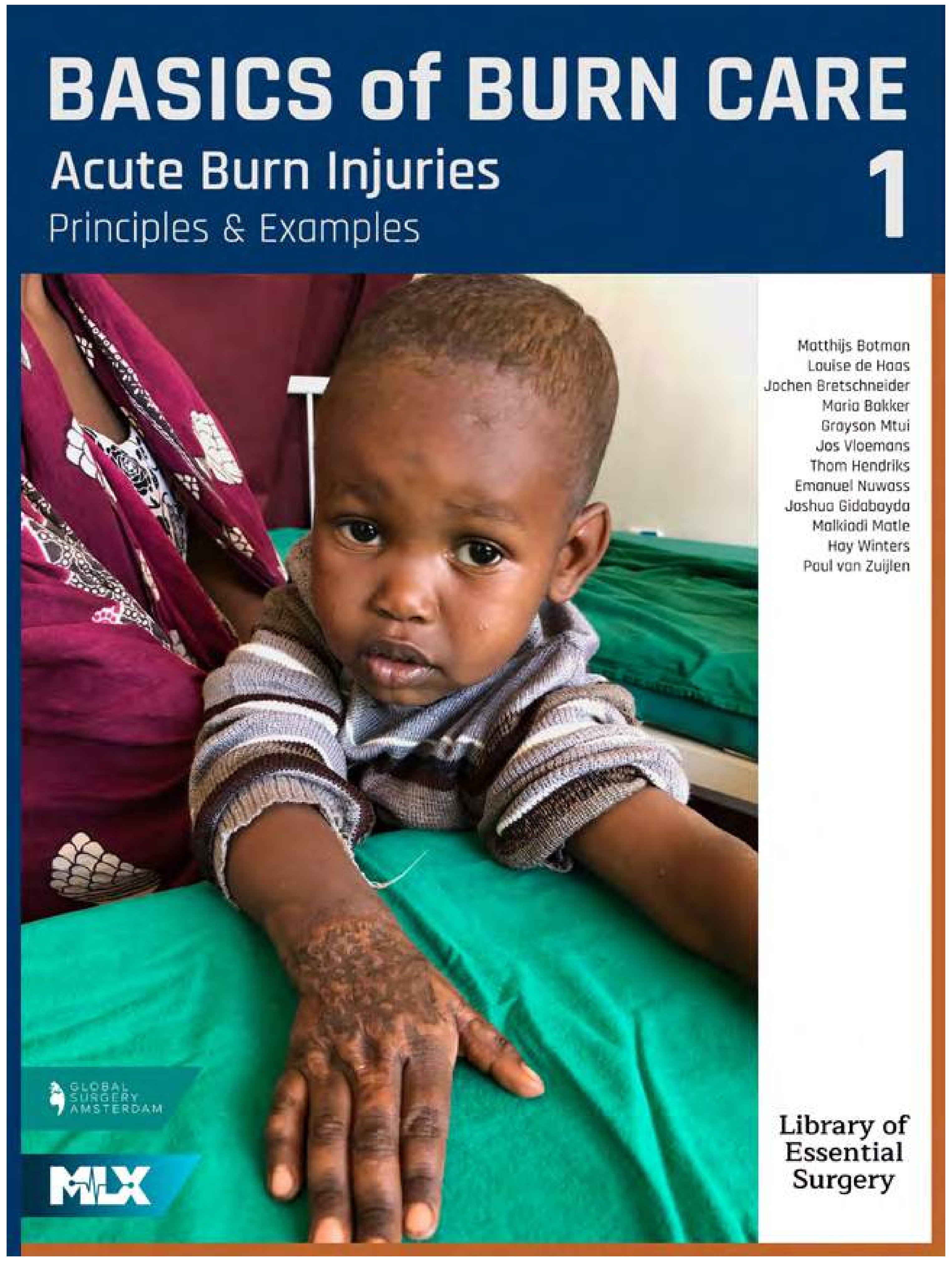

Amsterdam | October 2022,
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BASICS of BURN CARE

Acute Burn Injuries

PROJECT TEAM

M. Botman, L. de Haas, G. Mtui, M. Bakker, J. Bretschneider

GLOBAL SURGERY AMSTERDAM

Haydom Lutheran Hospital

Dutch Burns Foundation

Like a book, unlike a book

The eBook is an interactive document. Interactive buttons give additional information or offer options to test the knowledge gained by reading through the eBook.

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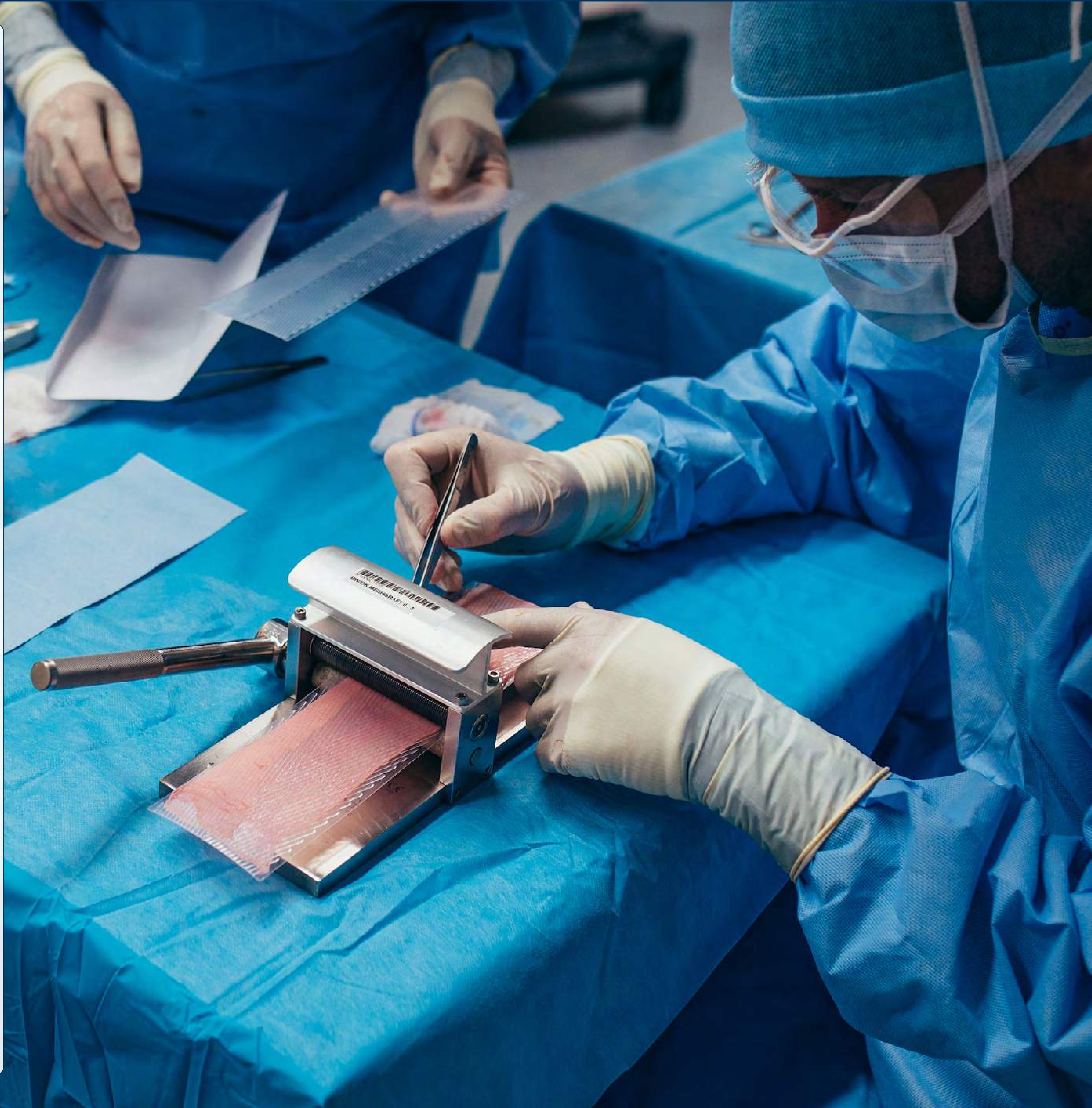

Preface

‘Worldwide, 5 billion people are lacking safe surgical care and as an important solution to this problem it has been calculated that at least 2 million health workers need to be trained. Burn injuries are among the most common and devastating of all injuries.

Access to safe and effective surgical care is essential to minimize morbidity and mortality for patients with severe burns. The vast majority of burns occur in low- and middle-income countries, but the best-equipped burn centers, as well as most of the trained health care workers, are located in high-income countries.

The initiators of this project are from the Netherlands and Tanzania and have been working in resource-limited settings to improve burn care by providing training in burn care for health care workers. It was realized that the impact of training would be much bigger if essential information on the treatment of burns and contractures would be easily available, all-year-round.

Experiences in the field showed that teaching materials were most effective when delivered with visual examples that include the perspectives of both health care workers and patients in their own setting.

This challenged us to come up with a fit for purpose solution: the development of two eBooks:

BASICS OF BURN CARE 1
ACUTE BURN INJURIES

BASICS OF BURN CARE 2
SCARS AND CONTRACTURES

In doing so, we were inspired by the principle of ‘One World, One Standard of Burn Care’, proclaimed by Dr. David Mackie during his chairmanship of the International Society for Burn Injuries (2012-2016). The principles of burn care are the same all over the world, only the situations differ: ‘Think Global, Act Local’. The eBooks deal with the basic principles of the treatment of burn injuries, whether the setting is resource-limited or not.

The eBooks have been developed in collaboration with contributors from different settings and with different backgrounds. They provided the opportunity to show practical examples from Tanzania, the Netherlands, Sierra Leone and Bangladesh.

We are very thankful to everyone who supported this project. In particular, we would like to express our gratitude to all the patients who allowed us to show the treatment of their burn injuries as an example for health care workers to learn from, in order to improve the treatment for other patients in the future.

On behalf of the editorial team,

Matthijs Botman

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Colophon

ETHICAL GUIDELINES

The Basics of Burn Care Project is a joint effort between hospitals, researchers and clinicians working in burn care. The project aims to improve healthcare for all patients with burn injuries around the world. One of the purposes of the project is to provide interactive educational resources that are globally accessible to all paramedics, doctors, and surgeons. To achieve these goals, the parties involved have jointly developed an eBook, called 'Basics of Burn Care'. This book contains medical information, case examples, pictures, and videos about the treatment of burns. When publishing this information, the privacy rights and copyrights of patients have been respected.

In addition, the following principles were considered when publishing the eBook.

1. The authors of the book have used anonymized data as much as possible.
2. Photos and videos identifying patients have been used only to the extent necessary for educational or scientific purposes.
3. Patients who participated in the project or whose data, photos or videos were used were always asked for permission in advance.
4. Patients can withdraw their consent for publication at any time. This can be done by sending an email to info@globalsurgeryamsterdam.com

DISCLAIMER

 The content has been carefully created by the authors.

This eBook should not be interpreted as a replacement for (local) guidelines under any circumstances, but is solely for medical education. In the rapidly changing landscape of medicine changes in treatment are required, therefore the content is in accordance with the standards and information at the time of publishing. However, due to these changes the authors do not warrant that the information contained herein is accurate or complete and disclaim all responsibility for any errors or omissions for results attained by using the content of this eBook.

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Photo by M. Botman

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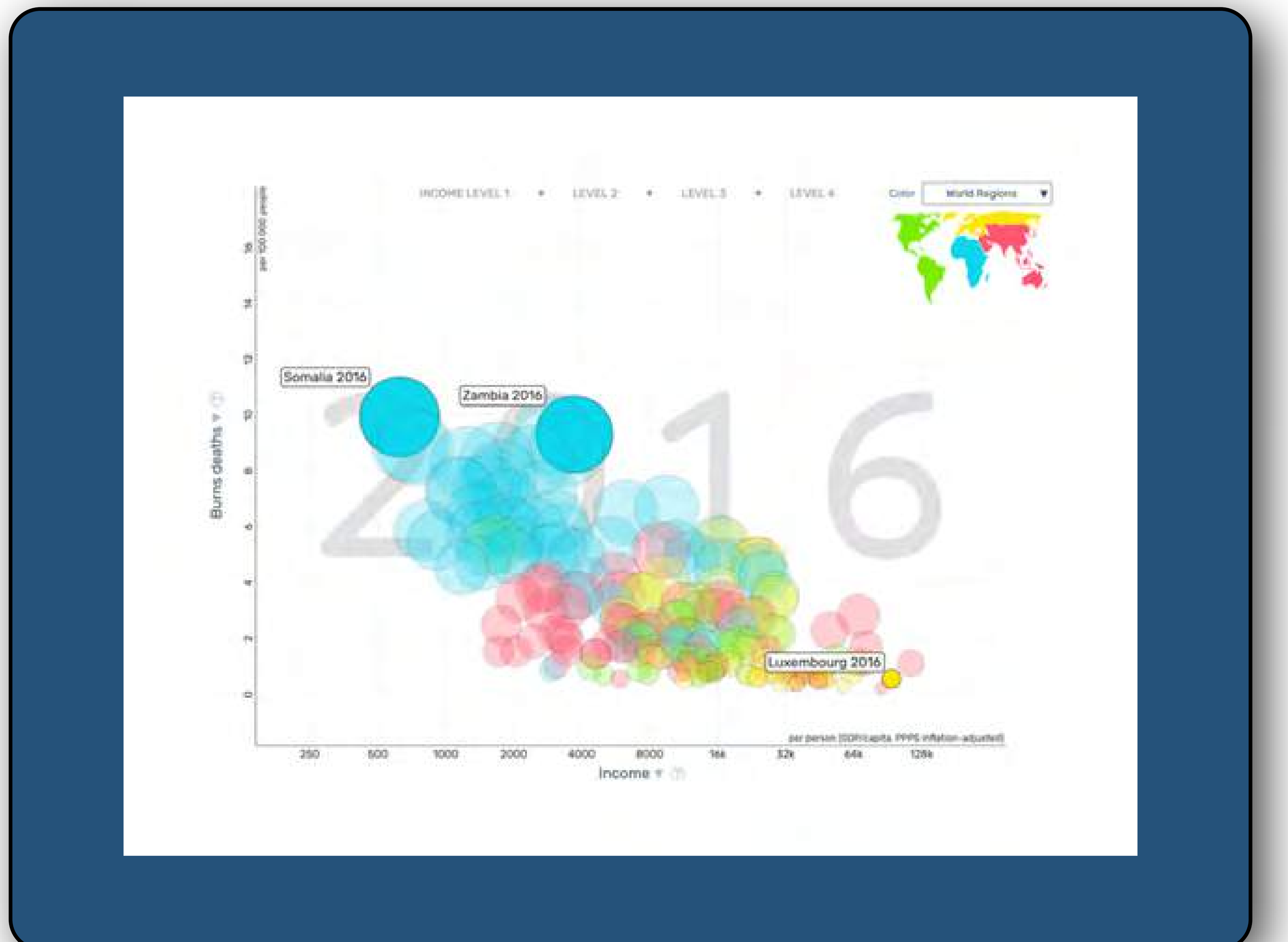


Burn injuries worldwide in 2016
Source: Gapminder.org

Burn injuries are a major global health problem that rank in the top 15 leading contributors to the burden of disease.

Worldwide, the rate of child burn deaths is 2.5 per 100,000 across 103 countries, with the highest rate in Sub-Saharan Africa (4.5 per 100,000). Data on the mortality rate for boys under five due to burns in Dar es Salaam in Tanzania shows even a number of 17 per 100,000. Over the past few decades, burn-related mortality in high-income countries has decreased.

However, burns still account for an estimated 180,000 deaths annually, and are among the leading causes of disability-adjusted lifeyears in low- and middle-income countries (LMIC), where approximately 90% of burn injuries occur. According to the WHO, nearly 11 million people worldwide were burned severely enough to require medical attention in 2004.

In LMICs, children are the demographic most at risk of burn injury. Children aged 10 years and below represented over 80% of the burn patient population, with children younger than 5 years of age at highest risk.

Scalds appear to be the most common type of injury and affect mainly boys. Adults sustain mostly flame burns. The most commonly affected areas for all ages are the upper extremities and trunk. Overall, most burn injuries are sustained in the home, particularly in the kitchen.

While most burns are unintentional, non-accidental injury is not uncommon. Children and the elderly are particularly vulnerable to non-accidental burns.

Patients with co-morbidities, such as blindness, deafness and epilepsy, have a greater risk of burn injuries. Epilepsy is often untreated in LMICs, resulting in a high number of epileptic seizures, making these patients exceedingly vulnerable to burn injuries.

Burn survivors have the burden of temporary or permanent disability and economic hardship, for both the victim and the family. A good understanding of the epidemiology is essential in order to direct burn prevention programs.

Pathophysiology

Understanding the pathophysiology of burns is essential to provide adequate treatment. Timely and effective emergency care of the burned patient can promote wound healing.

LOCAL RESPONSE

Burns are complex wounds. The direct effect of heat on the tissue causes coagulation of cellular proteins. Furthermore, the reaction of the body influences the circulation in the wound and surrounding area. For a better understanding of the pathophysiology of burn wounds, Jackson developed a wound model that describes three zones of tissue injury.

The Jackson Model of Burns

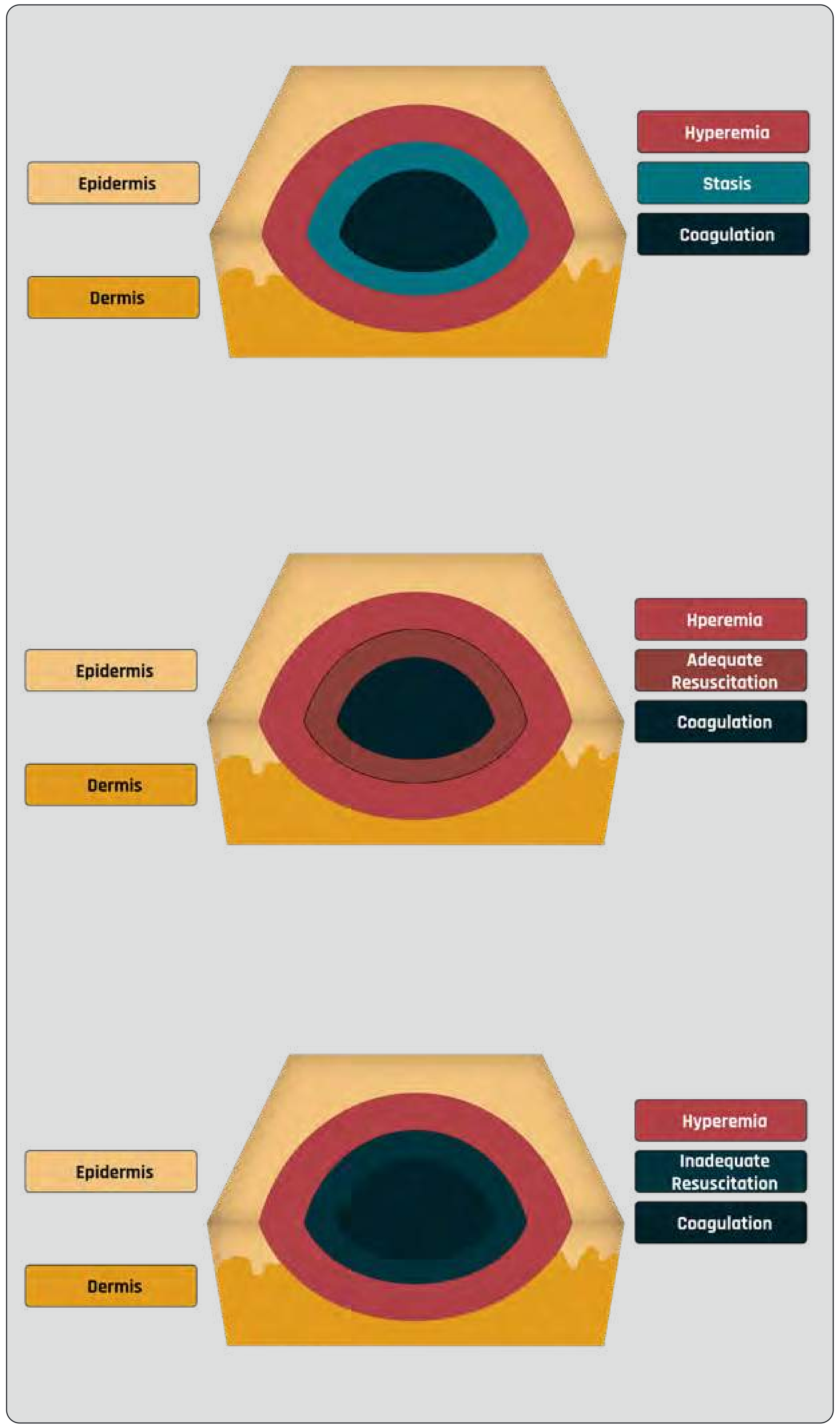
The '**Zone of Coagulation**' is the area of maximum damage. This zone has irreversible tissue necrosis caused by the direct effect of heat. Proteins become denatured and cell death is imminent, due to destruction of blood vessels resulting in ischemia of this area. The extent of this zone is mostly dependent on the temperature of the heat source and the duration of exposure.

Surrounding this central zone of necrosis is a '**Zone of Stasis**', with a reduction of blood flow that may lead to ischemia. The circulation of the skin and subcutaneous tissue is compromised. This zone may progress to full necrosis unless the ischemia is reversed. In the case of inadequate resuscitation, the ischemia will worsen and therefore the burn depth will increase.

Beware that even if burn resuscitation is performed adequately and areas of the burn appear viable initially, burn depth may increase and tissue may become necrotic three to five days after the burning, even when acute wound care is performed adequately (i.e. elevation of the affected extremities and performing escharotomy when indicated).

The '**Zone of Hyperemia**' is the area surrounding the zone of stasis. Inflammatory mediators such as histamine, serotonin, prostaglandins and bradykinin are produced in this zone. These mediators affect vascular integrity and thereby cause increased permeability of the blood vessels leading to edema.

The tissues of this area eventually return to normal. The zone of hyperemia may involve the whole body in major burns (i.e. adults with a Total Body Surface Area (TBSA) burned >20% and children with a TBSA burned >15%).



Local response Jackson model

SYSTEMIC RESPONSE

The skin is the largest organ of the body and chemically, thermally, biologically and mechanically isolates the interior from the outside environment. These functions are affected by burn injury, which causes a release of inflammatory mediators and neural stimulation.

Aside from local effects, general effects occur in large burns (>15% TBSA burned). These effects are often clinically significant.

The following effects may occur in large burns:

1. **The circulation** is affected due to loss of water, electrolytes and proteins (mainly albumin), causing increased vascular permeability. This results in hypovolemia and the formation of edema. Correction of hypovolemia during the shock phase may be life saving in the first hours after the burn.

2. **A hypermetabolic response** characterized by tachycardia, hypertension, peripheral insulin resistance and increased protein and lipid catabolism. This leads to an increased resting energy expenditure, hyperthermia, total body protein wasting, muscle wasting and stimulated synthesis of acute-phase proteins (e.g. cortisol, catecholamines and glucagon).

3. **Immunosuppression** increases the risk of infection due to depression of the immune mechanism.

4. **Impairment of barrier function** of the gut leads to translocation of bacteria. Early enteral feeding can prevent this.

5. **Systemic inflammatory response** affects the lungs resulting in Acute Respiratory Distress Syndrome (ARDS), even in the absence of inhalation injury.

6. **Long-term growth changes** in children may occur due to an increased central deposition of fat, decreased muscle growth, decreased bone mineralization, and decreased longitudinal growth of the body.

Etiology

The mechanism of injury varies with the age of the patient. Burns occur mainly at home and at work.

THERMAL BURNS

Fire

Fire injuries can be divided into flame and flash burns. A common cause of fire injury is clothes catching fire. There is a risk of inhalation injury due to inhalation of smoke. The hot air may cause edema of the larynx which may cause laryngeal obstruction. When fire occurs in a closed room, there is a risk of carbon monoxide intoxication due to inhaled toxins that can enter the bloodstream.

Flash burns

Flash burns are caused by exposure to a high temperature for a short period of time. Mostly the hands and face are affected. Due to the short duration of exposure, flash burns seldom cause an inhalation injury.

Scalds

Scalds are caused by hot liquid or steam. Scalds are the most common cause of burn injury in young children.

Burn wound depth depends on many factors:

- the temperature, the type and the amount of liquid
- duration of exposure

Hot oil and fat

Burns caused by fat are mainly the result of domestic accidents. The temperature of boiling water is 100 degrees Celsius, whereas the processing temperature of cooking fat or oil is 190 degrees Celsius. Although the heat capacity of fat is lower than water, burn depth may be as severe or even more severe.

Contact

A contact burn is caused by touching a hot, solid object. The burn depth is dependent on the temperature of the agent, the duration of contact and the pressure exerted on the skin. Young children and the elderly are more at risk of deeper contact burns. Deep contact burns should also raise suspicion of non-accidental injury.

CHEMICAL BURNS

Chemical burns differ from thermal injury and are less common, but may cause deep burn wounds.

Chemical burns are caused by exposure to:

- Household chemical products (Drain cleaners (Caustic soda), disinfectants (phenols), toilet bowl cleaners (sulphuric acid)).
- Industrial chemical products (Alkalis, acids, cement (lime)).
- Products used in the military (Phosphorus and vesicants)

History taking is most important. The depth of the burn depends on the type of chemical, concentration and duration of exposure. Different types of chemicals have different impacts on the skin. Acids produce coagulative necrosis, alkalis produce liquefactive necrosis and vesicants produce ischaemic and anoxic necrosis. The impact on the skin continues as long as the agent is not completely removed, inactivated, or sufficiently diluted.

ELECTRICAL BURNS

Electrical injury is a physiological reaction caused by electric current passing through the body. Electricity transforms into heat as it flows through body tissue. Therefore, electrical burns can produce not only tissue damage, but also organ damage (e.g. abnormal heart rhythm, muscle weakness, rhabdomyolysis, and kidney dysfunction). Injuries may occur with or without direct contact to the power source. A flash burn caused by a high voltage injury is an example of electrical injury without contact to the power source, and results in a burn of varying degrees, dependent upon the amperage. The depth of electrical burns depends on voltage, duration of exposure and pathway of the flow. Electrical injuries are divided into three groups:

Low voltage injury

Anything below 1,000 volts, from alternating current (AC) (e.g. household electrical supply) or direct current (DC) (e.g car battery).

Domestic low voltage injury is caused by 220-230V AC. When a circuit breaker is installed, the power is switched off instantly in case of a short circuit, before any damage to the skin or heart. If a circuit breaker is not installed, the power will not be switched off. Because of the alternating current, muscle spasm may prolong the duration of contact. At the entrance and exit sites, this may result in deep skin lesions and the victim may complain of muscle pain.

Furthermore, a common type of thermal injury by electricity is the flash burn which occurs when a person causes a short circuit. Direct contact with the source of electricity is not necessary for this burn. The severity of the injury is dependent upon the distance from the source and the amperage.

High voltage injury

Anything above 1,000 volts. Different types of burns can be distinguished.

Flash burns appear in body areas not covered by clothes as dermal and subdermal burns.

Heat radiation caused by the electric arch may cause direct burns to the skin and may also ignite clothing, resulting in full thickness burns.

Wounds at the entrance and exit site are always full thickness. When an entrance wound is obvious during prior examination, other parts of the body must be examined for exit wounds. If contact with the earth was over a large surface, exit wounds may be absent.

In between these sites, mainly in the limbs, extensive soft tissue necrosis may be present underneath normal skin. This manifests itself in a swollen and tense limb and resembles a compartment syndrome of a crush lesion. The victim complains of deep pain and tenderness. On investigation the limb is very tense and painful upon palpation, and signs of decreased circulation may appear. Soft tissue necrosis leads to the production of the breakdown products of myoglobin and hemoglobin. These substances can cause renal failure. ECG and full blood, including renal function tests, must take place.

Lightning

Lightning is high in voltage and amperage over a very short time period. A person can be directly struck by lightning, or through another object.

RADIATION INJURY

The most common type of radiation injury is sunburn caused by UV radiation. This type of injury can also be caused by ionizing radiation (e.g. gamma rays) or radio frequency energy.

FROSTBITE

Frostbite is a freezing injury, often affecting peripheral body parts. The duration of exposure to environmental conditions (such as temperature and wind), combined with risk factors such as vascular impairment will determine the severity of the injury. Ischemia caused by freezing may result in tissue loss. This may require amputation of affected body parts in the later stages, causing loss of function. Other long-term effects of freezing injury are cold sensitivity, sensory loss, hyperhidrosis and chronic pain. Although the pathophysiology of frostbite differs from burn injury, certain (surgical) principles overlap with the treatment of burn wounds.

Principles of wound healing

Burn wounds differ in some aspects from other wounds. Traumatic wounds are mostly challenging due to the risk of excessive blood loss, infection and damage to nerves, vasculature and underlying organs. Burn wounds require different treatment regimes because of different etiological agents and mechanisms of injury, and therefore have a different pathophysiology. In extensive burn injuries, the increased capillary permeability and subsequent loss of plasma from the circulation leads to hypovolemic shock if no proper treatment is administered.

Furthermore, loss of barrier function of the damaged skin and a compromised immune system increases the risk of infection, bacteremia and sepsis.

Moreover, the presence of eschar is another difference that causes topical treatments used in traumatic wounds to be ineffective for the treatment of (deep) burns, which demand the use of other dressing agents and topical creams.

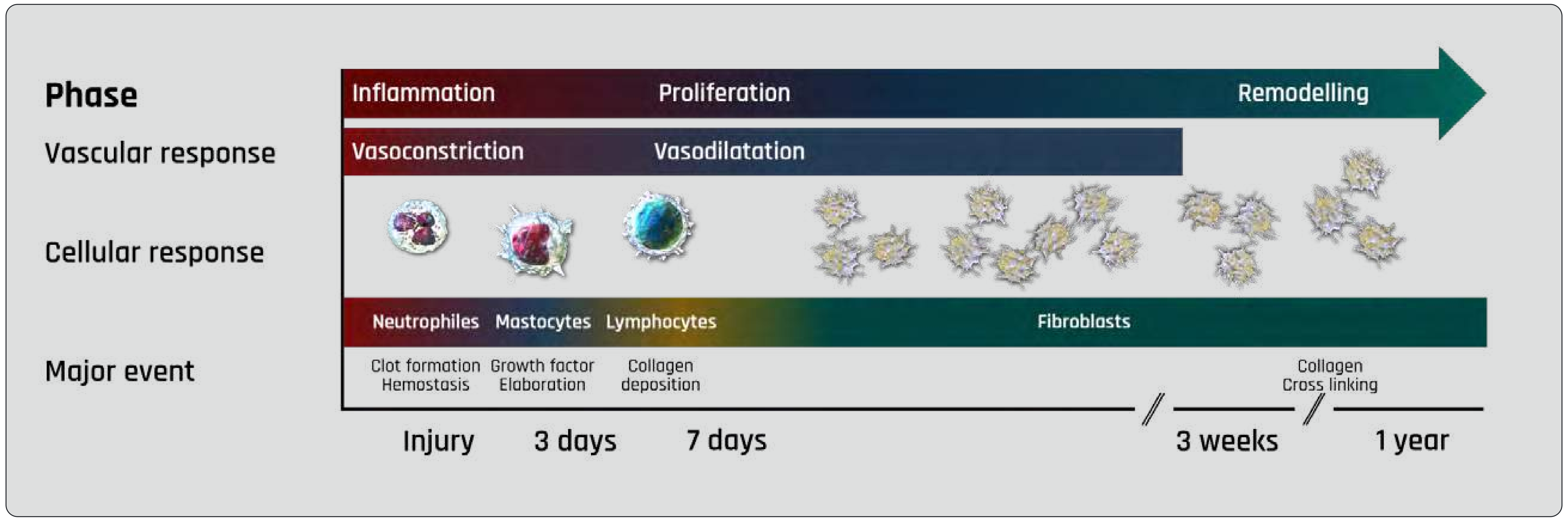
Nevertheless, healing of all wounds is a dynamic process that takes place in three main phases:

1. INFLAMMATORY PHASE
Time of injury to day 4. Key components of this phase are increased vasodilatation and fluid extravasation. Neutrophils and monocytes infiltrate the site of injury, initiating an immune response. This immune response is sustained by the recruitment of macrophages by cytokines. The main goals of this phase are to prevent infection during healing, to degrade necrotic tissue and to activate signals required for wound repair.

In chronic wounds, normal healing progression usually becomes arrested in the inflammatory stage. The presence of necrotic tissue, foreign material, and bacteria result in the abnormal production of matrix metalloproteases, which alter the balance of inflammation and impair the function of the cytokines.

2. PROLIFERATIVE PHASE
Day 4 to week 2-6. Keratinocytes and fibroblasts are activated by cytokines and growth factors. Keratinocytes migrate over the wound to restore the vascular network and assist closure. Fibroblasts produce collagen that deposits in the wound.

3. REMODELLING PHASE
Up to 18 months after wound closure. Collagen in the wound matures and strengthens.



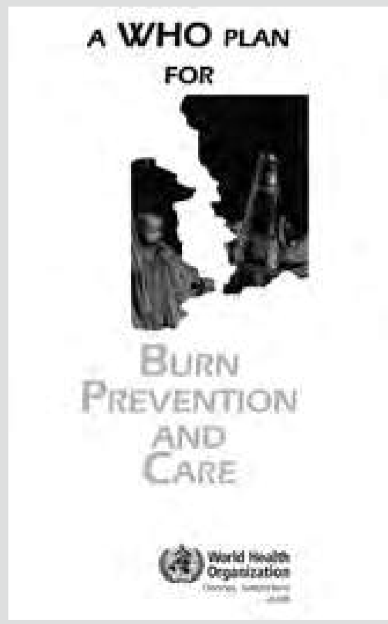
Wound healing

Prevention of burn injury

Prevention is the key. The best way to treat a burn is to prevent it from happening in the first place. There are a number of prevention strategies and recommendations for adults and children that effectively reduce burn risk.

The most important recommendations for children include the need for supervision of children's activities by adults in the presence of open fire, and educating children about the dangers of fire, electricity, steam, chemicals, hot fluids and oils.

The most important other general recommendations, as formulated by the WHO, include limitation of exposure to and use of open fires, and making sure that open fires are placed in the corner instead of a central area.



WHO document

Download possible

Evaluation & management

First aid – administered by a layperson

For first aid care of burns, the following advice should be adhered to:

1. Ensure that you have secured your own safety.

2. Then you may begin to apply the two main principles of first aid.
   These are:
   - stop the burning process
   - cool the burn by running lukewarm water over it

FLAME BURNS, SCALDS AND CONTACT BURNS
For ongoing flame burns, help the patient to “stop, drop, cover (face) and roll” in order to smother the flames. If available, use a fire blanket to assist with this.

For the immediate care of flame burns, scalds and contact burns, working from head to toe, remove any hot or charred clothing and jewellery as quickly as possible.

