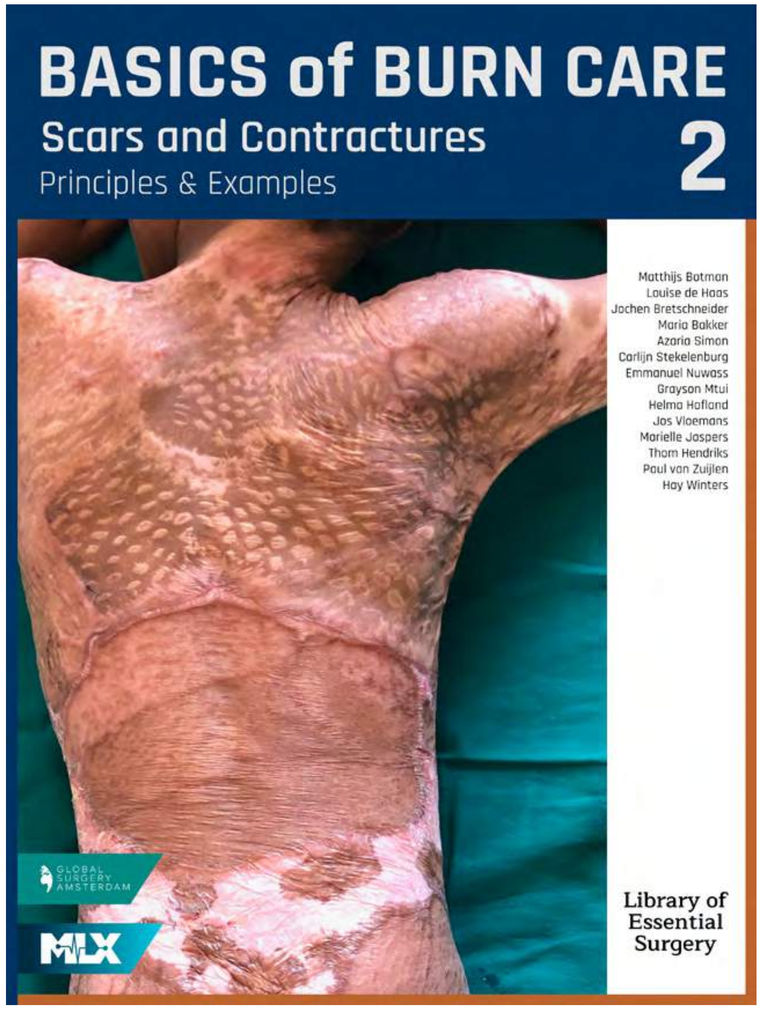

BASICS of BURN CARE 2

Scars and Contractures

Amsterdam | October 2022
1st Edition | v. 1.0.4

PROJECT TEAM

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SHOW HOTSPOTS

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

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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Basics of Burn Care 2
Principles

Photo by M. Botman

General information

Epidemiology

Burn injury can lead to scarring, including hypertrophic scars and/or contractures. Data on the incidence of hypertrophic scarring and contractures after burn injury is scarce, though estimates of the prevalence of hypertrophic scars vary between 32-72% (all data is from high-income populations). The reported prevalence of contractures, measured at discharge, varies between 38-54%, with a lower prevalence with a longer time after the burn.
However, this prevalence considerably varies between the limited number of studies, therefore the true prevalence is remains unclear. The numbers also depend on the population in question. Taking into account that 11 million people require medical care due to severe burns each year, this is an evident problem.

For example, in high-income countries, burn care has improved over the past decades which has lead to a shift in focus from mortality to morbidity. The improved survival of patients with deeper and more extensive burns leads to more patients with problematic scars that require aftercare and surgical treatment. In low- and middle-income countries, where more than 95% of fire-related burns occur, specialized burn care is limited. Burn care, including skin grafting, is often not available, or when it is, treatment is delayed.

In these cases, burn wounds heal by secondary intention, leading to problematic scarring, including contractures. Therefore, burn injuries are not only a major cause of prolonged hospital stays and death, but also a common cause of disfigurement and disability.

PREDICTING FACTORS
Injury and treatment characteristics are predicting factors for pathological scar formation. Predictive factors are the Total Body Surface Area (TBSA) burned, the required number of surgical procedures for an acute burn, and the healing process (duration of wound healing and hospital stay, and complications). Contractures are more likely to occur in severe burns, flame burns, children, females and burns to the upper extremity, specifically the shoulder and elbows.

Pathophysiology

WOUND HEALING

To understand the process of scar formation, firstly it is important to understand the process of wound healing. Normal wound healing consists of three overlapping phases: the inflammatory, proliferative, and remodelling phases.

Inflammatory phase

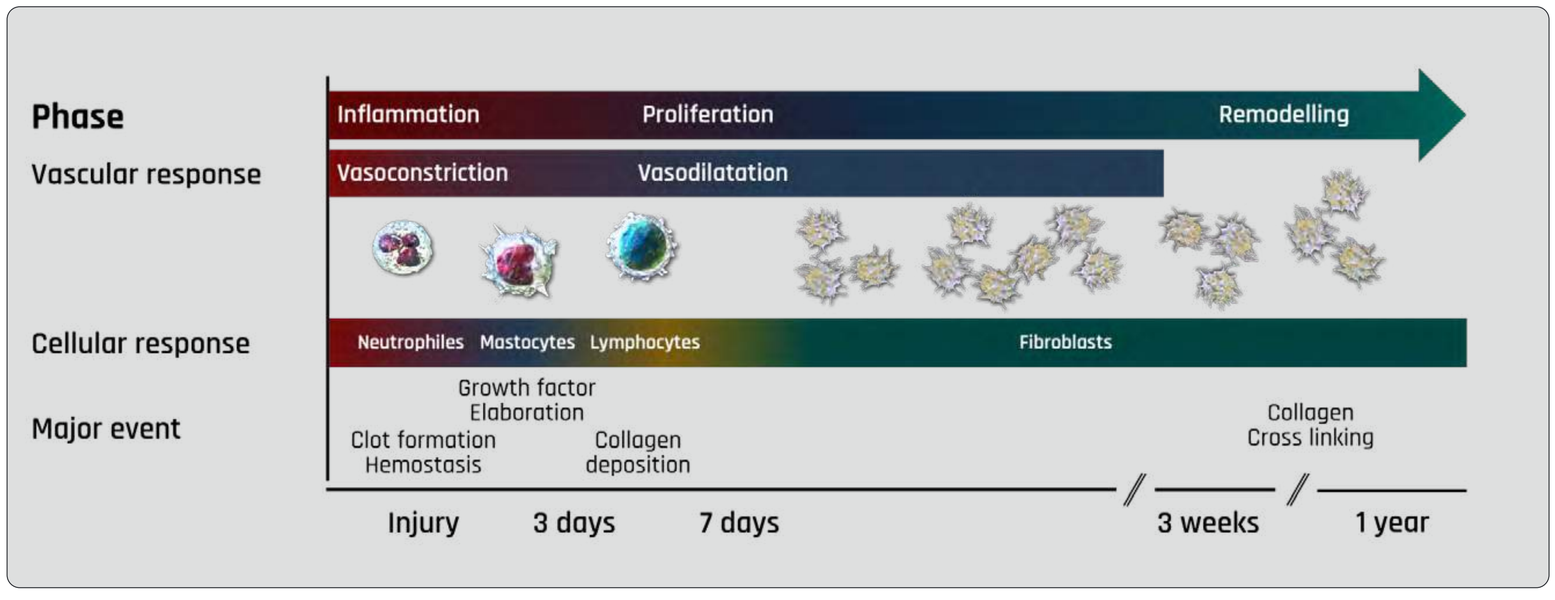
During the inflammatory phase (days 1-7), hemostasis by activation of clotting pathways induces the formation of a platelet and fibrin clot. After bleeding is controlled, several inflammatory pathways are activated, characterized by recruitment of pro-inflammatory cells into the wound site, such as neutrophils, lymphocytes and macrophages. The presence of macrophages plays multiple roles: The phagocytosis of debris and harmful pathogens prevents infection, while the secretion of signalling molecules such as growth factors, cytokines and chemokines are also important for the following proliferative phase. In addition, activation of mast cells results in the release of histamine and vasoactive molecules, increasing the vascular permeability, usually grossly visible as swelling/oedema.

Proliferative phase

The proliferative phase (days 4-21) results in the formation of granulation tissue due to the combined activity of macrophages, endothelial cells and keratinocytes. Activity of the macrophages stimulates fibroblasts to produce type III collagen and other growth factors, stimulating endothelial cells to induce angiogenesis that will result in new blood vessel formation. Other signalling molecules induce keratinocytes in the surrounding skin to migrate into and reepithelialize the wound to repair the skin defect.

Remodelling phase

The remodelling phase (days 21 – 1 year), also referred to as the maturation phase, is the most important phase in the mechanism of scarring. During this phase, the tissue is remodelled into scar tissue. The type III collagen is replaced by the stronger type I collagen that is layered in parallel bundles, in contrast to the normally basket-weaved layers of unscarred skin. As a result, scar tissue appears different to the surrounding unscarred skin. Finally, during the last stage of remodelling, wound contraction, modulated by myofibroblasts, results in the reduction of the scar surface area.



DETERMINANTS OF SCAR FORMATION

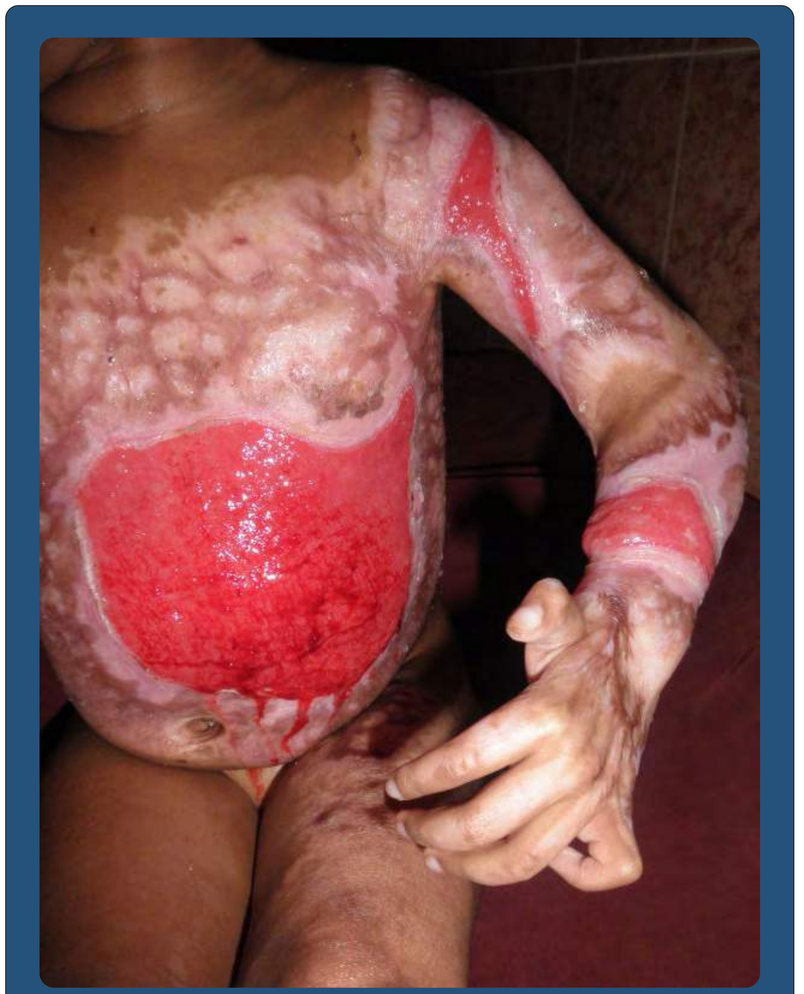
There are multiple factors that contribute to scar formation. **Inflammation and infection** are associated with greater neovascularisation and result in more excessive scarring, and prolonged reepithelialization (i.e. 'time to heal') also appears to be positively associated with excessive scarring.

Reepithelialization requires keratinocytes from the basal layer of the epidermis, which are also present in the sweat glands and hair follicles protruding deep into the dermal tissue. The number of keratinocytes present is dependent on the depth of the burn wound. In burn wounds that take more than 21 days to heal (deep and full thickness burn wounds), no keratinocytes are present, causing prolonged reepithelialization resulting in excessive scar formation.

Lastly, **extracellular matrix production and remodelling** play a role in the formation of a scar. Blood carries the cells required to produce new extracellular matrix. Blood supply for the healing of deep and full thickness wounds comes from the subcutaneous fat.

However, the fibroblasts originating in the fat tissue differ from those from the dermis, as they produce collagen that is much more firm and less susceptible to degradation than the collagen produced by fibroblasts from the dermis.

Scars have a tendency to contract. The deformity that remains after scar contraction around joint areas is often accompanied by a limited range of motion (ROM) and is defined as a 'contracture'. Although the exact mechanism of scar contracture development is unknown, it appears that excessive layering of collagen, together with an increased activity of the contracting myofibroblasts, both of which decrease the surface area, play a key role.



