Burn Reconstuction and Rehabilitation

Introduction
The management of burns takes place in **2 phases** (which may overlap). These are the **acute (often life saving) management** and **subsequent reconstruction**. The acute interventions start at the scene of the burn and continue during the resuscitation and later hospital stay. The reconstructive efforts may begin at a very early stage – important if maximal function is to be achieved.

Basic Burn Pathology
The severity of a burn is determined by **the length of exposure** and the **intensity** of the source. Human tissue has a high water content and therefore has a **high heat capacitance** – this mean that it **cools slowly** (much like tomatoes in a grilled cheese and tomato sandwich!!)

There are 3 "zones" in a burn injury which make up a target-like shape :

A. The central **"Zone of coagulation"** which contains irreversibly damaged and non-viable tissue
B. The middle **"Zone of stasis"** which contains marginally viable tissue where changes to the cells and their micro-circulation have occurred. With good burn management some of the tissue in this zone may be salvaged, resulting in a smaller defect.
C. The outer **"Zone of hyperaemia"** which contains viable but oedematous and inflamed tissue.

Basic First Aid
The management of burns **starts at the scene** of the burn. The **source** of the burn should be identified and **controlled** to prevent further injury to the victim and **ensure the safety** of the rescuers. It may also provide clues about **additional injuries**, such as inhalational injury in closed space fires or myocardial injury in electrical burns. If possible, the duration of the burn should be ascertained. The first thing to do after **controlling the source and securing the area** is to begin the **basic life support algorithm**:

- **A is Airway** – inhalational injury and most burns greater than 50% will most likely require intubation at some stage – it is better to intubate earlier, rather than allow the airways to become oedematous, when intubation may be difficult (or impossible). It is important to remember that burn victims may have an **associated cervical spine injury** and should be treated as such (c-spine control when moving etc).

- **B is for Breathing** – significant burns of the chest and abdomen limit chest wall movement and thus impair the ventilation. **Emergency escarotom**y should be undertaken (see later). Humidified oxygen should be administered.

- **C is for Circulation** – massive fluid loss should be expected and fluid administered to keep up with losses. 2 Large-bore peripheral venous access cannulae should be inserted, preferably through non-burned skin. During the **first 24 hours only crystalloid fluids** should be used and **no glucose containing solutions** should be given as the patients often have impaired glucose tolerance due to the metabolic stress response.

  Fluid is calculated according to various formulae, but the **Parkland** (or modified Brooke) formula is the most popular :

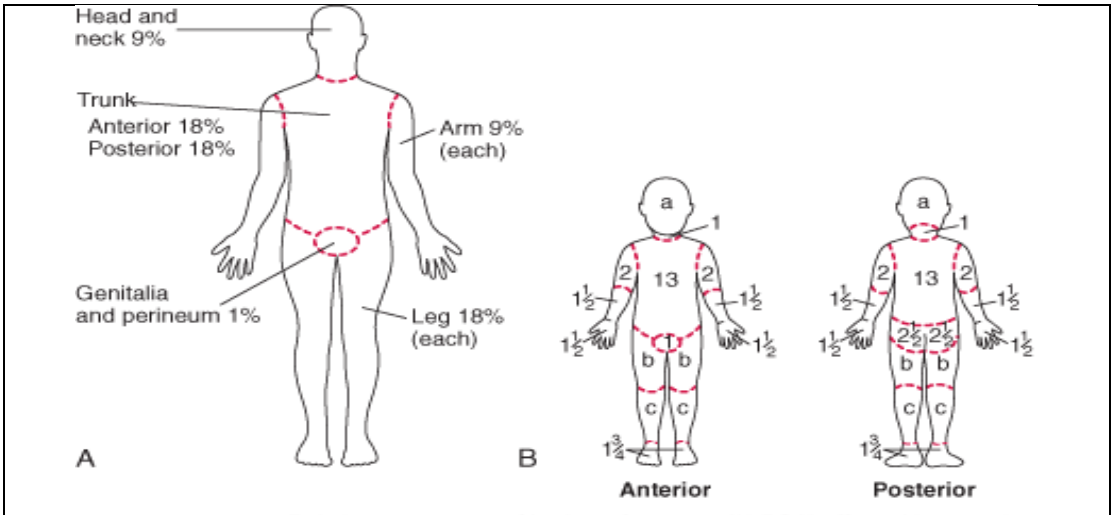
- For the **first 24 hours** :
  - 4ml x patient weight (Kg) x % of Burn
  - For example a 50% burn needs: 4 x 70 x 50 = **14 000ml !!!**
  - Administer Half (7000ml in the example) in the **first 8 hours**
- For the **second 24 hours** :
  - 2ml x weight x % burn