Ensure the burned surface area is cooled for 10 minutes by running lukewarm (15-30°C) water over the burn. Cold water causes vasoconstriction and may deepen the burn, however, if lukewarm water is not available, cold water is a better alternative to cool the affected area than no cooling at all. Cooling is effective for one hour after the burn. Following this, it is important to keep the victim warm to prevent hypothermia, especially in children.

COOLING BLANKETS
Cooling blankets may be used as a water substitute and are effective in directly cooling the burn at the accident site, when water is not readily available. However, these have the potential to cause hypothermia, especially in children, so should only be used at the site of the accident and during transport to the hospital.

Have you secured your own safety?

Only then should you start to stop the burning process and help the patient.

CHEMICAL BURNS
In order to treat chemical burns, firstly ensure your own safety and protection against the chemicals by using personal protective equipment, if available. This includes gloves, an apron, a protective face-mask and overalls. Then, remove all contaminated clothing as quickly as possible and brush or dry the chemicals off the patient using any suitable instrument, for example a towel or brush. Most chemical burns must be irrigated with copious amounts of lukewarm (15-30°C), running water, for 60 minutes.

The exceptions to this are:

- elemental sodium
- potassium
- lithium

Irrigating these with water can result in a chemical reaction that generates heat, worsening the burn. Therefore, for these 3 exceptions, soak the burn with mineral oil while waiting for medical attention.
Some chemical agents that can cause burns require specific treatments. One example is **hydrofluoric acid burns** that must be neutralised with a calcium-gluconate gel, if available. Additionally, burns caused by **bitumen** are contact burns and must be cooled for at least 10 minutes. Burns caused by **alkalis** require a longer period of extensive irrigation (>1 hour) in order to remove the chemical particles and keep the wound wet.

ELECTRICAL BURNS
For the immediate treatment of electrical burns, first turn off the power source before touching the patient. Then, remove all clothing and jewellery as quickly as possible and ensure that the burned area is cooled for 10 minutes with lukewarm (15-30°C), running water.
Ask for specialized medical assistance as soon as possible when needed.

On scene aid and emergency care – administered by a paramedic or physician

When administering emergency care at an accident site, the following first aid advice should be adhered to:

1. Before doing anything, secure your own safety
2. Then assess the patient using the ABCD method
3. Begin to apply the two main principles of first aid. These are:
   - stop the burning process.
   - cool the burn by running lukewarm water over it

For guidelines on the immediate care of specific types of burns, see previous page.

As paramedic or physician, perform an initial evaluation of the patient by using a systematic approach that involves both a primary and secondary survey, as described by the ISBI guidelines.

If a patient meets one of the referral criteria, ensure an early consultation with a burn centre, if possible.

Referral indications may differ by country and this is only applicable when a country has a burn centre available. This order of assessment is designed to ensure that the most life-threatening issues are treated first, and it is imperative to not be distracted from these by the obvious burn injury.

For any further treatment, accurate documentation is essential.

Evaluation and management at the emergency room

GENERAL INFORMATION

In order to treat burns at the emergency room, firstly start the initial evaluation of the patient by assessing the patient according to the ABCDEF method (**primary survey**). The entire evaluation should use a systematic approach involving both a primary and secondary survey, as described by the ISBI guidelines. This order of assessment is designed to ensure that the most life-threatening issues are treated first and it is imperative to not be distracted from these by the obvious burn injury.

The step-by-step appraoch will be described in the chapters ‘Primary survey’ and ‘Secondary survey’.

If a patient meets one of the referral criteria, ensure an early consultation with a burn centre. **Referral indications** may differ by country and this is only applicable when a country has a burn centre available.

ABCDE

Treat first what kills first

The primary survey

Immediate evaluation for patients with burns starts with the primary survey. This chapter focuses on the evaluation and management of adult patients. For pediatric patients, information is provided in another chapter.

Airway

The airway must be maintained while protecting the cervical spine.

Firstly, check that the airway is patent and free of any obstruction, indicated if the patient is able to speak.

However, if the patient is unable to speak then the airway must be secured. The onset of symptoms of inhalation injury may be delayed therefore it is important to pay attention to re-evaluation of the airway.

Then check for cervical spine injury. Injuries proximal to the clavicle are often associated with cervical spine injury, such as those caused by loss of consciousness and facial wounds. In the case of a suspected injury to the cervical spine, or where the mechanism of trauma is unknown, ensure that the cervical spine is stabilized.

Breathing & ventilation

The principles of look, listen, feel are applied here.

LOOK

LISTEN

FEEL

- **Look** by fully exposing the chest to assess the symmetry of the chest wall motion and the position of the trachea. The respiratory rate should also be measured, with a respiratory rate of <10 breaths per minute or >30 breaths per minute being a cause for concern.
- **Listen** for stridor and assess bilateral air movement, crepitus and rhonchi by auscultating the lungs.
- **Feel** by palpating the chest for pain and subcutaneous emphysema.

All major trauma patients should receive at least 15L of oxygen per minute. Pulse oximeter should be used to monitor oxygen levels. If 15 L is not available, supply the maximum amount that is available. If breathing is insufficient, assist ventilation by using a bag valve mask or intubate the patient. Any (semi-) circumferential burns on the trunk or neck that may impair respiration should be identified. In the case of circumferential burns of the trunk or neck, a rapid bedside escharotomy should be performed.

The patient should also be assessed for signs of carbon monoxide (CO) poisoning and this should be suspected in a patient with cherry pink mucous membranes with an altered level of consciousness. The oxygen saturation level measured is >95%, so this can not be used to monitor the saturation level in the blood. If this occurs, determine carboxyhemoglobin levels and administer 100% oxygen to the patient until carboxyhemoglobin levels are normalized. Be aware that CO poisoning can lead to hypoxemia.

Circulation

HEART RATE
To assess circulation, measure the heart rate. If the heart rate is >120 bpm, there are 3 causes that should be suspected.

- The first of these is **shock** and in this case insert 2 large bore IV lines and use boluses of Ringer's solution to obtain a radial pulse.
- Secondly, **other trauma** should be suspected which the patient should be evaluated for.
- Third and finally, inadequate **pain** management should be suspected and analgesia optimised according to the WHO pain ladder. Most burn injuries are extremely painful therefore the need for administration of intravenous strong opioids should be evaluated early on. If strong opioids are not available, reach out to the local protocols to find the most adequate alternative medication.

BLOOD PRESSURE
Blood pressure should also be measured. If the arterial blood pressure (BP) <90mmHg, shock should be suspected and the BP checked in relation to the pulse rate, with fluid resuscitation using boluses of Ringer's solution considered. The central capillary refill (CR) and the peripheral CR (all extremities) should also be assessed.

For circumferential burns on extremities, use the other corresponding limb for comparison and an escharotomy may be needed.

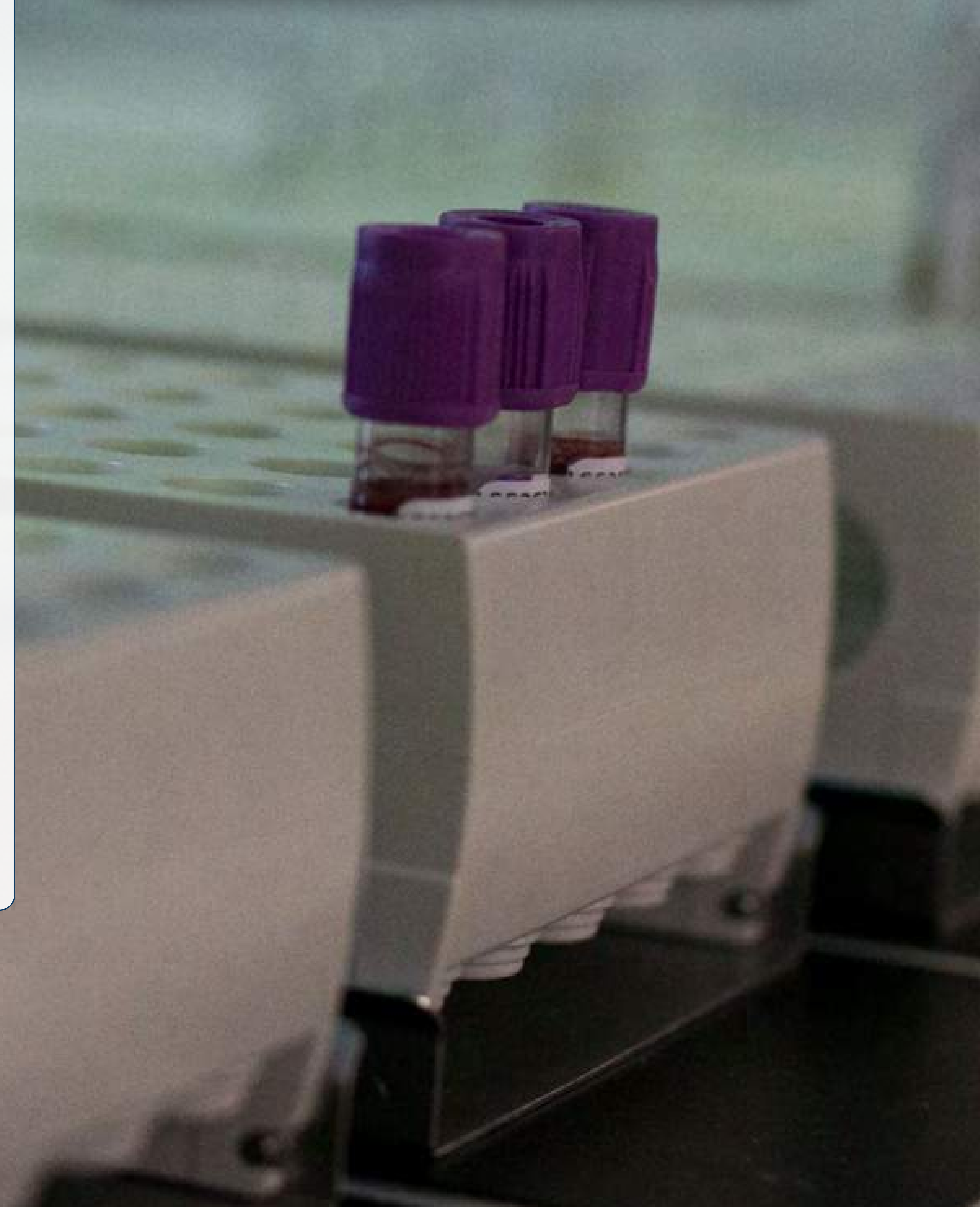
BLOOD TESTS
Blood must be taken by inserting 2 large bore IV lines. This should then be analysed for the following:

- Full blood count
- Urea, creatinine and electrolytes
- Liver function tests
- Coagulation factors
- Carboxyhemoglobin levels and/or toxicology tests if indicated
- Blood type and cross match.

Any bleeding must be stopped by applying direct pressure and the patient must be assessed for any early clinical signs of shock, for example anxiety; pale, cool and clammy skin; rapid breathing; and mental obtundation. Appearance of clinical signs of shock in burn patients is usually due to a cause other than the burn. It is important to note that pallor occurs with loss of 30% of blood volume and mental obtundation with loss of 50% of blood volume.

HEART RATE > 120BPM

Shock?
Other trauma?
Pain?



Disability, neurological deficits & gross deformity

Evaluate the mental status of the patient using the Glasgow coma scale and examine the pupillary light responses. The pupils should be equal, round and reactive to light and a Glasgow Coma Scale score of <8 is an indication for intubation. An alteration in mental status may be caused by CO-poisoning, cyanide intoxication, hypoxia, hypovolaemia, hypoglycemia or head trauma. I

Exposure & environmental control

Remove all clothing from the patient including nappies, jewellery, contact lenses and any other accessories, to prevent a tourniquet effect. Then perform a **head to toe examination** of the patient for associated injuries. In order to visualize the posterior surface, log roll the patient. As burn patients are at risk of hypothermia, check the **body temperature** and ensure that a warm environment is maintained using active warming if necessary. In order to assess **the extent of the burn injury**, use the methods of estimation for evaluating the extent of burn injury. In addition to the extent of the burn, it is also important to get an impression of the depth of the burn.

Fluid resuscitation

Fluids should be administered intravenously to adults with burns ≥15% TBSA and children with burns ≥10% TBSA. Fluids should be administered according to the Modified Parkland formula: 3ml Ringer Solution x weight (kg) x %TBSA burned. Half of the calculated volume should be given in the first 8 hours, **beginning from the time of the burn injury** and not from the time administration of fluids is commenced. The other half should be administered over the next 16 hours, i.e. over 8 - 24 hours post-injury.

CHILD, 24KG, 17% TBSA BURNED.

Fluid resuscitation started two hours after burn injury

Resuscitation fluids:

1. 3ml x 24kg x 17 = 1224 ml
   - Administer 50% of the fluid within the first
     6 hours post-injury: 612ml (= 102ml/h).
   - Administer 50% of the fluid over the next 16 hours: 612 ml (=38.25 ml/h).
2. In addition provide maintenance fluids (2.5% glucose and 0.45% NaCl) (100 ml x 10 kg) + (50 ml x 10 kg) + (20 ml x 4 kg) = 1430 ml
   - Administer 1430 ml/24h (=59.5 ml/h).

To prevent hypoglycemia in children up to 30kg, add maintenance fluids (2.5% glucose and 0.45% NaCl), administered continuously over the first 24 hours (commencing from when fluids are first administered). Calculate the volume of maintenance fluids required as follows:

- 100ml/kg/24h (<10kg)
- + 50ml/kg/24h (10-20kg)
- + 20ml/kg/24h (20-30kg)

In order to assess the efficacy of fluid resuscitation urine output is measured, however this is only possible with an indwelling urinary catheter (IDC). The urine output for various ages should be at least:

- **Infants** 1.0-2.0 ml/kg/hour
- **Children** 1.0-1.5 ml/kg/hour
- **Adults** 0.3-0.5 ml/kg/hour = 30-50 ml/hour

If the urine output is inadequate, administer extra fluids via boluses of 5-10 ml/kg and/or increase the volume of fluid to be administered within the next hour to 150% of the planned volume. In children, beware to only adjust the volume of resuscitation fluids and not the volume of maintenance fluids.

Remember that all resuscitation formulas provided are used as a guide and patients should be assessed frequently, with individual adjustments made to maintain adequate organ perfusion. Urine output is the most important way of monitoring the adequacy of fluid resuscitation and the volume of resuscitation fluids must be adjusted to maintain urine output within the reference ranges.

In children, if required, continue to administer maintenance fluids beyond the first 24 hours post-injury. Depending on parenteral capability and circumstances switch to oral fluids.

HEMOGLOBINURIA

Hemoglobinuria is an early complication of extended full thickness burns. It results from the rapid destruction of red blood cells, thereby releasing free hemoglobin into the plasma and consequential excretion of free hemoglobin in the urine.

MYOGLOBINURIA

Myoglobinuria is usually associated with rhabdomyolysis or muscle destruction, and may occur as a result of electrical burns, electrocution, blunt trauma or ischemia from compartment syndrome.

Prompt treatment is required for both hemoglobinuria and myoglobinuria by using fluids to increase urine output to 1-2 ml/kg/hr.

TREATMENT IN CHILDREN

Fluid resuscitation may be problematic in children. For example children with a large TBSA burned have high risk of hypoglycemia, fluid overload and dilutional hyponatremia. Therefore, to prevent this, measure blood glucose and electrolyte levels regularly, start administration of carbohydrates early and limit free water intake. Carbohydrates can be administered either by enteral feeding or by the addition of dextrose to the electrolyte solution.

VENOUS CUTDOWN OR INTRAOSSEOUS FLUID THERAPY

When veins are collapsed due to severe dehydration and standard peripheral or jugular intravenous access cannot be obtained, a venous cutdown or intraosseous fluid therapy should be considered. The method used should be selected according to the preference of the medical team and the equipment available. For intraosseous infusion, the needle can be inserted into the anteromedial aspect of the proximal tibia. If intraosseous infusion is unsuccessful, a venous cutdown can be performed into the greater saphenous vein, 1cm proximal to the medial malleolus.

ORAL FLUIDS

Oral fluids may be indicated in certain situations, including those where no IV or intraosseous access can be obtained; where only oral administration is practical; or where the alternative is no fluid resuscitation. Liquids that are typical of the patient's normal diet should be drunk, to the equivalent of 15% bodyweight per 24h for 2 days. 5g tablets of table salt (or equivalent) must be ingested for each litre of oral fluids consumed.
Oral rehydration solution (ORS) is also commonly used to replace fluid and electrolyte loss, when intravenous rehydration is unavailable. When a patient is unable to drink, ORS can be administered through a nasograstric tube.

DO NOT FORGET TETANUS PROPHYLAXIS

ADDITIONAL INITIAL MANAGEMENT AND DIAGNOSTICS

Gastroparesis

Patients with major burns are at high risk of gastroparesis. Therefore, to stabilize the gastrointestinal system, insert a nasogastric tube for adults with burns >20% TBSA and children with burns >10% TBSA. This prevents gastric dilatation, vomiting and subsequent aspiration.

Pain management

Pay attention to adequate pain management in the acute phase. For more information read the chapter ‘Pain management in the acute phase’. Given that most burn injuries are extremely painful, opioid analgesia should be provided intravenously, if available. Morphine at a starting dose of 0.05-0.1mg/kg of bodyweight should be used and the dose subsequently titrated, dosing every 3-5 minutes. The final dose is determined by the patient’s response. If morphine is not available use the best local treatment options to assure effective pain management for burn victims in your facility.

Antibiotics

Avoid the use of prophylactic systemic antibiotics for acute burns as there is no supporting evidence for their use and it may contribute to antibiotic resistance. As an exception, only for communities where streptococcal infection is widespread, prophylaxis may be given for 24 hours. However, late presentation with an active infection requires adequate treatment according to local protocols.

Investigations

Further diagnostic tests may be performed as follows:

- **ECG** for all electrical burns or for patients with pre-existing cardiac conditions.
- **X-Ray** assessment dependents on the mechanism of trauma and clinical findings.
- **Sonography** (FAST scan: Focused Assessment with Sonography for Trauma) of the abdomen and cardiac windows, dependent on the mechanism of trauma and clinical findings.

The secondary survey

When life-threatening conditions have been excluded or addressed in the primary survey, a secondary survey should be commenced.

1. **History**
2. **Full body examination**
3. **Burn wound assessment**
4. **Documentation and re-evaluation**

HISTORY
First and foremost check the identity of the patient, then take a quick **AMPLE history**:

Allergies

Medications

Past medical illnesses

Last meal

Events / environment related to injury

Next, take a **burn-specific history** according to the following five points. These five points will differ dependent on whether the burn is thermal or chemical in nature

1. **Etiology**
   of the burn i.e. the causative agent
2. **Intensity**
   of the burn. In thermal burn injuries this relates to the temperature, and in chemical burns, the concentration of the causative agent.
3. **Quantity**
   of the causative agent
4. **Duration**
   of exposure to the agent
5. **First aid**
   management at the accident site

If there is any information missing, ask family members or witnesses to the event.

	Thermal burn	Chemical burn
Etiology	Flame / contact / scald (and nature of scalding)	Agent / chemical substance
Intensity	Temperature and viscosity of the drink/food	Concentration of the chemical agent
Quantity	Pot of tea versus cup of tea	Splash versus immersion
Duration	Duration of exposure / contact	Duration of contact, also consider the condition of the skin
First aid	Method and duration of cooling	Irrigation and intensity of irrigation

5-point history - differences between thermal and chemical burns
Different questions must be asked in order to get an impression of the extent of a burn wound

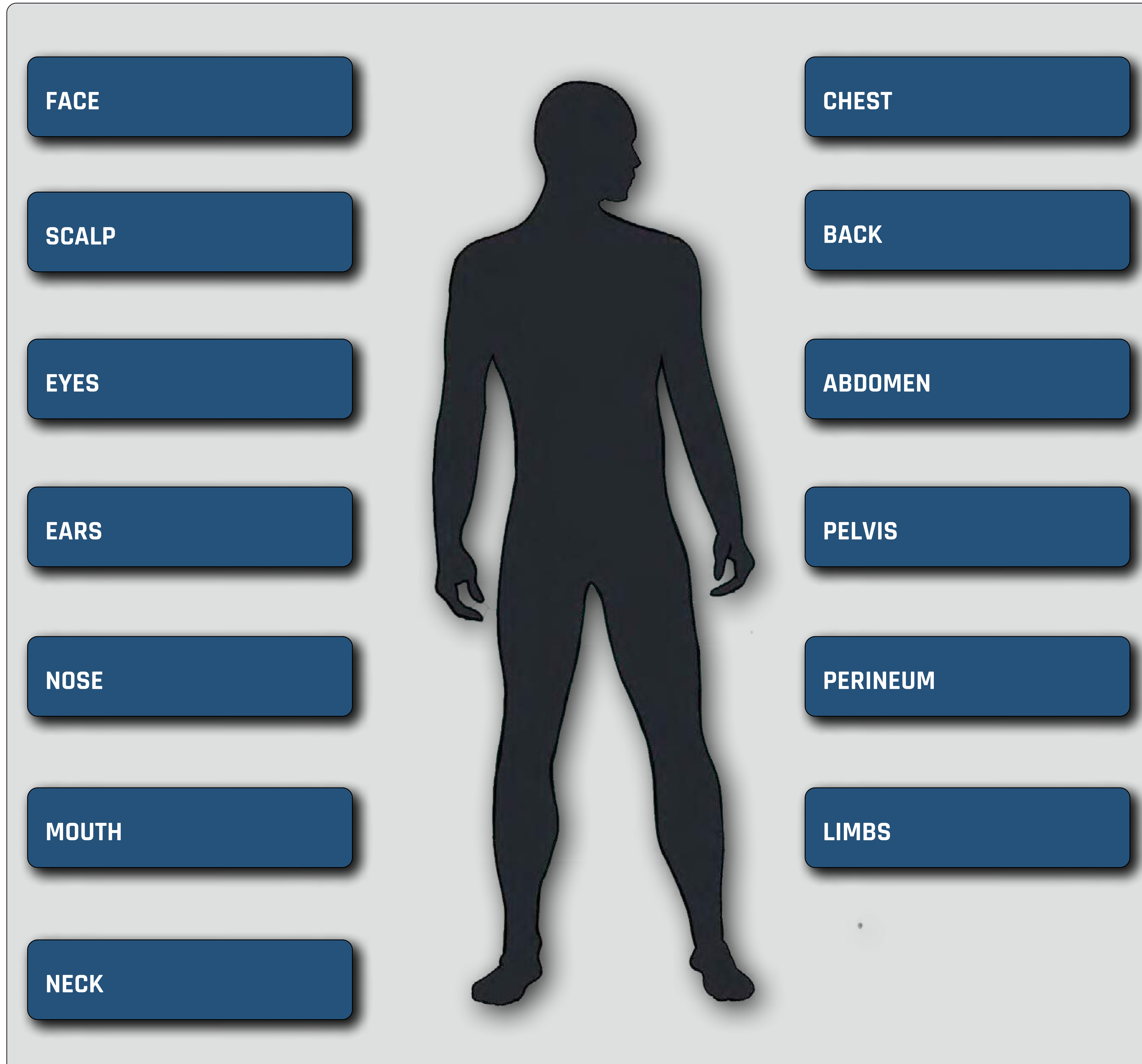
FULL BODY EXAMINATION
Start with the head and face.
See the information button below.

BURN WOUND ASSESSMENT
Thoroughly examine the burn injury by assessing the extent and depth during the secondary survey. To reveal hidden burns all clothes must be removed, for example a diaper on an infant that has sustained a scald may hide a deep burn. This step is essential for the treatment of the burn wounds and detailed information on how to perform the burn wound assessment is provided in the chapter 'Burn wound assessment'.

DOCUMENTATION AND RE-EVALUATION
It is imperative to document all findings accurately.

Re-evaluate

1. Primary and secondary survey
2. Laboratory investigations
3. Tests and tubes
4. Electrocardiogram
5. Tetanus administration



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STABILIZATION FOR REFERRAL

It is essential to only prepare a patient for referral to a burn centre once they are in a stable condition. Therefore, in order to prepare a patient for transfer to a burn centre, they must be stabilized in the following way:

Support the respiratory system by supplying 15L of oxygen through a non-rebreathing mask for all patients with major injuries. If 15 L is not available, supply the maximum amount that is available. The need for endotracheal intubation must also be assessed before transfer, as upper airway obstruction can progress rapidly.

In order to **stabilise the circulatory system**, start fluid resuscitation according to the Modified Parkland formula prior to transport and continue this during transport. To administer this, ideally obtain IV access through two large bore cannulas however if this is not possible, consider other routes of access for example using a peripheral venous cutdown (ankle or elbow), percutaneous central venous line (femoral, subclavian or internal jugular) or an intra-osseous needle. It is also important to prevent hypothermia.

Early management of the burn is important for adequate stabilization of the patient. Firstly, evaluate the adequacy of any first aid treatment provided, then move onto managing the burn. To do this, wash the burn with either 0.1% chlorhexidine solution or normal 0.9% saline, removing any blisters that have formed. The burn can then be covered with a sterile, non-adhesive bandage or clean cloth. Topical agents and prophylactic antibiotics should not be used.

Some burns have specific requirements for stabilisation. For example **head and neck burns** can progress rapidly, causing upper airway obstruction, therefore these patients should be in a seated position during transfer. Burns in the **genital area and perineum** require early urinary catheterization. Where there is burn injury to the **extremities**, these should be elevated to prevent edema.

If essential functions such as ventilation or circulation are compromised by **eschar formation**, this may be an indication for an early escharotomy.

Take care of adequate **pain management** in the acute phase of burn injury.

Given that most burn injuries are extremely painful, it is recommended to provide opioid analgesia intravenously. Morphine at a starting dose of 0.05-0.1mg/kg of bodyweight should be used, when available and the dose subsequently titrated, dosing every 3-5 minutes.

DON'T FORGET

Pain management

The final dose is determined by the patient's response.

Patients with major burns are also at a high risk of gastroparesis. Therefore, to stabilise the **gastrointestinal system**, insert a nasogastric tube for adults with burns >20% total body surface area (TBSA) and children with burns >10% TBSA. This prevents gastric dilatation, vomiting and subsequent aspiration.

There is also a risk of **tetanus** with burn injuries therefore tetanus prophylaxis must be administered at the first point of medical contact.

Management of the pediatric patient

There are differences in the etiology of burn injuries for adults and children. In children up to four years of age, scalds are the most common type of burn in most western settings, however from the age of five years, the causes of burns are similar to adults.

Pediatric burn patients should be assessed and treated using a primary and secondary survey, as for adults, however there are some modifications to this survey for children.

PRIMARY SURVEY (ABCDEF)

Airway

Airway obstruction in pediatric burn patients may occur, even in the absence of inhalation injury. This is due to the fact that the diameter of the pediatric airway is small and tissue is loose. Edema develops rapidly and therefore the threshold for intubation should be low.

Breathing

Children are more reliant on diaphragmatic breathing. Diaphragmatic movement may be impaired by circular burns, burns of the anterior and lateral aspect of the chest, and burns to the upper half of the abdomen. In these cases, escharotomy should be considered.

Circulation

When emergency venous access is required and percutaneous cannulation is impossible, the preferred technique to obtain access for fluid resuscitation is to insert an intraosseous needle.

Exposure & enviromental control

Pediatric patients are particularly susceptible to hypothermia and will need increased active warming. In comparison to adults, children have an increased body surface area to weight ratio which has several effects, such as a higher metabolic rate, greater evaporative water loss (also due to less fat and shivering) and greater heat loss.

> Signs of child neglect or mistreatment should also be looked out for.

Fluid

Fluid resuscitation should be started in pediatric patients with burns >10 % TBSA.

For children up to 30kg, provide maintenance fluids (2.5% glucose and 0.45% NaCl) in addition. Maintenance fluids, including a source of glucose, should be added to pediatric patient resuscitation fluids, as hepatic glycogen stores will be depleted after 12–14h of fasting.

This should be evenly spread over the first 24 hours, starting from the when the fluid administration is commenced, to prevent hypoglycemia. Calculate the volume of fluids required as follows:

- 100 ml/kg/24h (for the first 10 kg of body weight)
- + 50 ml/kg/24h (for 10-20 kg of body weight)
- + 20 ml/kg/24h (for 20-30 kg of body weight)

Urine output is used as a measure to monitor the adequacy of fluid resuscitation. Urine output should be maintained within the following reference ranges:

- **Infants:** 1.0-2.0 ml/kg/hour
- **Children:** 1.0-1.5 ml/kg/hour

> **Child, 12 kg, with 25% TBSA burned.**
> Fluid resuscitation started immediately after burn injury.
>
> **Resuscitation fluids:**
>
> 1. 3ml x 12 kg x 25 = 900 ml
>   - Administer 50% of the fluid within the first 8 hours post-injury: 450ml (56,25 ml/h).
>   - Administer 50% of the fluid over the next 16 hours: 450ml (28.75 ml/h).
>
> 2. In addition provide maintenance fluids (2.5% glucose and 0.45% NaCl)
>   (100 ml x 10 kg) + (50 ml x 2 kg) = 1100 ml
>   - Administer 1100ml/24h (46ml/h).

If urine output is inadequate, administer extra resuscitation fluids via boluses of 5-10 ml/kg and/or increase the volume of resuscitation fluid to be administered within the next hour to 150% of the planned volume. Beware to only adjust the volume of resuscitation fluids and not the volume of maintenance fluid.

In children, continue to administer IV maintenance fluids beyond the first 24 hours post-injury, if required. This is especially important when oral intake cannot be monitored properly. However, switch to oral intake when it is considered to be safe.

Always be aware of signs and symptoms of non-accidental injury in children, such as the patterns of non-accidental injury:

Sock or glove pattern (indicates immersion)
Cigarette marks
Donut sign

Children have a high risk of hypoglycemia, fluid overload and dilutional hyponatremia, especially those with a large TBSA burned. Therefore to prevent this, measure blood glucose and electrolyte levels regularly, start administration of carbohydrates early and limit free water intake. Carbohydrates can be administered either by enteral feeding or by the addition of dextrose to the electrolyte solution. Children are more prone to gastric dilatation, therefore it may be necessary to insert a nasogastric tube early on. Start enteral feeding very early in order to prevent loss of gut function and maintain nutrition, as children have a high metabolic rate and nutritional requirements.

SECONDARY SURVEY

History

Take a medical history according to the 5-point history, see I

- **Etiology**
- **Intensity**
- **Quantity**
- **Duration**
- **First aid management**

If there is any information missing, ask family members or witnesses to the event.

Always be aware of signs of non-accidental injury in children and evaluate any prior history or indications of other types of abuse or neglect during the history taking. If a non-accidental burn is suspected, always refer the child to a burn centre.

Suspicion of non-accidental injury should be raised when the history of the event does not match with the pattern of the injury or the history is unclear, contradictory or changing. This should also be suspected if the presentation of the child is delayed, the injury is not compatible with the level of development of the child or there are other signs of trauma or previous injury. The absence of the parents at the time of accident or admission to the hospital should also raise suspicions.

Patterns of non-accidental injury
Use the buttons

In low and middle income countries, patients may have been treated by traditional healers before the admission at your healthcare facility. Traditional treatment may include application of herbal products, eggs and ashes The choice may be determined by traditional believes and/or access and affordability of healthcare leading to late presentions with severe complications including sepsis.

PHYSICAL EXAMINATION

Estimating the extent of the burn wound

The palm method can be used to estimate the extent of the burn wound. Make sure to use the palm of the child as a reference. Compared to adults, children have an increased body surface area to weight ratio. Therefore, the Rule of Nines used in adults must be modified for use in children:

- **0-1 years of age**
  Head: 18% TBSA
  Single arm: 9% TBSA
  Single leg: 14% TBSA

- **1-10 years of age**
  Per year of age, add 0.5% to each leg and subtract 1% from the head up to 9% TBSA.

Depth of the burn wound

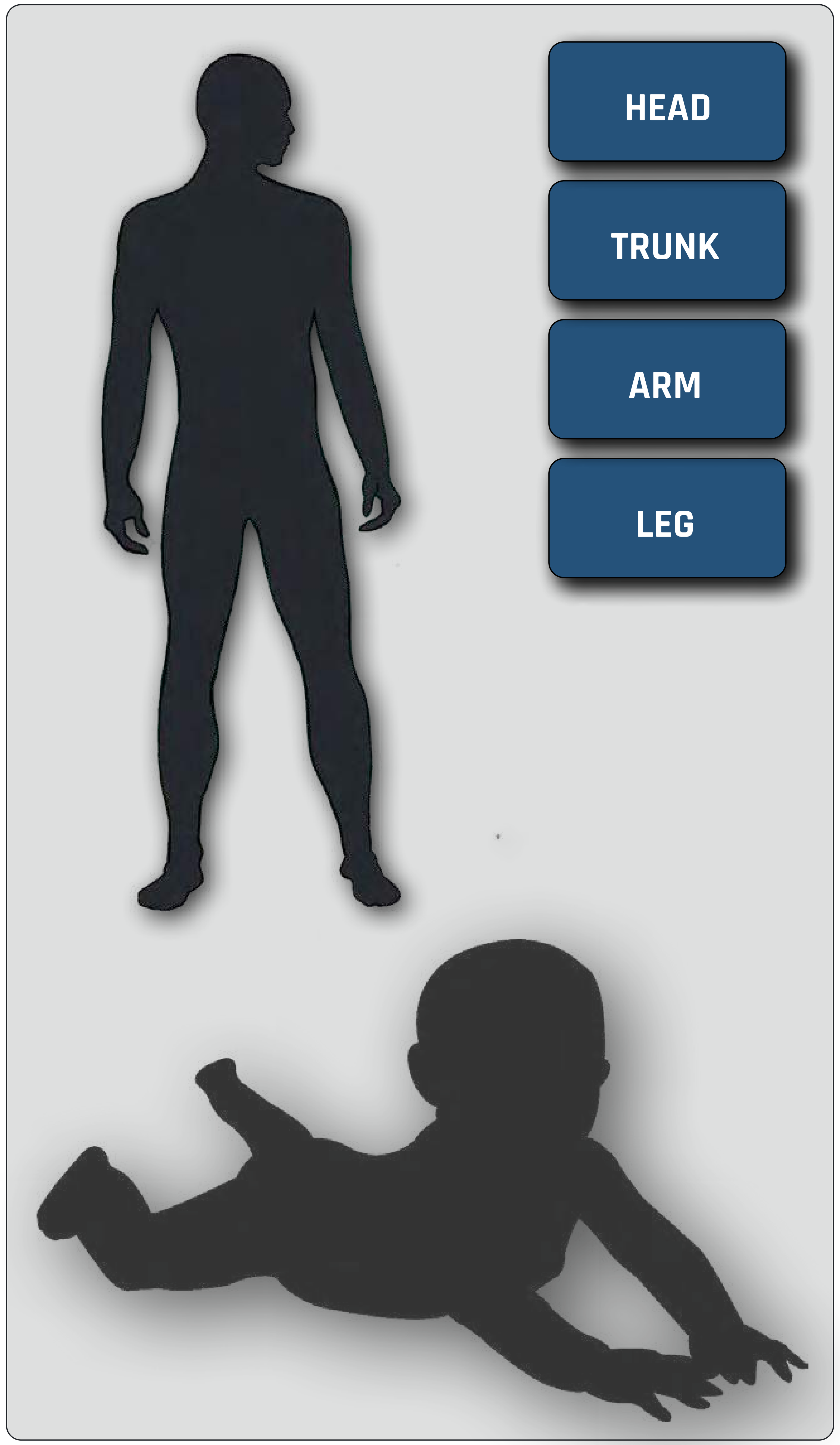
Perform a full body physical examination as described in the chapter ‘Examination and treatment at the emergency room’.

