b>Superficial thickness</b>	first degree	Epidermis involvement	Erythema, significant pain, lack of blisters	
<b>Partial thickness -superficial</b>	second degree	Superficial (papillary) dermis	Blisters, clear fluid, and pain	
<b>Partial thickness - deep</b>	third degree	Deep (reticular) dermis	Whiter appearance or fixed red staining (no blanching), reduced sensation	
<b>Full thickness</b>	fourth degree (fourth-degree is not a technical term, however it is often used to describe burns that reach muscle and bone. Third-degree sufficiently describes all burns of this nature.)	Epidermis, Dermis, and complete destruction to subcutaneous fat, eschar formation and minimal pain, requires skin grafts	Charred or leathery, thrombosed blood vessels, insensate	

## Basic treatment in the early resuscitation phase

Many patients with burns can be treated as outpatients in community hospitals, but certain groups should be transferred to specialized burns units. The American college of Surgeons recommends that the following groups of patients should be transferred to a burns unit:

- Partial-thickness burns greater than 10% of total body surface area in patients who are younger than 10 years or older than 50 years
- Partial-thickness burns over more than 20% of total body surface area in other age groups
- Burns that involve the face, hands, feet, genitalia, perineum, or major joints
- Third-degree burns in any age group
- Electrical burns, including lightning injury

- Chemical burns
- Inhalation injury
- Burns in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality rate
- Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or death
- Burn injury in children at hospitals without qualified personnel or equipment for the care of children
- Burn injury in patients who will require special social, emotional or long-term rehabilitative intervention

These factors are associated with poorer outcomes, and the patients benefit from the highly specialized care (Robert I Oliver Jr, 2009).

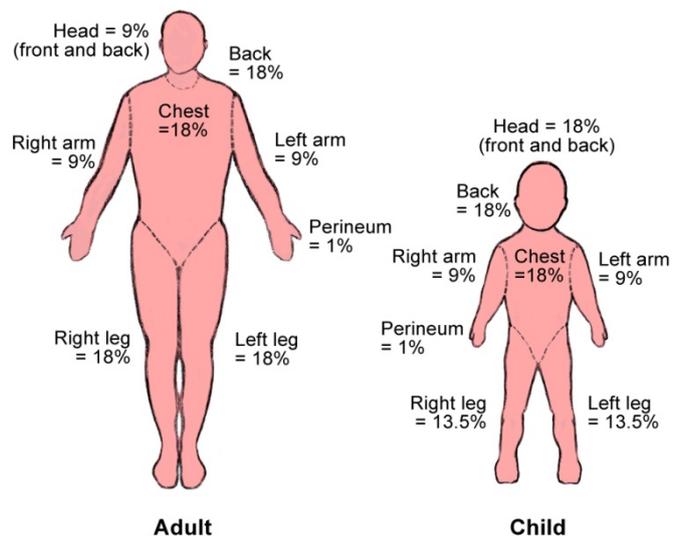
If there is signs of inhalation injury airways should be secured. Inhalation injury should be suspected if there is singed facial hairs and carbonaceous sputum. The circumstances during the accident should be elucidated, and if there is a history of a “closed space” inhalation injury should be suspected. In an explosion the the glottis will close and the injury will be kept above the glottis. Lower inhalation injuries can be expected in inhalation of steam and toxins.

The other crucial point during the early resuscitation phase is securing IV access. Patients with burns should preferably be provided with two access points. The sites for insertion should avoid burnt areas. The reason for this is mainly due to difficulties in securing the IV line on the burnt skin. There is a risk of both creating a tourniquet effect (if the catheter is secured by circumferential dressings) and dislodging of the catheter as edema develops.

Femoral catheters have an increased risk of infection, but it is acceptable if it is the only large

vein in a non-burned area. If a central catheter is considered necessary its insertion should be performed early, while anatomical landmarks are still visible. Central catheters also carry the risk of dislodgement with edema. In children an important alternative is intraosseous access, as insertion of intravenous peripheral catheters can be very difficult, especially if they are already hypovolemic. Intraosseous access was previously recommended only in children younger than 6 years, but according to current guidelines any age is acceptable. There are even reports of successful use in adults, and perhaps in the future it will be a commonly used alternative for adults as well. (Robert I Oliver Jr, 2009)

The further treatment plan in burn injuries depends on many factors. Age of patient, location, extent and mechanism of the burn injury are important. The extent of the burn injury is usually assessed with help of the rule of nines and diagrams in admission papers of the patient. The location of the injury is important both for cosmetic, functional and medical reasons.