- **D is for Disability**. Preventing further damage to the patient's tissue is critical. Often the ABC's can be rapidly assessed on the scene and this important step undertaken early. **Cooling the tissue is <u>key</u> to limiting the burn** (see the pathology of burns above as to why). As the skin is a heat capacitor, cooling often takes much longer than anticipated – after minor burns at home, **cooling with running tap water** (not ice) for up to 20 minutes is required. [Do NOT apply 'burnshield' until the tissue is sufficiently cooled]. Beware of excessive cooling and the **risk of hypothermia** in massive burns. **Chemicals should be irrigated off** the skin with lots and lots of running tap water. The only exception to this is white phosphorus (which tends to explode on contact with water!) and cause further burns.

After this resuscitation the patient should be stable enough to undertake an extensive search for any associated injuries (**the secondary survey**) – for example cervical spine, and other fractures should be excluded, carbon monoxide poisoning ruled out and inhalation injury diagnosed and managed. At this stage, **an initial assessment** of the **area** and the **depth** of the burns should be undertaken. Due to expansion of the "zone of stasis" the initial assessment **may change significantly** in the following hours to days.

Assessing the Area of the Burn

A good rule of thumb is that the **surface area of the patient's palm** (no fingers) is about **1% of the total** body surface area (TBSA). The **Rule of 9's** (see diagram below) is a useful tool in adult patients, however as children have proportionally larger heads, an age related modification of the rule of 9's is used – this is known as a **Lund & Browder Chart**.



Relative percentage of body surface area (% BSA) affected by growth

	Age				
Body Part	**0 yr**	**1 yr**	**5 yr**	**10 yr**	**15 yr**
a = 1/2 of head	9 1/2	8 1/2	6 1/2	5 1/2	4 1/2
b = 1/2 of 1 thigh	2 3/4	3 1/4	4	4 1/4	4 1/2
c = 1/2 of 1 lower leg	2 1/2	2 1/2	2 3/4	3	3 1/4

Assessing the Depth of a Burn

In the past, the burn depth was classified by degrees. Presently however, to simplify matters, we use a **descriptive classification**, which is more not only easier to remember but provides a guide to management. Remember that the depth of a burn may change depending on the initial management. Burn depth is classified as follows:

- **Superficial thickness**. This is a burn which involves **ONLY the epidermis**. The involved area is **red** and very **painful**, but healing takes place **in 2-5 days**. **No scarring results** from such as burn. An example of this would be a non-blistering sunburn.

- **Partial thickness**. These are burns which involve the **epidermis AND** a variable thickness of the **dermis**. This group is further sub-divided into:
    - **Superficial Partial thickness.** This involves the epidermis and the upper dermis, but the **dermal appendages** (hair follicles, sweat gland etc) are undamaged. Re-epithelialization occurs from the dermal appendages within **3 weeks and minimal scarring results**. Any **blisters** on a burn would indicate a superficial partial thickness burn.
    - **Deep Partial thickness**. These burns involve the **epidermis and a large portion of the dermis** and do not have the ability to re-epithelialize from appendages, but only from the unburned surrounding skin, which takes **weeks to months** and results in **moderate to severe scarring.**
- **Full thickness**. These are burns where the **full thickness of BOTH** dermis and epidermis are irreversibly damaged and **must be replaced** to avoid severe scarring and contactures.

Introduction : Burn Reconstruction

The goals of any reconstructive surgery are two-fold : maximise the patient's **function** and minimize the patient's **disfigurement**. In light of these two aims, the approach to burn reconstruction is ordered by priority:

- Urgent
- Essential
- Desirable

A. Urgent Reconstruction

These are procedures which are undertaken to prevent the loss of life, or major morbidity to the patient. These procedures are often **emergencies** and may be performed shortly after the initial stabilization of the patient. The **role of the trauma surgeon** is central during this phase of the reconstruction. Examples include escharotomy and escharectomy and the **coverage of irreplaceable structures**, such as brain, cornea, nerves and major blood vessels.