When focusing on the burn injury be aware that the child’s skin is much thinner than an adult’s and, for this reason, a scald caused by water of $70^{\circ}C$ results in a much deeper burn wound in children than in adults. The assessment of a pediatric burn is more difficult, especially when dealing with a scald. Color changes of the burned skin may differ from adults and these burns are often mixed depth, and may further deepen over 48 hours.

BURN CENTER REFERRAL CRITERIA

The requirements to transfer pediatric burn patients to a burn center are different from adults, see I

Children with burns exceeding 5% TBSA should be considered for transfer and those where non-accidental injury is suspected should be transferred immediately. If adequate pain relief, for example opioid continuous rate infusion, is unavailable or insufficient, transfer may be needed. Recommendations on referral depend on local circumstances. Please check local protocols if available and make a balanced decision with the local team in your facility if protocols are not yet available.



Explore the differences in adults and children
Use the buttons

Inhalation injury

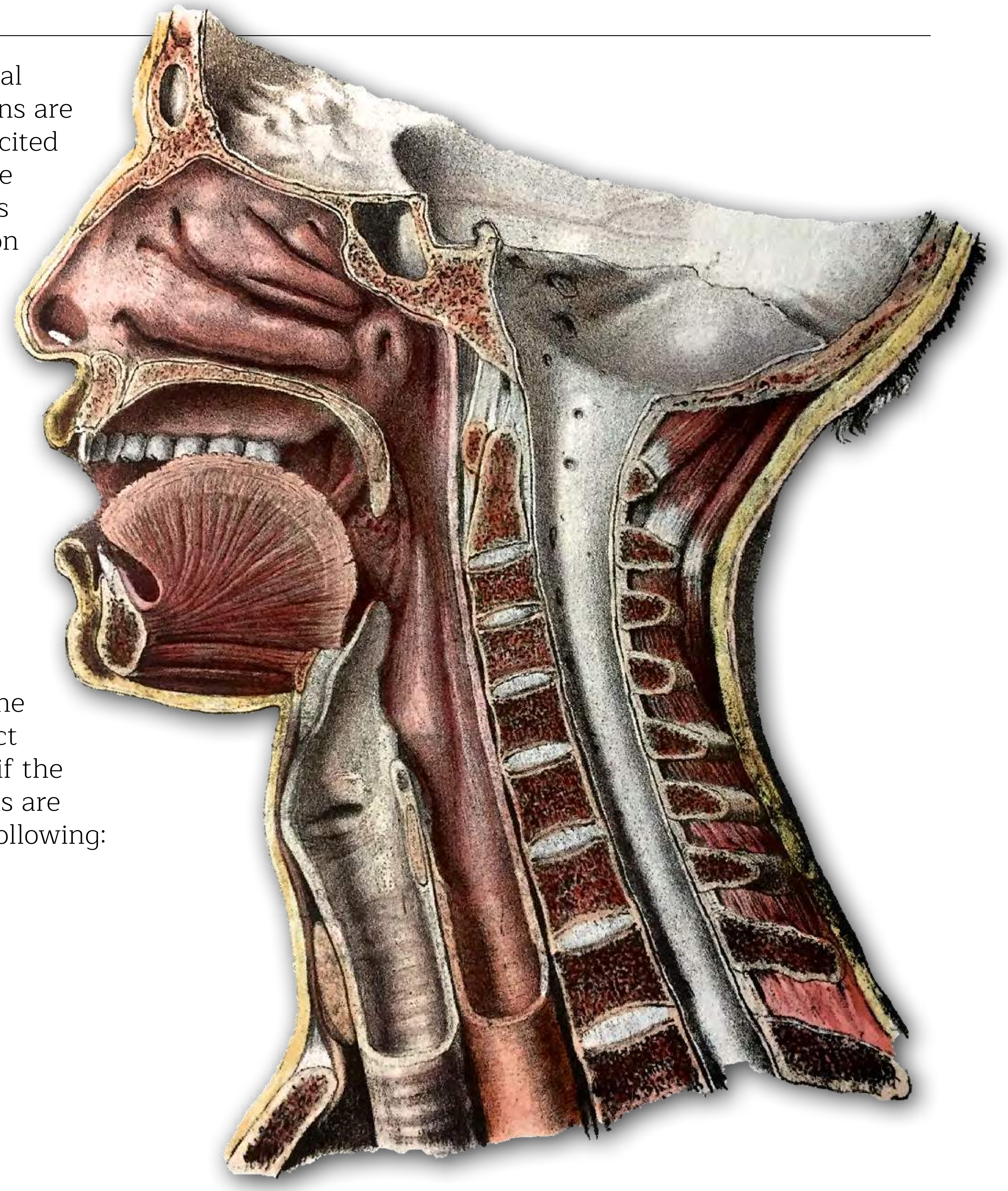
Inhalation injury can be classified in the following ways:

1. Injury to **the upper respiratory** tract (proximal to and including the larynx)
2. Injury to **the lower respiratory** tract (tracheobronchial injury)
3. Systemic inhalation **intoxication**

UPPER RESPIRATORY TRACT
The etiology of this injury is often inhalation of hot gases, causing a true thermal burn of the airway proximal to the larynx. These types of injury occur mostly in an enclosed space, with heat exposure for a considerable time. Other, rare, causes are injury due to pressurized steam inhalation or inhalation from explosions with high concentrations of oxygen/flammable gases under pressure; these occur mostly in industry. Burn injuries > 20% TBSA result in a significant systemic inflammatory response, which may lead to edema of the airway mucosa proximal to the larynx, resulting in obstruction of the airway.

The pathophysiological changes of these burns are the same as those elicited by thermal burns. The edema initially causes respiratory obstruction and later, loss of the protective function of the mucosa. It should be noted that these effects may persist beyond the time of maximal wound edema (between 12 and 36 hours).

During the clinical assessment, an inhalation injury to the upper respiratory tract should be suspected if the history and symptoms are consistent with the following:



SHOW HOTSPOTS

1. **History**
   The patient would have a history of exposure to flames, smoke, an explosion or chemicals. The duration of exposure and whether or not the exposure was in an enclosed space should be ascertained, as exposure in an enclosed space would indicate this type of injury. The patient may also have a history of a loss of consciousness.

2. **Physical findings**
   The physical findings of this type of injury include burns to the face (specifically the mouth, nose and pharynx); singed nasal hairs; soot in the oropharynx, nasal passages or proximal airways; carbonaceous sputum; and edema formation in the head and neck.
   Other signs and symptoms: The patient may also have difficulty breathing, indicated by tachypnoea (>30 breaths per minute) or signs of increased respiratory effort, including flared nostrils, tracheal tug, chest indrawings and use of the accessory muscles of ventilation. When examining the patient, listen for hoarseness, stridor, a productive cough and croup-like breathing.

3. **Further diagnostics**
   In all patients with a suspected inhalation injury, carboxyhemoglobin (COHb) levels should be measured. An initial chest X-ray is recommended. Other diagnostic tests may be requested if indicated.

4. **Treatment**
   For treatment of injuries when the airway is compromised, 100% oxygen should be administered at 15L/min through a non-rebreathing mask. The airway must also be secured via one of the following methods:
   - Jaw-thrust maneuver or chin lift
   - Oral airway device
   - Endotracheal intubation
   - Tracheostomy (surgical)

It is important to be prepared for emergency intubation at any time, therefore always have the appropriate equipment ready. If there is any concern about the security of a patient's airway, the patient should be intubated and the airway should be secured by the clinician most experienced in this area. Particular attention should be paid to children, as the small diameter of their airways mean even minor edema can lead to airway obstruction. Ensure that any decision with regards to intubating a patient is made in a timely manner.

The indications for intubation include stridor, respiratory distress, a reduced level of consciousness (Glasgow Coma Scale < 8), impending airway obstruction (indicating by increasing signs and symptoms of airway obstruction) and a need to facilitate safe transport of a patient.

Patients should be nursed in a semi-upright position with a moderate elevation of the head and trunk. The ability to provide optimal care for patients with inhalation injuries is dependent on the availability of intensive care facilities and clinical expertise.

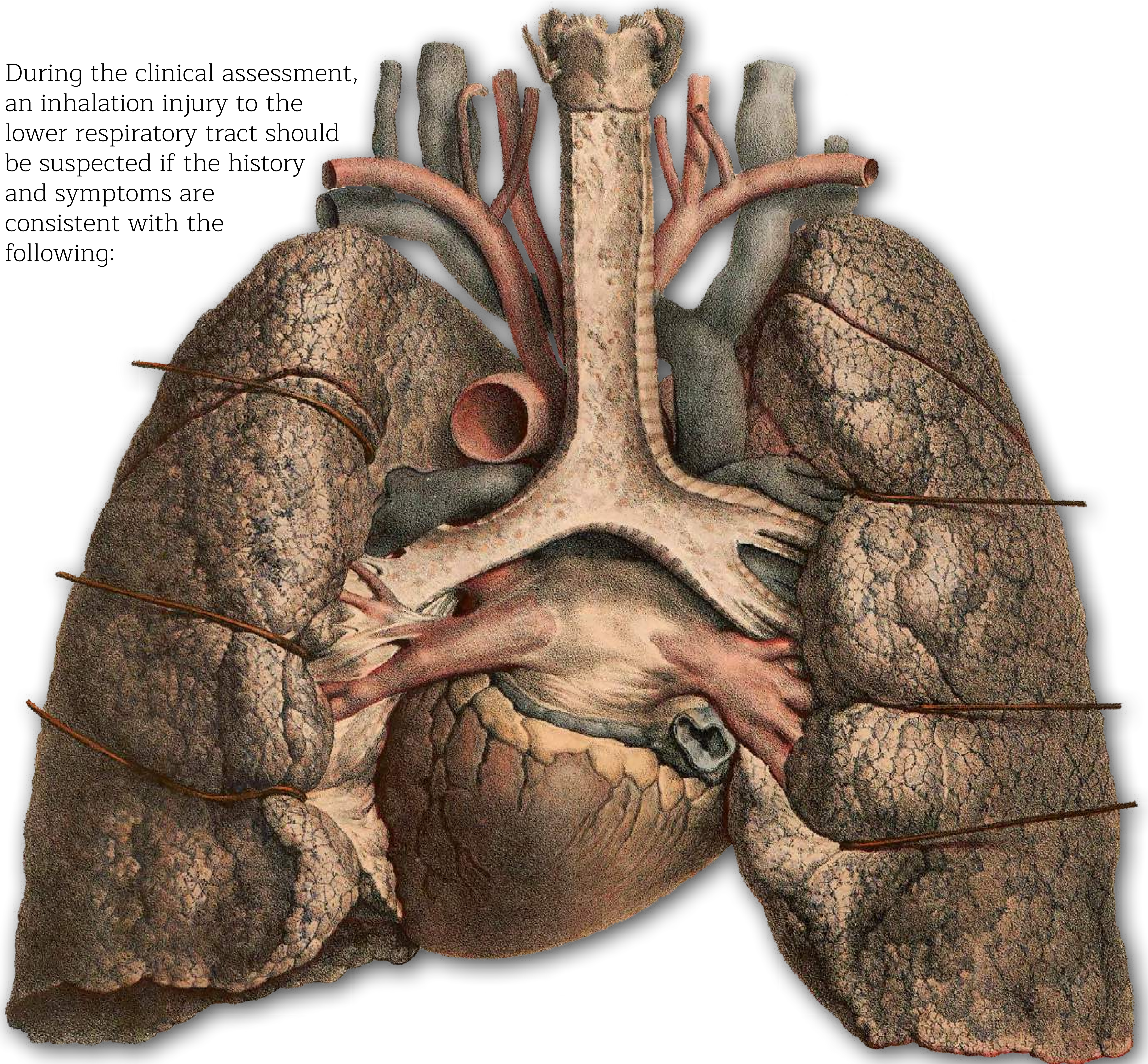
LOWER RESPIRATORY TRACT
The etiology of this injury is often inhalation of burning substances, such as chemicals in smoke, that cause injury to the lower respiratory tract. Inhalation of hot gases may also cause damage to the airway distal to the larynx, however this only occurs after exposure to extreme heat as the airway proximal to the larynx is efficient at dissipating heat.

The pathophysiology of these types of burns can be split into 2 types of injury:

Tracheobronchial injury
Inhalation of noxious chemicals and particulates, present in smoke from a fire, cause oxidation and reduction of compounds containing carbon, sulphur, phosphorus and nitrogen. Acids and alkalis are produced when these compounds dissolve in the moisture of the airways and alveoli, resulting in a chemical burn of the tissues of the lower respiratory tract.

Parenchymal injury
The lung parenchyma is involved in cast formation and plugging that may result in distal airway obstruction. Atelectasis and alveolar collapse are characteristic of damage to the lung parenchyma. This results in the inactivation of surfactant, formation of inflammatory exudates and a loss of hypoxic vasoconstriction.

During the clinical assessment, an inhalation injury to the lower respiratory tract should be suspected if the history and symptoms are consistent with the following:



1. **History**
   Similar to the upper airway injury, the patient would have a history of exposure to flames, smoke, an explosion or chemicals. The duration of exposure and whether or not the exposure was in an enclosed space should be ascertained, as exposure in an enclosed space would indicate this type of injury. The patient may also have a history of a loss of consciousness.

2. **Physical findings**
   The physical findings that are indicative of this type of injury include burns to the face (specifically the mouth, nose and pharynx); singed nasal hairs; soot in the oropharynx, nasal passages or proximal airways; carbonaceous sputum; and edema formation in the head and neck.
   Other signs and symptoms: The patient may also have difficulty breathing, indicated by tachypnoea (>30 breaths per minute) or signs of increased respiratory effort, including flared nostrils, tracheal tug, chest indrawing and use of the accessory muscles of ventilation. When examining the patient, listen for hoarseness, stridor, a productive cough and croup-like breathing.

3. **Further diagnostics**
   In all patients with a suspected inhalation injury, carboxyhemoglobin (COHb) levels should be measured. An initial chest X-ray is helpful in the diagnosis but to get the best information regarding the level and the severity of the injury a bronchoscopy is most useful.

4. **Treatment**
   Treatment is based mainly on respiratory support. High flow oxygen at 15L/min should be administered via a non-rebreathing mask. If higher levels of oxygen need to be administered or a toilet bronchoscopy is required to remove secretions, intubation and mechanical ventilation should be used. Prophylactic antibiotics and corticosteroids are not indicated for the treatment of smoke inhalation injury.

Patients should be nursed in a semi-upright position with a moderate elevation of the head and trunk. The ability to provide optimal care for patients with inhalation injuries is dependent on the availability of intensive care facilities and clinical expertise.

SYSTEMIC INHALATION INTOXICATION

Carbon monoxide (CO) and hydrogen cyanide (HCN) are the two gases that are most commonly associated with systemic toxicity associated with inhalation injury. Most patients with systemic inhalation intoxication suffer from mixed CO and HCN intoxication. The main pathophysiological process resulting from this systemic intoxication is cell hypoxia.

Carbon monoxide (CO) intoxication

This occurs because CO has a greater affinity for hemoglobin than oxygen, therefore forming carboxyhemoglobin and reducing the oxygen-carrying capacity of the blood. As a result, oxygen delivery to tissues is reduced leading to tissue hypoxia.

During the diagnosis, systemic intoxication injury should be suspected if the history and symptoms are consistent with the following:

CO intoxication should be suspected in all patients who present following inhalation injury or house fires, until normal blood carboxyhemoglobin (COHb) levels have been confirmed.

1. **History**
   The patient would have a history of being trapped in an enclosed space or steam filled room. There may also be burns associated with an explosion.

Q

2. Physical findings
Consider all patients with diminished consciousness to have CO intoxication unless proven otherwise.

3. Further diagnostics
COHb blood levels should be measured and will be increased in patients with CO intoxication. It must be noted that pulse oximetry in patients with CO intoxication is unreliable, as a pulse oximeter is unable to distinguish between COHb and oxy-hemoglobin. PaO2 levels may be within the normal range in these patients, as the dissolved oxygen in plasma remains unaffected despite total blood oxygen being low.

It is important to remember to consider CO intoxication in context, as signs and symptoms of diminished consciousness may also be present due to other causes.

4. Treatment
See treatment HCN intoxication

Cyanide (HCN) intoxication
This occurs when HCN is released by the combustion of nitrogen-containing compounds present in plastics, fabrics and paper. HCN is absorbed through the lungs and binds to the cytochrome system, inhibiting its function resulting in anaerobic metabolism.

HCN intoxication should be suspected in all patients who present following inhalation injury or house fires. The history, signs and symptoms are similar to CO intoxication.

1. History
The patient will have a history of being present around burning plastics or glue used in furniture.

2. Physical findings
These are non-specific, for example loss of consciousness and convulsions.

3. Further diagnostics
Blood cyanide levels cannot be measured in a time frame that is clinically useful.

4. Treatment
An unconscious patient (GCS < 8) should be intubated when the history and clinical findings mean intoxication is suspected. To treat HCN intoxication, administer 100% oxygen to the patient until carboxy-hemoglobin levels are normalized; this is often required for at least six hours, possibly longer if symptoms persist. HCN intoxication is often fatal as HCN is approximately 25 times more toxic than CO.

Burn wound assessment

When life-threatening conditions have been excluded or addressed in the primary survey, a secondary survey should be commenced including a thorough assessment of the burn wound.

ESTIMATING THE EXTENT OF BURN INJURY

General principles

Accurate estimation of the extent of a burn wound is essential to guide therapy and to determine whether transfer to a burn center is necessary. Epidermal burn wounds (i.e. erythema only) are not included in the assessment of TBSA burned. Be aware that the estimation of the percentage of TBSA in small burn wounds may easily be overestimated and the percentage of TBSA of large burns easily underestimated.

Palm method

Use the palm method for burn wounds with an assumed TBSA of <10%. Make sure the palm of the patient is used as a reference, not the palm of the clinician. The entire palmar surface of the patient's hand including the closed fingers is 1% TBSA in both adults and children.

Rule of Nines

Use the rule of nines for burn wounds with an assumed TBSA of >10%. Make sure the rule of nines is adjusted to the age of the patient.

Rule of nines adults

Head	: 9% TBSA
Each arm	: 9% TBSA
Each leg	: 18% TBSA
Anterior trunk	: 18% TBSA
Posterior trunk	: 18% TBSA

Rule of nines 0-1 years

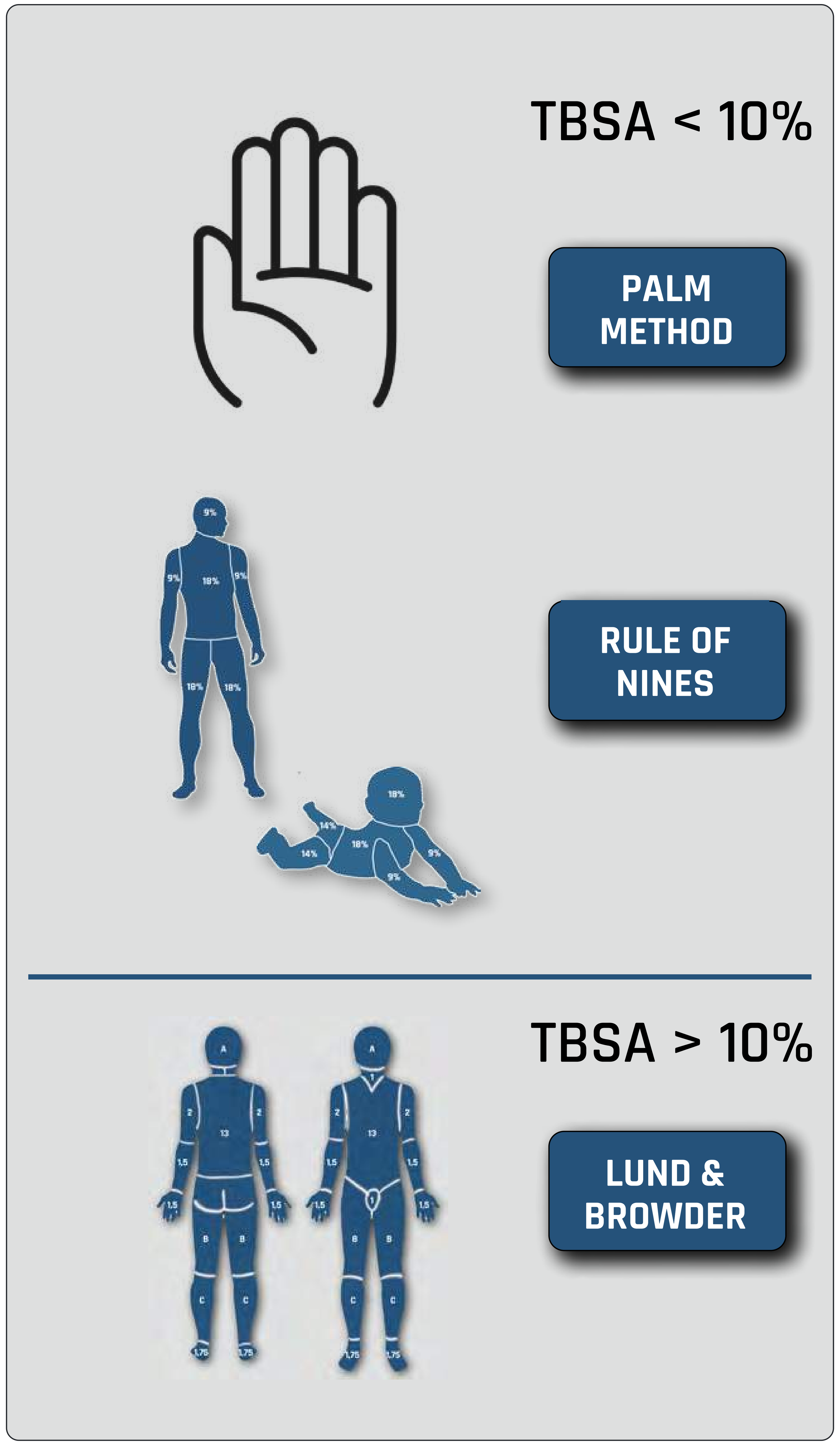
Head	: 18% TBSA
Each arm	: 9% TBSA
Each leg	: 14% TBSA

Rule of nines 1-10 years

For children over the age of one year, for each year above one, add 0.5% to each leg and subtract 1% for the head.

Lund & Browder

Instead of the rule of nines the Lund and Browder chart may be used to estimate an assumed TBSA of >10%. This method is more accurate than the rule of nines and more detailed, but requires an advanced clinician. Make sure the Lund and Browder chart is adjusted to the age.



Burn wound assessment methods
Use the buttons

BURN WOUND DEPTH
Accurate classification of burn depth is essential to determine the healing potential and the need for surgical treatment. Accurate classification may be difficult as most burns are not uniform; they comprise deep and superficial components. Furthermore, burns are dynamic and can develop into deeper wounds. Some burns may require several days to develop before a final assessment can be performed.

The depth of the burn can only be estimated. Only by means of Laser Doppler Imaging (LDI), 48 hours after burning, a more precise measurement of the depth is possible.

However, this method is only available in specialized burn centers. In general practice, the medical history and physical examination are the cornerstone of the classification of burn wound depth.

History

The medical history gives an indication of the depth of the burn before the wound is examined. Five questions/facts need to be asked to/established by the patient or caretaker:

1. What was the agent that caused the burn? Hot fat, fire, hot water, a gas explosion? In the case of a chemical burn, was the agent an acid or an alkali and what was the specific substance?

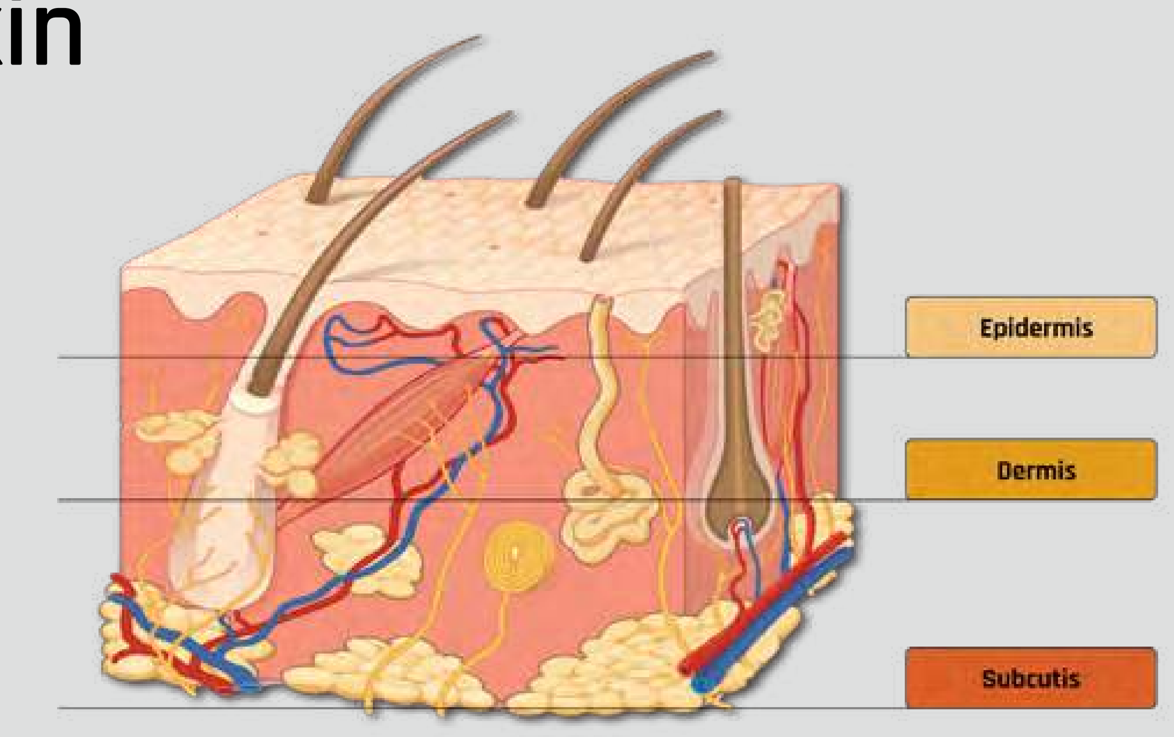
2. In cases of thermal injury, the temperature of the causative agent, and in cases of chemical injury, the concentration of the causative agent are important factors.

3. Next it is important to establish the quantity of the causative agent. For example, a pot of hot tea causes a deeper burn than a cup of tea of the same temperature.

4. What was the duration of exposure to the agent? In contact burns and chemical burns, long exposure may cause a deep burn even if the temperature or the concentration of is low.

5. Finally, it is important to know if sufficient cooling was applied after a thermal injury or if rinsing of the wound was performed after a chemical burn.

Skin

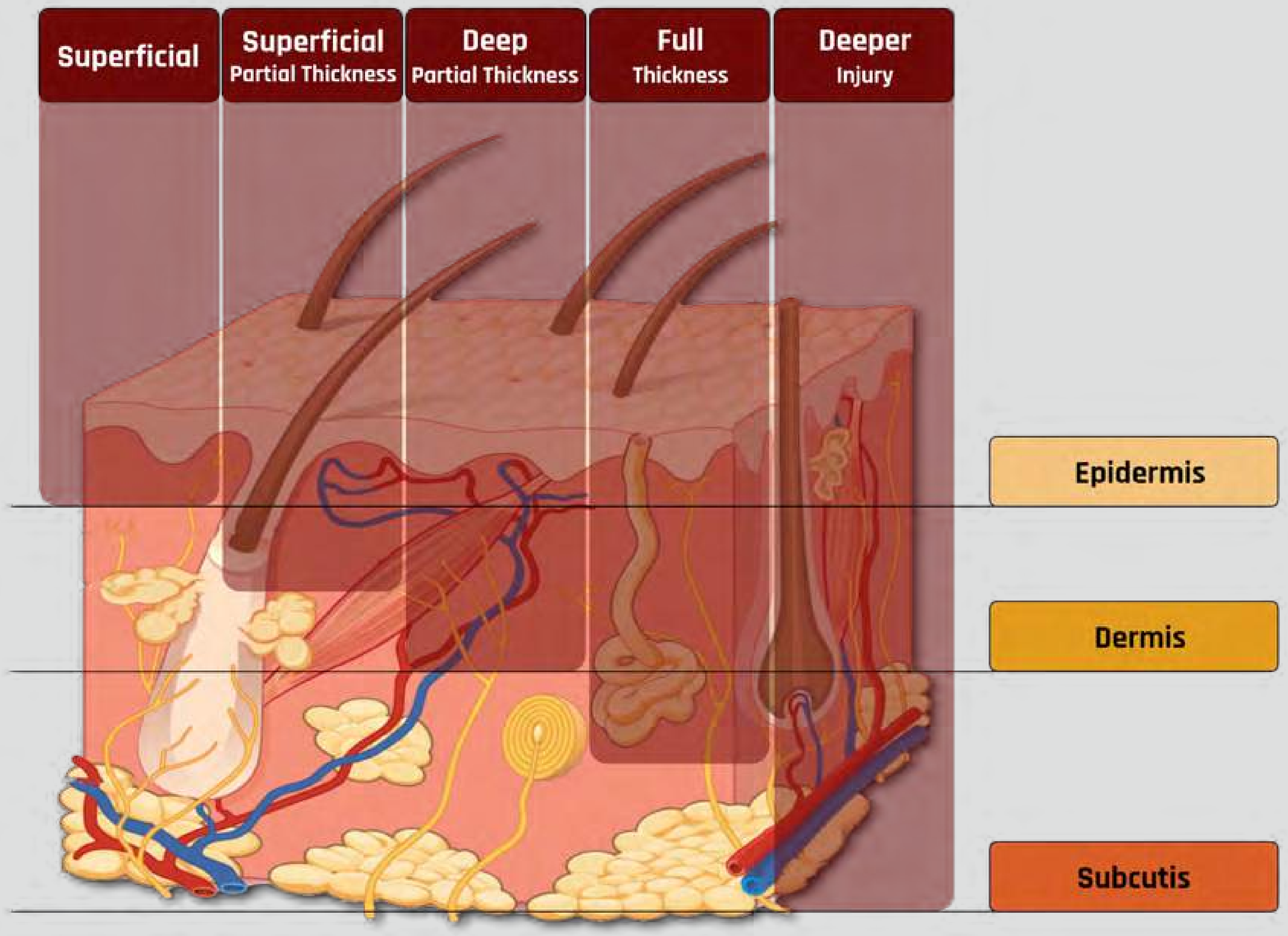


Burn depth, see next page

Specific points for non-accidental burns
Be aware of signs of a non-accidental burn (can be caused by any agent). Children and the elderly are particularly vulnerable to non-accidental burns. Evaluate previous indications of other types of abuse or neglect during history taking. When a non-accidental burn is suspected, always refer to a burn center.
Suspicions should be raised when:

- History of the event does not match the pattern of the injury
- History is not clear, contradictory or changing
- Presentation is delayed
- Previous injury
- Parents were not present at the time of the accident or during admission to ED

Depth	Appearance	Healing
Superficial[1] • First degree burn[2] • Epidermal burn[3]	Red and dry No blisters Positive capillary refill Supple Painful	Within a few days (5-10 days)
Superficial partial thickness • Second degree burn – superficial • Dermal burn – superficial (IIA)	Pink/red shiny Moist Blisters Positive capillary refill Supple Very painful	Within one to two weeks (<14 days)
Deep dermal partial thickness • Second degree burn - deep • Dermal burn – deep (IIB)	Mottled pink/red with white spots Ruptured blisters Capillary refill present but delayed or absent in some parts Supple to stiff Pain moderate to absent	Healing from islands of epithelium and border of the wound takes over two weeks (14-17 days)
Full thickness • Third degree burn • Dermal burn - deep	White/yellow/brown/black/red Dull surface No blisters or blisters attached to the wound Capillary refill negative Leathery Pain absent	No spontaneous healing
Full thickness with involvement of underlying tissues • Fourth degree burn • Subdermal burn	Comparable to aspects of full thickness burn After debridement: exposed subcutis, muscles or bone tissue	No spontaneous healing



[1] The classification by Shakespeare is applied
[2] Classification in degrees
[3] Classification of Derganc

Physical examination
This will reveal more important information to determine the depth of burn injury. To reveal hidden burns, all clothes need to be removed. For example, a diaper on an infant that sustained a scald may hide a deep burn. Assess these five points during physical examination:

1. **Color and aspect of the burn**
   A moist, pink surface indicates a superficial burn wound. If the surface is dry and dull or mottled, the burn is estimated to be deep dermal partial thickness to full thickness.

2. **Blisters**
   Blisters can be filled with fluid, lie loosely on the burn, or even be firmly attached to the wound. Blisters may be absent after removal of clothing or cooling with water.

3. **Capillary refill**
   Investigate the whole surface area of the burn. Always wear disposable gloves. An absent capillary refill indicates a deep burn. Remember that the wound is heterogeneous and can have various superficial and deep areas. In general, the central part of the burn wound is the deepest.

4. **Suppleness**
   The suppleness of the wound may vary from supple, like normal skin, to stiff, like leather. Note that edema can alter the suppleness.

5. **Pain**
   Pain level may vary from severe, in superficial burns, to almost absent, in deep burn wounds. Remember that deep burn wounds always have a border of a superficial burn wound.

Patterns of non-accidental injury are:

Sock or glove pattern indicates immersion
Cigarette marks
Donut sign

Some remarks

- Be aware that the initial diagnosis of the depth of the burn can be inaccurate, always check again yourself.
- An epidermal burn is not a wound, but an inflammation reaction of the skin. Be aware that erythema observed during first examination may alter to blister formation. When this is present, the diagnosis must be changed from an epidermal burn to a superficial dermal burn.
- Burns can be even deeper than full thickness depth. In burn wound classification the term fourth degree burn is often used. The tissues below the skin such as fascia, muscle and bones can be affected.
- In chemical burns, physical examination will fail you. These burns are very unpredictable.
- If a deep dermal partial thickness burn wound is not healed after three to four weeks, the diagnosis must be altered to a full thickness burn. At this point, surgery is often required.

Emergency management of chemical burns

Chemical burns can cause extensive tissue damage. Medical history is the most important, as some agents require a specific treatment. Chemical burns differ from thermal burns and require a specific approach. The information below highlights some of the important diffferences. Different questions need to be asked when taking the 5-point history to get an impression of the extent of a chemical burn.