Figur 1; Rule of nines in adults, used for assessing extent of burns in % of TBSA (Robert I Oliver Jr, 2009)

Circumferential burns carry a risk of compartment syndrome. The mechanism of the injury affects the probability of inhalation injury and the depth of the wounds. In inhalation injuries the amount volume required may increase by as much as 30-40% of the amount predicted by the Parkland formula. If treatment is not initiated promptly, and the inflammatory cascade is allowed to proceed uninterrupted volume requirements may also increase dramatically (Robert I Oliver Jr, 2009). The amount of fluid is also affected by the body mass index of the

patient. The fluid requirements decrease with increasing body mass index (Csontos, Foldi, Fischer, & Bogar, 2007)

## Types of fluid replacement and their role in therapy of burns

As fluid replacement is essential in the treatment of burns one of the first measures to be taken is to secure vascular access by a peripheral venous catheter for infusion of the fluids.

### Crystalloids

The most commonly used fluids for fluid replacement are the crystalloids. They are very basic solutions containing only certain minerals. They are cheap and generally well tolerated, but the fluid is usually rapidly lost to the extravascular spaces. The crystalloids can be isotonic or hypertonic compared to plasma.

#### *Composition of commonly used crystalloid solutions :*

Solution	[Na <sup>+</sup> ](mmol/L)	[Cl <sup>-</sup> ](mmol/L)	[Glucose](mmol/L)
D5W	0	0	278
Half-normal saline	77	77	0
Normal saline	154	154	0
Ringer's lactate	130	109	0
D5NS	154	154	278
Plasma	136-145	98-106	4.5-5.6

### Hypertonic saline

The appeal of the hypertonic saline is that the increased osmolality of the plasma keeps more fluid intravascularly, so the total amount of fluid replacement will be decreased comparing to isotonic solutions and the burn edema reduced. However, the increased concentrations of sodium is a double-edged sword. There is a risk that the plasma sodium concentrations will

reach a level of 158 mequiv/l which is associated with decreased levels of urinary output, renal failure and neurological complications (McPhee & Papadakis, 2009) (Tricklebank, 2009).

### **Normal saline**

Normal saline is sometimes referred to as physiological saline, when in fact it is not very physiological. The high chloride concentration compared to normal plasma values can cause hyperchloremic acidosis.

### **Ringers lactate**

Ringer's solution is the crystalloid with mineral composition closest to physiological.

Ringers lactate, or Hartman solution also contains lactate. The byproducts of lactate metabolism in the liver counteract acidosis, so that even though the solution has a pH of 6.5 it is an alkalizing solution. It is the solution recommended by the Parkland formula and thus is the main solution used in fluid resuscitation of patients with burn injuries.

### **Colloids**

The colloid resuscitation fluids share the property of containing large molecules, which helps prevent the escape of fluids out from the bloodstream, they expand the intravascular volume. Examples are plasma, albumin and dextrans. As much as 75-80% of the infused volume will stay in the intravascular space. (Marino, 2007) Despite the greater effect on cardiac output per infused unit, there is so far no evidence that colloids improve survival, and crystalloids continue to be the most commonly used resuscitation fluid. (Marino, 2007)

*Polygelatin solutions* are cheap, their average molecular weight is 35 000, which is isosmotic with plasma, and they do not interfere with crossmatching. Clinically significant coagulation defects are unusual, and they do not impair renal function. However, they have a relatively short half-life in plasma, only 4 hour.

*Hydroxyethyl starch* is a nonionic starch derivative. It is one of the most frequently used plasma substitutes, and the volume expansion is equivalent to, or slightly larger than the volume infused. It interferes with coagulation and solutions with a high molecular weight may cause acute renal failure and increased mortality.

*Dextrans* have a powerful osmotic effect, but interfere with crossmatching and have a rate of allergic reactions of 0.1-1%. The recommended dose of 1.5 g dextran/kg bodyweight should not be exceeded due to risk of renal damage.

*Human albumin solution* is a natural colloid. It is not recommended for routine fluid replacement due to limited supplies, and equally effective cheaper alternatives.

### **Colloids in burns**

In burns, a major component in the development of shock is extensive vasodilation and increased capillary permeability which means that this advantage of larger molecules may be lost, or it may even be a disadvantage. The proteins may escape to the extracellular matrix and increase edema. There is some disagreement as to how significant this is. First of all the duration of the capillary leak was earlier thought to be up to 24 hours, but recent studies have shown that it is considerably shorter, with a median duration of 5 hours. (Vlachou, Gosling, & Moiemmen, 2006) Secondly some studies have shown decreased mortality in critically ill patients receiving albumin, and some have reported successful resuscitation with colloids in

the early post-burn period (Tricklebank, 2009). Currently, there seems to be agreements that addition of albumin is beneficial in cases with hypoproteinemia (Diver, 2008). Cecile medicine, 2009 states that “albumin can be added to the resuscitation fluid to maintain a serum albumin level greater than 2.5g/dl”. Certain patients benefit more from the lower-volume resuscitation colloids provide, mainly those with larger burns (>40%), those with preexisting heart disease, geriatric patients and patients with associated inhalation injuries (Robert I Oliver Jr, 2009).