- ***Escharotomy*** is the **incision** of thick non-viable skin and subcutaneous tissue which may be **limiting** breathing or causing occlusion of blood flow to a limb. It is **not painful** (the skin is charred and the nerve endings not working) and the cut tissue **does not bleed**. It does not have to be done in theatre.
- ***Escharectomy (or sloughectomy)*** is the **excision** of non-viable burned tissue to healthy tissue with subsequent early graft closure. It is **painful** and often associated with **profuse bleeding** and is thus done in theatre. This is started 2-4 days after the initial stabilization and is done in **multiple stages**, limiting each stage to a maximum of 10% TBSA to prevent **hypothermia and excessive blood loss**. The technique of early

excision and closure is associated with lower wound infection rates, decreasing associated morbidity and improved survival.

Protection or coverage of the other vital structures may involve moisture chambers, or flap cover, depending on the severity and stability of the patient. The **plastic surgeon** is often called to assess the requirement for such procedures.

The treatment of Suppurative Chondritis

Acute bacterial infection of burned ears is very common (Pseudomonas is often the offending organism), when the ear cartilage is denuded of skin. Rapid **destruction of the cartilage** occurs and may be impossible to reconstruct later. A useful modality in the management is **gentamycin iontophoresis**. The basic principle of electricity - that **like charges repel and opposite charges attract** each other (Coloumb's Law) could be used for **local *ionized* drug administration** through tissue borders. Thus, in order to deliver a negatively charged drug, the negative electrode (cathode) is placed on epithelial surface where it is repelled and is attracted towards the positive (anode) one, which is placed elsewhere on the body. For **Gentamycin, which is positively charged**, the positive electrode is placed over the soaked swab or gel on the ear and the negative electrode is placed on the opposite side of the head. This technique allows the **local tissue concentration** to exceed that which may be achieved by intravenous use **without systemic toxicity**.

B. Essential Procedures

These procedures are undertaken to **achieve the goals** mentioned above. Although all members of the burn team are involved in the management of the burned patient during this phase of reconstruction and the role of the allied medical disciplines is critical to success. Such procedures can start as soon as the patient is stable enough (in the correct order of priority though).

The Role of the Allied Medical Disciplines

Physical and occupational therapists play an essential role in the acute management of all burn patients, even those who are critically ill. If a body part is left immobile for a protracted period**, capsular contraction** and **shortening of tendon and muscle groups** that cross the joints occur. This process can occur very rapidly. Passive ROM exercise and anti-deformity splinting can prevent this.

The Role of the Plastic Surgeon

During this phase, there may be large areas of tissue denuded of appropriate cover. The **early** provision of **stable durable cover** goes a long way to the prevention of excessive scarring, fibrosis and contractures. The range of motion, safe position for splintage and the concept of 'aesthetic units' may guide the surgeon in the provision of appropriate cover. Again, the **order of priority** is critical. Areas of exposed bone and tendon or joint surfaces are considered 'hard areas' and often left until other areas are covered – this is a critical management error and can considerably impact on the patient's future reconstruction.

The **replacement of the lost dermis** is key to the **prevention of excessive fibrosis** and scarring, while **the replacement of the lost epidermis** is key to the **prevention of loss of fluid and protein** which increases the metabolic demands of the patient. **Split thickness skin graft** has traditionally been the reconstructive method of choice as it achieved both of the above.

However, recent developments in **tissue engineering** have made both an epidermal and a dermal replacement available.

1. *Bio-engineered Dermis*

So called "**dermal regeneration templates**" comprised of a sheet of porous **bovine collagen** and **chondroitin-6 sulphate** matrix overlaid with a **thin silastic sheet**. It acts as a **scaffold** for dermal regeneration. Its unique action essentially **inhibits granulation** (and subsequent hypertrophic scarring) and promotes the growth of **neo-dermis** through the matrix. The **silicon sheet prevents the loss of fluid and protein** from the wound surface and acts like an epidermal barrier 9it not as effective though). Following application to a freshly excised wound, the collagen layer **is biointegrated** within the wound to form a vascular 'neodermis', a process that takes approximately 3–6 weeks. Once this stage has been reached, the silastic layer can be removed and an **ultrathin split-skin graft applied**. The matrix is poorly resistant to infection and the wound must be clean prior to application. Several such products are available in South Africa, such as Integra, Pelnac and Dermagen. Cost implications are an important drawback to their widespread use.