The questions below can be used to take a **5-point history:**

1. What was **the causative agent** and what was its concentration? If possible, read the label or packaging of the causative agent.
2. What was **the quantity** of the causative agent?
3. What was **the duration** of skin contact with the causative agent?
4. What was **the condition of the skin** at the time of exposure? For example, was the skin intact or macerated?
5. **Circumstances during skin contact** and what treatment has been administered already?

SPECIFIC AGENTS AND TREATMENT OPTIONS

The depth of a chemical burn depends on the type of chemical, concentration, amount, duration of exposure and first aid provided. Different types of chemicals have different impacts on the skin and therefore some causative agents have specific treatments.

Acids

These cause coagulating necrosis and therefore must be irrigated with plentiful amounts of lukewarm water. Early excision of these burns is required.

Alkalis

Found commonly in the form of caustic soda, present in many households as drain unblocker, these penetrate the skin easily. Therefore, immediate prolonged irrigation (> 1hr) with water is required.

Hydrofluoric acid

Burns caused by this chemical are not immediately noticeable. To treat these burns, firstly remove all clothing and immediately irrigate with copious amounts of water; speed and thorough washing of the acid is of primary importance for these types of wounds. Immediate treatment with calcium-gluconate gel (a specific treatment) is required, by massaging the gel into the skin, until the pain has subsided. If the nailbed of any affected fingers is discolored, the nail must be removed and the nail bed must then be treated with calcium-gluconate gel. If the TBSA burned is greater than 1%, hypocalcemia may occur and subsequent arrhythmias secondary to this.

Cement

Contact of the skin with cement (lime) does not immediately cause a burn, however prolonged exposure (> 45 minutes) to this substance occurs when clothing becomes impregnated and this can then become a significant issue.

Petrol and diesel

Similar to cement, petrol and diesel will only cause burns after prolonged exposure. Be aware of the systemic effects of these substances, as the endothelial cell damage caused my lead to liver, lung, spleen or kidney damage.

White phosphorus

This is found in grenades used in warfare and therefore wounds from this may occur in combat. Injuries from white phosphorus may also occur in industrial accidents or from accidents with fireworks. White phosphorus ignites when it comes into contact with air and can be extinguished with water. Wounds caused by this should be kept under running water and copiously irrigated until definitive treatment can be provided.

Emergency management of electrical burns

The spectrum of electrical injury is broad, ranging from minimal injury, to severe multi-systemic injuries with multiple organ involvement, to death. Therefore, some parts of the primary and secondary survey require particular attention.

PRIMARY SURVEY

As high voltage injuries may affect multiple organs, the patient should always be examined according to the Advanced Burn Life Support (ABLS) protocol. When A, B, C and D are stabilized, the victim must have all clothing and accessories removed. The immediate effects of electrical injury include cardiac dysrhythmias, respiratory arrest and seizures. Therefore, it is important to monitor all patients who have suffered a cardiac arrest, or patients where it is suspected that the electrical current has passed through the thorax.

Low Voltage (<1000V)	Current type, Voltage	Skin	Deep tissue	Other injuries
Car battery	Direct current (DC), 12V	Entrance and exit wounds	Only affected near the contact surface	No other injury
Domestic electrical supply	Alternating current (AC), 220-230V	Entrance and exit wounds	Only affected near the contact surface	Cardiac arrest Transient ECG changes

SECONDARY SURVEY

A history should be taken to ascertain how and when the accident occurred and with what sort of electricity. As shown in the table below, the severity of the injury increases with voltage level. Be aware that alternating current (AC) has a five times more severe impact on the human body than direct current (DC). Ask whether there has been any loss of consciousness, and if so for how long. The patient should also be assessed for the presence of amnesia, other associated trauma, and any indications of cardiac arrest or cardiac dysrhythmias.

Different types of burns can be distinguished once the patient has had all clothing and accessories removed, to allow detailed examination. Flash burns appear on the body areas not covered by clothes, as deep dermal partial thickness and full thickness burns. Radiative heat transfer, caused by the electric arc, may cause direct burns to the skin and may also ignite clothing, resulting in full thickness burns.

When an entry wound is obvious during the initial examination, other parts of the body must be examined for exit wounds, however if contact with the earth was over a large surface area, these exit wounds may be absent. Entry and exit wounds are always full thickness. In between these entry and exit sites, mainly in the limbs, extensive soft tissue necrosis may be present underneath apparently normal skin. This manifests itself in the form of a swollen and tense limb, resembling compartment syndrome or a crush lesion. The patient will complain of deep pain and tenderness in the limb and upon palpation, the limb is very painful, tense and there may be signs of decreased circulation. Soft tissue necrosis leads to the production of the breakdown products of myoglobin and hemoglobin, which can cause renal failure. Therefore, assess the peripheral circulation hourly when an entrance or exit wound on an extremity is observed.

<table>
<tr><th>High Voltage (>1000V)</th><th>Current type, Voltage</th><th>Skin</th><th>Deep tissue</th><th>Other injuries</th></tr>
<tr><td>Overhead train line</td><td>AC and DC
750V - 50 KV</td><td rowspan="2">Entrance and exit wounds
Flash burn
Electric arc
Flame burn (clothes)</td><td rowspan="2">Muscle, bone and soft tissue damage
Rhabdomyolysis
Compartment syndrome</td><td rowspan="2">Myocardial damage
Delayed arrhythmias
Cardiac arrest
Transient ECG changes</td></tr>
<tr><td>Overhead power line</td><td>DC,
10KV to 380KV</td></tr>
<tr><td>Lightning</td><td>DC, Extremely high</td><td>Entrance and exit wounds
Deep dermal and subdermal burn wounds</td><td>Near contact</td><td>Respiratory arrest followed by cardiac arrest
Corneal damage</td></tr>
</table>

FURTHER DIAGNOSTICS

For electrical burns, always perform an ECG and if any abnormalities are present, the patient should be admitted and the ECG repeated after 12 hours. If the ECG is normal, further observation is not necessary and the patient does not need to be admitted. In addition to the ECG, always take a full panel of laboratory tests, including bloodwork (for CBC, CMP, lactate, troponin and CK) and urinalysis.

TREATMENT

Patients who have injury as a result of a high voltage require admission to the intensive care. In areas where deep muscle damage is suspected, a fasciotomy and inspection of all compartments must be performed, as all necrotic tissue must be removed. Treatment of skin defects is the same as in wounds caused by thermal injury.

Burn wound surgery in the acute setting

ESCHAROTOMY

Pathophysiology

After sustaining a full thickness burn, the skin shrinks by approximately 10% and becomes stiff and leathery. The result of this response to a full thickness burn is called an eschar. Subsequently, a local inflammatory response occurs and edema forms in the area of the burn. In the case of (semi-) circular burns, these two factors cause an increased pressure on the underlying tissue. This increase in pressure has a number of potentially severe effects, dependent on the anatomical location of the burn.

- **Limbs:** If the pressure on the tissue exceeds that of the venous and lymphatic pressure, this will cause an increase in edema. If the pressure on the tissue exceeds arterial pressure there will be a loss of circulation. The clinical signs of a constricting burn may include swelling, pain at rest or during passive movement, pallor, decreased capillary refill, loss of arterial pulsations and Doppler blood flow signals, coolness and numbness.

- **Neck:** Deep burns in the neck area can obstruct the airway and in the worst cases, cerebral edema may develop.

- **Trunk:** An eschar on the chest can severely limit the movement required for breathing. This decreased air entry would be noted during the A and B sections of the primary survey and in ventilated patients, these types of burns cause increased ventilation pressures. Abdominal compartment syndrome (ACS) may also occur.

Indications

The timing of escharotomy, where an incision is made into the skin to the depth of the subcutaneous fat, is based on the clinical presentation. Bear in mind that poor circulation and ischemia rarely occur immediately after burn injury, therefore frequent reassessment of tissue perfusion is important. It should be ensured that there is no systemic cause of distal hypoperfusion such as hypoxia, decreased cardiac output, hypovolemia or peripheral arterial constriction. An escharotomy may be indicated in the following instances:

- **Limbs:** When a circumferential or near-circumferential eschar of the extremities compromises the underlying tissues or the circulation distal to it.

- **Neck/Trunk:** When a circumferential or near-circumferential eschar of the head, neck or trunk compromises aeration and breathing. Beware that near-circumferential burns in children, including those not extending to the posterior chest, may still reduce ventilation as breathing is principally diaphragmatic.

- **Abdomen:** When a circumferential or near-circumferential eschar of the abdomen is associated with evidence of intra-abdominal hypertension (IAH), or signs of ACS. Breathing may also be compromised.

ABDOMINAL COMPARTMENT SYNDROME

The signs and symptoms of ACS may include an unexplained reduction in minute ventilation or oliguria. It is important to note that the presence of an abdominal eschar is not always indicative of ACS, and conversely the absence of an abdominal eschar does not exclude the possibility of ACS. To diagnose ACS, measure intravesical pressure (IVP) through a catheter inserted into the urinary bladder.

The normal range for IVP is <5mmHg. Values between 12 and 25mmHg indicate the need for close observation and re-evaluation, and any value >25mmHg requires intervention. If measuring IVP through a urinary bladder catheter is not possible, a venous femoral catheter can be inserted.

Both types of catheterization allow monitoring of the intra-abdominal pressure (IAP). If measurements are not possible and any slowing or interruption of fluid flow in the catheter is observed in a patient with abdominal burns and adequate fluid resuscitation, there should be a high suspicion of an increased IAP.

PERFORMING AN ESCHAROTOMY

Pre-operative preparation

Before starting, it is important to make an appropriate surgical plan. Firstly, evaluate the location of the constricting burn then plan and mark your incision lines, avoiding critical nerves, veins and vessels. It may also be useful to mark important structures close to the planned incision site that could be at risk. In general, two incisions are recommended in severe constricting burns to fully release the pressure. For specific incision sites refer to the advice below:

- **Arm**: Make the two incisions along the longitudinal axis of the affected part of the arm on the medial and lateral side. Mark the ulnar nerve at the medial epicondyle of the humerus.

- **Hand**: Make the incision on the dorsum of the hand between the metacarpals. For the fingers, incise the ulnar aspect of the radial digits (thumb, index and middle finger), and the radial aspect of the ring and little finger, if required.

- **Leg**: Make the incision along the longitudinal axes of the affected part of the leg, near the neurovascular bundles in the medial and lateral axial lines. Mark the peroneal nerve at the neck of the fibula.

- **Foot**: Make the incision on the dorsum of the foot between the metatarsals.

- **Anterior chest and abdominal wall**: Make the incision in the mid-axillary lines, which can be joined by a transverse incision below the costal margin to allow adequate release.

- It is also important to evaluate the general condition of the patient and pay attention to their hemodynamic stability, fluid status and electrolyte management. Prepare the patient and/or relatives for surgery by explaining the procedure and possible post-operative complications. These complications may include incomplete release, hemorrhage, increased fluid loss, subcutaneous infection and neuromuscular injury. Systemic peri-operative antibiotics are not required for this procedure.

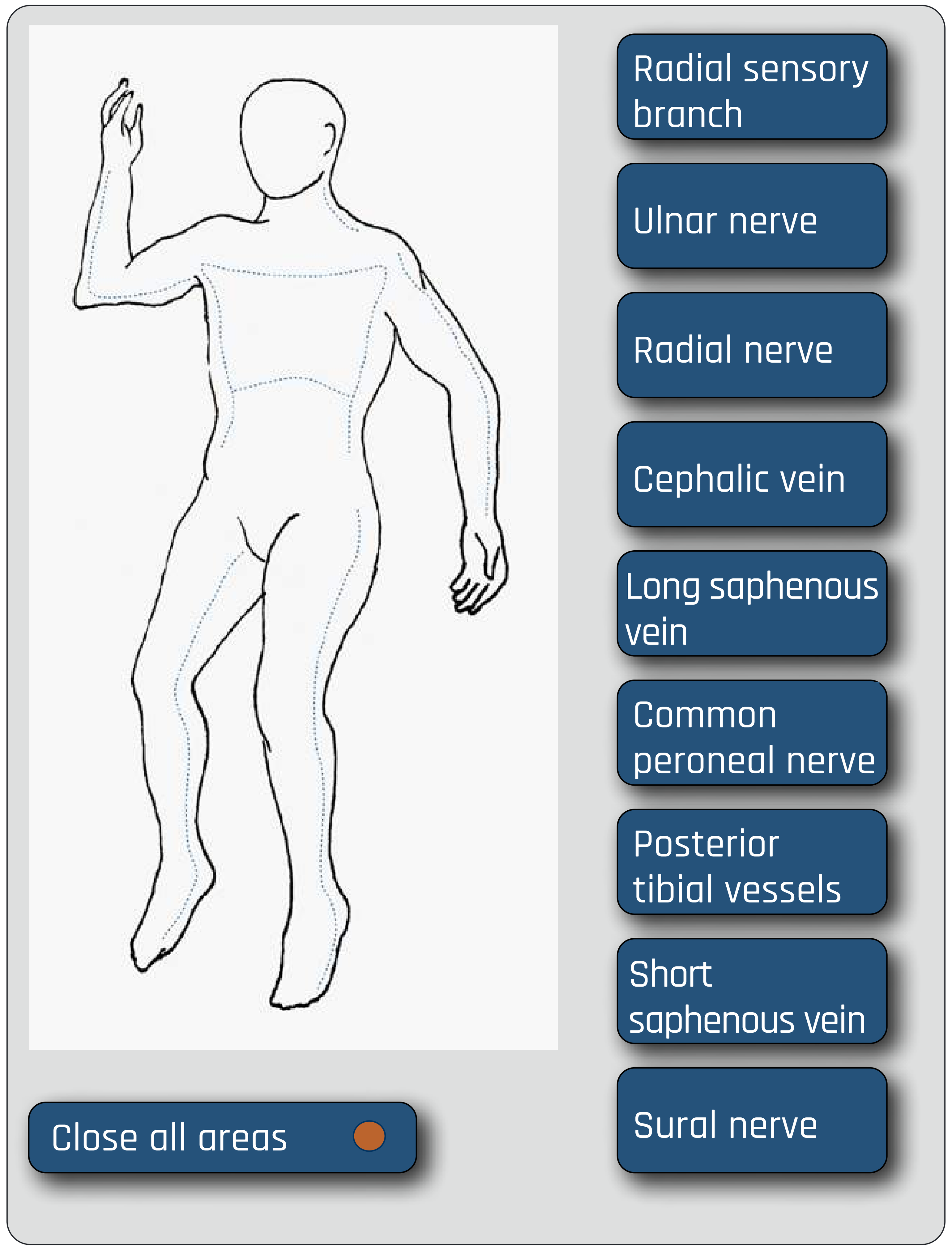
The equipment should also be prepared to include:
- Marker pen
- Antiseptic for surgical site preparation (chlorhexidine or non-alcoholic povidone-iodine)
- Sterile scalpel or electrosurgery set
- Local anesthetic (a solution with adrenaline is recommended to limit blood loss, there is no evidence that adrenaline is contraindicated for this indication)
- Dressing materials

Anesthesia
Attention should be paid to ensure adequate analgesia and sedation or anesthesia. Although an eschar consists of non-viable tissue where all cutaneous nerves have been destroyed, the incision should be made until it reaches healthy viable skin, where nerves are intact. General anesthesia is preferred, but not required, for an escharotomy. If general anesthesia is not available, ensure to provide adequate sedation.

Surgical procedure
To make the incision, use a scalpel or electrosurgery machine set to "CUT" when incising the eschar. Electrosurgery is favored over a scalpel because it causes less bleeding. The use of local adrenaline infiltration can also be very helpful to limit blood loss. Make an incision over your marked lines, through the entire thickness of the circumferential eschar down to the subcutaneous fat. To ensure decompression, the incision should extend 1cm into healthy skin. If this is not possible, continue the incision at least just proximally and distally to the adjacent joints.

Evaluate the result of your escharotomy by assessing the perfusion of the distal extremities using capillary refill time, continuous saturation monitoring with pulse oximetry and Doppler blood flow signals. In principle, an escharotomy is sufficient when only the burned skin layer is incised, leaving the subcutis intact. However, when an escharotomy is unsuccessful incisions should be reassessed. If the incisions are indeed adequate but the tissue perfusion remains poor, the presence of an acute compartment syndrome is probable and therefore a fasciotomy may be indicated. Note that a fasciotomy is rarely indicated and should only be considered for high-voltage electrical injuries or severe full-thickness burns, involving vital underlying structures. Hemostasis must also be ensured. Bleeding observed from the subdermal plexus and superficial veins may be stopped by electrosurgery, the application of thrombin-soaked gauze pads or light compression with plain gauzes.

Postoperative care
Cover the wound with alginate dressings. If these are not available, use a vaseline gauze followed by an absorbent dressing and a light bandage. Monitor the following parameters hourly, for at least 72 hours after the burn:
- Capillary refill time
- Doppler blood flow signals
- Pulse oximetry
- Sensation distal to the burned area
- Elevate the affected limbs.



Incision lines and at-risk areas

FASCIOTOMY
A fasciotomy is a releasing incision through the deeper underlying fascial layers.

Indications

Fasciotomies are rarely indicated, except for electrical burns or severe full-thickness burns with signs and symptoms of compartment syndrome. A fasciotomy is also indicated when the clinical signs and symptoms of compression persist, following an adequate escharotomy. In these cases, post-ischemic edema in the muscles distal to the constricting eschar may lead to a compartment syndrome, for which a fasciotomy is required.

Surgical procedure

A fasciotomy must be performed at an early stage of treatment, once the patient's ventilation and circulation have both been stabilized. A fasciotomy must be performed in a well-equipped operating theatre and requires general anesthesia. In contrast, an escharotomy can be performed in the emergency room or intensive care department of a hospital.

In very deep thermal burns and high voltage injuries, muscular necrosis may occur. This is a very severe condition that may also lead to rhabdomyolysis and renal failure. In this case, instead of performing a fasciotomy alone, additionally all suspect muscle compartments need to be explored and all necrotic tissue removed.

> Fasciotomies are recommended for high voltage burn injuries, with entrance or exit wounds in one or more extremities.

Pain management in the acute phase

Burn pain varies but is often very severe, especially the first few days post-injury. It should be noted that pain is subjective and in the acute phase, is commonly overlooked by doctors; this may be as a result of other elements of treatment being prioritized, sometimes due to clinical reasons. However, the fact that an objective measurement of pain is not possible may contribute to pain management not being prioritized. With the rise in patient reported outcome measurements (PROMS), the importance of adequate pain management has become more evident.

PAIN ASSESSMENT

Assess whether pain is due to the burn injury or caused by associated trauma. To do so, use a validated patient reported pain assessment scale to monitor pain levels and always record the findings.

For adults the Visual Analogue Scale (VAS) or Numeric Pain Rating Scale (NPRS) can be used.

For children aged over 3 years use the Faces Pain Scale, and for children aged 0-4 years use a behavioral pain scale, for example the FLACC Scale (Face, Legs, Activity, Cry, Consolability) or the COMFORT Behavior Scale.

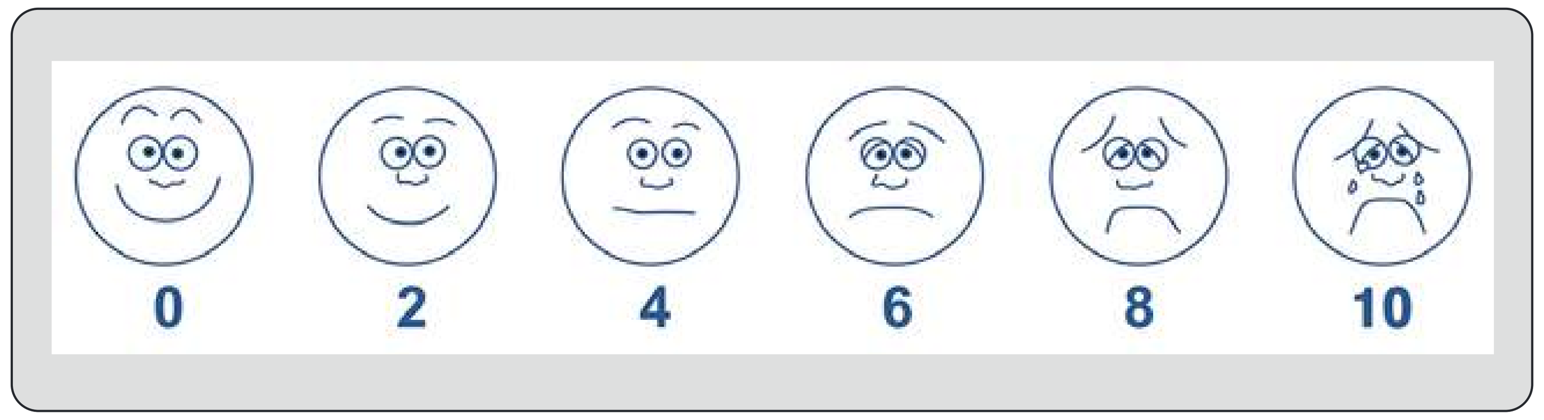
PAIN MANAGEMENT

Burn pain is highly variable and cannot be predicted by a clinical assessment of the patient. Therefore, a structured approach to burn analgesia, that incorporates both drugs and alternative therapies, is recommended.

Pharmacological treatment options

Use the World Health Organization (WHO) pain ladder as a guideline for the use of drugs in the management of pain. Pharmacological treatment includes paracetamol (acetaminophen) and non-steroidal anti-inflammatory drugs (NSAIDs), which are both of benefit in treating minor burns, usually in the outpatient setting.

For hospitalized burn patients, opioids are the cornerstone of pharmacological pain control however pain management should always be started by using non-opioid analgesics. Paracetamol should be utilized in all burn patients and NSAIDs can be added as a second step, provided there are no contra-indications (decreased renal function or other relevant comorbidities). For severe burns, always use opioid analgesics, in addition to non-opioid analgesics. In the acute phase of burn injury, an opioid is often indicated and should be administered according to hospital protocols. Analgesia should be tailored to each patient and



Visual pain scale for children
wongbakerfaces.org

Non-pharmacological treatment options may also be used and in general, there are four broad categories of non-pharmacological approaches. These are distraction, relaxation, hypnosis and cognitive behavioral therapy. Distraction may involve virtual reality therapy, movies and singing, and relaxation may involve breathing exercises, music, stress inoculation, aromatherapy and massage.

ANXIETY MANAGEMENT

Pain must be differentiated from anxiety and to do so, the Burn Specific Pain Anxiety Scale (BSPAS) should be added to the pain assessment scale being used. Psychological support is most helpful to address anxiety and can be provided by caregivers, all members of the treatment team or specialized experts, if available. Benzodiazepines may be indicated to relieve anxiety associated with burn injury.

Indications and procedures for referral to a burn center

BURN CENTER REFERRAL CRITERIA

There are many criteria for referral to a burn center. Please adhere to local protocols if available. Commonly used criteria are:

1. **Surface area**
   Burns covering >10% of TBSA in adults and >5% of TBSA in children require referral.

2. **Depth and location**
   Any full thickness burns or burns involving the face, hands, feet, genitalia, perineum or major joints should be referred.

3. **Etiology of burn**
   Electrical burns (including lightening injury), chemical burns or burns with an associated inhalation injury all require referral.

4. **Age**
   Children or elderly patients with burn injuries must be referred.

5. **Potential for complications**
   Patients with circumferential burns of the trunk or extremities require referral. Similarly, patients with burns associated with concomitant trauma, or burns in patients with comorbidities that may impact healing potential should be referred.

PREPARATION FOR TRANSFER TO A BURN CENTER

It is imperative that the patient is stabilized before transfer, and is only transferred once stable.

Respiratory system

Stabilize the respiratory system by supplying oxygen at a rate of 15L/min through a non-rebreathing mask for all patients with major injuries. The need for endotracheal intubation must also be assessed before transfer, as upper airway obstruction can progress rapidly.

Circulatory system

To stabilize the circulatory system, commence fluid resuscitation according to the *Modified Parkland formula* prior to transfer. To administer this, ideally obtain IV access through two large bore cannulas however if this is not possible, consider other routes of access for example using a peripheral venous cutdown (ankle or elbow), percutaneous central venous line (femoral, subclavian or internal jugular) or an intra-osseous needle. It is also important to prevent hypothermia.

Management of the burn wound

Firstly, evaluate the adequacy of any first aid treatment provided, then move onto administering early burn wound treatment. To do this, wash the burn with either 0.1% chlorhexidine solution or 0.9% saline, then cover the wound with a sterile, non-adhesive bandage or clean cloth. Topical agents should not be used if the referral centre can be reached within an acceptable time frame (1-2 hours).

Specific considerations

Some burns have specific requirements for stabilization. For example, head and neck burns can progress rapidly, causing upper airway obstruction, therefore these patients should be in a seated position during transfer. Burns of the perineum require early urinary catheterization. When there is burn injury to the extremities, these should be elevated to prevent edema. If essential functions such as ventilation or circulation are compromised by eschar formation, or they risk becoming compromised during transport, this is an indication for an early escharotomy before transfer.

Analgesia

Given that most burn injuries are extremely painful, opioid analgesia should be provided intravenously, if available. For example, morphine at a starting dose of 0.05-0.1mg/kg of bodyweight can be used. Subsequently, titrate the dose, dosing every 3-5 minutes. The final dose is determined by the patient’s response.

Gastrointestinal system

Patients with major burns are also at a high risk of gastroparesis. Therefore, insert a nasogastric tube for adults with burns >20% TBSA and children with burns >10% TBSA. This prevents gastric dilatation, vomiting and subsequent aspiration.

Tetanus

Tetanus prophylaxis must be administered at the first point of medical contact and it should be checked if it has been given when the patients arrives at a referral centre.

General management of burns patients after 24 hours

After the 'ebb phase' (the first 24-48 hours post-burn injury) the burn patient gradually evolves into the 'flow phase'. This section deals mainly with the care of patients during the flow phase.

PAY ATTENTION TO THE FOLLOWING MANAGEMENT PRINCIPLES

1. General nursing principles
2. Pain management and sedation
3. Delirium
4. Altered pharmacology
5. Fluid balance
6. Hemodynamics
7. Respiration
8. Gastro-intestinal tract
9. Nutrition
10. Renal support
11. SEPSIS
12. Psychological support

AIMS OF PATIENT CARE

The main aims of patient care are to maintain body homeostasis and to mitigate the pathophysiological responses to burn injury. The pathophysiological response during the first 48 hours is called the 'ebb phase'. This phase is characterized by hypovolemia and a low cardiac output. The 'flow phase' of the stress response follows the ebb phase. This phase is characterized by a hyperdynamic response and catabolism. It is important to prevent infection and to provide care, comfort and rehabilitation during patient management. The pathophysiological changes diminish with wound healing, therefore active surgical wound treatment aimed at early wound closure is imperative.

GENERAL NURSING PRINCIPLES

Semi-upright position

Nursing patients in a semi-upright position is recommended. This reduces edema of the head and neck, reduces the effort required for breathing and, for patients on ventilators, may help to reduce the incidence of ventilator-associated pneumonia.

Early mobilization

There is increasing evidence that mobilization helps to reduce muscle wasting and to reduce catabolism. Physiotherapy, exercise and getting the patient out of bed at the earliest opportunity are encouraged.

Ambient temperature

Patients lose heat by the evaporation of wound exudate. Energy expenditure to maintain body temperature must be minimized. In temperate regions in particular, patients should be kept warm and nursed ideally in an ambient temperature of more than 30ºC. This is especially important during dressing changes and in the operating theatre, when extra heat is lost by exposure and blood loss. Blood and fluid warming devices are recommended.

PAIN MANAGEMENT AND SEDATION

Treatment of pain and anxiety is not only important for mental wellbeing, but also reduces catabolism and facilitates rehabilitation.

Pain therapy

Non-pharmacological: The most effective form of pain therapy is effective wound coverage. Various non-pharmacological techniques are effective, including distraction, relaxation, hypnosis and cognitive behavioral therapy. Distraction may involve virtual reality therapy, movies and singing, and relaxation may involve breathing exercises, music, stress inoculation, aromatherapy and massage.

Medication: All patients can be safely prescribed paracetamol (acetaminophen). Paracetamol should be utilized in all burn patients and non-steroidal anti-inflammatory drugs (NSAIDs) can be added as a second step, provided there are no contra-indications (decreased renal function or other relevant co- morbidities) and are ideally prescribed together with a proton inhibiter. Slow-release opiate medication is effective, but beware of tachyphylaxis. For procedures such as dressing changes, Entonox (50% nitrous oxide in oxygen), low-dose Ketamine and short-acting opiates are useful, but require careful titration and monitoring. For patients on ventilators more sophisticated analgesia is required, such as continuous intravenous opiates and adjunct medication, to reduce endotracheal irritation and to suppress excessive coughing.

Sedation

Patients with burns have undergone a traumatic event. Admission to hospital, and intensive care in particular, add to feelings of disorientation and anxiety and a significant number will have some degree of post-traumatic stress disorder. Many patients have pre-existing psychological problems. For these reasons, sedative medication may be indicated. However, excessive sedation can have serious side effects, including listlessness, immobility, confusion and respiratory depression. Sedatives should be carefully titrated. Ideally, sedation prescribed in the form of hypnotics will encourage sleep at night, allowing the patient to be alert during the day.

A wide variety of drugs are available, including benzodiazepines, such as oxazepam and temazepam, augmented as appropriate by melatonin or haloperidol. For patients on ventilators, continuous intravenous medication may be more appropriate, for example midazolam or propofol. Drugs require continuous monitoring to prevent overdosing. It has been suggested that daily "wake up" periods, or titration to the Ramsay sedation scale (divides the level of sedation into six categories ranging from severe agitation to deep coma), should be included to facilitate accurate dosage.

RAMSAY Score	Sedation Level
1	Patient is anxious and agitated or restless, or both
2	Patient is co-operative, oriented, and tranquil
3	Patient responds to commands only
4	Patient exhibits brisk response to light glabellar tap or loud auditory stimulus
5	Patient exhibits a sluggish response to light glabellar tap or loud auditory stimulus
6	Patient exhibits no response

Ramsay sedation scale

DELIRIUM

Delirium is a serious complication in burn patients, characterized by psychological and/or motoric unrest. Treatment is difficult and specialized. The use of anxiolytic drugs, such as haloperidol and quietapine, together with psychiatric and psychological support, are indicated.

Pain, anxiety and delirium all improve markedly with wound healing. Therefore wound treatment remains the priority in caring for burn patients.

ALTERED PHARMACOLOGY

The pharmacological changes in burn patients have not been studied in detail, but are significant. Drug distribution is altered by changes in cardiac output, the presence of edema fluid and altered plasma protein levels. During the first 48 hours, hypovolemia lowers the rate and volume of drug distribution. Later, the volume of distribution is increased by the hyper metabolic state, while the presence of edema forms an ill-defined "third space" for water-soluble drugs. Elimination is affected by changes in liver function and, significantly, by an increased glomerular filtration rate in otherwise healthy patients. Drugs are also lost via wound exudate.

Drugs which bind to serum albumin, which is often low in burn patients, include diazepam, midazolam and morphine. Renal excretion of most antibiotics is increased. Studies have shown that antibiotic levels are generally low in burn patients and should be prescribed at relatively high dosages. The muscle relaxant succinyl choline is contra-indicated because of the risk of cardiac arrest following increased potassium release from myocytes. On the other hand, non-depolarizing drugs are less effective; curare-like drugs bind to alpha-1-glycoprotein, which is often increased in burn patients, and many are excreted in urine.

FLUID BALANCE

General principles

As the patient transitions from the ebb phase into the flow phase, fluid administration based on restricted urine production is no longer valid. From 48 hours post-burn, cardiac output increases; renal blood flow and glomerular filtration rate become elevated, together with the solute load, resulting in an osmotic diuresis. The renal concentration mechanism is impaired and urine production becomes elevated.

Burn patients lose water by evaporation from wounds, increased respiration, and increased urine production.

Approximate fluid requirements for adults (after the first 24 hours)

A useful formula for giving a rough estimate of hourly insensible fluid loss in burns is:

(15 + % TBSA BURNED)
X
TOTAL BODY SURFACE AREA
(in mls per hour)

Free internet calculators are available for measuring body surface area, based on height, weight and sex.

For a bedside estimation, typical values for TBSA are as follows:

- **Neonate** 0.25 m^2
- **Two-year old** 0.5 m^2
- **Ten-year old** 1.14 m^2
- **Adult female** 1.6 m^2
- **Adult male** 1.9 m^2

Fluid requirements can be estimated by adding at least 1 ml per kilogram body weight per hour for adequate urine output.

EXAMPLE

A ten-year old boy, weight 35Kg, with a 20% TBSA burned has an insensible fluid loss of approximately (25+20) x 1.14
=
51.3 mls/hour.
Anticipated urine production
=
at least 35 mls /hour.

Therefore, minimal total fluid requirement
=
51 + 35 = 86 mls/hour,
or approx. 2,000 mls per day.

This formula serves as an initial guideline only. Actual requirements are determined by clinical observation, especially thirst, hemodynamic parameters and laboratory tests. In contrast, for the reasons outlined above, urine production becomes an unreliable indicator of normovolemia. Patients may be allowed to drink freely, preferably calorie-rich fluids, which contribute to nutritional requirements. Intravenous fluids (e.g. glucose/salt solutions) may be necessary for patients unable to drink. Dehydration should be suspected if serum sodium concentration becomes elevated, especially if urine sodium is low.

HEMODYNAMICS

General principles

Following resuscitation, the pathophysiological response to burn injury manifests as hypermetabolism. Cardiac output increases, with tachycardia and a reduction in peripheral vascular resistance. There may be a tendency towards hypotension, especially if the circulating volume is low. It is important to give sufficient fluids.