## **Blood**

Blood transfusions are in general not recommended as fluid replacement therapy. Blood components can be useful, but their use should not be liberal as it carries a relatively high risk of infections and immunological and other adverse reactions. This also applies to burn victims. Even though blood transfusions may be needed in the therapy of burns a restricted approach should be attempted as it is associated with lower mortality and infectious episodes in patients with major burns. (Tricklebank, 2009) Infections are one of the major causes of mortality for patients with major burns. (Kamolz, 2010)

## **Methods for assessing fluid replacement adequacy**

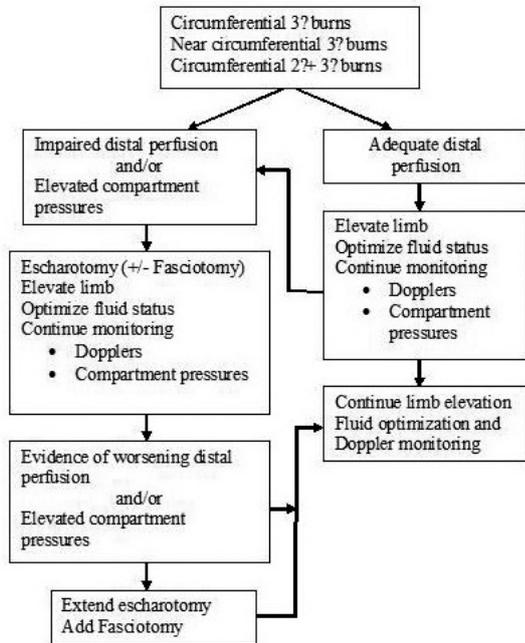
Every patient is different and will respond differently to the injury and to the therapy. To develop protocols that would assure the optimal fluid replacement in each patient without individual adjustments is essentially impossible. The adequacy of the protocols needs to be controlled by monitoring end-points that give an assessment of the tissue perfusion.

The classical method of end-point monitoring in major burn injuries is urinary output. It should be titrated to 0.5 ml/kg/h in adults and 1.0 ml/kg/h in children. Urinary output closely reflects renal perfusion; however an exact amount per hour that indicates an adequate perfusion is still unknown (Tricklebank, 2009). If the urinary output is too low the fluid rate should be carefully increased. Fluid boluses should be avoided as they cause transient increases in hydrostatic pressure and may increase edema (Robert I Oliver Jr, 2009). Closed loop resuscitation uses a computer to optimize the fluid rate to the urinary output. Such systems may be more accurate than human monitoring, and studies are currently being made (Tricklebank, 2009). There are several studies that discuss the fact that even though the renal perfusion and urinary output may be satisfactory it doesn't necessarily mean that the global perfusion is satisfactory (Tricklebank, 2009). Glycosuria may lead to osmotic diuresis, and a simple urinalysis during the first 8 hours is helpful to avoid overestimation of intravascular volume. Another confounding factor, especially in old patients, may be long-standing diuretics use. In this group of patients a Swan-Ganz catheter may be helpful. However, pulmonary vasoconstriction may give falsely high readings (Robert I Oliver Jr, 2009).

Other traditional methods for end point monitoring are not that useful in major burn injuries. Extensive edema may make non-invasive blood pressure monitoring difficult (Tricklebank, 2009). Patients with major burns may suffer from pain and anxiety, so tachycardia does not necessarily mean hypovolemia (Tricklebank, 2009). In addition these markers are often normal in the compensated phases of shock and also they may not detect occult cellular hypoperfusion. (Tricklebank, 2009) However, a trend showing gradual normalization of the vital signs is useful.