2. *Bio-engineered Epidermis*

These products consist of a bilaminate membrane of **nylon mesh fabric** bonded to a **thin layer of silicone**. The nylon mesh is **coated with peptides** derived from porcine type I **collagen**, in order to aid adherence to the wound bed and fibrovascular ingrowth. The silicone is semi-permeable. As the wound heals, the **nylon mesh separates**, and can readily be peeled away from the surface. It is **used for superficial partial-thickness burns** (where the epidermis is lost) or as a temporary cover for freshly excised full thickness burns. It is best reserved for clean wounds. When used in this manner, superficial partial thickness burns can be expected to **heal much faster**. There is also **significantly less pain, fluid loss** and metabolic derangement. Two products are available in South Africa, Keragen and Biobrane. As above, cost is their major drawback (a single hand 'glove' of engineered epidermis is R7000).

3. *Autologous Cultured Keratinocytes*

This technology is well established in major burn centres, especially in the USA, but remains in its infancy in South Africa, due to many factors. South African Law prevents the transit of human tissue across our borders and special government permission is required to send a skin biopsy to the Lab in Boston to start the process. The "epidermis" requires 6 weeks to be grown and loaded onto a nylon mesh and packaged for transport. The "epidermis" is then flown back (again requiring special permission) and must be on the patient within 24 hours of leaving the lab and thus requires strenuous theatre co-ordination. Naturally, this is a VERY expensive process and the costs may exceed the million ZAR mark, which is another barrier to general acceptance. Finally, recent bad (and unfounded) publicity relating to this product will hamper its general acceptance as a treatment modality.

C. *Desirable Procedures*

These are procedures which are often undertaken in the late phase of a burn, or electively once the patient has been discharged. It is during this phase when the role of the Plastic Surgeon is most appreciated.

Face : Reconstruction of burned areas takes place within well defined '**aesthetic units'** which allow the placement of scars at natural boundaries to minimise their impact. **Nasal reconstruction** is usually by means of a flap – **the paramedian forehead flap** (the Indian method) is the gold standard, but may not always be available. Prevention and treatment of **burn ectropion of the eyelids** is essential to prevent **corneal dryess and ulcers** which may lead to visual loss later on. **Full thickness skin grafts** from the retro-auricular area usually provide the best colour match. **Reconstruction of the eyebrows** is an underutilized effort but is always greatly appreciated by patients. **Full thickness grafts, flaps and microfollicular grafting** are applicable methods. Recently, an improved tattoo technique, known as "microblading" has shown some exceptionally good results and has become my preferred choice. **Ear reconstruction** in burns is often difficult and may be impossible in some badly burned patients. In these cases, a **prosthetic ear** may be of great value to the patient. Consideration of **an osseo-integrated implant** (with a magnet to hold the ear in place) should be done, as the glue is messy and may melt in the summer heat, leading to poor compliance.

Upper Limb : Late reconstruction is undertaken in **multiple stages** using a **proximal to distal sequence**. The use of flaps, skin grafts and z-plasties are common. In general, it is preferable to prevent upper deformities, than to reconstruct them secondarily. Aggressive ranging and splintage are essential, but occasionally, **kirchner pin fixation** of the joints in a safe position is required. The provision of stable cover is a management priority. In late cases with severe deformities, **arthodesis or amputation** may be offered to the patient. In highly selected cases, the use of **pollicisation** (the use of a finger to make a thumb) or **microvascular toe-to-hand transfers** may be applicable. Extensive rehabilitation following microsurgery is required for functional success.

Oedema Management

Burned and grafted extremities have **lingering oedema** that can contribute to joint stiffness. The use of custom-fitted compressive garments in the early phase is unjustified as they need to be frequently altered. Tubular or circumferential **elastic wraps, elevation**, and retrograde **massage** are useful in extremity oedema.