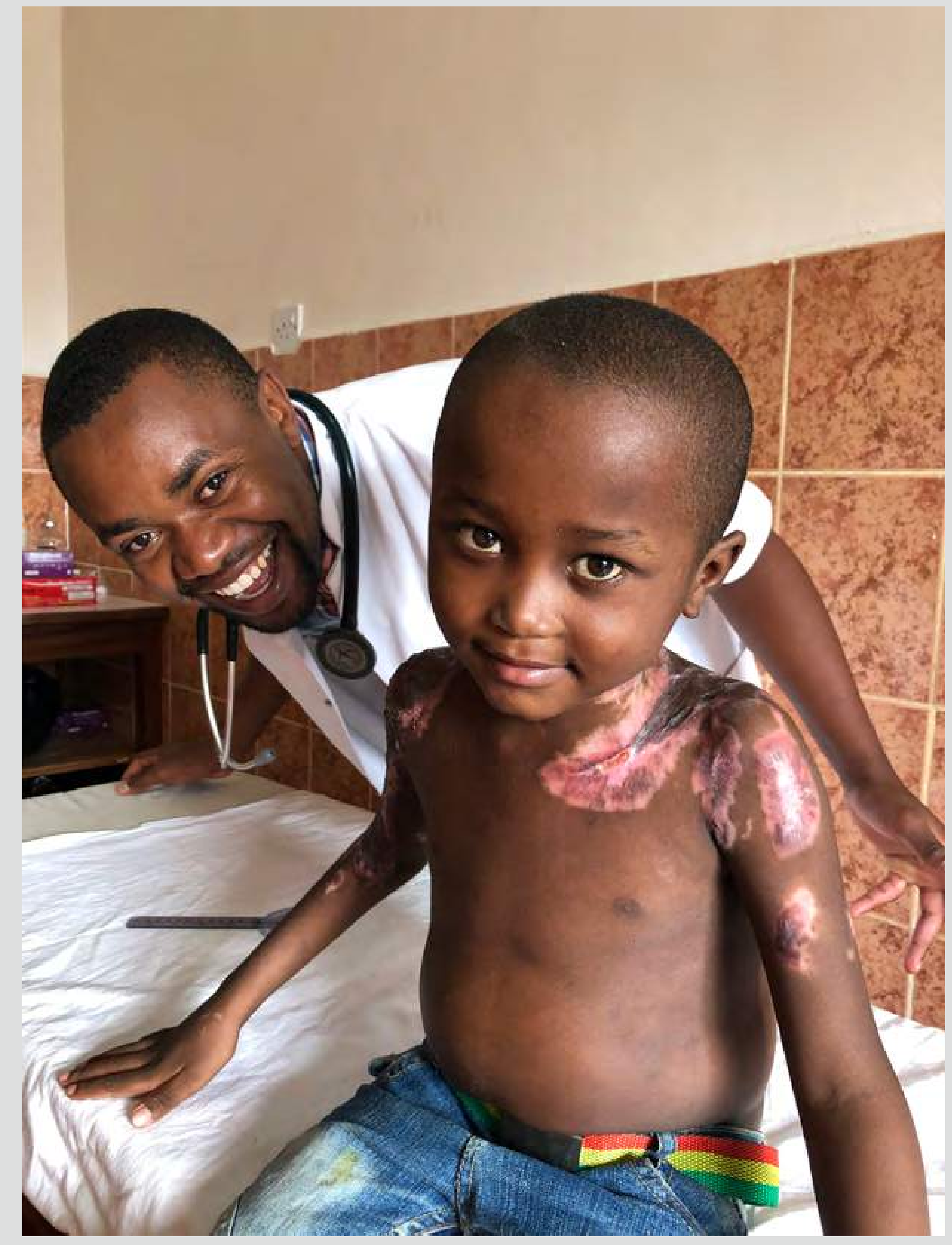
Propranolol has been found to be useful and can be titrated to attenuate tachycardia (e.g. less than 100 beats per minute). This beta-blocker reduces heart rate and cardiac effort, and may have beneficial effects on muscle catabolism. The drug is also mildly anxiolytic.

Anaemia

One of the frequent findings in children with severe burns in low and middle income countries is anaemia. Depending on the severity this can be treated following local protocols by giving iron rich nutritional supplements, iron tablets and folic acid or blood transfusions.

Thromboprophylaxis

As in all patients with reduced mobility, the risk of venous thrombosis is increased. In addition, burn patients display hypercoagulability. Thromboprophylaxis in the form of low molecular weight heparin is indicated.



RESPIRATION

General principles

As with other vital systems, the respiratory system is under increased strain in burn patients for a number of reasons.

The hypermetabolic response gives rise to increased oxygen demand and increased CO_2 production. Chest wall compliance may be reduced by burns of the thorax or abdomen and an escharotomy is indicated if burns in this area are extensive. Inhalation injury may severely compromise respiratory function.

Supportive measures

General measures include positioning the patient in a semi-upright position, which reduces the work of breathing. Atelectasis and pneumonia are common in burn patients, especially following smoke inhalation. Chest physiotherapy and frequent position changes are beneficial. Many patients become hypoxic; oxygen therapy is ideally titrated to oxygen saturation levels. Bronchodilators, such as salbutamol, can be freely administered if indicated. Acetyl cysteine is useful for loosening secretions.

Daily physical examination should include chest auscultation and any changes confirmed, if possible, by X-ray.

Oral hygiene is important and should include daily teeth brushing and rinsing with an antiseptic mouthwash. Dental work may be indicated for carious teeth or infected gums.

Mechanical ventilation (MV)

Indications: Endotracheal intubation may be a life-saving procedure following the inhalation of hot gases or, rarely, steam, causing burn injury to the upper airway in the first hours following injury. Intubation is then required urgently to prevent occlusion of the upper airway by edema. For more information about inhalation injury management during the first 24 hours read 'Initial evaluation and management – inhalation injury'. In other circumstances, MV is only indicated by the development of respiratory failure. This may develop even later than 24 hours following smoke inhalation, or following complications such as pneumonia or sepsis. However, the intervention should be avoided if possible. MV impedes cardiac output, increases fluid retention and increases the risk of pneumonia. MV in burns is an independent predictor of mortality. Patients on ventilators should be weaned as soon as is practicable. Less invasive forms of respiratory support, such as continuous positive airway pressure (CPAP) by mask might be appropriate but are problematic in combination with facial burns.

GASTROINTESTINAL TRACT

General principles

The gut is a potential reservoir of potentially pathogenic microorganisms and maintenance of gut integrity is an important facet of general care. Risks include the development of mucosal atrophy and increased intestinal permeability, which provides a route for bacterial translocation. Gastric stasis occasionally occurs and may be related to opiate medication. Gastric ulceration is reported, especially in patients with extensive burns. Intestinal stasis is unusual and may be an early sign of sepsis.

Advantages of enteral feeding

The most important measure to prevent gastrointestinal complications is the establishment of early enteral feeding, which attenuates villous atrophy, protects the gastric mucosa and preserves gut function. Feeding and can usually safely be commenced within a few hours of injury.

Practical aspects

Patients with burns of more than 20% TBSA may require supplemental tube feeding. Placement of a double lumen nasogastric tube (to monitor gastric retention) or, ideally, placement of a post-pyloric tube either via the nasal route or via a gastrostomy, is preferred.

As the stomach can be emptied mechanically, there is no need for patients to fast pre-operatively.

NUTRITION

General principles

Significant alterations in metabolism occur following burn injury and require additional nutritional support. Energy is lost in the form of evaporative heat loss, the hypermetabolic response to burn injury induces catabolism, proteins and minerals are lost via wound exudate and the patient loses weight.

EXAMPLE

A 40 year old, 80 Kg adult male, height 180 cm with a 30% TBSA burned.

BMR = (10 x 80)
+ (6.25x 180)
– (5 x 40) + 5
= 800

+ 1,125 – 200 + 5
= 1730.

Actual requirement = 1730 + 30% = 1730 + 519
= 2249 Kcal per day.

Malnutrition weakens the immune system and impairs wound healing. Therefore, nutritional support should be provided during the acute phase of recovery. Nutrition therapy describes how nutrients are provided to support nutrient intake. Additional nutrients can be provided orally, indicated for patients who are able to eat and drink, but who do not consume enough protein or calories on their own (e.g. fortified food or oral nutritional supplements). Nutrients can also be provided via enteral tube-feeding, if resources permit, especially for patients with significant burn injury (>20% TBSA). An additional advantage of a gastric tube is that the stomach can be emptied manually, so that pre-operative fasting can be kept to a minimum.

Feeding should commence within 12 hours of injury, and gradually advanced over a day or two until the goal intake of caloric requirements is reached. When nutritional therapy is started, monitoring nutrient intake and, if possible, consulting a dietician, are mandatory to minimize risks (e.g. overfeeding or gastrointestinal or mechanical problems).

Gastric stasis and retention occurs occasionally and may cause nausea, therefore feeding might have to be reduced temporarily. Domperidon (Motilium) may be useful to reduce nausea. If resources permit, introduction of a post-pyloric tube usually solves the problem.

	Adjusted formula
Men	BMR = (10 × weight in kg) + (6.25 × height in cm) - (5 × age in years) + 5
Women	BMR = (10 × weight in kg) + (6.25 × height in cm) - (5 × age in years) - 161

Harris Benedict Formula (modified) to calculate resting energy expenditure

Parenteral nutrition (e.g. provision of sterile intravenous fluids containing the full spectrum of nutritional needs) should be avoided unless all other means fail.

In LMICs, specialized nutritional support can be challenging due to limited resources. If resources do not permit enteral tube feeding, protein and caloric needs should be met orally as soon as possible. A multimodal approach can be followed including appointing a (nutritional) nurse or volunteers to help feeding the incapacitated patient, educating caregivers about the importance of adequate nutrient intake and encouraging them to stay with the patient to assist with nutrition. Some patients with extensive burn injury may develop dysphagia due to oral thrush. The risk is increased in patients receiving antibiotics.Oral thrush can be treated with nystatin.

Caloric requirements
According to the ISBI guidelines, patients with burns covering more than 20% TBSA burned should receive a high protein and calorie diet to meet their energy needs. Adults should receive 1.5-2 grams of protein per kilogram of body weight per day, and children 3 grams per kilogram of body weight per day. Examples of sources of dietary protein are meat, poultry, eggs and dairy products. Periods of fasting (e.g. pre-operatively) must be kept to a minimum.

The Harris Benedict Equation + 1% extra per % TBSA burned can be used as a guide to estimate caloric needs, see example

Free internet calculators are available for practical use of the Harris Benedict Formula.

Supplements
Patients require daily supplementation of vitamins (B,C and D). It has been shown that trace elements are rapidly depleted in burn patients, including copper, iron, selenium and zinc, which are important for wound healing. There is evidence to support supplementing glutamine. Diets should be composed with care. It safe to administer twice the recommended dosage of proprietary supplements.

Supportive measures
Hyperglycemia has been highlighted as a risk factor in intensive care patients therefore the aim is to maintain normoglycemia during the hypermetabolic phase. Insulin inhibits gluconeogenesis, diminishes proteolysis and stimulates fatty acid synthesis. Insulin therapy requires intensive monitoring and risks hypoglycemia. It is suggested that the use of anabolic steroids, although not without risk in children, increases lean body mass and improves wound healing.

RENAL SUPPORT
Renal injury
Acute renal failure (ARF) is uncommon in patients who have been carefully resuscitated with fluids in the first 48 hours. The main causes are hypovolemia, abdominal compartment syndrome (ACS) and septic complications. Early renal failure is associated with inadequate fluid resuscitation, or ACS, which results from excessive fluid resuscitation. Following sepsis, renal failure is a frequent component of multi-organ failure. Urine volume alone is an unreliable indicator of renal function (see remarks on fluid balance). Progressive increases in serum creatinine and ureum levels are more indicative. The RIFLE criteria (classification for acute kidney injury) have been validated in burns. Treatment comprises the identification and reversal of the cause.

Continuous Renal Replacement Therapy (CRRT)
If renal failure is progressive despite optimal measures, renal replacement therapy is indicated. Continuous veno-venous hemofiltration (CVVH) is the simplest and safest technique, but requires equipment and expertise. CRRT provides control of fluids and electrolytes and may be beneficial by filtering out reactive short-chain peptides.

SEPSIS
General information
Systemic microbial infection (sepsis) is the major cause of multi-organ failure (MOF) and death in burn patients surviving more than 48 hours. Preventative measures are therefore emphasized. These include meticulous hygiene, optimal wound therapy, patient isolation and maintenance of homeostasis. Systemic antibiotics are indicated when there is septicemia or hemolytic streptococcal wound infection, however the use of prophylactic systemic antibiotics should be avoided for acute burns. In communities where streptococcal carriers or infection is widespread, simple prophylaxis may be given for 24 hours only.

Signs and symptoms
Sepsis can present catastrophically or insidiously. Early signs include tachypnea, absent peristalsis and increased glucose intolerance. Hypotension and oliguria may herald the onset of MOF.

Treatment
Blood cultures should be taken immediately upon suspicion of sepsis, followed by high dosage intravenous antibiotics, preferably chosen based on microbiological data. Patients require extra oxygen. Extra fluids may be indicated for hypotension and to combat oliguria, but the risk of provoking lung edema is heightened.

Mechanical ventilation, inotropic support and renal dialysis may all be required to treat established MOF. The condition is potentially reversible, but mortality is high.

PSYCHOLOGICAL SUPPORT
Treatment of patients with burn injury must include psychological support. Attention must be given to psychological support in all phases including the admission and critical care phase, in-hospital recuperation phase and re-integration and rehabilitation phase. During the admission and critical care phase, psychological problems are characterized by overstimulation, under stimulation, delirium, impaired communication, sleep disturbance and pain. During the in-hospital recuperation phase, patients become more aware of the physical and psychological impact of the injury. Challenges include pain, anxiety, depression, sleep disturbance, grief and premorbid psychopathology. Around one third of patients develop symptoms of Post-Traumatic Stress Disorder. In the long term, during the rehabilitation phase, physical (e.g. itching, limited endurance and decreased function) and psychosocial (e.g. re-integration to work, body image, sexual dysfunction and acceptance) problems often occur. Psychologists and social workers should be consulted to provide psychological support, not only to the patient, but also to family members and caregivers.

Acute burn wound treatment

Photo by N. Keekstra

Treatment plan

LOCATION OF TREATMENT

After stabilizing a burn patient, decide if the current facility is the best place for the patient to receive further burn care. If the option is available, refer the patient to a well-equipped (burn) center and, if this is not done immediately, always reconsider the option of referral if required in the later stages of treatment.
Be aware that severe burns in neonates and pregnant women require individualized management, preferrably by a specialized team.

If the patient stays in the current facility, the next logical step is to make a treatment plan and to document this in the patient file. Although this may be a seemingly small step, the importance of defining the best possible treatment strategy tailored to the individual patient, should not be underestimated.
Burn management requires a multidisciplinary approach; involve the required experts such as intensive care specialists, pediatricians, psychiatrists, physiotherapists and dieticians.

GOALS OF TREATMENT

All the findings during the primary evaluation of the patient will determine the choice of treatment.
The goals of treatment are:

- to optimize wound healing and thus wound closure
- provide adequate pain management
- prevent wound colonization and infection
- to minimize scar formation.

SHOW HOTSPOTS

The ultimate goal is to optimize the quality of life for the patient, meaning that the initial treatment plan should be well designed, but also the effect of the treatment methods continuously evaluated. Delayed wound healing will promote scar formation and it is important to remember that the formation of granulation tissue during the healing process, is in fact the formation of scar tissue.
The longer the treatment delay, the more scar tissue which may lead to contractures, especially in burns near joints.
Do not forget, if appropriate, to advise the patient to stop smoking, given that smoking delays wound healing.

FACTORS DETERMINING THE TREATMENT PLAN

1. **Burn wound size, depth and location** are the main factors determining the treatment plan. The diagnosis of depth is not always definitive and the burn may deepen during the first 24 to 48 hours post-injury. Deepening of the burns cannot always be prevented, however optimizing wound conditions can reduce the impact of this. Wound conditions can be optimized by properly cooling the burn with lukewarm running water for 10 minutes as soon as possible after the injury, proper fluid resuscitation, adequate burn wound treatment, elevating affected limbs to reduce edema and optimizing the physical condition of the patient.
2. **Age, general physical condition and medication** are important to consider when formulating a treatment plan. For example, wounds in children heal faster than in in adults, which may influence the timing of surgery. Conversely, elderly patients have thin skin which takes longer to heal, therefore burns that appear superficial on initial examination may take weeks to heal, or deepen to full thickness. The patient's body homeostasis and the pathophysiological response to burn injury may interfere with the timing of surgical treatment. Before surgical excision, it should be ensured that dehydration is corrected and renal function sufficient, however do keep in mind that extensive, deep burn injuries can have severe systemic effects, therefore early surgical excision is required. Also, comorbidities should be taken into account. In low and middle income countries epilepsy, for example, is common in burn victims. Severe anemia is also frequently seen in burn patients, especially children. Mental illnesses are common in burn victims, both in high and low income settings. All comorbidities should be taken into account when developing a patients specific treatment plan. Medication use is another factor that may affect success of the treatment plan.

> **FACTORS**
> DETERMINING THE TREATMENT PLAN
>
> 1. Burn wound size, depth and location
> 2. Age, general physical condition, comorbidities and medication
> 3. Socioeconomic factors
> 4. Limitations of clinic facilities and the medical team

An example: Patients that have been taking corticosteroids for a long period of time may have a very fragile, thin skin, hindering the harvesting of a split-thickness skin graft.

3. **Socioeconomic factors** may play a role, especially in resource limited settings. A patient may refuse admission to the hospital due to a lack of funds, or refuse surgical treatment due to a lack of trust.

4. **Limitations of clinic facilities and the medical team** may interfere with the treatment plan. For example, the team may not be appropriately trained to perform burn surgery, the burn team may not be well prepared or equipped due to a lack of availability of materials, and specialized surgical techniques may not be within the skill level and competencies of the burn team, such as (free) flap surgery.

DECISION MAKING FOR ADEQUATE BURN WOUND TREATMENT

The general principles of burn wound treatment should be followed and always keep in mind the factors influencing the choice of treatment, and in the case of surgical treatment, the timing of surgery. Please read the following chapters in this section carefully to use all information to formulate the best possible treatment plan for each individual patient.

It should be decided whether **conservative treatment** or **surgical treatment** will be used. If surgical treatment is indicated, **early excision and skin grafting or delayed excision and skin grafting**, must then be chosen. In the case of early surgical treatment, its recommended to cover the wound temporarily to prevent colonization. In early and delayed surgery, a wound dressing that prevents wound colonization must be applied. A topical antiseptic such as SSD, Fucidin or honey is appropriate in most cases. In some settings patients with burn injury may present delayed with wounds that are already infected. This is more likely in low- and middle income countries. As a general rule, infection of a burn wound is not a contra-indication for skin grafting and, when the physical condition of the patient allows, radical debridement of the infected wound is indicated. However, in selected cases, especially in case of a pseudomonas infection, treatment with topical agents against pseudomonas is required as a first step before planning skin grafting.

Conservative treatment

For conservative treatment (both the temporary treatment awaiting surgery and fully conservative treatment), a choice should be made between the **closed wound treatment** method, the **semi-open** method and **exposure** of the burn wound(s). A fully **conservative treatment** is indicated for the following types of burns:

1. **Epidermal burns**

2. **Superficial partial thickness burns**

3. **Deep dermal partial thickness burns**
   In these wounds the burn depth may be heterogeneous, ranging from superficial partial thickness to full thickness, therefore initially, conservative treatment is advisable. Once the partial thickness areas of these wounds have healed, the deeper, full thickness parts will remain and may require surgery, dependent on size and location. This approach promotes the take of the skin graft if surgery is required, as the inflammation reaction that occurs during the healing process improves the blood flow to the wound.

Dressing change at the outpatient clinic

Additionally, initial conservative treatment reduces the surface area requiring wound excision and grafting, resulting in a reduction in surgery time and limits blood loss.

Surgical treatment
Surgery is indicated for the following types of burns:

1. **Deep dermal partial thickness burns**
   In these wounds, the burn depth may be heterogeneous, ranging from superficial partial thickness to full thickness. As stated before, starting first with conservative management is recommended but once the partial thickness areas of these wounds have healed, the deeper, full thickness parts will remain and may require surgery, dependent on size and location.

2. **Full thickness burns**
   The timing of surgery for these burns is dependent on the burn wound size, depth and location, but also on the general condition of the patient and the available resources (for example the safety of anesthesia and facilities for blood transfusion).

RE-EVALUATION OF THE TREATMENT PLAN
The treatment plan should be re-evaluated regularly for multiple reasons. For example, the diagnosis of the depth of the burn is not always definitive, as the burn may deepen during the first 24 – 48 hours post-injury. The treatment plan should be adjusted based on a change in diagnosis of the burn when necessary. Complications such as wound colonization and infection, or insufficient quality of the wound bed for skin grafting may occur, and the treatment plan should be re-assessed in light of these. Be prepared to switch from Plan A to Plan B as the examples below demonstrate.

Example 1
If a superficial partial thickness burn has not healed within the expected timeframe, the plan must be changed from Plan A (treatment with a topical agent) to Plan B (treating by burn wound excision and skin grafting).

Example 2
If a superficial partial thickness burn has not healed within two weeks due to wound colonization or infection, change from Plan A (conservative treatment) to plan B (surgical treatment). Infection is not a contraindication for wound excision and skin grafting.

Pain management

Attention to pain and anxiety management is essential in all phases of care, especially during wound inspection and cleansing. Pain levels in adults should be assessed with the Visual Analogue Scale (VAS) or the Numeric Pain Rating Scale (NPRS). For children aged over 3 years, use the Faces Pain Scale, and for children aged 0-4 years use a behavioral pain scale, for example the FLACC Scale (Face, Legs, Activity, Cry, Consolability) or COMFORT Behavior Scale.

PHARMACOLOGICAL APPROACHES

When changing a dressing on a wound, administer analgesia according to the WHO Analgesic Ladder. Always start with step one, non-opioid analgesics (paracetamol or non-steroidal anti-inflammatory drugs—NSAIDs). For wound dressings, often step two and/or three are needed. Step two consists of "weak" opioids (hydrocodone, codeine, or tramadol) and step three the "strong" opioids (morphine, hydromorphone, oxycodone, fentanyl, or methadone). For example, provide an oral opioid 30 to 60 minutes prior to a planned dressing change, such as 5 – 30mg morphine sulphate orally (immediate-release) every 3-4 hours, when required.

For dressings of larger burn wounds, the use of ketamine is widely recommended, especially in children. Ketamine is relatively safe and very effective. Awareness and pain sensation are suppressed while muscle function (including muscles of ventilation) remains unaffected. Follow hospital protocols for ketamine use during wound dressing.

DURING THE PROCEDURE, MONITOR PULSE OXIMETRY AND DO NOT LEAVE THE PATIENT ALONE.

NON-PHARMACOLOGICAL APPROACHES

Multidisciplinary interventions from psychologists, physiotherapists and pain management specialists can contribute greatly to the burn patient's recovery. In general, there are four broad categories of non-pharmacological approaches to pain management:

- Distraction (e.g. virtual reality therapy, movies, singing)
- Relaxation (e.g. breathing exercises, music, stress inoculation, aromatherapy, massage)
- Hypnosis
- Cognitive behavioral therapy

Steps	Medication
I	**Mild pain** non-opioid analgesics such as nonsteroidal anti-inflammatory drugs (NSAIDs) or acetaminophen with or without adjuvants
II	**Moderate pain** weak opioids (hydrocodone, codeine, tramadol) with or without non-opioid analgesics, and with or without adjuvants
III	**Severe and persistent pain** potent opioids (morphine, methadone, fentanyl, oxycodone, buprenorphine, tapentadol, hydromorphone, oxymorphone) with or without non-opioid analgesics, and with or without adjuvants

WHO Analgesia ladder

Management of blisters

INTACT BLISTERS
The majority of guidelines and studies suggest de-roofing of the blister is best, as it has the advantages of providing some pain relief and allows adequate assessment of the burn wound; sometimes a deep dermal partial thickness burn can be hidden under the vesicles of the blister. [Photo 1 and 2] However, there are some indications for leaving the blister intact, for example small blisters (<6mm) that do not cause any discomfort may be left intact. In settings where resources are limited and modern dressings are not available, the snip-open procedure may be an alternative for de-roofing. [Photo 3] In this procedure, the blister is snipped open, leaving the walls to drop down and cover the area of raw skin underneath, acting as a "biological dressing". Be aware that the treatment strategy must be re-evaluated daily and, depending on the outcome of the burn wound (re)assessment, a change in treatment may be necessary.

RUPTURED BLISTERS
Large areas of loose tissue where blisters have ruptured should be removed, using gauzes and/or sterile scissors or forceps.

DRESSING THE WOUND

1. After de-roofing a blister, first of all the depth of the burn must be re-established. Next, treat the wound according to the depth. In clear superficial wounds, a membraneous dressing like human allograft skin or an amniotic membrane (biological dressing) or a synthetic dressing (Aquacel, Suprathel or alginate wound coverings) can be applied.

LOOSE TISSUE WHERE BLISTERS HAVE RUPTURED SHOULD BE REMOVED

Many of these dressings can be left on the wound until healing is complete. In deep partial thickness wounds or if the depth of the wound can not be established, it is safest to choose a topical antiseptic such as silversulfadiazine cream or Fucidin ointment. These wound coverings must be changed daily. In mixed depth wounds, the deepest part determines the choice of the wound covering.

2. After a snip-open procedure, the walls of the blister function as a "biological dressing". On top of this, apply a Vaseline gauze followed by a bulky dressing or bandage. Leave this dressing in place until soaked, or until the "sniff test" indicates there is an offensive smell. Continue in this fashion until healing is completed, up to a maximum duration of one week. After one week, if the wound has not completely healed, the blisters should de-roofed and dressed accordingly.

3. For an intact blister, apply a dry bandage to protect the wound or leave it open.

4. For dirty or contaminated wounds, or in the case of late admission (>24 hours post-injury), dressings should be changed more frequently.

BLISTERS

1. Intact blisters
2. Result after deroofing of the blisters
3. Ruptured blisters
4. Result after removing all loose tissue

Cleaning and debridement

Cleaning and debridement at the emergency room and/or later in the treatment process are essential to prevent infection and to facilitate wound healing.

Ensure proper pain management before starting, as described previously.

The aim is to remove loose, dead skin and other dirty elements that may adhere to the wound, such as dust and/or remnants from previous topical treatment.

Cleaning of the burn wound is commonly performed using a hand-held shower head to remove dirt gently by irrigation and wiping.

The definition of debridement is the medical removal of dead, damaged, or infected tissue. It is also a form of cleaning, specifically 'medical cleaning' and may involve specific medical techniques. These techniques can be mechanical, chemical, enzymatic (e.g. Nexobrid), biological (e.g.maggot therapy) and/or surgical.

MECHANICAL DEBRIDEMENT

This is commonly referred to as the conservative mechanical removal of loose material without the use of sharp surgical tools or other techniques. The dead tissue that is already loosened by autolytic processes, is removed by gentle rubbing with gauzes soaked in diluted aqueous chlorhexidine (0.1/0.2%), 0.9% saline or soap and water. Alcohol based solutions should not be used. Dermal burns can be supported to heal by themselves this way.

Full thickness burns require grafting and, if feasible, early surgical debridement and grafting is recommended. However, in circumstances that do not permit early surgical escharectomy, the removal of the entire eschar can be achieved in full thickness burns by daily soaking, gentle rubbing and rinsing. However, this may take up to two to three weeks and should be followed by delayed grafting when the burn wounds and the general condition of the patient are fit for surgery.

SURGICAL DEBRIDEMENT

For burns this should take place in the operating theatre with adequate anesthesia. In burn surgery, an escharectomy is a debridement in which the eschar (the dead skin in a full thickness burn) is removed surgically until a healthy wound bed is achieved.

This can be done with a scalpel, electro-surgery or hydrosurgery.

Escharectomy is recommended for deep burns at an early stage, after the burn injury grafting, during the same procedure. In specific situations, such as resource constrained settings, the escharectomy is not performed at an early stage and/or may not be followed by immediate skin grafting. The skin grafting may be delayed until the patient is in a better condition.

Conservative mechanical removal of loose material without the use of sharp surgical tools or other techniques.

Topical agents

There are many different topical agents used for burn care worldwide. Please adhere to local protocols, if available. Some of the most often recommended agents are listed below.

TOPICAL AGENTS – BASIC BURN CARE

Silver sulphadiazine cream (SSD) (Flammazine®)

This agent has a broad antibacterial spectrum, acting against both Staphylococcus aureus and Pseudomonas aeruginosa. The disadvantage of SSD is that a slough layer will form over the wound, making the assessment of burn depth difficult. Furthermore, SSD cannot be used indefinitely, preferably no longer than one week as the cream may cause hypergranulation and maceration of the healed skin.

- **Application**
  Preferably apply 0.5 cm thick layer of SSD onto dry gauze. If SSD is in short supply, apply it onto Vaseline gauze.

- **Dressing frequency**
  Daily. Do not use for more than 7 days. Prolonged application increases the risk of hypergranulation.

Honey mixture

This agent is comprised of 1/3 honey and 2/3 ghee/vegetable oil/glycerin/water, and has antibacterial properties, acting against Staphylococcus aureus.

- **Application**
  Apply the honey mixture onto Vaseline gauze.

- **Dressing frequency**
  Once every 2 or 3 days

5% Acetic acid (diluted vinegar)

This agent acts against Pseudomonas. Acetic acid may be useful in resource deprived settings since it is relatively inexpensive and widely available.

- **Application**
  Be aware that this agent causes pain upon application. Soak the acetic acid onto a Vaseline gauze.

- **Dressing frequency**
  Twice daily

Povidone-iodine (Betadine®)
This agent is less suitable for initial treatment than SSD, as it has a lesser antibacterial effect on burn wounds. It can be a useful alternative later in the treatment, for example in the treatment of small facial burn wounds. Povidone-iodine acts against Staphylococcus aureus.

- **Application**
  Apply the povidone-iodine onto Vaseline gauze.
- **Dressing frequency**
  Daily

Silver nitrate solution (0.5% $AgNO_3$)
This agent acts against Pseudomonas and can be used for the treatment of hypergranulation.

- **Application**
  Apply the solution onto Vaseline gauze.
- **Dressing frequency**
  Daily

Papaya
Papaya contains papain which causes enzymatic debridement. This reduces necrosis, formation of proud flesh (hypergranulation), and has antibacterial properties.

- **Application**
  Preferably use a ripe papaya and mash until smooth. Apply this pulp gently to the wound and cover with a gauze.
- **Dressing frequency**
  Daily

Pineapple
Pineapple contains bromelain which has the same properties as papain in papaya. In practice, papaya is used more often than pineapple, as papaya is more widely available and less expensive.

- **Application**
  Preferably use a ripe pineapple and mash until smooth. Apply this pulp gently to the wound and cover with a gauze.
- **Dressing frequency**
  Daily

TOPICAL AGENTS – FURTHER CARE

Fusidic acid (Fucidin®)

This agent is not suitable for use in the initial treatment of the burn wound, but can be used at a secondary stage of treatment. Fusidic acid acts against Staphylococcus aureus however resistance occurs after approximately 1 week of use. Therefore another topical antibiotic should be used after 1-2 weeks, for example Mupirocin (Bactroban®).

- **Application**
  Apply onto Vaseline gauze.

- **Dressing frequency**
  Daily, do not use for longer than 1-2 weeks.

Sodium hypochlorite solution in paraffin (Eusol)

This agent is used to remove slough from a ‘dirty’ or highly contaminated wound bed, and to induce granulation tissue formation. Eusol is frequently used for (neglected) deep dermal partial thickness burns of the scalp, to prevent colonization of the wound by commensal bacteria within the hair follicles.

- **Application**
  Eusol in paraffin impregnated dry gauze
  If a ‘Eusol in paraffin’ mixture is not available, soak a Vaseline gauze in Eusol, apply a layer of Eusol-soaked gauze as a second layer and cover both with dry dressings and a bandage.
  If a dilute solution of Eusol is used then the bandage will dry out very quickly.

- **Dressing frequency**
  Daily, or twice daily in the case of highly contaminated wounds. Do not use for longer than 7 days.

Cerium nitrate silver sulphadiazine cream (Ce-SSD) (Flammacerium®)

This agent acts against Staphylococcus aureus and Pseudomonas aeruginosa and inactivates toxic products from the eschar. Ce-SSD is used to cover burns of >20% TBSA until surgery is performed and is also used for the treatment of facial burns. It creates a dry ‘crust’ and reduces evaparotive water loss from the burned surface area.

- **Dressing frequency**
  Apply daily until a crust has formed, which usually occurs after 3 days. Therefore, this topical agent is generally used for a maximum of 3 days.

Mafenide acetate solution (Sulfamylon®)

This agent has a broad spectrum of antibacterial activity.

- **Application**
  Apply onto Vaseline gauze at least 0.5cm thick.

- **Dressing frequency**
  Daily, but more frequently if a wound is exudative.

Enzyme alginogel (Flaminal®)

This agent has a broad spectrum of antibacterial activity and is easy to use. Enzyme alginogel is available in two forms, Flaminal Forte® and Flaminal Hydro®. Flaminal Forte® is used for wounds with large amounts of exudate and Flaminal Hydro® is used for wounds with moderate to light exudate.

- **Application**
  Apply onto Vaseline gauze, at least a 0.5cm thick layer.

- **Dressing frequency**
  Every other day. Both forms of the agent (Flaminal Forte® and Flaminal Hydro®) can stay in place as long as the gel structure remains intact, normally 1-4 days.

Mupirocin (Bactroban®)

Although this agent is not suitable for use during the initial treatment, it can be used during the secondary stage of treatment. Mupirocin acts against gram-positive bacteria such as Staphylococcus aureus.

- **Application**
  Apply onto Vaseline gauze.

- **Dressing frequency**
  Daily

Nitrofurazone (Furacin®)

This agent has a broad spectrum of antibacterial activity and is easy to use, however it is not effective for Pseudomonas. Nitrofurazone is often used to cover a split skin graft after transplantation.

- **Application**
  Apply onto (Vaseline) gauze.

- **Dressing frequency**
  Daily, do not use for more than 5-7 days.

Hydrocortisone/oxytetracycline/ polymyxin B (Terra-Cotril)

Officialy, Terra-Cotril is an eye ointment, however this agent also acts against Pseudomonas and reduces hypergranulation in burns.

- **Application**
  Apply onto a (Vaseline) gauze.

- **Dressing frequency**
  Daily. The ointment is not available in large volumes (as it is marketed as an eye ointment) and therefore is not used on large surface areas. When used to treat hypergranulation, use until a satisfactory result is observed. This is often as soon as after a few days of treatment.

Dressings

DRESSING BURN WOUNDS
When dressing burn wounds, in the treatment plan choose the dressing strategy for the patient based on the specific burn wound(s) in the specific treatment setting. Prepare the patient with adequate pain management and ensure that all materials are prepared before starting to dress the wound. Work in the most sterile manner possible, using clean gloves that must be changed in between patients. For each patient, preferably a new basic dressing pack should be used. Ensure to cover all parts of the burn wound completely to prevent the edges of the wound from drying out, and select the dressing technique appropriately to enable the patient to exercise.

The frequency of dressing changes depends on the type of burn wound and type of topical agent used. Contaminated wounds should be redressed daily. When removing dressings, take care to do so gently otherwise newly formed tissue will be damaged. If the dressing is adherent to the wound, soak it with water and wash the burn wound gently after removing the dressing.

DRESSING MATERIALS
The basis for burn dressings in most places worldwide is a Vaseline gauze or palm tree oil-impregnated gauze. A second layer with normal gauzes is recommend to protect the Vaseline gauze layer. Fixation is performed with a bandage or strapping.

There are many other dressing materials that can be used according to local protocols. Some of the options are listed below:

Hydrocolloid dressings
Occlusive wound therapy provides a moist wound environment. When the inner layer of the dressing comes into contact with exudate, a gel will form which facilitates autolytic debridement of the wound.

- **Use**
  These dressings are used for superficial and deep dermal partial thickness burns.
- **Application**
  The adhesive sheet should be applied directly to the wound and can be left in place for several days, depending on the amount of wound exudate.
- **Example**
  Duoderm®

Polyurethane film dressings
These are semi-permeable dressings, permeable to water vapor, oxygen and carbon dioxide, but impermeable to liquid water and bacteria.