A child with burn wounds, partly re-epithalized and with excessive scarring, that need to be grafted

Definitions of scars

MATURE AND IMMATURE NORMOTROPHIC SCARS

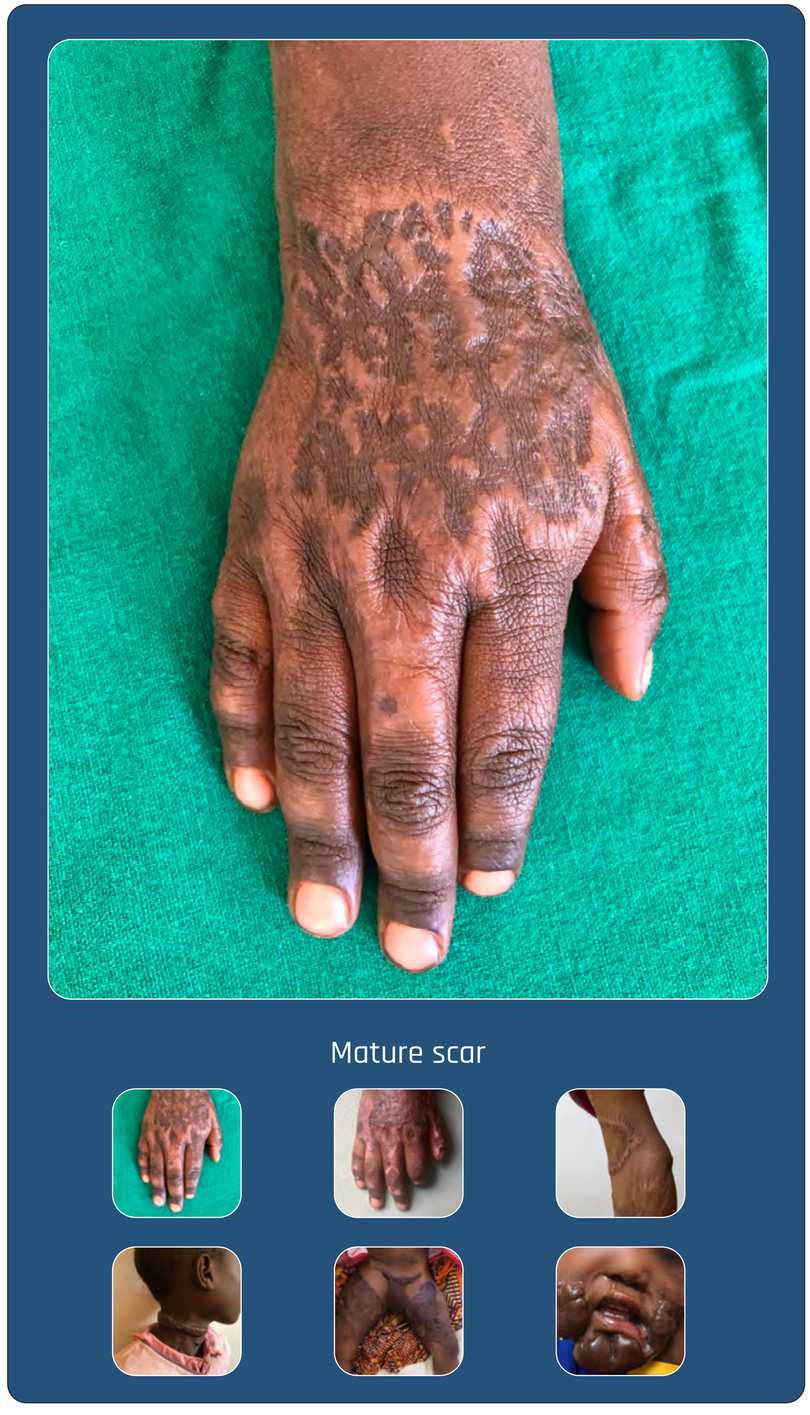
As soon as the wound has healed, the maturation phase starts. In the case of normal scar formation, first an immature scar is formed. Immature scars are red, and may be either flat or a little elevated, and can also be itchy. After several months to years, the pink colour will fade to a pale scar and a hypo-pigmented area remains with a slightly altered skin pattern, forming a mature scar. Complete recovery of the skin, sometimes to an (almost) normal appearance, may take years.

HYPERTROPHIC SCAR

Scar formation in hypertrophic scars is excessive, but does not extend beyond the borders of the original wound. It starts developing after wound healing and reaches a maximum around six months, then progression stops. The hypertrophic scar is heavily swollen, red, may show contraction, and has an irregular surface. These scars are characterized by itching and may also be painful. Regression of the scar is slow, and it may take years for the red colour and itching to diminish. The scar can remain irregular, widened and elevated.

KELOID

Keloid is excessive scar formation that extends beyond the borders of the original wound. It may start to develop shortly after wound healing, but can occur up to a year after. The major risk factors for keloid are ethnicity (people with dark skin tones and Asian populations) and age (20-30 years). Keloids most commonly occur in scars on the ear lobe, shoulders, and sternal notch. Simple surgical excision of a keloid is rarely recommended because it has high recurrence rates with new keloids that may become even worse. An optimal treatment has not yet been developed.



Mature scar

CONTRACTURES

Scars have the tendency to contract, especially when located around joints or other areas where the mobility of the skin is essential for the function of body parts (e.g. eye, mouth, genitals). The deformity that remains after scar contraction is often accompanied by a limited ROM and is defined as a 'contracture'. Although the exact mechanism of scar contracture development is unknown, it appears that excessive layering of collagen together with an increased activity of the contracting myofibroblasts, both of which decrease the surface area of the skin, play a key role. Scar contractures can cause considerable limitations to daily life and surgical treatment by 'contracture release' is often indicated to improve function and quality of life. Nonetheless, the most important measure to prevent scar contractures and to improve the long-term sequelae of burns is starting prompt treatment after the burn injury has occurred.

MARJOLIN'S ULCER

A Marjolin's ulcer is a cutaneous malignancy that arises from areas of longstanding scars and chronic wounds, for example at the site of an old burn scar. In most instances, biopsied lesions demonstrate well-differentiated squamous cell carcinomas (SCC) but can also be basal cell tumors or melanomas. Marjolin's ulcers are aggressive and have a poor prognosis with a high rate of recurrence but can be prevented by adequate (burn) wound treatment. Adequate treatment requires a multidisciplinary approach and we strongly advise to check the hospital protocol for the treatment of SCCs (e.g. additional investigations and therapeutic options) when suspicious of a Marjolin's ulcer or consult a specialist.

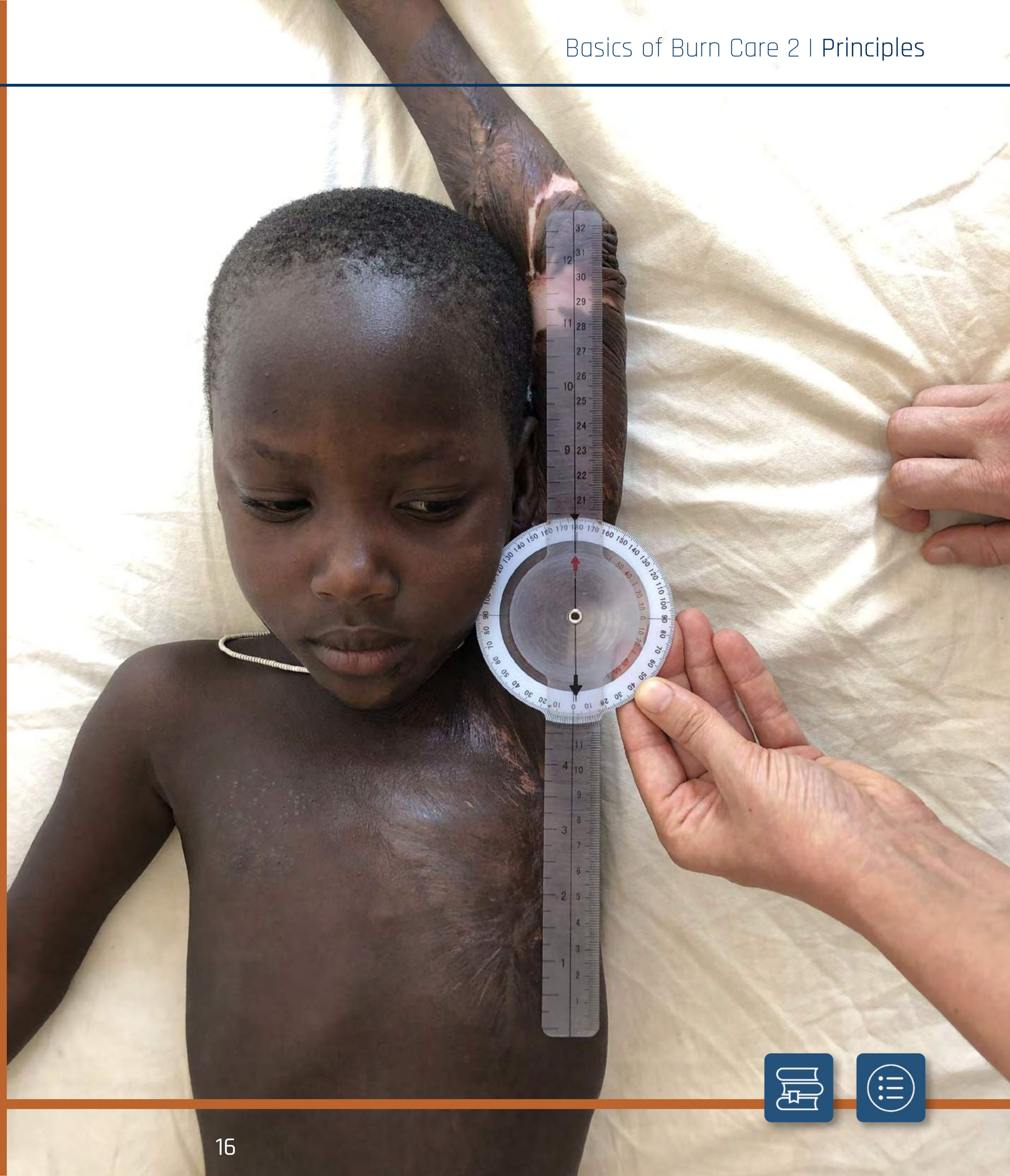
Contracture axilla Bangladesh

Problems related to scars from a patient's perspective

Problematic scars can influence a patient's quality of life in several domains, for example scars may lead to functional and/or cosmetic impairment. Patients may experience pain and irritation in the form of an itch, cosmetic problems such as colour changes and thickness, depression or irregularity of the scarred skin, and functional problems due to stiffness and contractures. Furthermore, recurrent wounds and ulcers can appear in unstable scars.
Chronic ulceration in a scar may be a sign of an aggressive malignancy (Marjolin's ulcer).
Scar assessment scales, including the patient's perspective, are helpful to evaluate the quality of a scar and identify problems related to scars in a systematic manner. More information on how to use these scales can be found in the section 'Scar assessment'.
Since the use of patient reported scar assessment scales, it became apparent that the presence of itching and pain is often more problematic for patients than the actual appearance, emphasizing the value of these scales.

Sc

Evaluation and management



Scar assessment

To be able to discuss the treatment options for different scars and scar related problems, it is important to be able to assess the characteristics and the severity and of a scar by using assessment tools. These can be either measurement devices or scar assessment scales. For daily clinical practice, scar assessment scales are preferred as they are easy to use and inexpensive (i.e. there is no need for training or expensive equipment). Various scar assessment scales are available, some report only the opinion of the clinician and others include the patient's perspective. Clinician reported scar assessment scales focus on items such as colour (white – pink/purple – red), thickness (flat – slightly raised – prominent), and consistency (soft – moderately hard – hard). A patient-reported scar assessment scale has the ability to also evaluate scar symptoms and quality of life, which is important for all scar treatment modalities, especially for surgery. For example, if the patient is satisfied with the scar, the opinion of the surgeon is less important and surgery may be avoided. An example of such a scale is the Patient and Observer Scar Assessment Scale (POSAS).

The POSAS is a frequently used scar assessment scale and measures scar quality by evaluating visual, tactile, and sensory characteristics of the scar from the perspective of the observer (i.e. clinician) and patient.

Scar assessment scales are also useful to evaluate the development of the scar over time and to determine the effect of therapy. Ensure to document the outcomes of scar assessment in the patient record.

In addition to scar assessment scales, measurement devices are available. Measurement devices are based on various biomechanical techniques with diverse degrees of complexity, for example colorimetry, ultrasound, laser, oxygen tension, and 3D imaging techniques. These techniques require expensive equipment and trained staff, and are of no advantage for the assessment of scars in the clinic, but can be useful for research purposes. In the clinic, scar assessment scales will suffice.