## Risks of overhydration

### Compartment syndrome



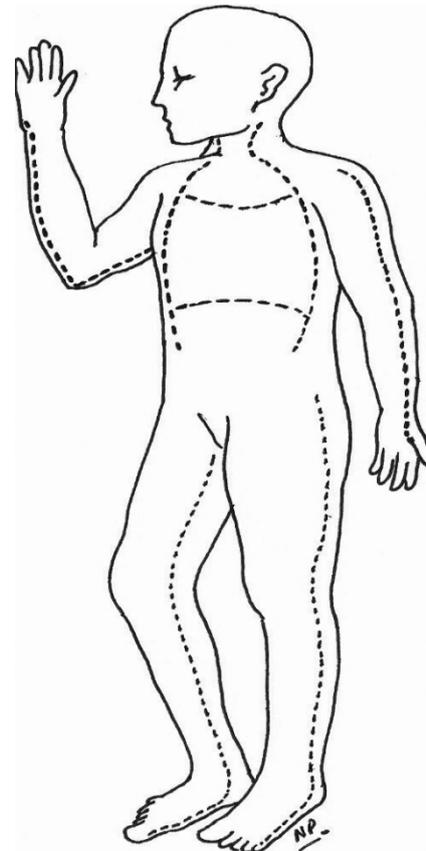
Figur 2: Decision-making algorithm for escharotomy in severely burned extremities. (Neelu Pal, 2009)

Compartment syndrome is a situation where blood supply to one area of the body is cut off. As edema is developing the interstitial tissue increase in size, and is dependent on the surrounding tissues to stretch and expand. Some areas are encapsulated by connective tissue with little ability to stretch, typically the limbs. Burned skin may also have very decreased ability to stretch.

This inability to stretch will lead to an increase in pressure in

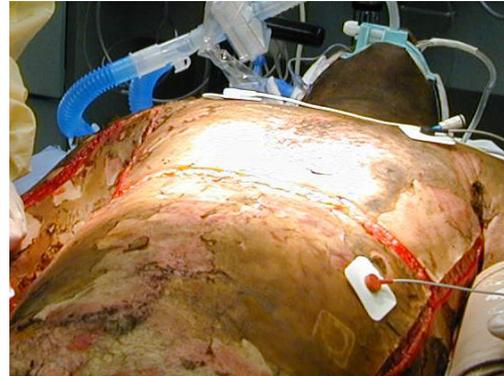
these compartments. When the pressure rises above 30 mmHg blood supply will be interrupted, with devastating consequences. Compartment syndrome can occur in several circumstances like circumferential burns, overhydration of patients with burns, fractures etc.

In localized circumferential burns there is an obvious risk of compartment syndrome of the affected part. In severe burns with general edema there is a risk of developing compartment syndrome of unburned limbs, abdomen and chest.



Figur 3: Diagrammatic representation of escharotomy incisions over the chest, neck, and limbs. (Robert I Oliver Jr, 2009)

Symptoms of compartment syndrome are extreme pain, worse on movement, paraesthesias, cool limb. The pulse of the distal limb/body part may still be palpable, as it isn't lost until the pressure in the compartment exceeds the systolic pressure. In abdominal compartment syndrome the symptoms are increased peak inspiratory pressure, decreased urinary output despite massive fluids, hemodynamic instability and tight abdomen. In chest compartment syndrome the symptom is mainly increased peak inspiratory pressure.



**Figur 4: Escharotomy to release the chest wall and allow for ventilation of the patient. (Neelu Pal, 2009)**

If there is suspicion of compartment syndrome pressures should be measured either by arterial line monitors with the needle placed in the compartment (in limbs), or by a urinary catheter (in abdominal).

The treatment of compartment syndrome is decompression by thoughtfully placed escharotomies. Patients with abdominal compartment syndrome should also be provided with a nasogastric tube, and possibly a peritoneal catheter to drain fluid. Laparotomy is a last resort. Patients with abdominal compartment syndrome have a high mortality (60%) even after surgical decompression (McPhee & Papadakis, 2009).

## Other complications

The general edema may be increased by over-zealous hydration. Consequently pulmonary edema may be worsened, and if there is ARDS there is a risk that this will be more severe than in an optimally hydrated patient. Patients with low cardiac reserves may benefit from a pulmonary artery catheter. Risk of developing infections, like pneumonia, also seems to be increased.

## Protocols

Protocols are attempts to simplify the fluid needs of the patient, they are educated guesses. They help the caregivers estimate the most optimal starting point. A good formula should not only estimate the optimal fluid amount, but it should also be easy to use. Cumbersome formulas with many calculations are less likely to be used consistently; perhaps especially in large disasters where they are of even more value. It is important to remember that the timespan starts from the time of the injury, and not from the moment the patient enters the hospital. Patients sometimes arrive from outlying hospitals, and it is important to obtain information about how much fluid is already given. If the patient is underresuscitated the amount of fluid needed may increase by up to 30% comparing to the estimate made by the Parkland formula (Robert I Oliver Jr, 2009).