- **Use**
  These dressings are only suitable for small, superficial dermal, lightly exudative wounds.
- **Application**
  Apply the adhesive sheet directly to the wound and this can be left in place for several days, depending on the amount of wound exudate. Only change these dressings when the edges are coming loose.
- **Examples**
  Tegaderm®, OpSite®

Hydrogel dressings
These are high water content, gel dressings that facilitate autolytic debridement of the wound and assist with maintaining a moist wound environment.

- **Use**
  These dressings are suitable for high levels of wound exudate.
- **Application**
  These dressings can be left in place for several days, depending on the amount of wound exudate.
- **Examples**
  IntraSite®, Aqua clear®, Nu-gel®

Silicon-coated nylon dressings
These dressings function as a non-adherent, silicone net dressing layer, therefore reducing damage caused by dressing changes. These dressings have a meshed structure that allows drainage of exudate.

- **Application**
  Apply the dressing to the wound and change every two to three days, depending on amount of exudate.
- **Example**
  Mepitel®

Biosynthetic skin substitute dressings

These dressings mimic the function of the skin, by replacing the epidermis, dermis, or both. Therefore they allow re-epithelialization to occur but should only be used when there is extensive experience in the burn center.

- **Application**
  These dressings may be left in place until the wound has healed.
- **Examples**
  Biobrane®, TransCyte®

Fiber dressings

These calcium alginate dressings are absorbent, biodegradable and derived from seaweed. They maintain a moist wound environment that stimulates healing, while limiting wound secretions and minimizing bacterial contamination.

- **Use**
  These dressings are suitable for moderate to high levels of wound exudate. They are useful for large abdominal or upper torso scald burns, or for the coverage of a donor site.
- **Application**
  When changing dressings, remove any loose material. If any dressing material is stuck to the wound, apply a topical ointment (e.g. oil, Vaseline or even SSD) to limit interference with the healing process. Using this method, the dressing can be easily removed after one or two days.
- **Examples**
  Kaltostat®, Aquacel®

Antimicrobial dressings

These dressings are thought to reduce the risk of invasive infection.

- **Application**
  Aquacel Ag® may be kept in place until the burn has healed. When soaked, the dressing should be replaced.
- **Examples**
  Aquacel Ag® (fiber dressing with silver), Contreet® (hydrocolloid with silver)

Burn wound infection

INFECTION PREVENTION AND CONTROL

A clean hospital environment should always be maintained. As infection is mainly spread by the hands of healthcare workers, hand hygiene guidelines should be taught, implemented and monitored. Alcoholic hand rub should be used in-between patients and hands must be washed when soiled.

RISK FACTORS FOR INFECTION

- Delayed presentation
- >20% TBSA burned
- Delayed burn wound excision
- Extremes of age (very old, very young)
- Patients with impaired immunity

DIAGNOSIS OF INFECTION

Most burn wounds will be colonized by bacteria as early as 3 days post-injury. Wound colonization is defined as the presence of multiplying micro-organisms on the surface of a wound, with no immune response from the host and with no associated clinical signs and symptoms. Wound colonization can cause impaired wound healing, so when an unexpected delay in wound healing is observed, a wound swab must be taken. At the same time, the topical agent used for local therapy should be changed. Most commonly, the topical agent is changed to an anti-Staphylococcal therapy (e.g. Fucidin®, Bactroban®, honey or Furacin®) until definitive results from the wound swab are obtained.

The signs and symptoms of burn wound infection vary. For example, this may be a change in wound appearance such as the appearance of purulent discharge, erythema, tenderness, warmth, edema or surrounding cellulitis. Pseudomonas infections are common following burns and can be recognized by their characteristic green color, sweet smell and hypergranulation. Increased pain or a rapid change in the clinical condition of the patient (such as tachycardia, tachypnea, oliguria, fever or hyperthermia) can also indicate a burn wound infection.

If infection of a burn wound is suspected, wound swabs must be taken. Whether or not it is possible to perform wound cultures, the wound and dressings should be looked at for an indication of infection. Pseudomonas infections will color the dressings blue-green and have a characteristic sweet “grape-like” odor. Wounds infected with Streptococcus are bright red.

Systemic antibiotics are indicated when there is septicemia or hemolytic streptococcal wound infection, however the use of prophylactic systemic antibiotics should be avoided for acute burns. In the case of infection, clean the burn wound by hand held showering, irrigation and wiping to remove dirt, dressings and topical ointment. A suitable topical agent should then be applied. Which topical agent to apply differs, dependent on the type of bacterial infection.

For Pseudomonas infections, SSD (Silver Sulfa Diazine, Flammazin®), 0.5% acetic acid or 0.5% silver nitrate ($AgNO_3$) solution can be used. For Staphylococcus infection, fusidic acid (Fucidin®) or mupirocin (Bactroban®) can be used.

Burn wound infection is not a contraindication for excision and skin grafting, however in the case of an infected wound with a generalized/systemic infection (e.g. septicemia), a compromise is required and only the infected eschar should be excised. This may also be a suitable option for patients with low hemoglobin in low-resource settings. A skin graft can then be performed later when the patient’s condition has improved.

Be aware that it is possible to have infection under the eschar. Shortly after the burn injury, the eschar provides a natural barrier to infection, however during the process of wound healing, separation of the eschar occurs and provides a portal of entry for bacteria. The blood flow deep to the eschar is poor and infection may follow. Infection of the eschar is an indication for surgical removal.

Management of granulation tissue

Granulation tissue is new connective tissue with a combination of small blood vessels and fibroblasts that is formed during the process of wound healing by secondary intention. Hypergranulation tissue is recognized by the observation of spongy, friable, deep-red colored tissue.

Hypergranulation tissue usually occurs due to excessive inflammation. This is especially true for deep dermal burns and full thickness burns that are not treated with skin grafts and may become subject to stimuli causing excessive inflammation, such as infection, dermatitis, occlusive dressings, use of SSD for > 1 week, friction from external devices or foreign bodies.

MANAGEMENT

Small areas of hypergranulation tissue can be treated with topical agents that reduce moisture. For example:

- Zinc oxide ointment
- Silver nitrate stick (Vaseline should be applied to the healthy skin surrounding the burn to protect it)
- Oxytetracycline hydrochloride and hydrocortisone acetate (Terra-Cotril®)
- Papaya
- Topical Steroid, Class III or V.

Larger areas of hypergranulation tissue may require surgical excision. Excision of these larger areas of hypergranulation should be followed by skin grafting to cover the wound.

Thoracic hypergranulation tissue

Conservative treatment strategies

It is very important to keep in mind that there is an important difference between a fully conservative treatment and a temporarily conservative treatment.

The **fully conservative treatment** is indicated in superficial partial thickness burns. The treatment of deep dermal partial thickness burns is often started conservatively, but may need surgery later.

A **temporarily conservative treatment** is also indicated in deeper burn wounds. This can be for a short period of time in an early excision and grafting strategy, or for a longer period when delayed grafting is chosen, due to limited resources or specific patient characteristics.

In general, there are three strategies for the conservative treatment of burn wounds.

CLOSED WOUND METHOD

This is a closed dressing of any kind, that isolates the wound from the environment, usually in combination with a topical agent (e.g. SSD).

Indications

In general, closed wound management is preferred over exposure of the burn wound. Perform proper cleaning and debridement, if required, before applying a dressing. This method is the best way to ensure prevention of infection and preparation of the eschar for early tangential excision. The number of dressing changes should be adjusted according to the needs of the individual patient.
See the next chapter for more detailed information.

SEMI-OPEN WOUND METHOD

A semi-open dressing usually consists of a thin protective gauze loosely covering the burn wound, fixed with a strapping or a loose bandage. It's often used in combination with a topical agent (e.g. SSD).

Indications

This method of management is often used for facial burns, perineal burns, posterior burns and bedridden patients. It is also useful in situations where there are limited personnel, equipment or resources.

EXPOSURE OF THE BURN WOUND

The burn wound is left open to dry. Different topical agents may be used, but be aware that ointments and creams stick to clothes and sheets, and also attract dirt. In superficial dermal burns this is a painful method and not recommended.

Indications

This method of management should be used for deep dermal partial thickness burns and full thickness burns. It can be used when early excision is not possible, to bridge the time before the eschar separates spontaneously. This method is in particularly useful for large surface burns in situations where there are limited personnel, equipment or resources. A study in Sierra Leone showed that the open method had as good or better early outcomes than the closed method, at significantly lower costs.

Management

Clean the burn wound daily by washing or showering and use a bed cradle to prevent sheets and blankets from touching the burn wound. From day one onwards, a dry and adherent crust develops which may be left in place up to a maximum of four days, or until cracks appear in the crust. If cracks appear in the crust, this makes the wound more prone to infection. If separation of the crust is present, perform debridement in small pieces by cutting away the free crust and stop this blunt dissection when an area where the crust is still adherent is reached.

Large surface burn
This is an example of 'Exposure of the burn wound'. A bed cradle is used to prevent the sheets and blankets from touching the burn wound.

Conservative treatment - closed method

INDICATIONS

This method is recommended for most burns in burn protocols. It is used for fully conservative treatment of superficial partial thickness burns, but also for deeper defects, although for these this is often as a temporarily conservative treatment while awaiting surgery. It is also the most frequently used method for post-surgical burn wound treatment. Whether this treatment method can be used is dependent on the availability of the resources required.

Proper preparation of the patient and the burn wound is required before a dressing can be applied. See the 'General principles' section for more information.

CLOSED WOUND MANAGEMENT FOR DIFFERENT BURN WOUNDS

Epidermal burns

No specific treatment is required for these burns. Dressings are not required and any topical agent (e.g. body lotion, Vaseline) available may be used to reduce the pain.

Superficial partial thickness burns

These burns benefit from occlusion for long periods of time. Therefore, membranous dressings are frequently used to provide a moist wound healing environment and protect the wound from contamination. The type and frequency of dressing should be chosen according to the wound condition, preference of the burn center and availability of the materials. See 'Topical agents' for an overview and indications for use, and 'Dressings' for the various options and indications for dressing materials.

Deep dermal partial thickness burns

It is advisable to start with conservative treatment for these burns because burn depth may be heterogeneous. This can range from superficial partial thickness in some areas, to deep dermal partial thickness or even full thickness in other areas. Once the superficial areas of the wound have healed, the deeper parts will remain and these may require surgical treatment depending on the size of the wound. Choose the type and frequency of dressing according to the wound condition, preference of the burn center and availability of the materials. See 'Topical agents' for an overview and indications for use, and 'Dressings' for the various options and indications for dressing materials.

Full thickness burns

Full thickness burns require surgical treatment. A closed dressing is preferred until the day of surgery and SSD or a povidone-iodine soaked gauze are frequently used prior to surgery. When possible, early excision should be performed however if this is not feasible, for example in a resource-limited setting, these burns can also be dressed using the open wound management technique (exposure of the burn wound), until eschar separation has begun.

Full thickness burns with exposed bone or tendon

In these burns, the wound bed with exposed bone or tendon must be kept moist with a closed wound method. SSD, or if available NPT or Flamminal Hydro®, should be applied to allow granulation tissue to form as when bone or tendon is exposed, granulation tissue may help to achieve a graftable wound bed. Consider bone fenestration to promote the formation of granulation tissue from the bone marrow. A surgical approach using well vascularized flaps to cover essential non-graftable structures, is recommended.

Specific burn areas - tips & tricks

FACIAL BURNS

Face

Patient comfort is important when treating facial burns and there are a variety of treatment options available to treat these. Vaseline is often used for superficial burns. In terms of patient comfort, deeper facial burns can be treated with Cerium Nitrate–Silver Sulfadiazine (Ce-SSD). Upon admission, start by rinsing the burn wound with water and subsequently apply Ce-SSD (within 24 hours of injury) once daily, for at least 48 hours (maximum 72 hours) post-injury. Following this, wash the wound daily with chlorhexidine (or running water), rinse with running water and leave the wound open until healed or treated surgically. If Ce-SSD is not available, Silver Sulfadiazine can be used, however, this has more disadvantages for the patient. For example, when using Silver Sulfadiazine, a full daily dressing change is required and patients are less comfortable due to the use of a full dressing.

Ear and nose

During the daily dressing change, ensure to remove all topical agents and apply a proper dressing to prevent the cartilage from drying out and to prevent chondritis. It is most important to minimize pressure on the ear when treating these wounds.

Eyes

Chemical burns must be irrigated with copious amounts of running water. In the case of burns surrounding the eye, use an eye ointment to prevent the eye from becoming dry. Keep other topical agents and bandage materials clear of the eyes.

Mouth

Leave any crusts around the mouth intact to prevent discomfort, bleeding, infection and scarring. For burns on the lips, use Vaseline frequently to prevent crust formation.

Scalp

Burns of the scalp require special attention. The skin over the scalp is thick, has multiple epithelial layers in the hair follicles, including deep matrixes, and has a rich blood supply. Therefore, even deep dermal partial thickness burns have good healing potential. However, hair follicles may harbor a large bacterial load that can cause infection and delay spontaneous wound healing. Therefore, prevention of infection and prevention of scab formation are key to allowing uncomplicated wound healing.

Example of a burn of the scalp

In order to fully expose the burn, shave all the hairs of the scalp fully as this will reveal hidden burns, and the extent and depth of the burn can be evaluated. To shave the scalp, use a fresh, simple, disposable razor blade. Apply a local antiseptic, such as SSD, to keep the wound moist. In the case of neglected or contaminated wounds, the preferred agent to treat (neglected) deep dermal partial thickness burns of the scalp is Eusol in Paraffin, as this reduces the invasion of the wound by commensal bacteria from the hair follicles. During every dressing change the wound must be extensively cleaned. SSD causes hypergranulation when used for more than a week, therefore move to using a different local antiseptic, such as povidone-iodine, after about seven days of SSD use. The scalp must continue to be shaved carefully on a weekly basis.

In cases of delayed referral with an infected scalp burn, hypergranulation and/or scab formation, the wound must be thoroughly cleaned. Sedation or even general anesthesia may be needed to do so, as all hairs and granulation tissue must be removed. Once the wound has been cleaned extensively, administer the initial treatment with daily application of Eusol, replaced later on with a local antiseptic such as povidone-iodine.

BURNS TO THE REST OF THE BODY

Neck

Limit the use of dressings to allow movement of the neck and prevent stiffness. A soft collar should be applied to prevent contracture formation. Ensure that both the head and neck are positioned in a neutral position, for example by not using a pillow in bed.

Chest

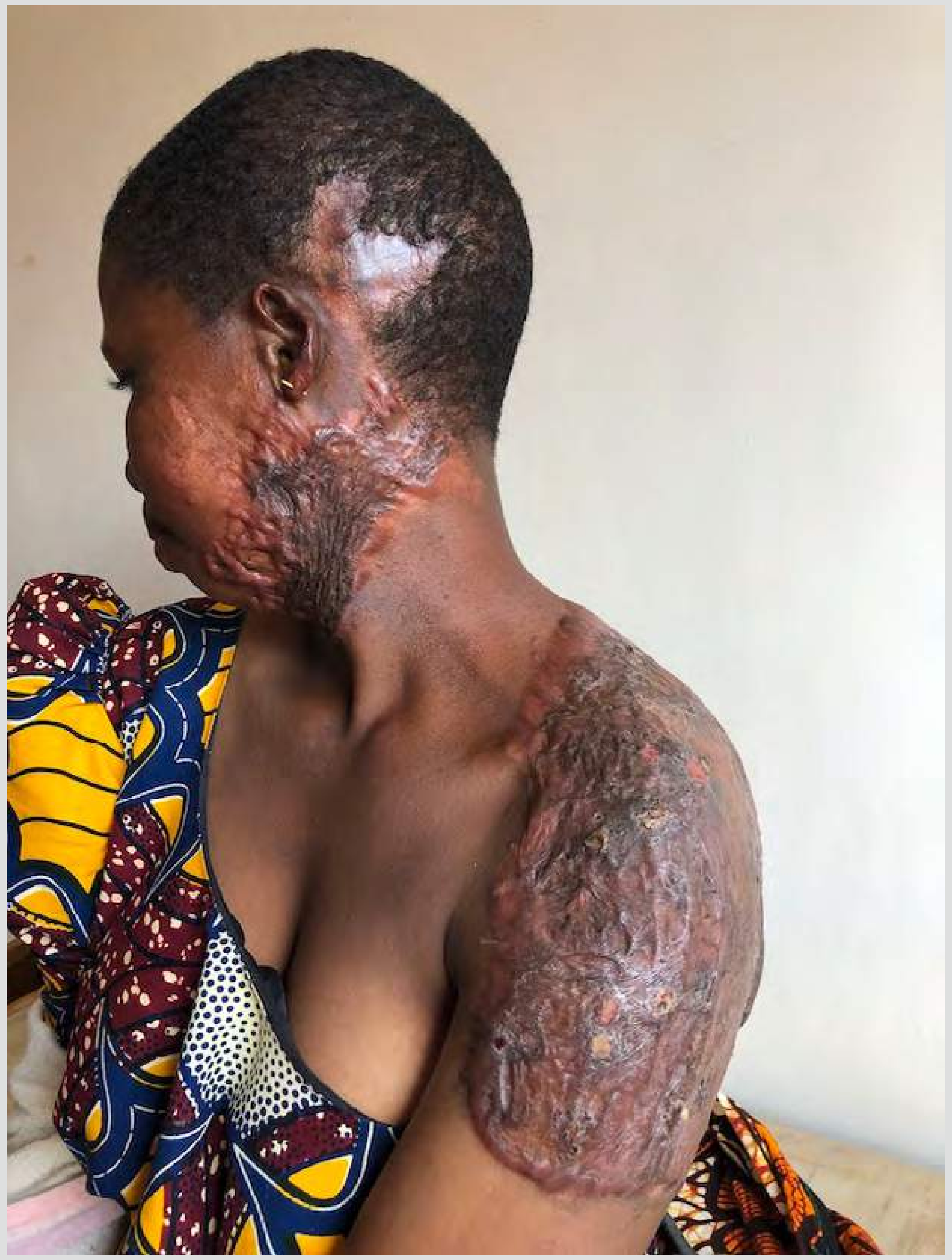
Create a T-shirt-like dressing to prevent the dressing from moving and becoming loose. Use thin wound-dressing material to enable adequate breathing and movement.

Breasts

Due to gravity, breasts have continuous traction on them which delays wound healing, therefore the breasts should be supported with a bra-like dressing to reduce traction.

Upper extremities and shoulders

Limit the use of dressings over joints to allow movement and prevent stiffness. During the day this permits exercise and during the night splints can be applied. Limbs should also be elevated to prevent the formation of edema.



Burn from a fall into a fireplace, as result of a seizure

Hands

In the case of (semi-)circumferential burns, ensure to leave the fingertips uncovered in order to evaluate capillary refill; this is especially important during the first 24 hours post-injury. Limit the use of dressings over joints to allow movement and prevent stiffness.
Each digit should be dressed separately with a Vaseline gauze and the preferred topical agent, however if this is not feasible, for example in small children, apply a dressing to each digit and then make a wand like dressing.

Each digit should be dressed separately

Remember to always leave the thumb free to enable movement and prevent stiffness. In some cases, the hand may be wrapped in a plastic bag with ointment. This enables movement of the hand and this technique helps to avoid the use of a tight dressing, especially in the first few days post-injury. Always elevate the hands (and arms if they are included in the burn injury) by placing them on a pillow, to reduce edema formation.

Genital area

Burns of the genital area are prone to infection, therefore a semi-open dressing technique should be used and the dressing changed when soaked. For children, the dressing can be put into the diaper and no further fixation is required. If the burn impedes urinary flow, a urinary catheter should be placed.

Knees

Limit the use of dressings to allow movement and prevent stiffness, and apply a splint during the night to prevent contracture formation.

Feet

Burns of the feet are prone to infection as not all patients wear shoes and socks to keep the dressing clean. Ask the patient to wear shoes or sandals, or provide a plastic bag once the wound has been dressed. Ensure to apply a Vaseline gauze, with the preferred topical agent, between each digit to prevent them from sticking together. Limit the use of dressings over joints to allow movement and prevent stiffness.

Fire burn of the lower extremity including the foot

Enzymatic debridement

Debridement of burn wounds can be achieved using both surgical and non-surgical methods. Enzymatic debridement is a form of non-surgical debridement; the most commonly described and clinically applicable form of enzymatic debridement is NexoBrid®. NexoBrid® contains bromelain, derived from the stem of the Ananas comosus (pineapple), and consists of proteolytic enzymes.

These enzymes are capable of debriding eschars without harming healthy tissue, thus selectively debriding the burned tissue and providing a healthy wound bed. Be aware that NexoBrid® is relatively expensive, limiting its use in low-resource settings, and training is required before this can be used in the setting of a clinic.

INDICATIONS

- Thermal burn wounds (flame, scald, contact)
- The treatment must to start < 48 hours post burn injury
- For cases of burn-induced compartment syndrome (BICS) to prevent the need for escharotomies
- A maximum of 15% of TBSA can be treated per session. Treatment can be performed on consecutive days, for example treating 15% TBSA on day 1 post-burn and treating the next 15% TBSA on day 2 post-burn.

PROCEDURE

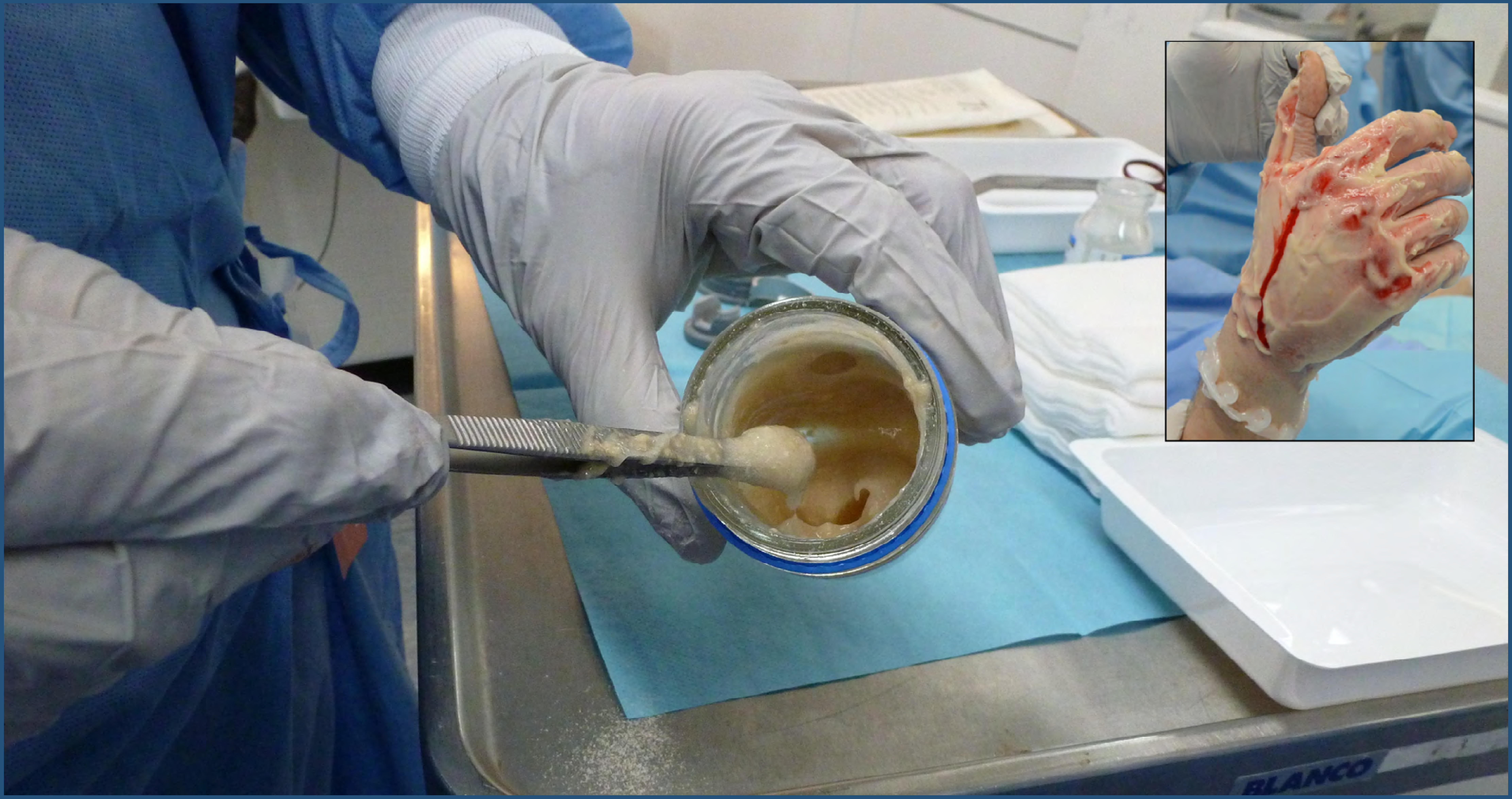
Training is required before this technique can be used in a clinic. The debridement procedure consists of three phases:

1. Pre-soaking phase (>2 hours): This stage has two aims, the first of which is to prevent infection. The second aim is to "soften" the wound bed as the enzymes function better on moist, soft eschar, than on hard, dry eschar
2. Treatment phase (4 hours)
3. Post-soaking phase (>2 hours): This stage uses the same methods as the pre-soaking phase, however in this phase the aim is to "dissolve" the remaining eschar in the gauzes.

POST-TREATMENT

After the enzymatic debridement, a healthy, debrided wound bed is observed and it is imperative to preserve and protect this wound bed. In the case of deep dermal partial thickness or full thickness burns, a critical decision that must be made post-debridement is whether to perform skin grafting, or to await spontaneous re-epithelialization.

USE OF NEXOBRID



1. Preparation of the Nexobrid ointment

2. Pre-soaking phase

3. Treatment phase: After removing the bandage scrubbing to remove dead tissue

4. Left: Before Nexobrid treatment, Right: Result after 6 hours

Negative pressure therapy

The role played by negative pressure therapy (NPT) in burn care is increasing. NPT is applied to improve the quality of the wound bed by stimulating blood flow to the wound bed, removing exudate and reducing edema.

When applied on top of skin grafts NPT can support graft survival, and when applied on top of a dermal substitute it supports bio-integration.

NPT is mainly considered as an option for challenging anatomical areas such as the axilla, neck and groin.

INDICATIONS

- Management of burns showing slow healing progress.
- Preparation of the wound bed before skin grafting, for example for burns with exposed bone and tendons.
- Use of a bolster dressing over a skin graft.
- Use of a dressing to integrate a bilaminate dermal substitute (e.g. Integra®).

PROCEDURE

The NPT system should be applied according to the instructions and left in place for several days, usually between 3 and 5 days. An advantage of NPT is that it allows less frequent dressing changes, therefore reducing the burden on nursing staff, bacterial colonization and opioid requirements. NPT also provides secure wound coverage, allowing patients to be discharged. When the NPT system is removed after a few days, evaluate the condition of the wound and decide whether to continue with the NPT, depending on whether there is still an indication for its usage.

Vacuum system over Integra® applied to both ankles
Source: I.G. Alana, Ann Burns Fire Disasters. 2013

Surgical care of burn wounds

Different surgical methods are used for burns, each with different timings and indications. In the emergency situation there can be a requirement for an escharotomy and sometimes a fasciotomy (e.g. in electrical burns).

An early burn wound excision, escharectomy with skin grafting, is often performed within 10 days of the injury. If the excision of affected tissue is performed at a later stage, the late escharectomy is also referred to as surgical debridement or necrotectomy. Sometimes this involves amputation of structures like fingers. toes or limbs. Apart from skin grafting techniques, other methods that can be used for the burn wound reconstruction are direct closure, local flaps, distant flaps and free flaps.

SURGICAL PLAN

The focus in this chapter is the treatment of burn wounds with skin grafts as this is the most frequently applied technique. An important aspect is the timing of the procedure. For every burn wound it is recommended to make an appropriate surgical plan, including the technique of choice and the timing of the procedure, based on an evaluation of the patient's general condition, the burn wound(s) characteristics, and the skills and resources available.

Evaluate the general physical state of the patient.
It is important to optimize the condition of the patient before surgery. Therefore, it should be ensured that dehydration is corrected and the hemoglobine level, feeding status and kidney function are good enough to plan a surgical procedure.

Evaluate the size, depth and location of the burn wound.
Start by evaluating the largest areas that can be safely excised and make sure to always excise these areas first. Typically, these are the posterior or anterior aspects of the trunk, or the extremities. The extent of the total surface area that can be safely excised in one stage is dependent on multiple factors, for example the experience of the burn team and the availability of facilities for blood transfusion both affect this. The total surface area that it is possible to excise in one stage also depends on the availability of a donor site for an autologous graft or allograft, or the availability of skin substitutes. Any skin defect larger than 3cm in diameter which has not healed after 2-3 weeks should be considered for grafting, especially if the defect is around the joints.

Identify the availability of potential donor sites for skin grafting.
The method chosen should be the one that best manages the skin and soft tissue defect. An autologous graft is only possible when the skin can be safely harvested from the donor site.

When planning the harvesting of skin from the donor site, the systemic insult to the patient should be taken into account. If an autologous graft is not possible due to either the condition of the wound, the patient's physiology or a lack of donor sites, temporary skin coverage must be attempted, for example by using donor skin (allograft), if available.

Evaluate the resources and skills of the burn team.
Consider referral to a better equipped and functioning healthcare facility, consider of the possibility of an e-consult to obtain expert advice and check the availability of tools and materials.

TIMING OF BURN WOUND EXCISION AND SKIN GRAFTING

Early excision

Although not clearly defined, early excision is performed within a few days post-burn (up to a maximum of 10 days post-burn). Up until this point, wound colonization is limited. Early excision and skin grafting is the optimal standard of care, where resources permit. The aims of early excision are to remove dead tissue, improve the patient's response to the burn injury (extensive deep burn injuries lead to severe systemic effects on the body) and to close the burn wound as soon as possible.

Delayed/late excision

Delayed/late excision is useful for mixed superficial partial thickness and deep dermal partial partial thickness burn wounds because at this stage, 14-21 days after the burn, partial thickness areas of the wound are healed. The remnants of necrotic tissue are still present in the wound bed and may require debridement. Clean areas without signs of re-epithelization require skin grafting. For burned areas with thick skin, the debridement can be delayed, even up to three weeks post-burn. Use Ce-SSD or another antibacterial topical agent until surgery. The delayed strategy is also commonly used in resource-limited settings where patients often present late and in a poor general condition. Other factors that are important to take into account are the skills of the local team, the anesthetic risks, the quality of the surgical instruments (e.g. a well-functioning dermatome) and the availability of blood transfusions.

FACTORS INFLUENCING THE TIMING OF EXCISION

Size and depth of the wound

For surgery of extensive deep burns, covering approximately > 20% TBSA, the surgery should be planned and undertaken preferably within the first few days post-burn, and certainly within the first 7–10 days post-burn. The presence of extensive deep burns is a vital indication for removal of the eschar as these burns have severe systemic effects. Up to the time of surgery, ensure to cover the wound with antibacterial topical agents. If Ce-SSD is used prior to surgery, wound excision can be delayed for more than 10 days post-burn.

In extensive burns, a staged excision and grafting approach with short time intervals between each surgery limits the perioperative risks. The larger the size of the burn excised in one stage, the greater the duration of surgery, decrease in temperature during surgery and volume of blood loss. As a guideline, do not excise more than 15% TBSA in one stage, however this depends on the facilities of the burn team, for example the availability of facilities for blood transfusion, surgical equipment and expertise of the burn clinic.

For surgery of deep dermal burns, covering approximately < 20% TBSA, surgery may be performed at an early stage however this is not mandatory. It is recommended to excise and graft the burn wound around 10 days, and no later than 3 weeks post-burn. When performing surgery at an early stage, be aware that the diagnosis of burn depth may not be accurate and that the depth of the burn may vary between different areas of the wound. Post-excision, it is difficult to assess the condition of the wound bed and the wound may be unsuitable for grafting. The ability to assess the wound bed is dependent on the experience of the clinician and where there is limited experience, it is advisable to start with conservative treatment for deep dermal burns instead of early excision. This conservative treatment will allow parts of the wound to heal spontaneously before surgery, therefore reducing the wound surface requiring excision. This means grafting is reduced, resulting in a reduction in the duration of surgery, blood loss and donor site morbidity.

Location of the wound

Extensive full thickness burns on the posterior and anterior aspect of the trunk, and burns of the extremities (excluding hands and feet) require early excision and skin grafting as the optimal standard of care, where resources permit. Delayed excision is advised for functional areas of the body, for example the hands and face, and does not lead to an inferior outcome provided the following principles are used:

- Reduce bacterial invasion by applying appropriate local therapy.
- Plan excision and grafting as soon as partial thickness areas of the wound have healed, usually around 10 days post-burn injury.
- Do not excise deeper than necessary - excise only necrotic tissue and preserve as much healthy tissue as possible.
- Perform excision before the formation of granulation tissue.

Age

Children and the elderly have thinner skin and therefore may sustain a deep burn wound, even after a small thermal injury. Burn wounds in children also heal faster than in adults and as a result, superficial partial thickness burns heal quickly. Parts of the burn that have not healed after 14-21 days can therefore be excised and grafted. Keep in mind that excision and grafting should ideally be performed before the formation of granulation tissue.

In adults the healing process takes longer, therefore 2 weeks should be allowed for the superficial partial thickness areas of the burn to heal. Excision and grafting can be performed after these 2 weeks.

Other factors

The availability of resources, number of patients in the clinic and general condition of the patient all affect the timing of excision of an eschar. When resources and logistics do not permit early excision, for example due to a large number of patients or a lack of available skills, a conservative approach with topical agents may be indicated.

Burn wound excision and coverage

SURGICAL EXCISION

Techniques

- **Tangential excision**
  This technique uses a sequential approach where thin slices of eschar are progressively removed until only viable tissue remains.
- **Excision to the depth of the fascia**
  The burn wound and subcutaneous tissue are removed to a pre-determined depth, typically carried out to the depth of the deep fascia. This technique is recommended when subcutaneous tissue underlying the burn wound is not viable enough to enable vascularization of the skin graft.

Methods

- **Sharp excision**
  Sharp excision can be performed with a simple scalpel, a hand-held dermatome (e.g. Weck knife (Goulian knife), Watson knife or Humby knife) or a power-driven dermatome. The various types of dermatomes are used for tangential excision.
- **Electrosurgical excision**
  Electrosurgical excision is performed with a monopolar instrument. The advantage is the coagulation of blood vessels to limit blood loss.

- **Hydrosurgical excision**
  Hydrosurgery is a technique that allows selective removal of necrotic and granulation tissue. The device (Versajet®) is based on the Venturi principle. A jet of water under very high pressure is released into chamber that has an opening on one side, creating a vacuum. Through the opening, non-viable tissue such as softened necrosis and granulation tissue can be taken up from the wound, preserving healthy tissue. For this reason, hydrosurgical excision is not suitable for fresh burns with a firm necrosis. The Versajet® Hydosurgery System is widely used to perform hydrosurgery, but can only be used when resources permit due to the high costs of the disposable materials required. Proper training is advised before using the Versajet®.