Scar management

PRINCIPLES OF SCAR MANAGEMENT

First of all, adequate burn wound treatment is essential to minimize problematic scarring. After the burn wound has healed and a scar is present, patients often experience scar-related problems. It is of utmost importance to first identify the scar-related problems before starting treatment; therefore, scar management always starts with proper scar assessment. For more information about scar assessment, see 'Scar assessment'. Once the scar-related problems are identified, a treatment plan can be made. Treatment may focus on symptoms requiring non-invasive treatment such as pain and itchiness, or on functional limitations such as limited range of motion (ROM) due to contractures, requiring surgical treatment.

PREVENTIVE MEASURES TO MINIMIZE PROBLEMATIC SCARRING

Adequate burn wound treatment during the wound healing phase is essential to minimize problematic scarring, including contracture formation. As described earlier in 'Pathophysiology of scars', inflammation, infection, prolonged reepithelialisation, extracellular matrix production, and remodelling may all influence scar formation. A number of preventive measures can be taken during the wound-healing phase:

- The use of adequate topical agents and wound dressings to establish a moist wound healing environment. This is especially important for superficial partial thickness burns.

- Adequate debridement of necrotic tissue, either by mechanical debridement or surgical debridement. This is especially important for deep dermal burns.

- Reducing the risk of infection by infection prevention and control, and daily dressing and cleaning of the wound.

- Preventing the formation of granulation tissue and performing adequate management in cases of hypergranulation.

- Timely wound closure; perform surgery (often excision and skin grafting) when indicated. This is especially important for deep dermal partial thickness burns and full thickness burns. The main factors influencing the timing of surgery are size and depth of the wound. Early excision, within a few days post-burn (up to a maximum of 10 days post-burn), is preferred over delayed excision for deep dermal burn wounds, whereas for deep partial thickness burns it is acceptable to wait two or three weeks until spontaneous healing has occurred.

Once the wound has healed and the maturation phase has begun, preventive measures include:

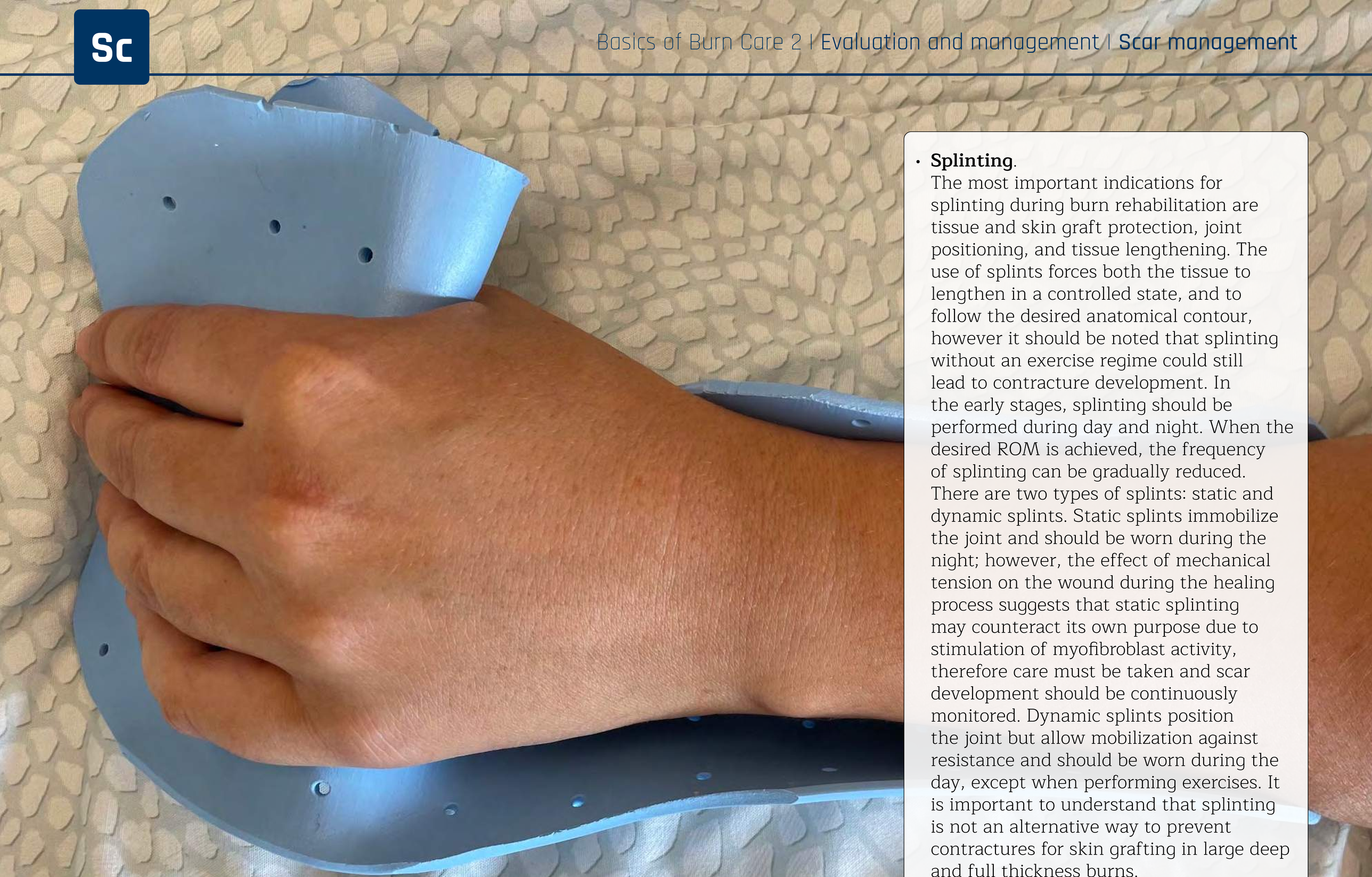
- **UV protection**.
  A scar in the maturation phase is prone to sunburn and high levels of UV radiation can increase the amount of dark pigment/melanin. Advise the patient to avoid sun exposure and to use sunscreen at regular time intervals, preferably SPF 50+, until the end of the maturation phase (1-2 years after the burn injury). When sunscreen is not available, for example in resource-limited settings, it is advised to instruct the patient to limit the exposure of burned areas to direct sunlight by the use of umbrellas, covering clothing, and caps.

- **Moisturizers**.
  Hydration of scars can be beneficial in scar management, especially to prevent or treat pruritus, but also to normalize scar size and reduce pain. Any kind of moisturizer can be beneficial (e.g. body lotion) and patients can choose whichever product they prefer, however the use of topical corticosteroids should be avoided.

Specific measures to prevent the development of contracture formation should be started as early as possible to minimize the development of contractures and to achieve optimal ROM. A physiotherapy rehabilitation program should be started, including the following key components:

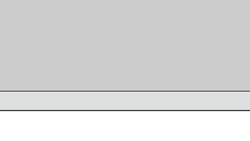
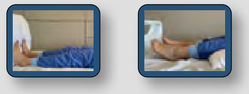
- **Stretching and mobilization**.
  To attain and maintain ROM and aid lengthening of the scar, stretching and mobilization should be started as early as possible. In particular, when delayed grafting is chosen, it is exceedingly important to start mobilization while waiting for grafting. There are three types of mobilization: active, active assisted, and passive. Active mobilization is performed by contraction of the antagonistic muscle group of the extremity and can be started as soon as the skin graft allows; usually a minimum of one week after surgery. Active assisted mobilization is performed by the affected extremity with the additional assistance of the other hand to maximize the ROM. Passive mobilization is performed when the patient is in a relaxed state and the physiotherapist moves the extremity.

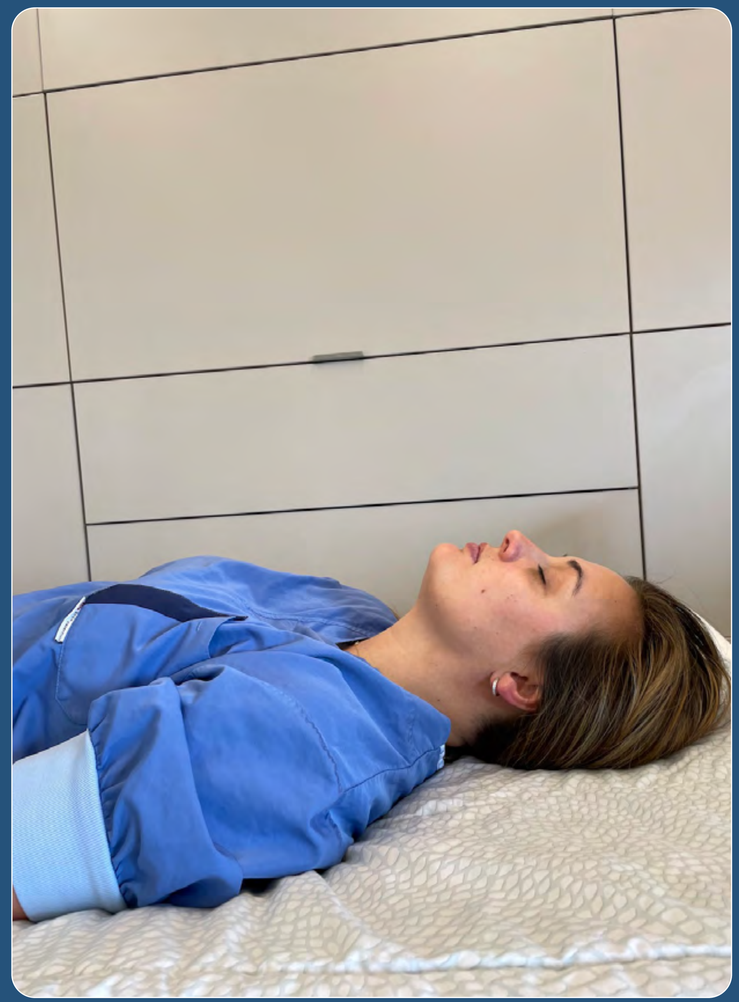
- **Anti-contracture positioning**.
  After a burn injury, the burned body part will move into the most comfortable position by following the path with the least resistance, usually a flexed position in the direction of the core, hence flexion contractures occur most often. Anti-contracture positioning counteracts this flexing tendency and should be started as early as possible in the rehabilitation program. Several common anti-contracture positions are described. This positioning of a joint could be achieved in an active way, requiring a highly motivated and consistently cooperative patient, or in a passive way with the use of splints. Note that the positioning regime must be followed during most of the day, except during exercise.



- **Splinting**.
  The most important indications for splinting during burn rehabilitation are tissue and skin graft protection, joint positioning, and tissue lengthening. The use of splints forces both the tissue to lengthen in a controlled state, and to follow the desired anatomical contour, however it should be noted that splinting without an exercise regime could still lead to contracture development. In the early stages, splinting should be performed during day and night. When the desired ROM is achieved, the frequency of splinting can be gradually reduced. There are two types of splints: static and dynamic splints. Static splints immobilize the joint and should be worn during the night; however, the effect of mechanical tension on the wound during the healing process suggests that static splinting may counteract its own purpose due to stimulation of myofibroblast activity, therefore care must be taken and scar development should be continuously monitored. Dynamic splints position the joint but allow mobilization against resistance and should be worn during the day, except when performing exercises. It is important to understand that splinting is not an alternative way to prevent contractures for skin grafting in large deep and full thickness burns.

TABLE ANTI-CONTRACTURE POSITIONING

Anatomical Location of Burn	Comfortable position following the path of least resistance	Anti-contracture position – positioning and splinting strategy	Images
Mouth	Microstomia	A mouth splint may be used, but is often not very comfortable for the patient.	
Neck – anterior	Flexion of the neck	Place the neck in extension. Do not place a pillow behind the neck. Ensure that the head is tilted back when in a seated position.	
Axilla	Adduction of the shoulder	Ensure that the arms are abducted by 90 degrees, both when in a lying as well as seated position. Achieve this with the support of pillows or foam blocks.	
Elbow	Flexion	Position the elbow in extension. A splint can be used.	
Wrist and hands: metacarpal-phalangeal joint (MCP), interphalangeal joint (IP)	MCP – hyperextension IP – flexion	Place the wrist in 30-40 degrees extension, the MCPs in 60-70 degrees flexion, the IP joints in extension, and the thumb in radial abduction. Instructions how to make a hand and wrist splint	
Groin/hip	Flexion and adduction	Make sure the legs are extended. Limit sitting and side lying. Do not place a pillow under the knees.	
Knee – posterior fold	Flexion	Place the knee in extension using an extension splint. Do not place a pillow under the knees.	
Feet: ankle, metatarsal-phalangeal joint (MTP)	Ankle – plantar flexion MTP – dorsiflexion	Position the foot in a neutral position with dorsiflexion of the ankle at 90 degrees, using a pillow or splint for support.	



Neck in right position

TREATMENT OF SCAR RELATED PROBLEMS

Scar therapy mainly focuses on relief of the inconveniences that the patient suffers from, though evidence regarding the effect of the different treatment options on scar maturation is limited. Time is the most important factor for the treatment of scar related problems, as over time most scar related problems will improve however this process may take years. It is of utmost importance to inform the patient about what to expect as this may affect whether the patient decides to accept or decline a proposed treatment.