Formula	Fluid in First 24 Hours	Crystalloid in Second 24-Hours	Colloid in Second 24-Hours
<b>Parkland</b>	Ringers lactate (RL) at 4 mL/kg per percentage burn	20-60% estimated plasma volume	Titrated to urinary output of 30 mL/h
<b>Evans</b>	NS at 1 mL/kg per percentage burn, 2000 mL D5W*, and colloid at 1 mL/kg per percentage burn	50% of first 24-hour volume plus 2000 mL D5W	50% of first 24-hour volume
<b>Slater</b>	RL at 2 L/24 h plus fresh frozen plasma at 75		

	mL/kg/24 h		
<b>Brooke</b>	RL at 1.5 mL/kg per percentage burn, colloid at 0.5 mL/kg per percentage burn, and 2000 mL D5W	50% of first 24-hour volume plus 2000 mL D5W	50% of first 24-hour volume
<b>Modified Brooke</b>	RL at 2 mL/kg per percentage burn		
<b>MetroHealth (Cleveland)</b>	RL solution with 50 mEq sodium bicarbonate per liter at 4 mL/kg per percentage burn	Half NS titrated to urine output	1 U fresh frozen plasma for each liter of half NS used plus D5W as needed for hypoglycemia
<b>Rule of 10</b>	1. Estimate burn size to the nearest 10. 2. %TBSA × 10 = initial fluid rate in mL/hr (for adult patients weighing 40 kg to 80 kg). 3. For every 10 kg above 80 kg, increase the rate by 100 mL/hr		

## Parkland formula

The Parkland formula was the first formula introduced, and continues to be the most frequently used formula.

The Parkland formula was introduced by Baxter and Shires (Tricklebank, 2009). It is based on infusion of ringers lactate.

The formula is 4 ml per kg bodyweight per % TBSA. The first half of the total amount should be infused during the first 8 hours, and then the rest evenly over the next 16 hours. An extremely large volume of fluid may be required. For example, an injury over 40% of the total body surface area in a 70-kg victim may require 11.2 L in the first 24 hours [4 mL x 40(%) x 70 (kg) = 11,200 mL]. The first 8-hour period is measured from the hour of injury. These guidelines may be inadequate, since

### *Modified Brooke*

1.  $2 \times 70 \times 50 = 7000 \text{ ml}$
2.  $7000/2 = 3500 \text{ ml}$
3.  $3500/8 = \underline{438 \text{ ml/hr}}$

### *Parkland*

1.  $4 \times 70 \times 50 = 14000 \text{ ml}$
2.  $14000/2 = 7000 \text{ ml}$
3.  $7000/8 = \underline{875 \text{ ml/hr}}$

### *Rule of 10*

1.  $50 \times 10 = \underline{500 \text{ ml/hr}}$

Comparison of initial fluid rate calculations for an adult weighing 70 kg with a 50% TBSA burn using the Modified Brooke, Parkland, and rule of 10. (Chung, et al., 2010)

crystalloid solutions alone may be insufficient to restore cardiac preload during the period of burn shock. (McPhee & Papadakis, 2009) It is currently the most commonly used protocol, however its limitations are apparent as most centers modify it (Tricklebank, 2009).

## **Vitamin C**

Oxidant stress is important in the damage made by the inflammatory cascade, and there is a lot of interest in if and how anti-oxidants can be used to decrease the damage. Several studies have been made on the effects of vitamin C in victims of burns (Robert I Oliver Jr, 2009) (Tanaka, Lund, Wiig, Yukioka, Matstuda, & Shimazaki, 1999). One study showed that a high dose (66mg/kg/h) of ascorbic acid during the first 24 hours after the thermal injury significantly reduced the amount of fluid required for resuscitation, and also reduced severity of respiratory dysfunction (Tanaka H, 2000) There is no consensus on the optimal dose of ascorbic acid. Short term a dose of 66mg/kg/h is safe in most patients, but safety in patients with renal failure and patients who are pregnant is less certain (Robert I Oliver Jr, 2009).

### Permissive hypovolemia

A study made in 2007 by Arlati et al. investigated the approach of permissive hypovolaemia. The patients in the (Arlati, Storti, Pradella, Bucci, Vitolo, & Pulici, 2007)

## **Conclusion**

Fluid management in the early phase of resuscitation of patients with burns is complex. To help the caregivers during this phase several different protocols have been made. Apart from improving survival rates directly by being beneficial to the patient, a good protocol should be easy to follow for the caregiver. The principals of therapy are evolving as understanding of the very complex pathophysiology of burn shock is increasing. From basic replacement of

volume deficit and prevention of metabolic acidosis to optimizing the amount of fluid and blunting the effects of the mediators of burn shock.

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