Scar Management

This is an essential aspect of outpatient burn therapy. **Hypertrophic scarring** is seen in **deep dermal burn**s that are allowed to heal with dressings only. This seems especially true in areas of **highly elastic skin**, such as the lower face, submental triangle, and anterior chest and neck. **The wound hyperemia** that is universally seen following burn wound healing should begin to **resolve approximately 9 weeks** after epithelialisation, increasing redness is a sign of impending hypertrophic scar and is due to increased angiogenesis. A number of methods may be useful to improve the appearance and function of burn scarred tissue. These interventions include scar massage, compression garments, topical silicone, steroid injections, and of course, surgery.

1. **Scar massage**

This can be quite effective in limited areas of scarring and can be performed by either the patient of a family member. This is done **several times** each day as **firm, slow, circular massage**. The pressure need not be excessive – a light blanching is all that is required. The use

of **moisturizing skin emollients** is beneficial in **reducing friction**, protecting the **fragile burned skin and improving the dryness**.

2. **Compression Garments**

Although controversy remains over the issue, experience supports the use of garments to **facilitate control of broad areas of hypertrophic scarring**, particularly in young children in whom this process seems to be more severe. Compression garments should be **worn 23 hours a day** until such time as wound redness subsides, usually **12-18 months after injury**. Growing young children require frequent **refitting** and replacement. Garment fit must be verified after manufacture, as a poorly fitting garment is less effective and can be uncomfortable.

3. **Topical Silicone**

This should be applied to **healed wounds only**. It is available as **sheets** or as a **topical gel**, which dries to a thin film. The **exact mechanism is still uncertain**, but the current theory is that the **prevention of transdermal moisture loss** is the mechanism of action. Silicone sheets can be placed beneath compression garments or can be held in place by a number of elastic devices, however **firm pressure is not required** for the silicone to be effective.

4. **Steroid Injection**

Steroid injection [I use **depo-medrol** (high potency) and celestone-soluspan (moderate potency)] **directly into hypertrophic scars** is effective in many, but not all patients. With high dose steroids, some **hypopigmentation** is inevitable and the steroid injections themselves are **quite painful**. The total dose should be limited **to 80-120mg (2-3 vials)** and can only be **repeated every 4 weeks,** for a period of **6 months**. An alternative which I have found effective in patients not responsive to steroids is to inject verapamil (isopteran) 2.5mg/ml (1 vial, 2ml). Orthostatic hypotension is almost universal and patients should be warned about this.

5. **Pruritis Managment**

Pruritus (itching) is a frequent part of burn wound healing. This typically begins shortly after the wound is healed**, peaks in intensity 4-6 months** after injury, and then gradually subsides in most patients. It can be very **troubling at night**. It may be managed with **massage**, **moisturizer**s, and **oral antihistamines** at night. Topical selective anti-histamine ointment (H1) blocker is reportedly very effective, but was not generally available in South Africa until recently. Lycoderm Labs (pharmacist@lycoderm.co.za) will be able to mix 5% Doxepin on order. Localized highly pruritic scars often respond to a steroid injection.

6. **Laser Scar Remodelling**

This is a new and very exciting development. The use of **fractional, high energy, short pulse carbon dioxide lasers** over the scar has been shown to break up scar tissue, cause remodelling of the collagen to a more normal structure and improve skin texture. The exact mechanism is not well understood but the elaboration of Heat-Shock Proteins (HSPs) following the laser burn may be a key cytokine. The International Scar Symposium was recently held in South Africa and I privileged to be a speaker at this event. What was apparent to me was that the amazing results that have been shown are the result of both exceptional new technology as well as operator dependant skill in the use of these lasers – clearly expert skill is more critical to success.

Prosthetics

Not all burn wounds can be reconstructed. Sometimes the damage is too extensive and all described options are unavailable. Prosthetic "reconstruction" with wigs, hair-pieces, moulded

noses, ears, cheeks and hands have given these disfigured patients the ability to engage with others to variable degrees. Prosthetics can be fixed in place with glue (melts in the heat), magnetized to osseo-integrated implants or fixed to spectacles. The skill of the prosthetist in matching colour and texture is essential to compliant use of the prosthetic.

Conclusion

Historically, the goal of the burn team was survival, however presently the ultimate goal of all burn care is **reintegration**. Burn care does not stop with wound closure. Ideally, the patient should be returned to their family and community. This may not be possible and special needs groups and "burn camps" may provide a much needed starting block for burn survivors. Successful burn care requires hard work by a focused multidisciplinary team over the continuum of care, from resuscitation through reconstruction, rehabilitation, and reintegration.