Scar related problems from a patient's perspective and the related treatment options:

Itchiness and pain

- Skin care, including the advice to avoid heat if possible, apply cooling showers or baths, and the use of moisturizing ointments and/or cooling ointments.
- Physiotherapy and occupational therapy focusing on silicones combined with pressure therapy, splinting, and massage therapy

Altered thickness compared to healthy skin

- Physiotherapy and occupational therapy focusing on skin care, silicones combined with pressure therapy, splinting, and massage therapy.
- In cases of small and linear hypertrophic scars, surgical resection of the scar and primary closure can be performed. Ensure to wait until the scar has completely matured.

Skin irregularity

- Dermabrasion can be used to smoothen the irregular surface of the scar by controlled mechanical removal of the epidermis and partial-thickness dermis.

Color difference between healthy skin and scar

- Redness disappears over time when the maturation phase has completed. A dark color appears over time when exposed to direct sunlight. Skin care in the form of daily sun protection should be advised to reduce the progression of color changes.
- Laser therapy can be used to treat remaining redness or hyperpigmentation. Furthermore, dermabrasion might be an option.

Stiffness of the scar and related functional impairment

- Physiotherapy and occupational therapy focusing on stretching and mobilization, and anti-contracture positioning and splinting.
- In selected cases, fat grafting may be indicated.
- In cases of functional impairment as a result of a scar contracture, burn scar reconstruction may be indicated.

Scar related psychological problems

- Ensure psychological support when indicated for the patient and family.

Scar related problems from a clinician's perspective, diagnosis and treatment options:

Increased vascularization

- Diagnosis: Increased vascularization can be assessed by pressing a finger or Plexiglas on the scar, when the red/purple color will disappear. Increased vascularization is a sign of an active scar in the early maturation phase.

- Treatment: Over time, during the maturation phase, vascularization will disappear. No specific treatment options are available for the treatment of increased vascularization

Pigmentation disorders

- Hyperpigmentation (most visible in light skin types) and hypopigmentation (most visible in dark skin types)

- Diagnosis: After eliminating the influence of vascularization, the amount of pigmentation of the scar can be observed. Intralesional injections of corticosteroids, sometimes used for the treatment of hypertrophic scarring, are frequently the cause of pigmentation disorders.

- Treatment: Skin care in the form of daily sun protection helps to prevent hyperpigmentation. Where resources permit, laser therapy and dermabrasion may be used to treat hyperpigmentation disorders.

Altered thickness

- Hypertrophic scars and keloids

- Diagnosis: Hypertrophic scars are characterized by thick, raised skin that does not extend beyond the boundary of the original wound. Keloids grow past the boundaries of the original wound.

- Treatment of hypertrophic scars: Different treatment options for hypertrophic scars are available, including physiotherapy and occupational therapy focusing on skin care, and silicones combined with pressure therapy. Sometimes, intralesional injections of corticosteroids are used, however there is no protocol that specifies the appropriate concentration. In selected cases, dermabrasion and excision and primary closure may be indicated. When primary closure is not an option because of minimal tension margins, other surgical techniques may be used. Options for burn scar reconstruction are provided in Chapter 1.3 ‘Scar treatment’.

- Treatment of keloids: An optimal treatment for keloids does not exist. All general conservative measures apply including physiotherapy and occupational therapy focusing on skin care, and silicones combined with pressure therapy and splinting. If these are not successful after 4-6 weeks, intralesional injections with corticosteroids, 5-FU, bleomycin, or verapamil may be considered. If this is also unsuccessful after 12 months, surgical excision and closure (with or without local flaps), combined with iridium, intralesional injections of corticosteroids, localized radiotherapy, or intralesional cryotherapy may be considered.

Altered pliability: stiffness

- Diagnosis: Pliability or stiffness of the scar can be examined by pinching the scar. Altered pliability and related stiffness may be caused by contractions, also called burn scar contractures, and can lead to a reduced ROM over a functional area, such as a joint. Scars may also become adherent to underlying structures (e.g. tendons, bone, muscles) when the subcutical fat layer is damaged by very deep burns, and the resulting scar stiffness is observed.

- Treatment: Physiotherapy and occupational therapy focusing on stretching and mobilization, and anti-contracture positioning and splinting. In selected cases, fat grafting may be indicated for adherent scars. When stiffness results in reduced function, burn scar reconstruction may be indicated. For further information about surgical treatment, refer to Chapter 1.3 'Scar treatment'.

Reduced surface area

- Diagnosis: A reduced surface area may be the result of scar contraction, also called a scar contracture, resulting in limited ROM of a joint.

- Treatment: When ROM is limited and function is impaired, surgical treatment may be indicated. For further information refer to Chapter 1.3 'Scar treatment'.

All treatment options mentioned above are discussed in more detail in the following paragraphs.

Physiotherapy and occupational therapy
Physiotherapy and occupational therapy play an important role in the prevention and treatment of burn scars. Physiotherapists and occupational therapists are part of the multidisciplinary team involved in burn management and have many overlapping roles and skills. They are important in all phases after burn injury, until the maturation phase (commonly 12-18 months after the beginning of scar formation). During these phases, the emphasis of the activities of scar management may change. Specific aspects of scar management performed by the physiotherapist and occupational therapist include skin care, stretching and mobilization, anti-contracture positioning and splinting, compression, applying silicone products, and massage. All aspects are described in more detail below. Since physiotherapy and occupational therapy play such an important role in the prevention and treatment of burn scars, refer to the clinical guidelines of the ACI Statewide Burn Injury Service 'Burn Physiotherapy and Occupational Therapy Guidelines' for more in depth information.

Skin care
Skin care may include different aspects. After burn injury, thermoregulation of the skin may be impaired and the ultraviolet barrier and sebaceous gland functions may be damaged, therefore daily washing or showering of the skin is indicated. Furthermore, patients may experience pruritus and pain; any commercially available skin cream or lotion may diminish itching and relieve pain. It is a question of trial and error to find which cream gives the best results for the patient. If cooling of the skin is not possible, menthol cream (3 to 5%) offers the same result and creams with antihistaminic properties may be used to decrease itching; doxepin cream 5% has been demonstrated to be effective for this purpose. There is no role for corticosteroid creams or ointments in the treatment of burn scar related problems.

Stretching and mobilization, anti-contracture positioning and splinting
Stretching and mobilization exercises are essential in scar management to regain and attain ROM. Physiotherapists often guide these exercises and this is commonly required for 12-18 months post-burn, until the scar maturation phase has completed. Burned skin and active scars contract over hours rather than days or weeks, therefore, it is important to ensure adequate anti-

contracture positioning and splinting. For examples and more detailed information on stretching and mobilization, and anti-contracture positioning and splinting, refer to ‘Preventive measures to minimize problematic scarring’ earlier in this section.

Pressure therapy
Pressure therapy is indicated for pain, pruritus, and thick scars, all of which are symptoms of hypertrophic scars. Compression aims to flatten the scar and there are various ways to achieve this, but this is dependent on the available resources. Examples of ways to achieve compression include cohesive flexible bandages, elastic stockings, and customized or off the shelf pressure garments.

Silicone products
Silicone gel and silicone sheets are indicated for the treatment of pain, pruritus, and altered thickness related to hypertrophic scars. Silicones are available in sheet, liquid, and putty forms, and can be combined with pressure therapy and splinting.

Massage
Massage of a hypertrophic scar may be effective in reducing pruritus, pain, and stiffness. The aim of massage is to break up the collagen bundles that form during scar formation. Beware to instruct the patient on how to perform the massage specifically as incorrectly performed massage of an inactive scar can backfire and activate a scar.

Other treatment options
Other treatment options include intralesional corticosteroid injections, laser therapy, dermabrasion, fat grafting, and excision of hypertrophic scars. These treatment options require specific training and equipment and are mainly performed in specialized clinics, therefore detailed information is beyond the scope of this eBook.

SURGICAL TREATMENT
Burn scar reconstruction
Burn scar reconstruction In some cases, problematic scars may require surgical treatment. Read more about surgical treatment in Chapter 1.3 ’Scar treatment’.

1

Scar treatment

Introduction to burn scar reconstruction and contracture release surgery

Burn scars are infamous for their poor cosmetic appearance and contracture formation. It is the contracture formation specifically that often leads to functional impairment and thereby creates the need for surgical reconstruction. However, poor cosmesis and deformation anywhere, but especially of the face, can be a reason for social rejection and isolation. Therefore, cosmetic reconstruction can be of great importance to burn victims.

Contractures often cause reduced mobility and thus functional impairment. Most commonly, contractures involve one or more joints, but they can also form a constricting band around the circumference of an extremity, interfering with muscle function. If this is around the thorax or abdomen it can debilitate respiratory function, or interfere with normal urogenital function if in the genital area.

The main principle in reconstructive surgery is the restoration of function, with the ideal reconstruction restoring both form and function. It is obvious that reconstruction for functional movement of the extremities is different from reconstruction of burn scars and defects of the face, however the same principles apply, and functional improvement often also means aesthetic improvement.

It is beyond the scope of this eBook to deal with all the possibilities for aesthetic improvement of facial burns, but it is a common misconception that anything is possible in plastic surgery, and burn victims will often bear visible scars due to their trauma. Other features of burn scars such as discoloration and itching can be debilitating and therefore cause functional impairment. These are dealt with in the chapter ‘Scar management’.

In this chapter the focus will be on the treatment of functional impairment caused by burn scar contractures.

Contracture lower extremity

General priniciples of burn scar contracture treatment

Contractures can be caused by deformities of bone, ligaments, tendons, muscle, and skin. Often, burns and burn contractures are limited to the skin and subcutaneous tissue, and in these cases all the underlying tissues and structures are normal and functional; however, this cannot be taken for granted and should be evaluated carefully before attempting reconstructive surgery. Fibrosis of deeper layers or loss of functional tissue (nerves, tendons, arteries, veins, ligaments, and cartilage) can seriously impair the outcome of reconstructive surgery and should be taken into consideration.

After prolonged exposure (loss of consciousness, epilepsy), burns can be particularly deep and may involve deeper functional structures. Contractures may also result from causes other than burns, such as fractures, penetrating high-pressure trauma (for example hydraulic oil), cytotoxic snakebites, and local necrosis due to other factors (Volkmann's contracture).

Careful examination of the affected area can provide a lot of information, for example, if the joint is easily mobile within the limits of the contracture, it is less likely that the deeper structures are affected. If the joint is completely immobile, but the skin over it can be moved up and down, the contracture may reach the deeper structures and release of a skin contracture will not result in adequate functional improvement.

If the muscles feel supple and normal upon palpation, good results may be achieved, however, if the muscle feels hard and fibrotic, the functional gain of skin release surgery is likely to be limited. In most burn contractures, the functional restriction lies in the skin, therefore surgical treatment often means releasing the skin contracture and closing the created skin defect with a flap or a graft. In general, surgery for contractures is only successful if the correct aftercare, such as splinting and physiotherapy, can be provided. Setting up a service for treatment of burn contractures should always have a multidisciplinary approach. Muscles and ligaments will shorten over time if their movement is restricted by a contracture of the skin, even when they are not primarily affected by the burn. These structures need to be gently stretched, trained, and sometimes even splinted over a long period of time to regain adequate function. The longer a contracture has been present, the more difficult it will be to restore full range of motion (ROM) and the more important the aftercare becomes.

Contracture upper extremity preoperative

Different types of contractures

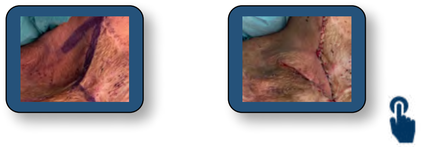
It is important to address different characteristics of a contracture, like size, depth, location, shape and quality of surrounding skin before selecting an adequate treatment option.

Based on specific characteristics experts have proposed classifications for post burn scar contractures. In our experience, these classifications are useful for understanding contracture release surgery, however every contracture has its own characteristics. Describing different classifications for specific joints and developing this into flowcharts is an oversimplification of the reality.

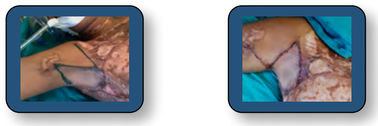
The classification of Ogawa (Br. J. Plast. Surg. 2003) for axillary scar contractures gives an idea of such a system. This classification system was used and modified by Botman and Hendriks (Plast. Reconstr. Surg. Glob. Open 2020).

Later in this chapter, we will refer to some of the characteristics and how they may help to make choices for the burn scar reconstruction.