Evaluation of the wound bed after burn wound excision

The ability to assess the wound bed post-excision is dependent on the experience of the clinician. A well-vascularized, viable wound bed with punctate bleeding is essential for good graft take. While it is not always possible to remove all necrotic tissue without also damaging essential structures, a skin graft can survive or heal over a small necrotic area by bridging, or may heal by secondary intention.

Limiting blood loss during and after excision

In order to limit blood loss, the burn wound and donor site can be infiltrated subcutaneously with a vasoconstrictor and/or a topical hemostatic agent, such as epinephrine solution soaked in sterile gauze. For limb surgery, torniquets may be used however the length of time the tourniquet has been applied for must be recorded. When the wound is being excised to the level of the fascia, electrosurgery can be used to minimize blood loss. More generally, other topical hemostatic agents such as thrombin and fibrinogen can be used.

Prevention of hypothermia and opting for a staged burn excision will also reduce blood loss. Finally, compression dressings and elevating the limb are techniques that can be used to limit blood loss.

Options for burn wound coverage

Definitive coverage can be achieved in multiple ways, as shown by the reconstructive ladder:

- Direct wound closure
- Split-thickness skin graft (SSG)
- Skin substitutes in combination with a skin graft
- Full thickness skin graft (FTG)

Hypothermia

Monitor the temperature during surgery and be aware of hypothermia. Make sure to keep the patient warm with a bottle of lukewarm water (make sure the water is not any warmer, this will cause burns), isolation sheet or a bair hugger and cover the head of the patient to prevent heat loss from the head. When the temperature drops <36 degrees and you are not able to keep the body temperature the surgeon should stop the surgery. When body temperature is too low this has consequences such as a higher risk of surgical site infection, coagulopathy, increased transfusion requirements, altered drug metabolism and adverse cardiac events. There are further options for reconstruction on the ladder and more information regarding these techniques can be found in the eBook:

Basics of Burn Care 2
Scar and contracture management.

- Tissue expansion – used to cover soft tissue defects and deeper structures
- Tissue transfer – used to cover smaller burn wounds, soft tissue defects and vital, deeper structures
- Local flaps
- Pedicle flaps
- Free flaps

When the burn wound is too large to be covered with an autograft, a skin substitute can be used. Examples of these include human tissue allografts, dermal regeneration matrices, xenograft-derived temporary wound coverage, amniotic membranes and cell-based therapies. However, in a low-resource setting staged burn excision or conservative treatment are also adequate options.

DONOR SITE SELECTION
When selecting a donor site, the following should be taken into account:

- **Information delivery** – The most important factor to consider when choosing the location of the donor site is to adequately inform the patient, or their parent/guardian, of the expectations and to involve them in the decision-making. It may take some time for the patient to fully understand the principle of skin grafting.
- **Size of the defect** – The size of the graft should be adjusted to the size of the burn wound. Bear in mind that after harvesting a SSG, the graft will shrink in size and that enlargement of a mesh graft is inefficient; a mesh ratio 3:1 is, in reality, an enlargement of two times the graft area, and a mesh graft ratio 6:1 an enlargement of four times the graft area.
- **Donor site morbidity** – Either a scar, or at least a change in skin pattern or color, remains after harvesting a donor site. Choose a donor site that is well tolerated by the patient, for example the thigh and the scalp which are suitable donor sites in many cases. However, be aware of the higher rate of complications (folliculitis, alopecia and visible hypopigmented scars) when using the scalp as a donor site for patients with hair type VI-VIII (those of black, African descent).
- **Esthetic appearance** – When grafting the face, a good color match is essential. Consider the scalp as donor site when grafting the face and preferably do not use a mesh graft due to the ‘honeycomb’ effect.

GRAFTS

Harvesting methods

- Hand held, electric or air-powered dermatome – These methods are good for excising thin strips of skin with a large area and homogenous thickness.
- Hand held knife – This method is used when there is no power dermatome available and the knives used are those such as the Humby knife and the Watson knife. There are disadvantages to this method, including irregular edges and the grafts being of variable thickness. Furthermore, the length of the knife makes it logistically impossible to access and harvest from certain areas of the body.
- The Sober dermatome - This is a low-cost device specially developed for low-income countries and has a fixed thickness of 0.25 mm (0.001 in.).

Determining the thickness

Prior to harvesting the SSG, the thickness of the graft must be determined; usually a thin graft is used. The knife or settings of the dermatome should be adjusted to the preferred thickness, as indicated:

- Thin (Thiersch-Ollier): 0.15-0.3 mm
- Intermediate (Blair-Brown): 0.3-0.45 mm
- Thick (Padgett): 0.45-0.6 mm

Graft expansion - meshing

Meshing of an SSG allows the escape of serum and blood from the wound, minimizing the risk of hematoma or seroma formation which could compromise graft take. Furthermore, meshing allows enlargement of the skin graft enabling a large wound to be covered by a small piece of donor skin. With the use of a meshing device, different ratios of meshing (1:1, 1:1.5, 1:2, 1:3, 1:4, 1:6, 1:9) can be selected.

A mesh graft larger than 1:3 cannot be applied to a wound that has been excised at an early stage as the exposed wound bed in the open areas of the graft will dry out and is prone to infection. When a graft larger than 1:3 is used, a secondary covering with a meshed allograft (sandwich grafting) prevents the exposed areas from drying out and protects against infection. When meshing skin in a ratio 1:4 or larger, large sheets of split thickness skin are required, as the mesh graft may become unmanageable. In these cases, if resources permit, a Meek micrograft is preferred over a meshed SSG. A larger mesh ratio causes increased scar formation at the recipient site, therefore when grafting functional areas such as joints, a smaller mesh ratio should be used. For functional areas it is advised to use a full sheet graft, meshed with a 1:1 ratio. A mesh ratio of 1:1 provides good drainage and causes less scarring than a larger mesh ratio.

When a meshing device is not available, it is possible, although time consuming, to mesh the graft manually with a scalpel.

Graft expansion – Meek micrograft

The Meek technique uses a split thickness skin graft cut into squares, which is then further divided into multiple square-shaped islands using a Meek-dermatome. These are then placed onto pre-folded gauzes with which a true expansion of 1:9 is achieved.

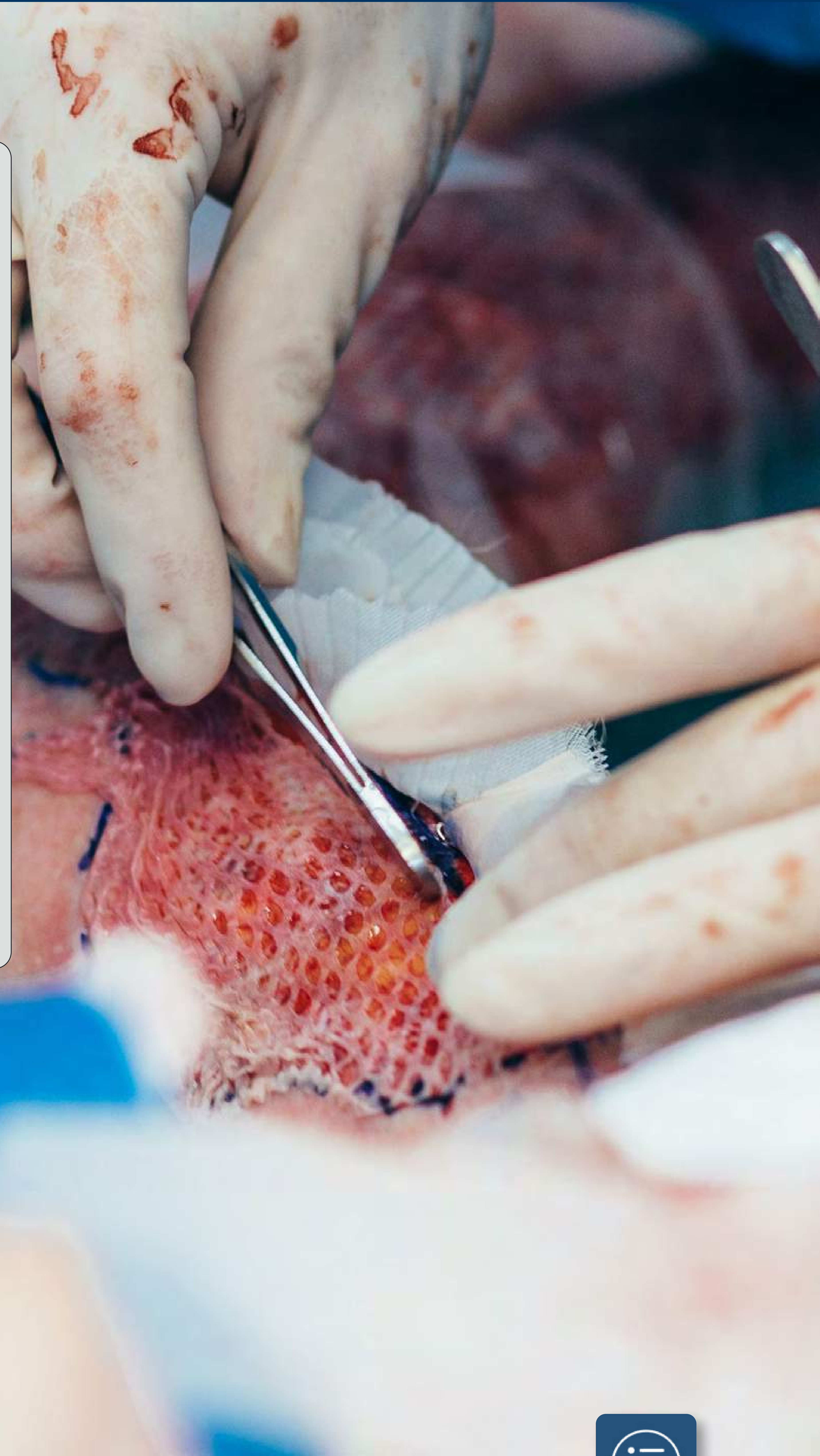
This technique is mainly indicated for extensive burn wounds covering a TBSA of 30% or more, however this technique may also be used for burns covering 5 – 20% of TBSA. Equally, this technique is indicated if the availability of donor sites is limited, as the Meek technique requires a smaller area of donor site to cover the same wound area. To perform a skin graft using the Meek micrograft technique, further training is required.

On the first day after the procedure, the graft(s) must be examined for bleeding or hematoma formation as, similarly to a meshed skin graft, hematoma formation will cause graft necrosis. Once the polyester gauzes are removed after 7-10 days, the take-rate of the graft can be determined.

Transplantation and fixation

After harvesting and expanding the skin graft, the transplantation can be performed. Meticulous hemostasis of the wound bed prior to transplantation of the skin graft should be ensured, as a hematoma formed under the transplant cannot be removed once the graft is fixated, and will cause graft necrosis.
Fixation of the graft can be performed using a surgical stapler. The greatest advantage of this being that it is not time consuming. Fibrin glue can also be used, negating the need to remove staples which is advantageous for the patient, especially children. However, fibrin glue is relatively expensive therefore when resources are limited, (absorbable) sutures should be used.

For areas with a high risk of shearing forces, a tie over dressing is recommended. A moist dressing should also be applied, for example Furacin® or Bactroban®, and circumferential contact between the graft and the wound bed ensured.



POST-SURGERY

Donor site management

Ensure good hemostasis of the wound before covering the donor site. Donor sites benefit from occlusion for long periods of time, at least one week, or until healing has occurred. To enable this, use a humid and heat-preserving dressing such as Opsite®, Kaltostat® or Mepilex®.

However, if these are unavailable, use a moist dressing such as a Vaseline gauze soaked in an antiseptic agent. If the donor site has not healed after the occlusive dressing has been removed, a topical agent such as SSD or Fusidic acid can be used to treat the open defects.

Re-harvesting of the donor site

The same donor site can be re-harvested once the wound has healed completely and the epithelium appears stable. In practice, re-harvesting can be performed after two weeks.

Evaluation of results

- **Assessment of graft take**
  The ability to reliably assess the graft take is highly dependent on the experience of the clinician. During the process of graft take, the skin graft becomes incorporated into the wound bed and the success of a skin graft primarily depends on the extent and speed at which vascular perfusion of the wound bed is restored. Generally, graft take is ascertained at day 5-7 by clinical evaluation and assessed by the rate of re-epithelialization.
- **Recording graft take**
  Graft take must always be noted and this is recorded as the percentage of successful graft take (i.e. re-epithelialization). A graft is usually deemed successful if greater than 80% graft take has occurred upon clinical evaluation.

Management of graft infection

If graft infection is suspected, remove the occlusive dressing and continue treatment with topical agents. Evaluate the condition of the wound daily and decide whether re-transplantation should be performed.

Surgical treatment - specific cases and areas

HIGH PERCENTAGE TBSA BURN WOUNDS

Wound care prior to surgery

Topical treatment with Ce-SSD has been shown to reduce mortality and morbidity in severely burned patients with extensive burn wounds, covering 20% or more of TBSA. Cerium nitrate is a (lanthanide) metal that decreases endotoxin production and release of inflammatory mediators. Additionally, it forms firm layer of cerium nitrate making excision easier. Burn wounds covering less than 20% of TBSA may initially be treated with SSD and once the eschar has resolved, treatment is changed to antiseptics such as Fusidic acid, mupirocin or povidone-iodine.

Staged burn wound excision and skin grafting

Staged excision is an appropriate option for burns covering a large TBSA. Tangential excision causes massive blood loss, limiting the TBSA that can be excised, however staged grafting enables a burn wound to be excised over multiple surgeries, limiting the peri-operative risks. Staged grafting is also an appropriate option when large areas of eschar are excised and limited donor sites are available. The burn wound can be closed over multiple surgeries and the graft can therefore be harvested from the same donor site again after healing. Between surgeries, the wounds are temporarily covered with allografts, however if unavailable, an alternative is local wound dressing using topical antimicrobials. The main disadvantage of this method is that it is time consuming and wound colonization or even infection may occur in the meantime, delaying wound healing and resulting in more severe scarring.

FACIAL BURNS

The diagnosis of the depth of burn in the face cannot be accurately determined until at least 10 to 14 days post-injury. For the forehead, it may even be necessary to wait for three weeks. Often, the scar outcome is still better when continuing conservative treatment instead of performing surgery. If a deep full thickness burn persists beyond this timeframe, consider excision and skin grafting. Before performing excision and skin grafting of the face, ensure to excise and graft other large areas of the burn first. A suitable donor site should be made available, preferably the scalp, to ensure the outcome of grafting is more favorable than continuing with conservative treatment after 14 days. When treating facial burns, the graft should not be meshed due to the 'honeycomb' effect that it creates. If preferred, after excision, a temporary skin substitute can be used to cover the wound for 24 to 48 hours. This enables hemostasis and may improve graft take.

Grafting in facial burns

BURNS TO THE HANDS

In cases where there are extensive burns that include the hands, excision and grafting of hand burns should be performed after the excision of other, larger areas of burn to optimize survival of the patients. However, restoring hand function is obviously very important for daily activities and quality of life for every patient.

If required, escharotomies are indicated as emergency procedures. The timing of surgery is dependent on the extent of the burn. In isolated, full thickness burns, early excision and grafting is preferred and early exercising should be promoted. In cases with extensive burns, the surgery for hand burns may be minimized (until large areas of the burn at other locations have been grafted), and instead internal (K-wire) splinting, external splinting and/or physical therapy, to preserve the range of motion, should be focused on. Timing of the surgery then depends on the donor sites remaining and condition of the patient, do not wait longer than necessary. In very deep burns (partial) amputations may be unavoidable.

The skin on the dorsal side of the hand is thin and vulnerable to deep burns. On the volar side, the skin is thicker and stronger and a longer period to await re-epithelization is permitted. Meticulous cleaning, debridement and, when the wound bed is ready for grafting, proper positioning and fixation of grafts, is required to optimize the healing process. For positioning and fixation of the fingers, K-wires may be used. An adequate post-operative dressing technique with Vaseline gauzes will provide the correct pressure required to secure the grafts and to protect them against shearing forces that may damage the fragile new skin. As soon as the grafts show good take, exercises should started to keep the fingers mobile.

Split skin graft of the hand
The skin graft is meshed manually with a scalpel. For positioning of the fingers K-wires are used.

Debridement and split-thickness skin grafting

GENERAL PRINCIPLES
See: Burn wound excision and coverage

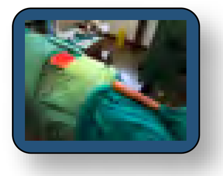
SURGERY
Preparations
1. Prepare your equipment.

2. Prepare the patient for surgery, for larger SSGs general anesthesia is often required.

3. Choose a suitable donor site, preferably the the medial thigh. When donor sites are limited, skin can be harvested from the scalp, legs, forearm or the abdomen and back.

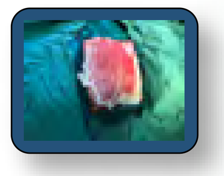
4. Take a ruler to measure the length and width of the wound to be grafted. Draw the outline of the sized graft at the donor site, this area should be usually a bit larger due to shrinking of the skin graft.

5. Clean the donor site and the burn wound with an antiseptic (Iodine, betadine or chlorhexidine) and apply sterile draping.



Debridement of the burn and preparation for transplantation
1. A well performed debridement is key to success. Use a surgical blade or the hand dermatome to remove the granulation tissue from the burn wound (see video 1).

2. Cover the wound with an adrenaline-soaked gauze to reduce bleeding. The commonly used concentration for topical application of adrenaline is 30 mL of 1 mg/mL of adrenaline in 1000 mL of normal saline (solution of 1 in 33,000).



Harvesting the SSG
1. Lubricate the skin of the donor site with a normal saline or Vaseline gauze. Avoid the use of oily lubricants.

2. Use dry swabs and the hands of an assistant to apply traction to the donor site. You need to understand how to use the dermatome available in your clinic. In low-resource settings it may be a hand dermatome (Humby or Watson knife).

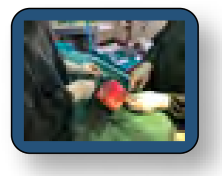
3. For both tools an essential step is to adjust the required depth. A number 10 surgical blade is used, and only the bevel should fit in between the knife and the guard of the dermatome to obtain a thin graft. The blade should never be able to fully enter the space, then there is a risk of taking a full thickness graft. When this happens, there are no options for primary closure and the graft should be sutured back where it was taken. We recommend to use an electric dermatome if available as these are safer.

4. After harvesting, place the skin graft on a wet gauze to keep it moist while waiting for all the skin to be harvested until the transplantation takes place (see video 2).

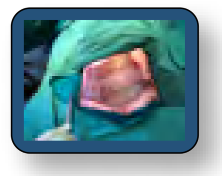
5. Cover the donor site with an adrenaline-soaked gauze to reduce bleeding.

Transplantation of the SSG

1. Place the skin graft with the dermal (i.e. shining) side up onto a firm surface and perform meshing with a meshing machine or perform manual fenestration of the graft with a blade. 

2. Apply the split-thickness skin graft to the wound bed with the dermal (shining) side down. 

3. Distribute the graft to cover the burn wound.

4. Use scissors to trim excess skin graft if needed. 

5. Use a skin stapler and/or fibrin glue when available or select a suture (usually a rapidly absorbable suture size 4.0 or 5.0) to secure the skin graft. When using sutures, first apply 4 interrupted sutures to the wound bed, one in each corner, then apply a continuous suture around the border of the graft.

6. Use a dry swab to apply pressure to the skin graft to ensure there is no residual hematoma.

7. Apply a compressing anti-shear dressing with Vaseline gauze soaked with an antiseptic agent over the skin graft. 

POSTOPERATIVE CARE

1. Avoid compression and especially shear forces on the grafted areas.

2. Inspect the graft on day four or five postoperatively. If it starts to smell earlier, inspect immediately, clean gently and apply a topical antibacterial agent.

3. Dress the donor site, preferably with an occlusive dressing. Leave the dressing on the donor site area in place for 10-14 days. Different types of non-occlusive dressings may also be used, such as Vaseline gauze soaked in an antiseptic agent. If soiled, remove only the outer layer and reapply a new outer bandage.

4. The graft will remain fragile for about 3 weeks, protect it with a bandage and keep the skin supple with body lotion or Vaseline.

SSG Harvesting from the scalp

GENERAL PRINCIPLES
The scalp is the preferred donor site for split-thickness skin grafts (SSG), especially in children. Be aware that this technique requires training. When one is not trained, it may only be used when no other donor site options are available and it is preferred to ask for guidance from an experienced colleague.

1. The scalp of children has a relatively large surface area, as a consequence it offers relatively large SSGs.

2. Postoperative pain is limited compared to other donor sites.

3. Regrowth of hair conceals the donor site, which would limit potential cosmetically unfavourable outcomes, such as differences in pigmentation of the donor site.

4. The scalp has a faster re-epithelialization rate and therefore allows for an earlier second or third harvest from the same site.

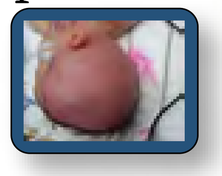
Patients (or the responsible adult) should be informed of the possible complications of using the scalp as a donor site. Please note, complications are rare.

- **Short-term complications**: scab formation and folliculitis.
- **Long-term complications**: alopecia and scar hypertrophy.
- Be aware of the higher rate of complications (folliculitis, alopecia and visible hypopigmented scars) when using the scalp as a donor site for patients with hair type VI-VIII (black, African descent).

Preferably, shave the hair of the planned donor site shortly before surgery. This will save time and during surgery and prevents unnecessarily manipulation of the head.

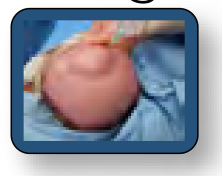
SURGERY
Preparations
1. Evaluate if the scalp is adequately shaved.

   TIP: If there is a risk of harvesting the skin outside the boundary of the scalp, the hairline should be indicated with a surgical marker.

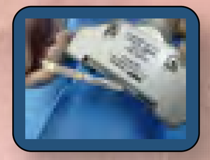


2. Disinfect the donor site (and the burn wound) with an antiseptic (Iodine, betadine or chlorhexidine) and apply sterile draping.

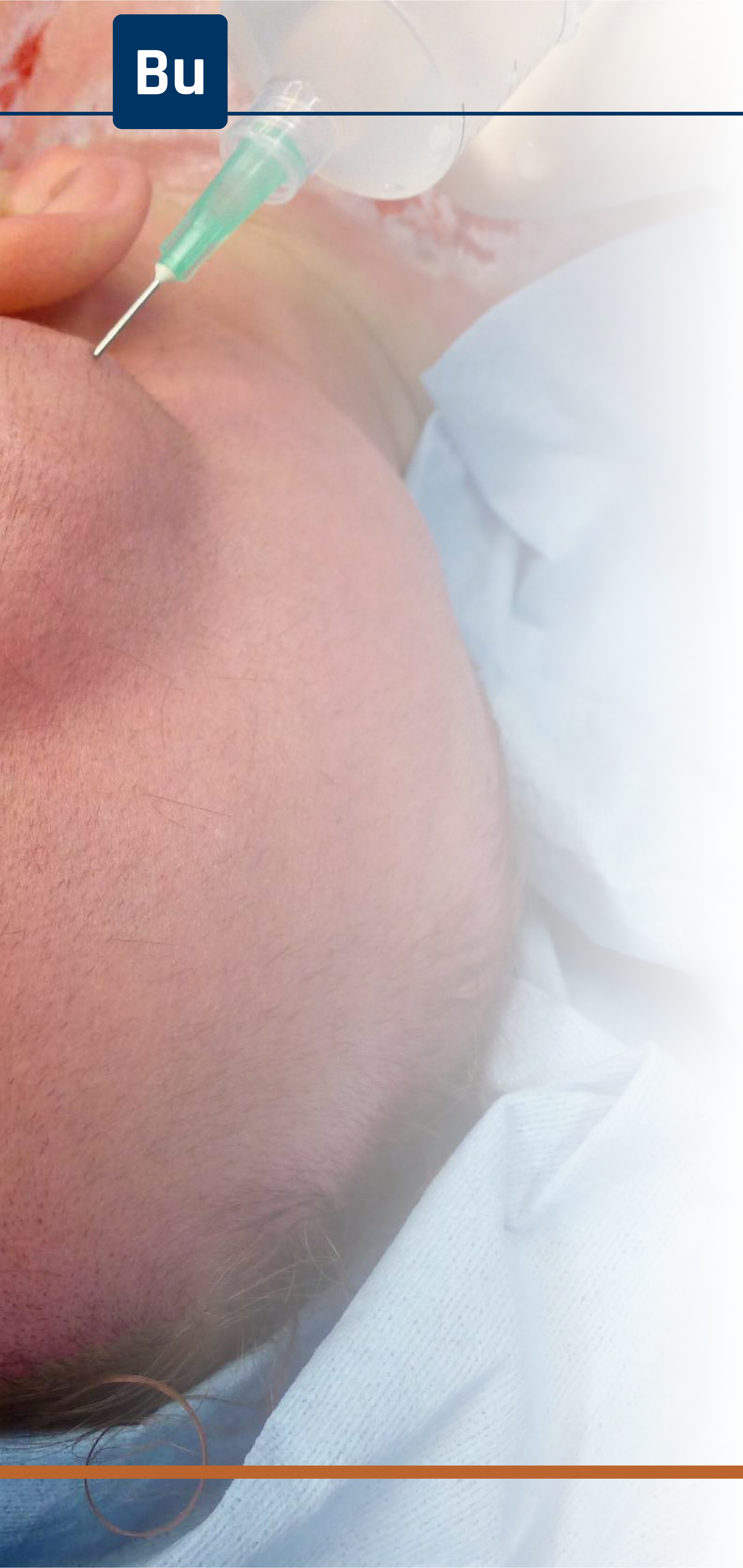
3. Infiltrate the donor site, using a sterile physiological saline solution (NaCl 0.9%). When preferred, epinephrine with lidocaine can be added to reduce bleeding. Infiltrate the subgaleal space to create a cushion that allows harvesting of a wide strip of skin.



4. Set the dermatome. Determine the size of the blade and adjust the thickness and width.



TIP
Beware that in practice the thickness of the graft may vary with the same dermatome setting. Therefore, check the space between the dermatome blade and guard with a size 10 scalpel blade. Only the bevel of the blade should enter to get the right graft thickness. Lubricate the skin of the donor site and the dermatome with saline solution.



Harvesting and dressing

1. Harvest the SSG using the dermatome.

2. Achieve hemostasis.

   TIP: Apply a gauze soaked in adrenaline solution (10 mg adrenaline in 1L NaCl 0.9%) to the donor site.

3. Dress the donor site. For example using alginate dressings or Vaseline gauzes with tetracycline ointment. Either dressing is subsequently covered with absorbent cotton gauze and secured with an elastic bandage and/or elastic stocking.

POST-OPERATIVE CARE

During the first three to five days after surgery it might be necessary to change the outer bandages as the dressing may migrate due to shearing forces. When alginate is used, the dressing will stay moist due to the exudate, therefore it is not yet adherent.

After three to five days, the upper bandages and absorbent gauze can be removed. The alginate dressing has formed an adherent crust, which will detach from the donor site when healed.

MANAGMENT OF COMPLICATIONS

Folliculitis and scabs are treated conservatively. Shave the affected area with a margin of approximately two centimetres and perform daily rinsing with a chlorhexidine solution. Use a topical antiseptic to cover.

Meek technique

GENERAL PRINCIPLES

The Meek technique is a useful technique for patients with extensive burn wounds who do not have sufficient donor sites available to close the burn wounds with general autologous skin grafts at once, even after meshing.

With the Meek technique, a split-thickness skin graft (SSG), cut into squares, is further reduced to square-shaped islands with the Meek-dermatome. The square cut into smaller squares is placed on pre-folded gauzes, with which an expansion of 1:9 is achieved.

Specific tools are needed, as explained later in this chapter.

When resources are limited and there is no availability to perform the Meek technique, staged grafting is an alternative. The burn is closed during multiple surgeries to limit the peri-operative risks. The graft can be harvested from the same donor site again after healing. A disadvantage is that this strategy takes a lot of time and extensive scarring of the burn may occur.

SURGERY

Preparation

1. Choose a suitable donor site, preferably the thigh or scalp.

2. Shave the donor site. When the scalp is used, the donor site is preferably shaved prior to surgery when the patient is conscious.

3. Clean the donor site and the burn wound with an antiseptic (Iodine, betadine or chlorhexidine) and apply sterile draping.

4. Decide which amplification of the skin graft will be needed (1:2/1:3/1:4/1:6/1:9). In practice, 1:9 is most commonly used to cover the largest possible area with minimal donor side morbidity.

5. Count the number of corks that are needed. One cork is 4.2 cm, however the amount of cork required depends on the amplification of the skin graft. Measure either with an unfolded plisse of the correct amplification, or cut out the size of an unfolded plisse from a mesh and use that as a measuring tool. For example: if 18 plisses of 1:3 are required, then the donor site is 18x4.2.

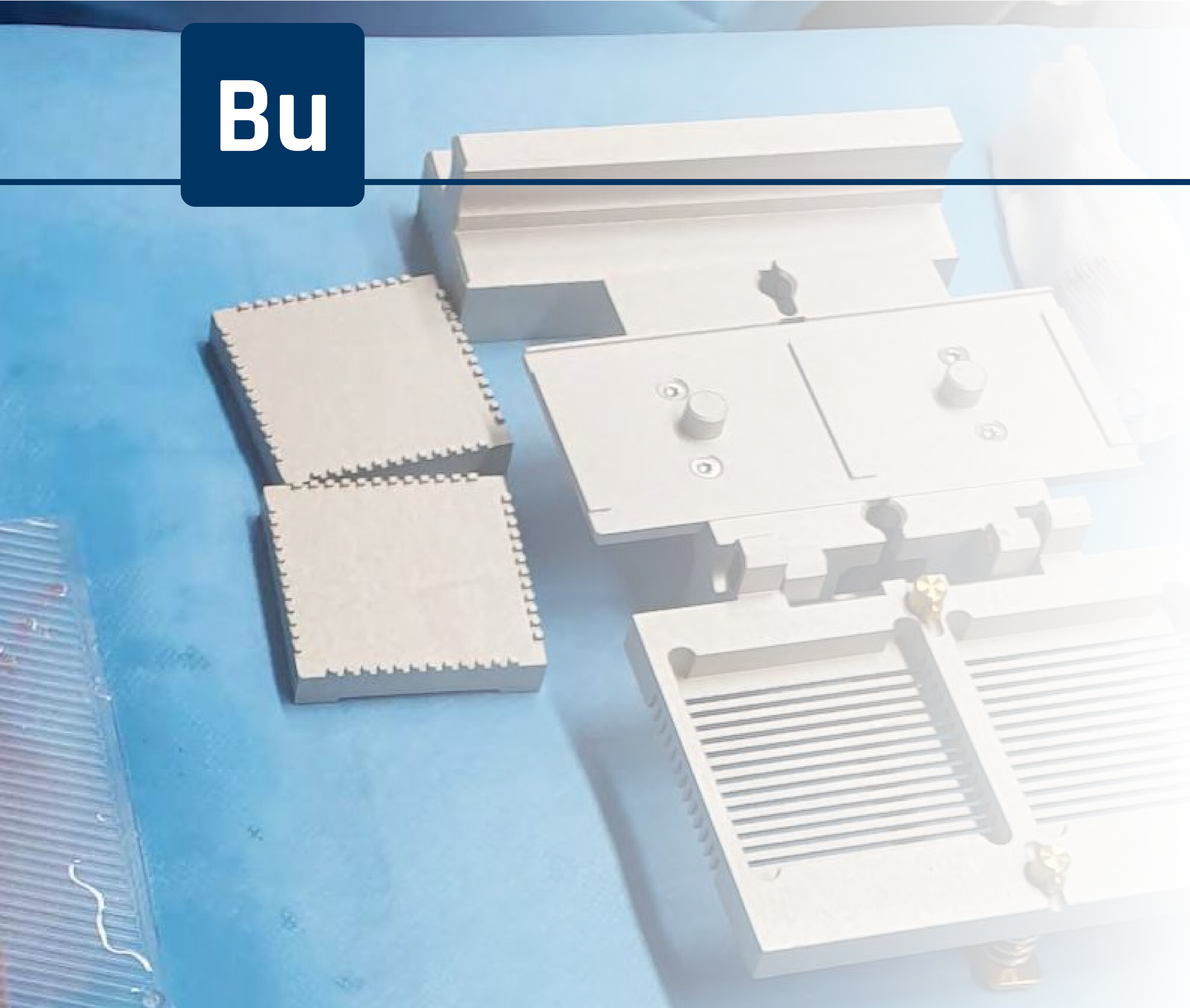
6. Set the dermatome. Determine the size of the blade and adjust the thickness.

Debridement

Remove the eschar/granulating tissue from the wound with a normal surgical knife, weck blade, Humby knife or dermatome, to obtain a healthy wound bed. Cover the wound with an adrenaline-soaked gauze and dress it with a temporary bandage to reduce bleeding.

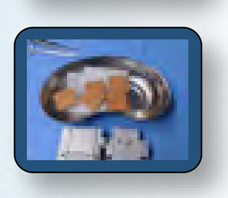
TIP

Beware that in practice the thickness of the graft may vary with the same dermatome setting. Therefore, check the space between the dermatome blade and guard with a size 10 scalpel blade. Only the bevel of the blade should enter to get the right graft thickness.



Harvesting

1. Harvest the SSG using the dermatome. Prevent the use of oily lubricants at all times.

2. Dampen the cork plates in saline solution.

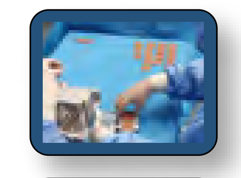
3. Place the skin graft on a carrier or a soaked gauze, spread the skin graft out with the dermal (shiny) side up and cover it with saline-soaked gauze to prevent dehydration.

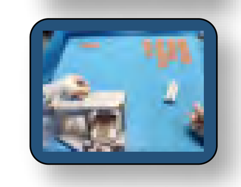
4. Cover the donor site with an adrenaline-soaked gauze or (wet) Kaltostat to reduce bleeding.

Expansion/ Meek technique

1. Apply cork plates on the dermal (i.e. shining) side of the skin graft and cut the skin graft on the edge of the cork plate with a blade. Make sure the skin graft is not bigger than the cork plate, but stays within the edges of the cork.

2. After all the skin grafts are placed on cork plates, the corks are cut with the Meek-dermatome or with a surgical blade 10 or 15 in both directions, leaving small squares of skin grafts.

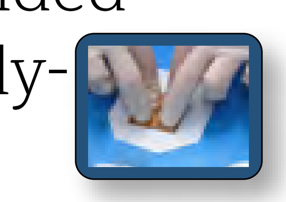




3. Spray all the cork plates with the cut skin grafts (epidermal side of the skin graft on the cork plates up) with an adhesive dressing spray.