Type I
Small and thin burn contractures
(a superficial or small part of the joint is affected)

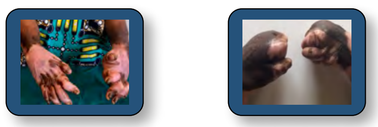


Type II
Linear band burn scar contracture (creating a fold with two healthy sides)



Type III
Linear band burn scar contracture with diffuse scarring of the surrounding skin (often one side is more affected than the other side)

Type IV
Broad band burn scar contracture



Type I contracture in the neck treated with a interposition flap - before surgery

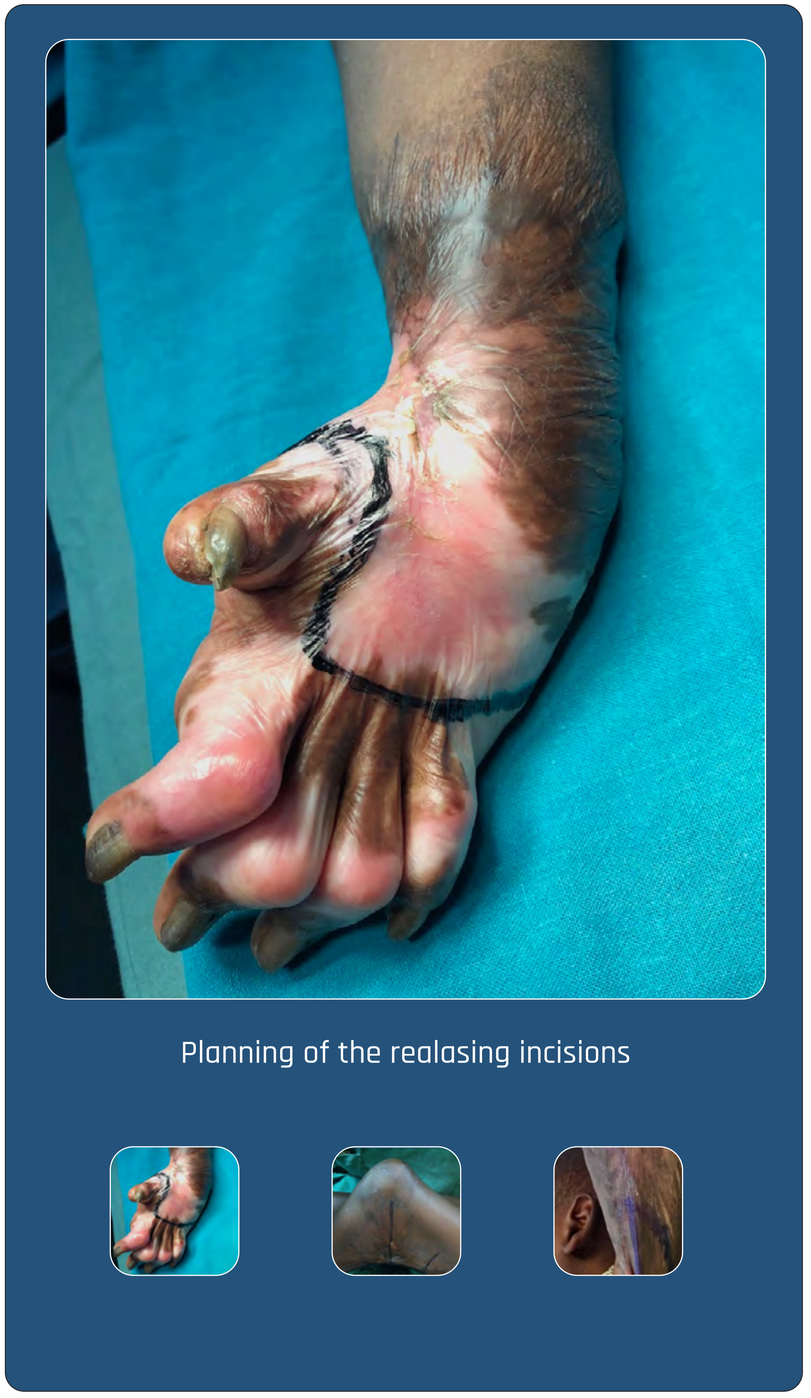
Surgical burn contracture release

The importance of planning of the release incision an reconstruction of the defect
Scars can contract to varying degrees, from a narrow single line to a large 3 dimensional area. Different scars necessitate a different approach and this is where knowledge and experience can make a huge difference. In general, the most effective scar release is obtained with an incision perpendicular to the contracture formed by that scar.

In joint contractures, the release incision should be made perpendicular to the direction of the restricted movement of the affected joint, and in line with the axis of that joint. This means, the release incision 'points' at the pivot of the joint. At the time of planning the release incision, it is mandatory to also have planned the reconstruction technique for the defect (examples at the pictures on the right side).

In practice, the release incision 'points' at the pivot point of the joint. However, this does not mean that the release incision has to be made from one side to the other in the flexor crease of this joint as this will interfere with the local flaps. Therefore, this approach is only used when it is clear from the outset that local flaps are not feasible and that a skin graft will be used. When local flaps are used, they need to be designed carefully to achieve the best effect. One thing to be avoided at all costs is the designing of local flaps that subsequently fail to form skin bridges across the defect, resulting in a larger defect with frayed, undermined edges. To avoid this, flaps should be carefully planned and measured.

Detailed information about local flaps is provided in the following Section 'Techniques for reconstruction of the defect'.



Planning of the realasing incisions

Techniques for reconstruction of the defect

After the contracture is released, the defect should be closed. Different options are available according to the 'reconstructive ladder' which can be used as a stepwise approach for tissue reconstruction. The 'reconstructive ladder' implies that it is best to use the easiest and safest method that will achieve an adequate result. For example, not using a microvascular free flap if an equally good result can be obtained with a local flap. There are no 'hard' rules in this; the 'reconstructive ladder' is just a way of considering your options carefully.

The easiest first step on the reconstructive ladder, is the option of doing nothing (i.e. to not perform a reconstruction of the defect), meaning the wound will heal by secondary intention. Often, this is not the best option but it always is an option. An example of a situation where this option is sometimes chosen is the contracture of the mucosa inside the mouth. Due to the fast re-epithelialization in this area, healing by secondary intention of the defect can be preferable to grafting, especially when local flaps are not possible. The first step on the reconstructive ladder above doing nothing is primary closure, followed by skin grafting, local flaps, regional flaps, distant flaps, and at the end of the ladder more complex and difficult procedures, such as microvascular free flaps or microvascular allotransplants. In this chapter we will discuss some considerations regarding flap choice. Instead of the reconstructive ladder, some surgeons prefer to call it a reconstructive elevator because it shows that you have the option to skip levels and go immediately to the level of the required technique. We also like the modern idea of the reconstructive supermarket: the doctor and the patient shop around to select one or more adequate treatment modalities for the medical condition of this patient. It's important to realize that apart from patient factors, also the skills and experiences of the doctor and setting in which she/he works influence the choice made.

Reconstructive ladder

Doing nothing (healing by secondary intention)

Primary closure

Skin grafting

Local flaps

Regional flaps

Free flaps

The first step on the ladder, **primary closure**, is rarely an option in contracture release surgery because there is often a shortage of skin that needs to be addressed.

The second step on the ladder is **skin grafting**, which is often needed for broad band contractures (type IV). The broad scarring, caused by an extensive burn wound, limits the availability of nearby normal tissue for local flaps. Considerations for the usage of skin grafts in reconstructive surgery include: shrinkage of the graft (and therefore recurrence of the contracture), infection, and loss of the graft. Furthermore, the availability of required equipment should also be considered, including dressings; means of fixation in difficult areas (groin, axilla); color match; and expected functional and aesthetic outcome. Full thickness grafts (FTG) are likely to have less shrinkage and provide better skin quality than split skin grafts (SSG), but are limited in their size and availability. The addition of a dermal matrix can improve the quality of a SSG, but dermal substitutes are very expensive and not available in many countries.
For further information and a 'How to perform' see 'Basics of Burn Care 1: Acute Burn injuries, Harvesting Full Thickness Graft (FTG)'.

Local flaps Local flaps are considered to be more complex and difficult than skin grafts, but in scar contracture treatment local flaps are preferable to skin grafts. When the indication and execution of local flaps are right, they provide superior results to skin grafting. Local flaps use local skin and the underlying subcutaneous fat, including its blood supply, to close a defect. This leads to better quality of tissue if well performed. However, it also means that sufficient skin must be available and also has to be able to reach the defect, while preserving the blood supply of the flap. The design of local flaps is based on judgment of the quality of the local tissues - skin availability, quality, laxity, and blood supply are all important factors in these considerations.

In general, the rule is that the tissue added to the length will be removed from the width. In the extremities, width means circumference. Local flaps are often a good option in type I, II and III contractures. When designing local flaps, it is very important to take the 3-dimensional configuration of the affected area into consideration. In textbooks, flaps are often explained by 2-dimensional drawings, making it difficult to understand the importance of the third dimension in a clinical case. As described earlier, in burn contractures the scar has often ‘moved away’ from the axis of the joint, thereby causing the contracture. The elbow is a perfect example that demonstrates this principle.

In contracture release surgery for type IV contractures, local flaps alone are usually not enough and additional skin grafts are needed. Sometimes skin grafting is the only option but often a combination of skin grafts and local flaps is possible. In this case there are generally two options. The first (and preferred) option is to use one or more local flaps to form a bridge of comparatively good skin over the most important part the joint, the joint crease, and graft the areas proximal and distal to this bridge. The second option is to graft the central portion (the area around the flexor crease) and create smaller flaps proximally and distally. An example of the second option is a symmetrical Z-plasty that does not provide enough length alone. In cases with a well vascularized wound bed, a skin graft can be added in the middle.

Axillary contracture

Finger contracture – Z-plasty and FTG preoperative

Regional flaps are considered the next step on the reconstructive ladder and originate from a nearby area, mostly unaffected by the burn. In general, they are raised from their origin and stay attached via only their vascular pedicle, thus enabling a great freedom of movement around this vascular pedicle.

These flaps can be muscle only, musculocutaneous, or fasciocutaneous. Examples of muscle flaps are the latissimus dorsi flap, the pectoralis major flap, and the gastrocnemius muscle flap. These muscle flaps can be used for contracture release, but will have to be covered with a skin graft.

Therefore, the use of muscle flaps should be limited to situations where the use of only a skin graft is impossible or undesirable, for instance when tendons, nerves and blood vessels are exposed.

Some muscles, such as the latissimus dorsi and the pectoralis major, can be used as musculocutaneous flaps, where the overlying skin is transposed with the muscle. This provides excellent skin quality, but the additional bulk can be an unwanted side effect. Mostly, the donor sites can be closed primarily. An example of a commonly used fasciocutaneous flap is the proximally or distally based radial artery flap, frequently used for soft tissue reconstruction of the elbow or the hand respectively. In the last decades, perforator flaps have become more and more important and their use has significantly increased. These are locoregional flaps based on a small vascular pedicle, allowing translation and/or rotation. Distant flaps are pedicled flaps from another body part, and the best known and most commonly used distant flap is the groin flap, frequently used for deep defects in the hand. The cross-leg flap is another example that is used less often these days. More detailed information on regional and distant flaps is mainly beyond the scope of this eBook, but some examples are given throughout the next chapter.

Tissue expansion is achieved by implanting an inflatable silicone prosthesis under a healthy area of skin and subcutaneous tissue. By inflating this prosthesis, the overlying tissue is stretched, but also growth induced. After repetitive inflation to the desired size, a 2-3 month period of consolidation is allowed so that a substantial increase in skin surface area occurs in the desired region . After removal of the tissue expander, this tissue can be used as a local, locoregional or regional transposition flap to cover an adjacent defect. This method is a way of enlarging flaps before using them and defects on the scalp are frequently treated in this way. Tissue expanders are foreign bodies and therefore have a considerable risk of infection, and are also expensive and not readily available in many countries. The use of this method is beyond the scope of this eBook and further details will not be provided.

Microvascular tissue transfer has become an important part of reconstructive surgery in the past 50 years, however requires a lot of technical equipment and facilities. This eBook focuses on the treatment of burns and burn contractures in resource-limited settings, where these facilities are generally not available. Even in high resource settings, this technique is often not required in contracture release surgery. Therefore, in this eBook mostly regional free flaps will be recommended as an excellent way to move healthy tissue to a debilitated area.

Tips and tricks for specific areas

This chapter provides information in relation to the information in Section 1.4, ‘How to perform’, but does not follow the step-by-step format. Contractures from burn injuries are seen all over the human body, but some areas often present in a similar way. This enables us to provide useful tips and tricks from past experience.

Burn contractures and/or defects in the face and on the scalp can not only create functional impairment, but also cause social problems or even isolation due to cosmetic disfiguration. Functional problems are often seen around the eyes, from loss or retraction of the eyelids, causing lagophthalmos, ectropion, or inadequate eye opening. Reconstructive surgery of the eyelid can be quite complex and should not be performed without proper training; however, contracture release and full thickness grafting are relatively simple procedures that can be of great help in these contractures. Even relatively small grafts can make a big difference in eyelid function.

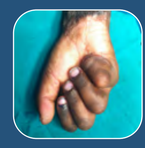
Contractures around the mouth can cause problems in lip function and thereby inadequate closure of the mouth. This can lead to impairment of speech, mastication, and swallowing. Z-plasties can be very useful in this region, but sometimes grafts are needed, in which case FTGs are preferred in this region. Donor sites can be found around the ear or supraclavicular region, providing the best match in color and texture.

Defects on the scalp can lead to necrosis of the exposed bone of the skull, especially if there is no remaining vital galea or periosteum. In these cases, skin grafting has little chance of success as there is no vital wound bed for the graft. Large rotation flaps of the scalp can be used to close these defects. Often the donor site can be closed primarily, but if this is not possible, a skin graft can be used on the vital periosteum, with good chance of success. Another way of creating a vital wound bed for a skin graft is to chisel away the outer table of the skull. The cancellous bone then can be skin grafted.

SHOW HOTSPOTS

Flexion contractures of the hand are common in young children that burn their palmar hands and fingers. The result is a mitten like appearance of the hand, with the fingers contracted into the palm of the hand.

Mitten like appearance of the hand



The neck can be a site of functionally debilitating contractures. For smaller burns, local flaps can be used, but for the larger burn contractures such as the well-known ‘chin on chest’ contracture, large flaps or grafts are needed. Skin grafts can be useful in this area but are likely to still lead to recurrence, therefore regional flaps are often the best solution. The pectoralis major flap, the latissimus dorsi flap, the Epaulet flap, and the deltopectoral flap are useful flaps in this region. Dissection of these flaps is beyond the scope of this eBook, but even without these flaps, adequate results can be obtained with (full thickness) skin grafts.

In most cases, a complete functional range of motion can be obtained after contracture release. Sometimes, local flaps can be used to cover parts of the created skin defect, but in almost all cases skin grafts will be needed. It is advisable to use full thickness skin grafts as they provide a better skin quality on the palmar surface of the hands and fingers. Sufficient skin for a graft can easily be obtained from the groin.
The graft should not be taken too small; you are likely to need more than you think. The skin from the groin is of good quality, and is thin enough to be pliable and have a good take. The scar will be hidden under the

When contractures of the fingers are released, it is of utmost importance to fix the fingers in extension, as body has the tendency to pull the fingers into a flexed position again. This will hamper the take of the grafts and facilitate recurrence of the contracture.

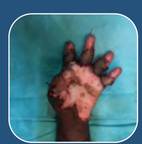
We strongly advise axial K-wires through all affected joints in order to provide a stable fixation; often 1.0- or 1.2-mm wires are strong enough and the wires can be left sticking out of the fingertips for easy removal. It can be helpful to bend the K-wires at the tip to prevent them from getting lost inside the body and they usually stay in place for three to four weeks, until the full thickness grafts have healed completely.

If a pin tract infection occurs, the K-wires need to be removed earlier. After removal, exercises should be performed several times a day and splinting in extension is recommended during the night. This should be done for an extended period of time, sometimes up to one year.

The ideal removable splint is made from plastic and has Velcro straps for fixation.

These will not be available in many places, but a thick splint, made of Plaster of Paris and fixed with an elastic bandage will also be sufficient and will last for months, provided it is made thick enough.

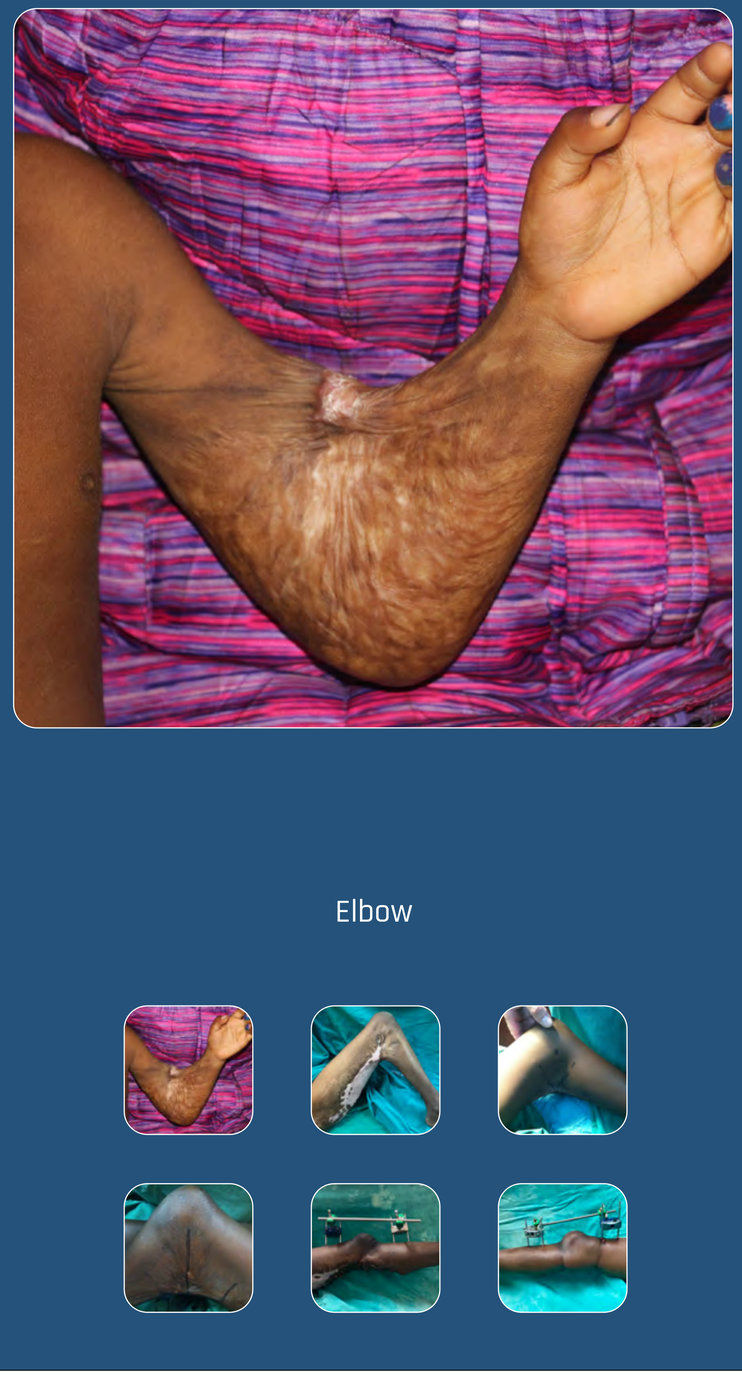
Example of a contracture that needs k-wires for the fingers



Contractures of elbows and knees often are very similar; they have a scarred area on one side (lateral or medial) and the other side is unaffected (type III contracture). When the scar pulls up and away from the pivot point, it forms a fold in line with the axis of the extremity, thereby stretching the good skin on the unaffected side and enlarging the surface area. This means that on one side of the contracture, there is an area of good skin and on the other side there is contracted damaged skin; together they form the fold.

The good skin is ideally situated for a local flap, for example a 5-flap plasty, also known as a jumping man. This technique is described in Section 2.1.4.3 'How to perform - Combined flaps'. In these cases, the flaps are made of good skin and inserted into the release incisions made in the contracted skin. This works best if the two sides of the fold are close together. Due to the typical configuration of these contractures, they can often be released with local flaps only, without the need for grafts; however, should grafts be needed, do not hesitate to use them.

The hip/groin and shoulder/axilla regions are complex in their anatomy and functional mobility. Correct assessment of the contracture and the amount of release needed is crucial, as defects can be substantial and should not be underestimated. In these regions, large flaps are often needed. The thoracic wall can provide a large flap that can be inserted into the contracture after release. This can be achieved using a banner flap, or an asymmetrical Z-plasty (also called an interposition flap). This technique is described in Section 2.1.4.3 'How to perform - Archetypal Z-plasty'. Often the burn scar, and therefore the contracture, is either on the dorsal or ventral side, but rarely on both. The banner flap should be taken from the unaffected side to ensure good skin quality. The donor defect can be closed primarily, but if a skin graft is needed a SSG will normally be sufficient, and should not cause problems or risk recurrence if the design is well chosen. In the groin area, the banner flap can be raised from the inner aspect of the thigh or can be taken from the infragluteal region. Interposition flaps can be designed around a vascular pedicle that perforates the fascia and used as perforator-based flaps, which can be islanded and rotated around their vascular pedicles. The dissection of perforator flaps is beyond the scope of this eBook.



Elbow

Specific techniques to manage contractures

How to perform:

4.1. An archetypal Z-plasty >

4.2. Interposition flaps >

4.3. Combined flaps >

Photo by J. van Kesteren

How to perform - Archetypal Z-plasty

General principles
The Z-plasty is an example of a local flap where a Z-shaped incision creates two convergent, triangular-shaped transposition flaps, which subsequently swap positions. This exchange recruits adjacent tissue, increasing the length of tissue in the direction of the contracture. The angles and limb lengths of the Z-plasty determine its result and can be tailored to its intended effect, therefore the Z-plasty is a very versatile concept. The archetypal symmetrical Z-plasty is shown in Figure 1.

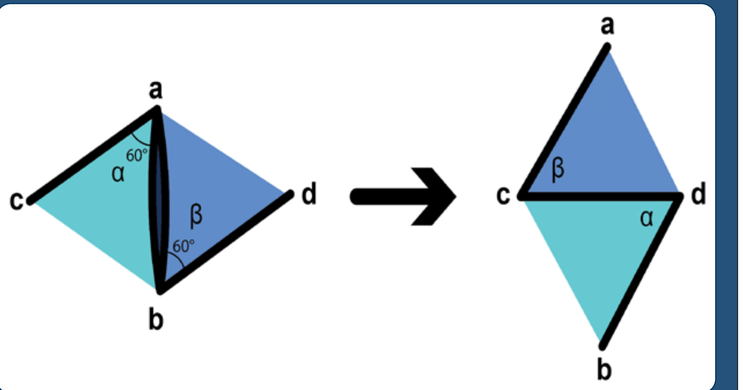


Figure 1 - The archetypal Z-plasty

By using a Z-plasty, misaligned tissues can be repositioned, tension can be redistributed, and scars can be lengthened. Z-plasties are often used for burn contractures on all mobile parts of the body (the neck, axilla, elbow crease, hands, groin, knees, ankles etc.).

As already discussed in the chapter 'Surgical burn contracture release', scar contractures can vary from a single strand to a large three-dimensional area. This variation calls for different approaches. Symmetrical Z-plasties in burn contracture treatment are often very effective for single strand contractures.

Considerations

- Tissue slack (Figure 2) is an important concept and should always be assessed when designing a Z-plasty, as it determines the maximum angle and length of the Z-plasty limbs.

- The larger the angle and the longer the limbs, the greater the lengthening, but more dissection is required and more slack has to be available.

- In a classical linear band contracture with an equal amount of non-affected skin on both sides, a symmetrical Z-plasty with angles between 50° and 70° provides the best results.

- Geometrically, a 60° Z-plasty provides a length increase of approximately 75% of the central limb, though this increase in length is only possible if there is sufficient tissue slack available in the direction perpendicular to the contracture. This means that the sides of the triangles should not be designed longer than the amount of this tissue slack + 33% of the slack. For example, 3cm slack in the direction perpendicular to the central limb is required to be able to design a 60° Z-plasty with limbs of 4cm.

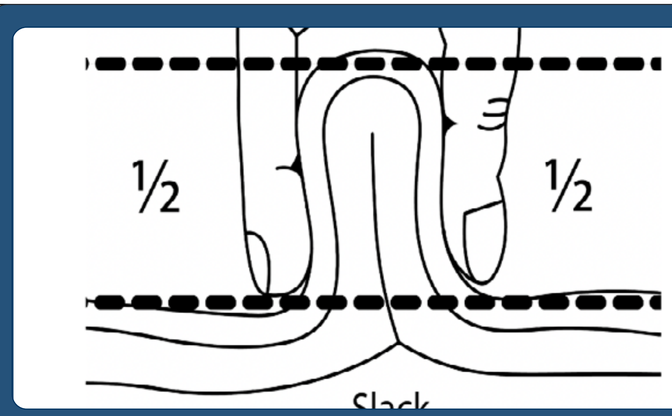


Figure 2 - A pinch grip used to determine the slack

- It has been shown that in practice, the real length gained by a Z-plasty is often less than its theoretical gain as indicated by geometry. The elasticity of the skin plays an important role here: the better the elasticity of the adjacent skin, the greater the amount of length gained. Besides the direct lengthening effect, even more lengthening may be gained over time, for up to 1-2 years after the procedure. In cases where there is little tissue slack and a relatively long contracture, multiple Z-plasties are indicated.

- Experimental data also shows that in contrast to what is indicated by geometry, a singular large Z-plasty often provides a greater increase in length than multiple, smaller Z-plasties of the same total length. This means that when there is adequate slack, one larger plasty is better.

- Angles less than 30° will compromise vascularity of the flap tips and should therefore be avoided.

- Angles greater than 75° will commonly create standing cutaneous deformities (dog ears) that require excision in a later stage. This is because the tetrahedral effect of the Z-plasty becomes more evident with increasing angles.