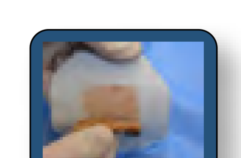
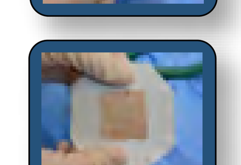
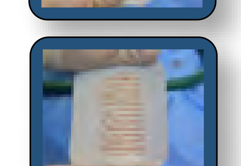
4. Wait for 5- 7 minutes.

5. Press the cork plates on the pre-folded polyester gauze. The pre-folded polyester gauze is folded on a tin-foil.

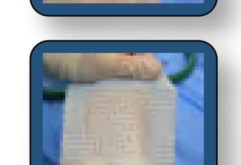


6. Remove the cork, leaving the square-shaped islands of autograft on the gauze.

7. Expand the prefolded polyester gauze by pulling on the edges. First pull the ribbed edges and then the smooth edges.

8. Remove the polyester gauze from the tin-foil.



9. Perform hemostasis of the burn wound and staple the polyester gauze to the wound with the graft side down.


Dressing

1. Cover the polyester gauze with gauzes soaked in topical antiseptics (for example furacin-oil) and dress with dry bandages.

2. The donor site is checked for hemostasis and the wound is dressed with the preferred local dressing material (foam dressing, alginate dressing, semipermeable film dressing or Vaseline gauzes).

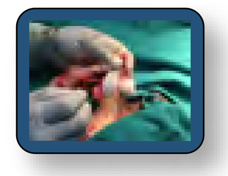
POST-OPERATIVE CARE

The first day after the surgery, the patient should be examined for bleeding or hematoma formation. The dressings, soaked in local antiseptics, are changed on a daily basis. Remove the staples fixing the polyester gauzes in place after a week. Remove the polyester gauzes when the epithelialization is complete, usually at least 7-10 days after surgery. When the polyester gauzes are removed, the wounds are inspected and treated with local antiseptics such as Fucidin®, Bactroban® or Betadine®.

Harvesting Full Thickness Graft (FTG)

GENERAL PRINCIPLES

Compared to split-thickness skin grafts (SSG), FTG's are thicker and more resistant to contraction.



Harvesting a FTG creates a full thickness donor site defect that needs to be closed. This means that the amount of skin that can be harvested is limited by the skin elasticity. FTGs are therefore mostly used to cover relatively smaller areas of special anatomical and functional importance (head, eyelids, perioral areas, joints, neck and hands) and/or when esthetics, color match and elasticity are of greater importance. Be aware that the risk of failure of the take of FTG's is higher than of a SSG. This is because the thicker layer has higher requirements to survive the first couple of days before blood vessels connect with the new skin. Therefore, FTGs are not very often used in acute burn surgery, but the technique is very useful in contracture release surgery.

SURGERY

Preparation

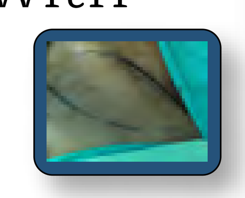
1. Prepare your equipment (scalpel, dissecting forceps, sutures and scissors).

2. Prepare the patient for surgery and decide on general, regional or local anesthesia.

3. Choose a suitable donor site. The donor site is chosen according to availability and color match. The quality and availability of donor sites in the lower abdomen and groin regions is often of good quality and esthetically preferred for larger FTGs.

4. To reduce scarring and tension of the wound, skin should be harvested along the direction of collagen fiber bundles in the dermis (Langer's lines or relaxed skin tension lines).

5. A template of the defect can be made by drawing on flexible material (gauze or sterile paper) with sterile ink or methylene blue. Be aware that the defect may increase after a debridement. Start with the debridement before harvesting the skin.



6. After drawing the template for the FTG, pinch the edges of the donor site together to ensure that there is enough overlapping skin to close the gap by approximation. Then you may lengthen the incisions to facilitate proper primary closure.

7. The donor area is disinfected with an antiseptic (Iodine, betadine or chlorhexidine), marked and infiltrated with local anesthetics with epinephrine.

Skin harvesting

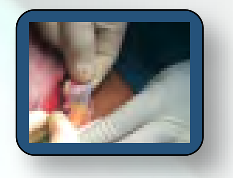
1. A FTG is harvested using a scalpel. Some experts also use scissors.

2. Begin by making a shallow incision along the ink line.

3. Angle the scalpel towards the center of the spindle.

4. Grip one corner of the spindle with forceps and gently pull upwards to create tension on the skin and expose the adipose tissue beneath the skin graft.

5. Angle the scalpel upwards towards the dermis when separating the graft from the adipose tissue.



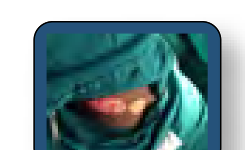
6. Subcutaneous adipose tissue should be removed from the dermis with fine scissors, prior to transplantation of the graft to the recipient site.

7. Hold the graft, dermis side up, around the index finger and cut away the yellow fatty tissue, until the skin appears light blue.

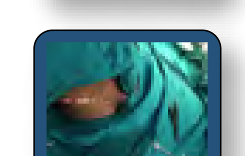
Donor site closure

1. Before closing the donor site, adequate hemostasis is required.

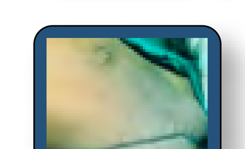
2. The donor site is closed primarily by local advancement of the adjoining skin with absorbable or non-absorbable sutures.



3. Close the gap with a subcutaneous suture or an absorbable suture.



4. Then close the skin with a continuous suture, intra- or percutaneously.



5. Steristrips can be applied, if available, followed by dry gauze.

Graft placement and fixations

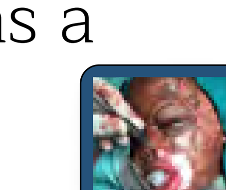
1. The wound is debrided and the FTG must be placed on non-infected, well vascularized tissue for optimal survival of the FTG.

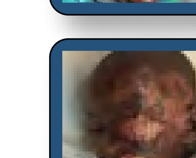
2. The FTG is placed onto the recipient site and sutured into place using fine, absorbable sutures (size 3.0, 4.0 or 5.0).

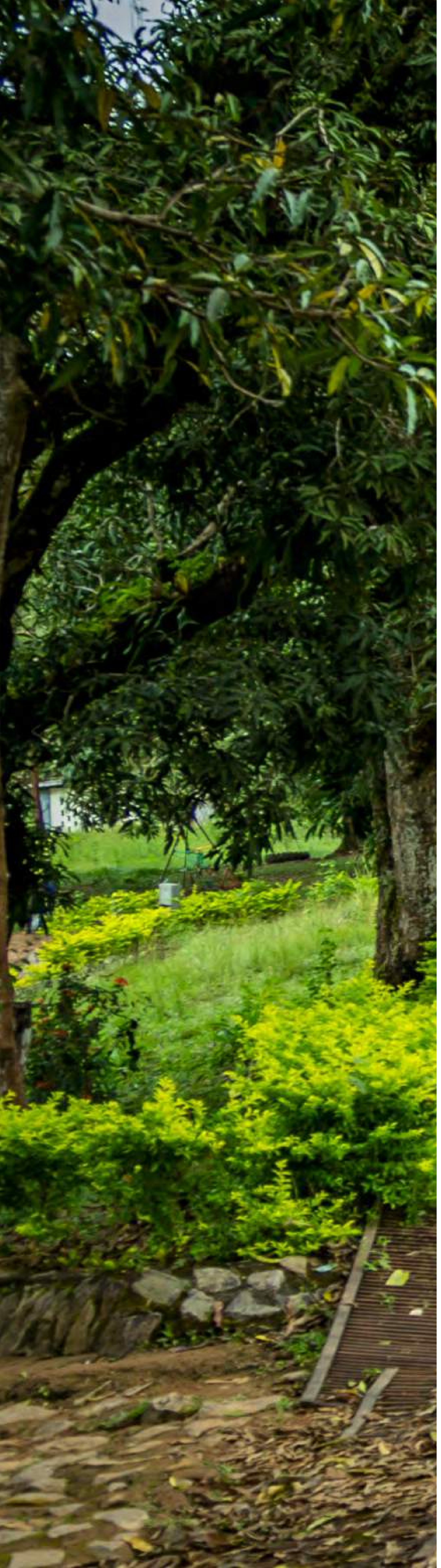
3. To fixate the graft to the recipient site quilting sutures may be used.

4. Small incisions can be made in the FTG to limit the risk of hematoma and seroma formation underneath the graft, which may inhibit revascularization. However, more stab incisions will lead to a more contracting scarring process so requires a balanced tradeoff.

5. A tie-over dressing can be used to better fixate the graft to the wound bed, especially when the wound bed has a concave surface. A Vaseline gauze with tetracycline ointment can be used and sutured on top of the graft with a non-absorbable suture.







Basics of Burn Care 2
Examples

Photo by J. van Kesteren

Head and neck

Photo by M. Botman

Preview

Face





Face

This 5-year-old boy had sustained burn wounds to the face, the focus of this example. The right arm and chest were also involved. The patient was treated at Haydom Lutheran Hospital in Tanzania, a tertiary hospital. This case shows how choices need to be made with regards to where to start with grafting when patients are not fit to undergo grafting of all areas affected at once. It also highlights that multiple surgeries may not be affordable, making the right choice even more important.

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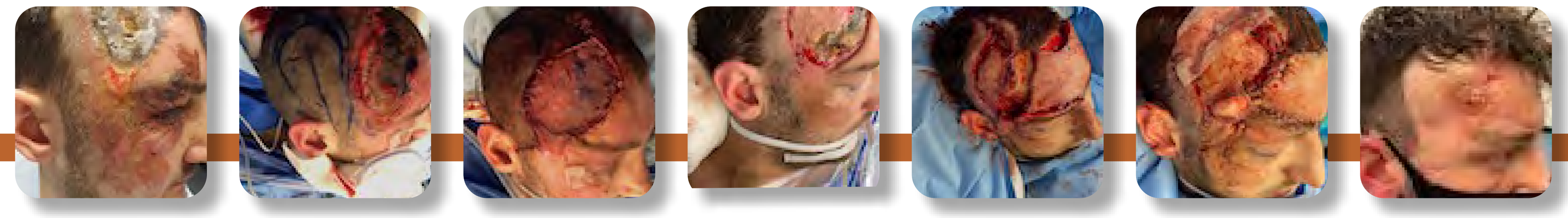
Preview

Scalp



Scalp

A 25-year-old man was injured by a high voltage electric shock. His scalp, right wrist and left thigh were affected. The patient presented at an emergency department of a large regional hospital in the Netherlands. Initially, it was not known that the patient had sustained a high voltage injury. This had led to an incomplete primary and secondary survey. Three days after the trauma, the patient presented at a Dutch Burn Center. The focus of this example is on the impact of an electrical burn and the surgical treatment of the scalp burn.

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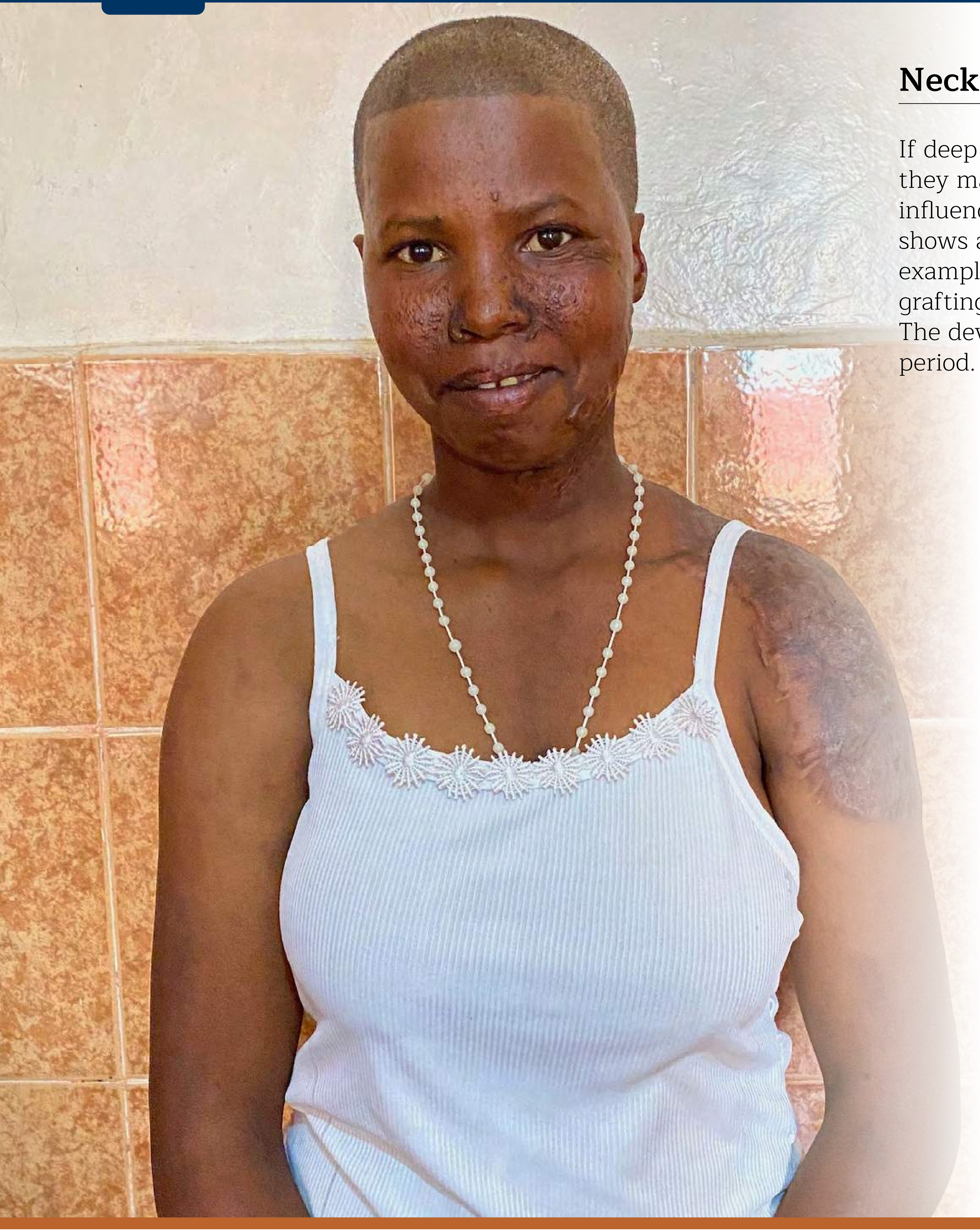
I Q1 Q2 Q3

Preview

Neck



Neck

If deep burn wounds of the neck are not treated properly in the acute phase, they may cause severe contractures. The care provided will have a major influence on the subsequent scarring and the long-term outcome. This case shows a patient with burns of the face, neck and left shoulder. In this example from Tanzania, the surgical treatment provided was excision and grafting. The scars healed with no further cosmetic treatment in this setting. The development of the scars over time is presented, over a 2-year follow-up period.

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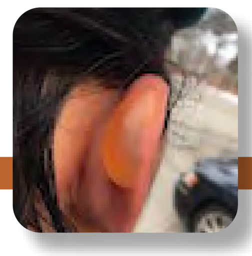
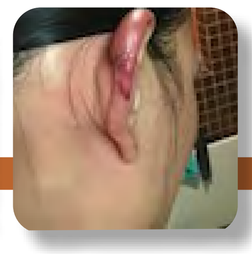
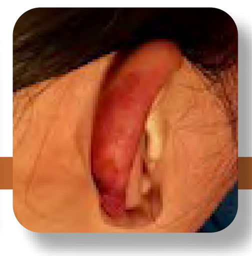
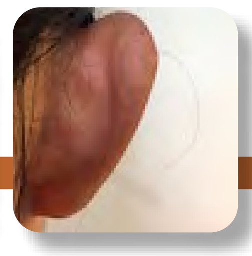
Preview
Ear

Ear

This example shows thermal injury caused by cold. The patient sustained a cold injury while he was on a ski mountaineering trip in Switzerland. He was treated at a general hospital in Switzerland.

On the day of the cold injury, he and his party had ascended 700 meters, to reach the summit of the Wildstrübel at 3245 meters. Having reached the summit, they skied down. The outside temperature was approximately -18 degrees Celsius and a strong wind blew.

MEDICAL HISTORY
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Q1 Q2 Q3 Q4

Trunk

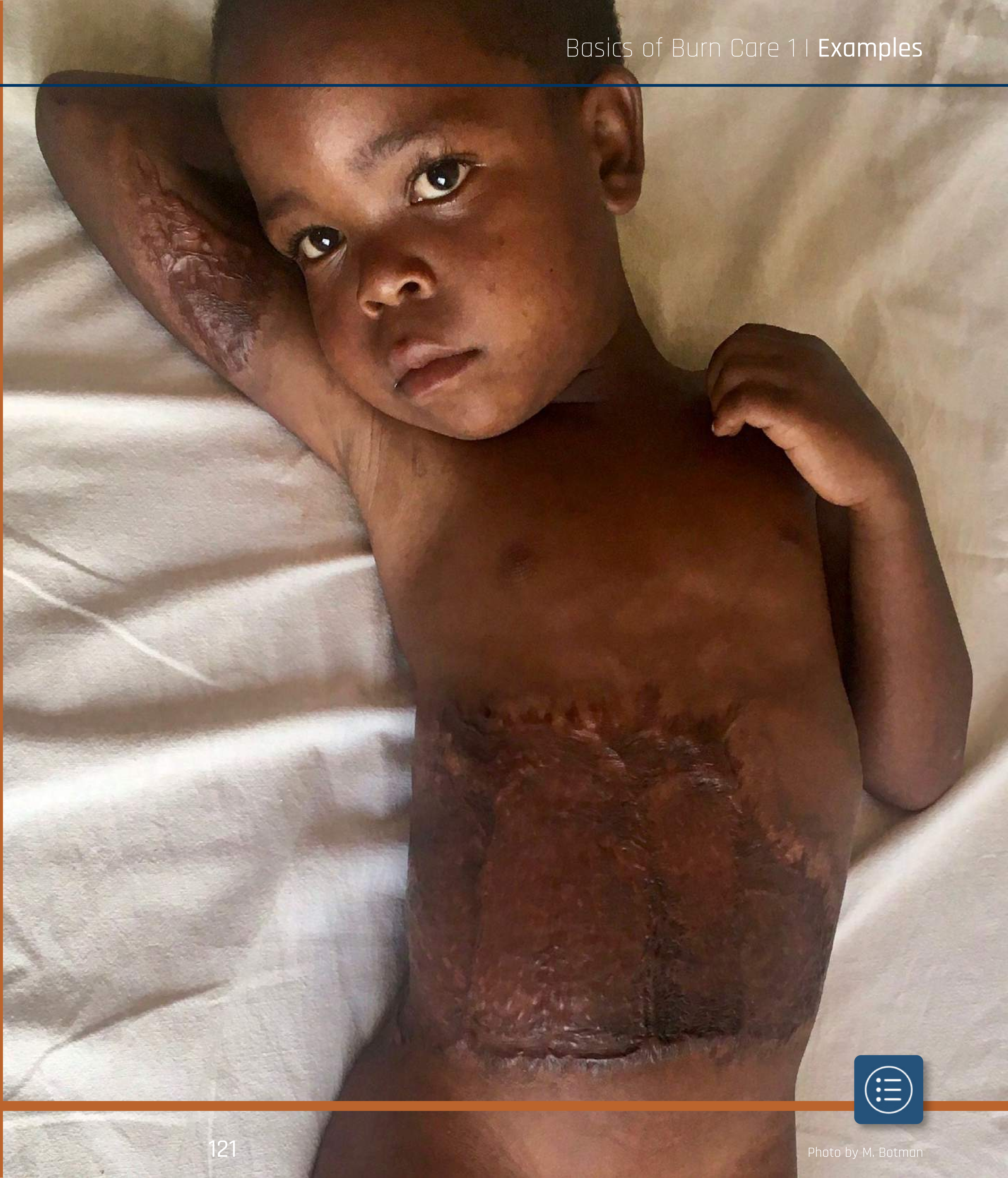

Photo by M. Botman

Preview

Abdomen

Abdomen

Burns of the abdomen are common but are not likely to cause contractures unless they extend to the groin area (see chapter lower extremity). However, larger areas need to be grafted as shown in this example. For patients that are living remotely, like this example in Tanzania, it can be difficult to get the surgical care needed but the grandmother of this child succeeded.

- MEDICAL HISTORY
- PHYSICAL EXAMINATION
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- LESSONS LEARNED

Preview

Shoulders, back and buttocks

Shoulders, back and buttocks

This example shows a 9-year-old girl with a severe burn of the posterior trunk. Most of the deep burn injuries affecting the posterior of the trunk, encountered in rural Tanzania, were caused by burning clothes, a cause of severe mortality and morbidity in patients. Patients with a TBSA burned > 40% have a high mortality risk in low-resource settings.

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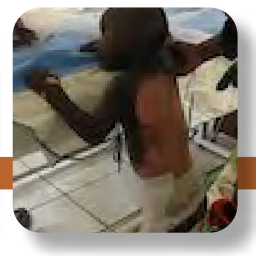
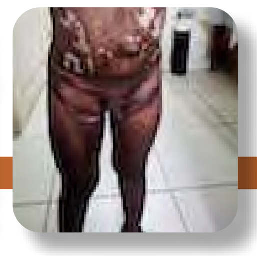
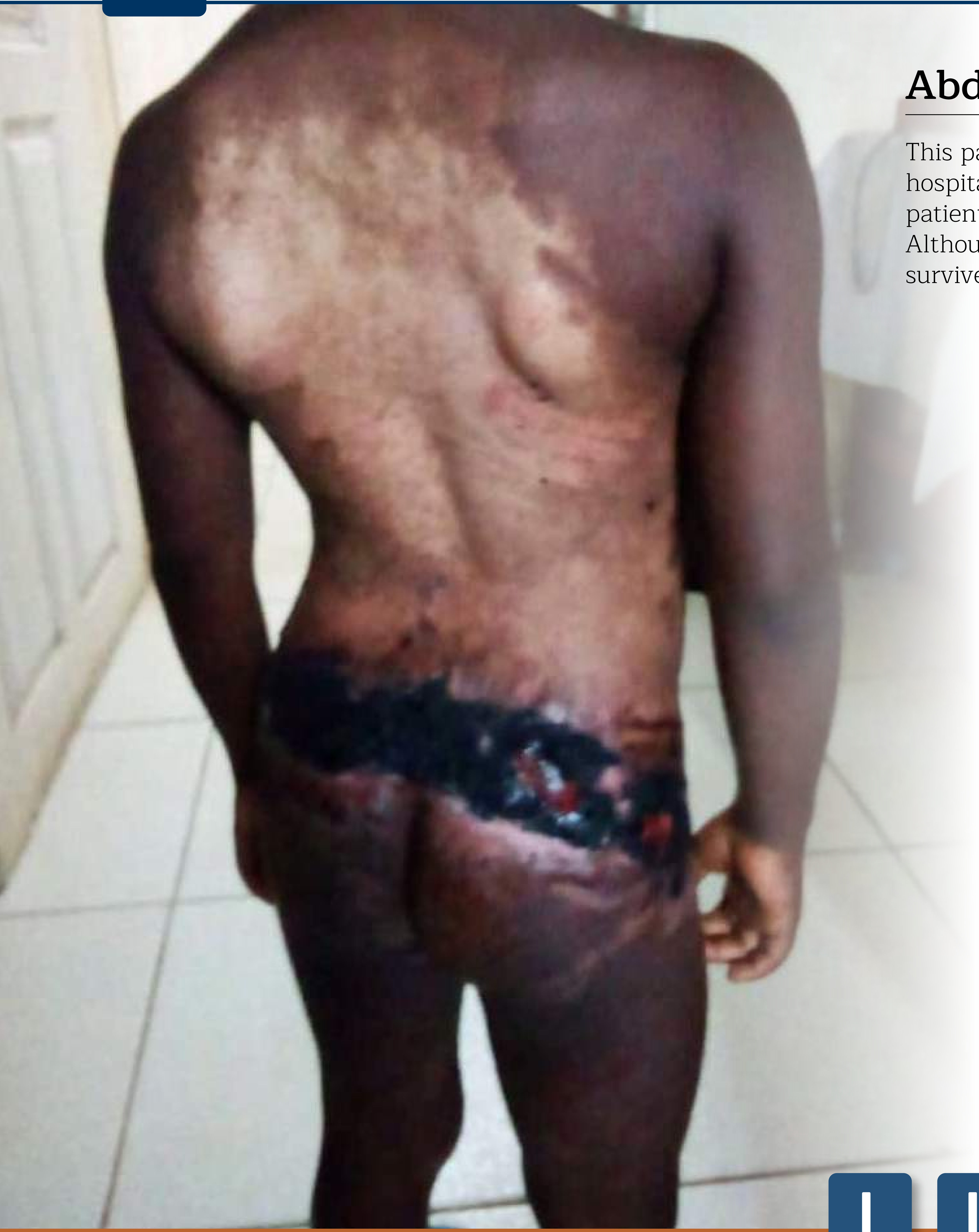
Preview

Trunk, arms and legs





Abdomen, back, buttocks, arms and legs

This patient sustained burn wounds due to hot water and was treated at a hospital focused on mother and child care in Pujehun, Sierra Leone. Caring for patients with large burns can be challenging in resource-limited settings. Although this patient's chances were slim and resources scarce, this child survived his burn injuries.

- MEDICAL HISTORY
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- SECONDARY SURVEY
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- CONSERVATIVE MANAGEMENT 2
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Upper extremity

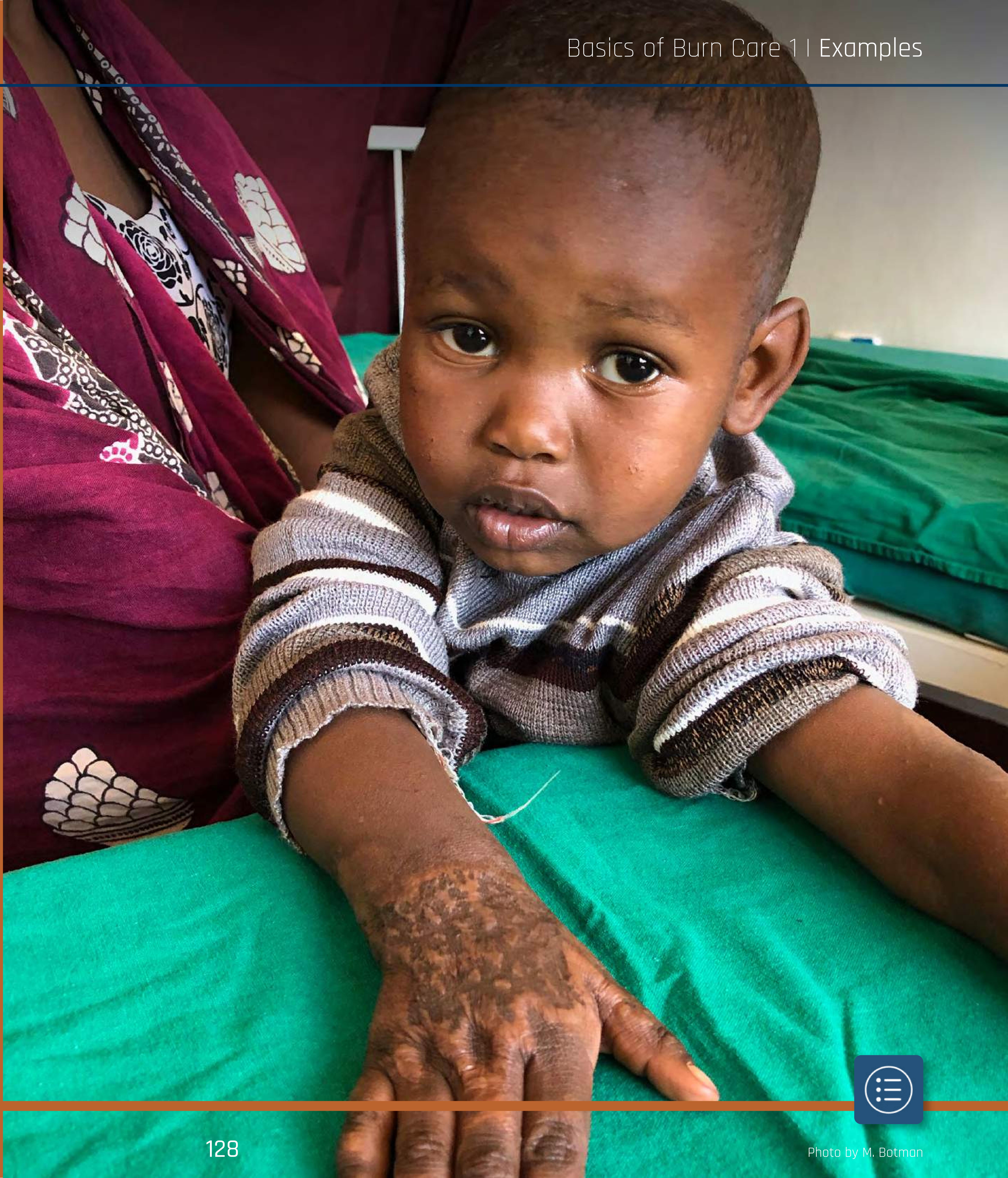

Photo by M. Botman

Preview

Shoulders, upper arm and back

Shoulders, upper arm and back

This example shows a young boy with large burn wounds, including a circular burn on the right upper arm. The parents took the child quickly to the hospital where an emergency escharotomy was performed. Adequate treatment for a severe burn like this requires a foundation of good knowledge in the family/community on what needs to be done after a burn happens. Distance from a hospital and the availability of transport are important factors that determine timely arrival at a healthcare facility. The facility needs to be capable of providing safe and effective care and last but not least, the care available should be affordable.

Keep in mind that nine out of ten people in low- and middle-income countries do not have access to safe and affordable surgical care when needed.

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I

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Preview

Arm

Arm

This 5-year-old boy had sustained burn wounds to the arm, face and the chest. The treatment of the face has already been presented in the head and neck section. This example focuses on the right arm. How the delayed grafting strategy was performed in Haydom Hospital, Tanzania is shown for this patient.

- MEDICAL HISTORY
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Hand

Hand

Burns to the hand require special attention because of the importance of the hand in daily functioning. The thinner skin on the dorsal side of the hand requires more often coverage with skin grafts. Burns on the palmar side of the hands can more often be managed conservatively due to the thicker layer of the palmar skin, however, in deeper burns skin grafting is also very important here. Dressing technique is an important skill in burns of the hand. Be aware that the thumb is as important as the four other fingers put together.

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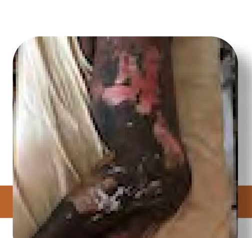
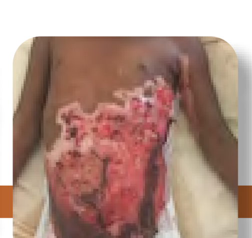
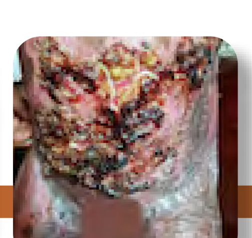
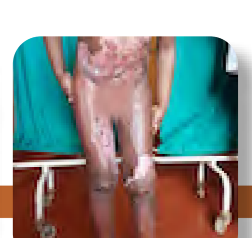
Lower extremity

Photo by M. Botman

Preview

Groin and upper leg



Groin and upper leg

A 5-year-old girl was presented at the emergency department of the Haydom Lutheran Hospital in Tanzania, after a fire-related burn injury involving the groins, extending to the abdomen and lower extremities. The picture shows how difficult it can be to estimate the extent of the burn by inspection shortly after the burn injury. As seen on pictures taken at a later stage, the burn deepens and a larger area is affected a few days later.

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Preview

Knee 1

Knee - 1

The patient in this example sustained a burn wound to his left knee. He was referred to the outpatient department of *Burn Center Beverwijk* in the Netherlands, three weeks after the burn injury. The burn wound was debrided and the defect closed by an islanded perforator-based flap. Perforator-based flaps are have a good cosmetic outcome and very useful for burn reconstruction. However, they require specific knowledge and skills and a Doppler device is needed.

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Knee 2

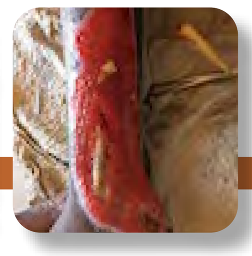
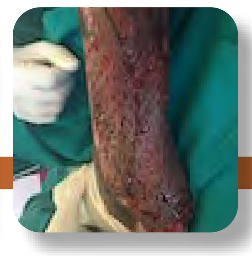
Knee - 2

A 48-year-old epileptic patient had sustained burn wounds after falling into the fire in rural Tanzania. He did not come to the hospital immediately but went to a traditional healer first. This case demonstrates the treatment of the deep burn wound on the upper leg and knee with the patella exposed. A muscle flap was used to cover the defect on the knee.

Preview

Lower leg



Lower leg

A 25-year-old woman was brought to the emergency department of the Haydom Lutheran Hospital, Tanzania. She was known to suffer from epilepsy and had sustained extensive burns after falling into a fire during a seizure. Epilepsy is a common cause of burn injuries in low- and middle-income countries. This example focuses on the deep burn wound on the lower leg with bone exposure.

MEDICAL HISTORY
PHYSICAL EXAMINATION
CONSERVATIVE MANAGEMENT
SURGERY
POSTOPERATIVE CARE
OUTCOME
LESSONS LEARNED

Preview

Foot and toes

Foot and toes

This example shows a young child with severe burn wounds that did not receive adequate burn care. After a delay, the patient and his parents arrived at a hospital offering surgical burn care. Unfortunately, they disappeared before surgery could be performed. Later, they explained that they were afraid of the hospital bills. Two months later they returned to the hospital, desperately, with the child in a very bad condition. The patient survived however was disabled with severe contractures of knee and foot. This example shows challenges of providing adequate burn care in resource-limited settings.

MEDICAL HISTORY

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LESSONS LEARNED

Q1 Q2

Addendum

Further reading

Principles

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Glossary

ABLS	Advanced burn life support
AC	Alternating current
ACS	Abdominal compartment syndrome
ARDS	Acute respiratory distress syndrome
BICS	Burn induced compartment syndrome
BPRAS	Burn specific pain anxiety scale
CO	Carbon monoxide
COHb	Carboxyhemoglobin
CR	Capillary refill

DC	Direct current
ECG	Electrocardiogram
FLACC scale	Face, Legs, Activity Cry, Consolability scale
FTG	Full-thickness skin graft
GCS	Glasgow coma scale
HCN	Hydrogen cyanide
IAP	Intra-abdominal pressure
IDC	Indwelling urinary catheter
LDI	Laser Doppler imaging
LMIC	Low- and middle-income country

NPRS	Numeric pain rating scale
NPT	Negative pressure therapy
NSAID	Non-steroidal anti-inflammatory drugs
SSD	Silver sulphadiazine cream
SSG	Split-thickness skin graft
TBSA	Total body surface area
VAS	Visual Analogue Scale