The three-dimensional characteristics of a Z-plasty

The tetrahedral effect of a Z-plasty refers to the natural tendency of a Z-plasty to provide depth in addition to length (Figure 3). A tetrahedron, also known as a triangular pyramid, is a shape characterized by four triangular surfaces, four corners, and six edges. The tetrahedral effect is most evident when conducting a Z-plasty on non-elastic materials such as neoprene or paper. When conducting a Z-plasty on an elastic cutaneous surface, this depth is witnessed less clearly because the skin stretches and shapes itself to follow the body contours. However, in specific areas such as an axillary or interdigital fold, the tetrahedral effect can be put to use by adding depth to the flexor crease over the affected joint when performing a release of a burn contracture. Due to the nature of the Z-plasty being a three-dimensional configuration (the tetrahedral effect), closing a Z-plasty in a flat, two-dimensional configuration gives rise to dog ear deformities (a characteristic bunching of excess tissue above the surface of the skin at the end of a scar after wound closure), because the tissue does not fit into a two-dimensional plane.

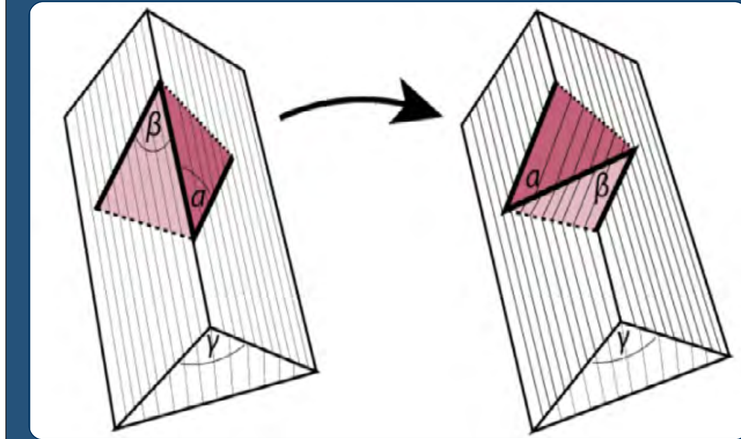


Figure 3 - Three-dimensional aspects of the z-plasty

PROCEDURE

Preparations

Surgical instruments

- Surgical pen.

- Ruler (to measure the slack and the length of the limbs of the Z-plasty to make sure they are the same length). A protractor can be useful but most surgeons can estimate the angles adequately by eye.

- Scalpel (usually with a #10 or #15 blade, depending on the size of the Z-plasty).

- Dissecting forceps (such as Adson or other fine tissue forceps).

- Hand held retractors (such as small single toothed skin hooks for small Z-plasties, or Senn retractors for larger Z-plasties)

- Scissors (such as Metzenbaum or Iris).

- Mono- or bi-polar electrocautery, when available.

- Needle holders.

Sutures
Usually a non-absorbable, monofilament suture will suffice, though larger Z-plasties under a lot of tension may sometimes require an absorbable suture in the dermal plane.

Markings of flap design
- Before marking the flap, it is essential to determine the line of maximum tension (the direction of the contracture). This can be done by extending the affected joint or body part. Then, the direction and amount of slack should be determined using the pinch test.

- After the assessment of the affected area, the surgeon can mark the design of the Z-plasty. The archetypal Z-plasty consists of a central limb (typically in line with the scar)(A-B) and two peripheral limbs of equal size at an angle of 60° (A-C and B-D (see Figure 1)

Anesthesia
- Depending on the localization of the contracture, the estimated size and extent of the surgery, and patient characteristics, a Z-plasty can be performed under local, regional, or general anesthesia. For example, a small Z-plasty to release a webspace contracture in an adult can be performed under WALANT (Wide Awake Local Anesthesia No Tourniquet), whilst multiple Z-plasties on a major burn contracture in a child should be performed under general anesthesia.
- When using local anesthetic, it is recommended to anesthetize first, and then to disinfect and drape. This ensures that the anesthetic has sufficient time to work properly.
- Even when the procedure is performed under general or regional anesthesia, it is advised to infiltrate the operative site with local anesthetic and adrenaline/epinephrine. This will greatly reduce the bleeding during the operation, make the dissection easier, and provide postoperative pain relief. Allow 30 minutes for the adrenaline/epinephrine to have the optimal effect and use a long-lasting local anesthetic agent for optimal postoperative pain relief.

Positioning
The positioning of the patient is depending on the localization of the burn contracture.

Sterilization and dressings
Make sure that the entire site is dis-infected and that the sterile drapes do not restrict movement, so that the affected body part can move freely during the procedure. This can help improve exposure and allows immediate assessment of the effect of the contracture release.

A contracture of the axilla seen from different angles

Surgery

1. Start with the central limb incision (the incision in the direction of the contracture). 1

2. Then make the incision that will give the maximal release (one of the peripheral limbs) through all the fibrotic tissue, into the subcutaneous fat down to the level of the fascia, and elevate the triangular flap between the two incisions. The depth of the dissection can be within the subcutis, or in a suprafascial plane. A subfascial plane is often not recommended because it limits the mobility and elasticity of the flap. Maintaining adequate blood supply to the flap while achieving the required mobility are also factors that need to be taken into account.

3. The flap can now be transposed and the adequacy of the rest of the design determined. If the design is still adequate, continue with the next incision, if not, adjust the design. 2

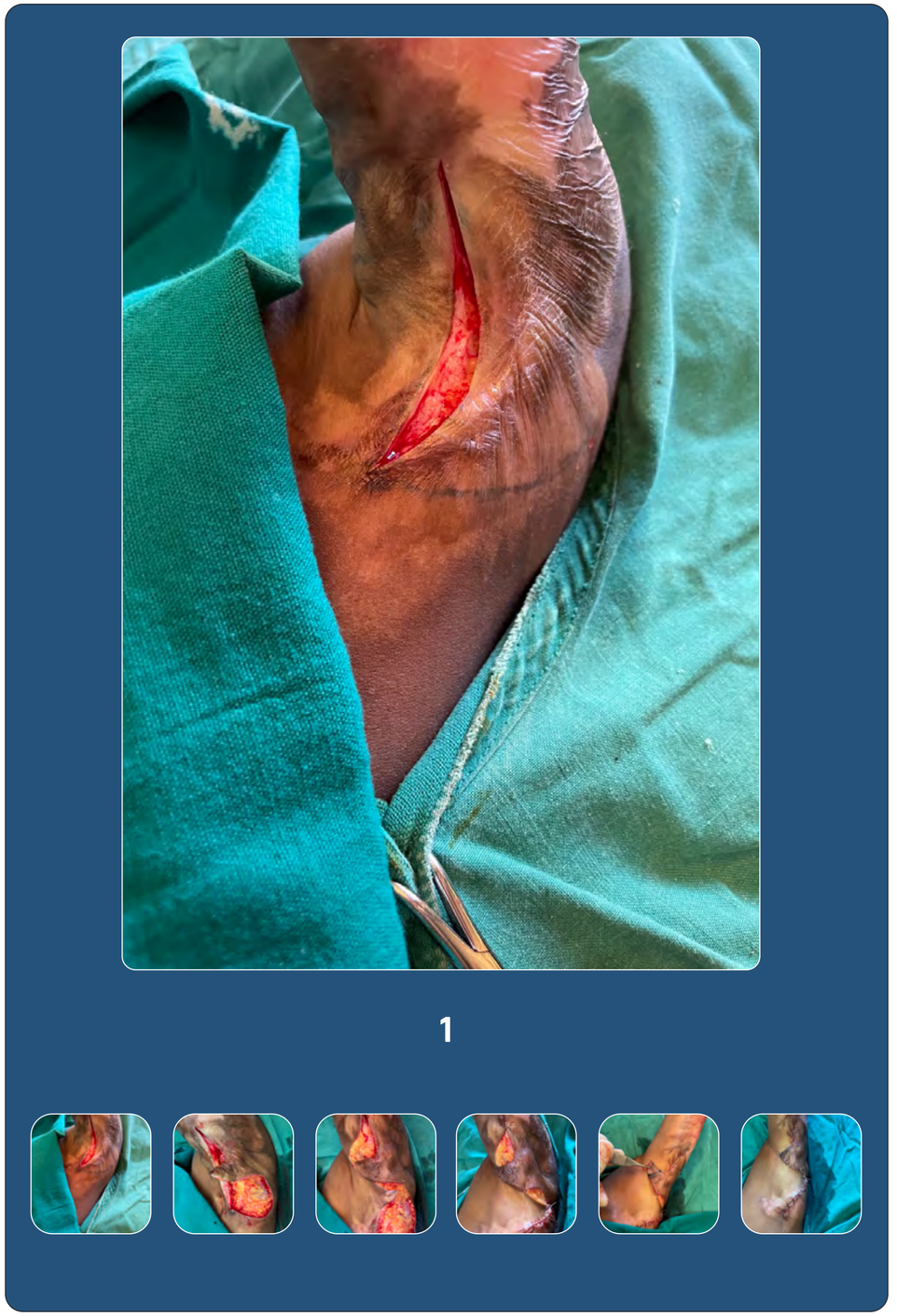
4. Once all incisions have been made, dissect the second triangular flap so that the transposition of the flaps can be done easily. In a well-designed Z-plasty the flaps will almost fall into place by themselves. Make sure that the flaps are the same thickness all over, or become thicker at the base. 3

5. Check for active bleeding and coagulate if necessary. Be cautious when coagulating on the skin flaps as this could damage the vascularization.

6. Suture the flaps. It is recommended to start by putting the tips of the triangular flaps in their new position. If the flaps include a thick layer of subcutis, subcutaneous sutures can be used to minimize tension on the skin. Continue to suture one limb of the Z-plasty. Cutting a small piece of (one) of the flaps is often required to ensure that the size of flap matches the size of the defect. 4

7. Monofilament sutures are advised to close the skin. In small children or difficult anatomical locations, absorbable sutures can be convenient and avoid the need for removal. 5 6

8. Depending on the size and location, a small drain can be placed.



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Dressing and fixation
In most cases, a simple dressing with dry gauzes can be applied as a first layer. If the flaps have the tendency to move away from the underlying tissue layer (this is called 'tenting'), an elastic bandage or even a tie-over dressing can be applied. Joints that have been affected by a contracture have the tendency to return to their contracted position and this must be avoided. Therefore, fixation of the affected joint in a position opposing the contracture is advised until the wounds have healed. A Plaster of Paris slab splint is an adequate way to achieve this, and K-wires are a very useful alternative in the hands, fingers, and toes, where plaster may be less effective, especially in young children.

Postoperative care
After surgery, it is recommended that the dressing is changed after 3-5 days, or earlier if there is a risk of infection. Sutures should be removed after 2-3 weeks if they are non-absorbable.

If K-wires are used, it is recommended that they are removed after 3-4 weeks due to the risk of infection. Splinting can be continued for a longer period, until there is no further risk of recurrence. If the affected joint is not fixed for long enough in the position opposing the contracture, there is a high risk of recurrence of the contracture.

Physiotherapy
Active movement and exercises to maintain the gained range of motion (ROM) should be started as soon as wound healing permits. The availability of physical therapy makes a big difference. If physical therapy is not available, the importance of exercises should be emphasized to the patient and adequate instructions need to be provided. Splinting can be continued between exercises and during the night. Splinting during the night is sometimes continued for months, even after full healing of the wounds and return to normal use of the affected limb. Splinting works well when the skin quality is good, but is less effective in stretching remaining scar tissue and in these cases additional surgery to add extra tissue where needed may be more effective, followed again by appropriate positioning after the additional procedure.

Evaluation of results
Patients should continue to visit a doctor until wound healing is complete. It is advisable to measure and document the ROM preoperatively, and to monitor the development of ROM postoperatively. It should be explained to the patient that the ROM will continue to improve for months, provided that they do their exercises. One year post-procedure, the final measurement can be made and the result can be evaluated by both patient and doctor.

Management of complications
As burn scars are very fibrotic and therefore often poorly vascularized, complications in wound healing are common. Wound breakdown, necrosis, and infection are the most common complications. This is particularly true when wounds are closed under tension. When a local flap such as a Z-plasty does not provide enough tissue to close the wound without tension, it is advised to either add a skin graft or accept that the joint cannot be fully extended (yet).

Antibiotic treatment can be initiated when indicated for infection. Small areas of necrosis and minor wound breakdown can be treated conservatively by cleaning the wound and applying anti-bacterial dressings. The small defects will heal by secondary intention and quite often, the end result will still be adequate in terms of contracture release and no further treatment is required. Larger breakdowns with extended necrosis should be surgically debrided. If the defects are substantial (for instance a complete triangle of the Z-plasty has become necrotic), it is advised to treat this area with a skin graft as soon as the wound bed allows. Without this secondary surgery, these cases will very likely end with a recurrence of their contracture.

How to perform - Interposition flaps

General principles

For the surgical treatment of broad contractures that cover larger areas (e.g. are not a single strand), an archetypal Z-plasty is not the best solution; these more extensive burn contractures often require a different approach. If no slack is available in the surrounding skin, a skin graft might be the best option, but if slack is present next to the broad scar, an interposition flap may well be a better option to provide vascularized elastic skin (Figure 1).

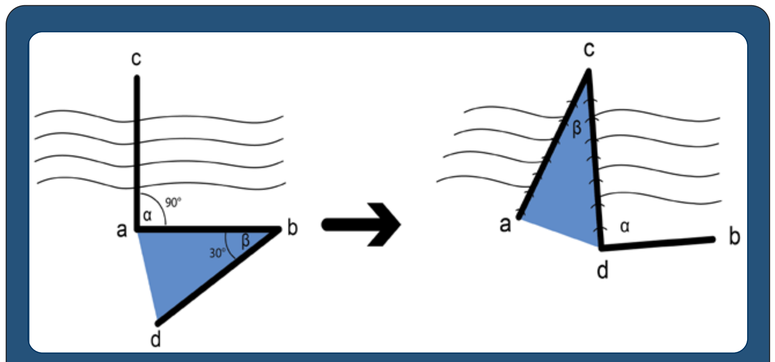

Figure 1 - Example of a interposition flap

An interposition flap can be seen as a Z-plasty with a 90 degree release incision in the pathological (scar) tissue, followed by an inlay of a triangular flap of (preferably healthy) tissue. The Z-plasty angles are asymmetrical in order to facilitate this. This 'asymmetrical Z-plasty' is also known as a 'banner flap', as the triangle of healthy tissue resembles a 'banner'. Interposition flaps do not necessarily need to be triangular and can be shaped to suit the local situation. The theory behind these flaps is best understood by the relatively simple interposition flap explained in this chapter. With growing experience, surgeons will see more possibilities and solutions, and can start varying, combining, and fine-tuning techniques to create the optimal treatment for each contracture.

As contractures are characterized by problematic amounts of skin tension, the incisions made in the affected skin in the direction of the contracture have a tendency to shrink, while the incision in the healthy skin has the ability to stretch. In order to account for these effects, it is often wise to release the contracture and to dissect the interposition flap in a stepwise fashion.

Doing so provides the opportunity to assess the need and availability of tissue intra-operatively. It also allows the operating surgeon to adjust the length of the incisions to meet the needs of the individual contracture at hand.

PROCEDURE

Preparations

Surgical instruments

- Surgical pen.
- Ruler (to measure the length of the limbs).
- Scalpel (usually with a #10 or #15 blade, depending on the size of the interposition flap).
- Dissecting forceps (such as Adson or other tissue forceps).
- Hand held retractors (such as single toothed skin hooks for small flaps, or Senn retractors for larger flaps).
- Scissors (such as Metzenbaum or Iris).
- Mono- or bi-polar electrocautery, when available.
- Needle holders.
- Sutures (usually a non-absorbable, monofilament suture will suffice, though larger interposition flaps with a lot of tension may sometimes require absorbable sutures in the dermal/subcutaneous plane).

Markings of flap design

- Before marking the flap, it is essential to determine the line of maximum tension (the direction of the contracture). This can be done by extending the affected joint or body part. Then, the direction and amount of slack should be determined by using the pinch test.

- After the assessment of the affected area, the surgeon can mark the contracture release incision perpendicular to the direction of the contracture. To be effective, the incision should run all the way down the scar tissue causing the contracture into the healthy skin. Then, the interposition flap can be designed. The interposition flap itself should be on the healthy, non-contracted skin with the most available amount of slack.

- The width of the contracture defines the length of the flap, while both the amount of slack available and the amount of tissue needed to lengthen the contracture defines the base of the flap, and thereby the angle of the triangle.

- To ensure the blood supply to the tip of the flap, the length should not normally be longer than two to three times the length of the base of the flap.

- With this design, the healthy tissue will be interposed into the defect created by the release of the contracture, with tension-free donor site closure.

Anesthesia

- Depending on the localization of the contracture, the estimated size and extent of the surgery, and patient characteristics, an interposition flap can be performed under local (WALANT), regional, or general anesthesia.

- When using local anesthetic, it is recommended to anesthetize first, and then to disinfect and drape.

- Even when the procedure is performed under general or regional anesthesia, it is advised to infiltrate the operative site with local anesthetic and adrenaline/epinephrine. This will greatly reduce the bleeding during the operation, make the dissection easier, and provide postoperative pain relief. Allow 30 minutes for the adrenaline/epinephrine to have the optimal effect and use a long-lasting local anesthetic agent for optimal postoperative pain relief.

Positioning

The positioning of the patient is dependent on the localization of the burn contracture.

Sterile field

Make sure that the entire site is disinfected and that the sterile drapes do not restrict movement, so that the affected body part can move freely during the procedure. This can help improve exposure and allows immediate assessment of the effect of the contracture release.

Surgery

1. Start with the releasing incision down all the fibrotic tissue to the healthy skin, creating maximum release.

2. Determine whether the rest of the design (the interposition flap) is still adequate. Does the defect that is created by the release match the flap? Is it still possible to close the donor site (in other words: the base of the flap)? If so, continue with the next incision; if not, adjust the design.

3. When all incisions are made, dissect the transposition flap so that the transposition of the flap can be done easily. In a well-designed transposition flap the flap will almost fall into place by itself. Make sure that all dissected skin is the same thickness all over, or slightly thicker at the base. The dissection should be within the subcutaneous or suprafascial tissues, depending on the localization of the contracture.

4. Check for active bleeding and coagulate if necessary. Be cautious when coagulating on the skin flap, as this could damage the vascularization.

5. When suturing the transposition flap, it is recommended to start by closing the donor site because this is where the tension will be, then the interposition flap can be sutured in place. If the local skin has a thick layer of subcutis, subcutaneous sutures can be used to minimize tension on the skin.

6. Monofilament absorbable sutures are advised for the skin layer, especially in small children or difficult anatomical locations, as they avoid the need for removal.

7. Depending on the size and location, a small drain can be placed.

Example of an asymmetrical Z-plasty used as an interposition flap

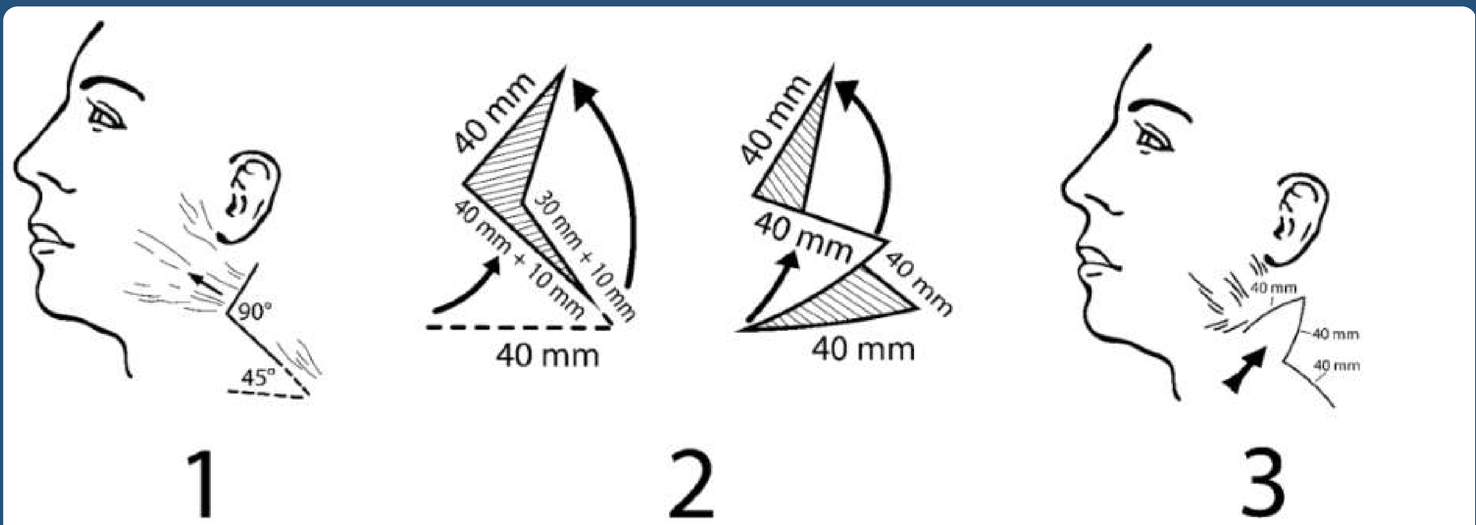

Figure 2 - A stepwise dissection facilitates intra-operative customization of flap design.

Above is an example provided by Limberg (Figure 2). On the left is a patient with a neck burn contracture. The initial plan was to conduct an asymmetrical Z-plasty with 90° and 45° angles, and limb lengths of 4 cm. The first incision is made in line with the contracture and the second incision is made perpendicular to the contracture, creating maximal release (1).

After these incisions are made, the amount of tissue shrinkage is evaluated, revealing a shrinkage of 1 cm (2). In order to account for the shrinkage effect, the central incision is extended by 1 cm. Only after this correction can the Z-plasty be completed by making the third incision (2).

Dressing and fixation
In most cases, a simple dressing with dry gauzes can be applied as a first layer. If the flaps have the tendency to move away from the underlying tissue layer (this is called 'tenting'), an elastic bandage or even a tie-over dressing can be applied. Joints that have been affected by a contracture have the tendency to return to their contracted position and this must be avoided. Therefore, fixation of the affected joint in a position opposing the contracture is advised until the wounds have healed. A Plaster of Paris slab splint is an adequate way to achieve this, and K-wires are a very useful alternative in hands, fingers and toes, where plaster may be less effective, especially in young children.

Postoperative care
After surgery, bandages should be changed after 3-5 days, or earlier if there is a risk of infection. Sutures can be removed after 2-3 weeks if they are non-absorbable.

If K-wires are used, it is recommended that they are removed after 3-4 weeks due to the risk of infection. Splinting can be continued for a longer period, until there is no further risk of recurrence. If the affected joint is not fixed for long enough in the position opposing the contracture, there is a high risk of recurrence of the contracture.

Physiotherapy
Active movement and exercises to maintain the gained ROM should be started as soon as wound healing permits. The availability of physical therapy makes a big difference. If physical therapy is not available, the importance of exercises should be emphasized to the patient. Splinting can be continued between exercises and during the night. Splinting during the night is sometimes continued for months, even after full healing of the wounds and return to normal use of the affected limb. Splinting works well when the skin quality is good, but is less effective in stretching remaining scar tissue and in these cases additional surgery to add extra tissue where needed might be more effective, followed again by appropriate positioning after the additional procedure.

Evaluation of results
It is recommended that patients are re-evaluated by their doctor until the scars have healed, ideally at least after six weeks, three months, six months, and one year. It is advisable to measure and document the ROM preoperatively, and to monitor the development of ROM postoperatively. It should be explained to the patient that the ROM can continue to improve for months, provided they do their exercises. The final evaluation measurement can be made one year after the procedure.

Management of complications
As burn scars are very fibrotic and therefore often poorly vascularized, complications in wound healing are common. Wound breakdown, necrosis, and infection are the most common complications. This is particularly true when wounds are closed under skin tension. When a local flap does not provide enough tissue to close the wound without tension, it is advised to add a skin graft or to accept that the joint cannot be fully extended (yet).

Antibiotic treatment can be initiated when indicated for infection. Small areas of necrosis and minor wound breakdown can be treated conservatively by cleaning the wound and applying anti-bacterial dressings. The small defects will heal by secondary intention. Quite often, the end result will still be adequate in terms of contracture release and no further treatment is required. Larger breakdowns with extended necrosis should be surgically debrided.

If the defects are substantial (for instance a complete triangle has become necrotic), it is advised to treat this area with a skin graft as soon as the wound bed allows. Without this secondary surgery, these cases will very likely end with a recurrence of the contracture.

How to perform - Combined flaps

General principles

In addition to a Z-plasty and an interposition flap, another option for surgical treatment of burn contractures is the use of combined flaps. With this technique, multiple flaps can be combined into one design. This is illustrated by a combined flap design known as the 'jumping man', due to its resemblance to a jumping person, a five-flap plasty that is often very effective in burn contracture reconstruction.

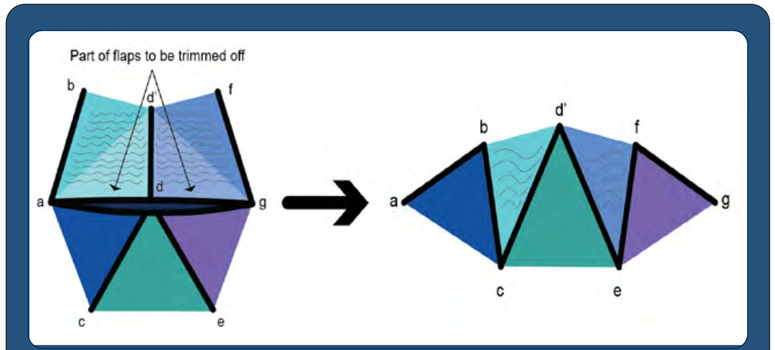

Figure 1 - The Jumping man flap

The five-flap plasty refers to a double-opposing Z-plasty combined with a central Y-V advancement (Figure 1).

The reason this technique fits so well is because post-burn contractures have the tendency to form a fold with an affected (burned) side and a non-affected side. The configuration of the jumping man can also be described as 3 release incisions on the affected scarred side, followed by 3 interposition flaps from the healthy side. To be effective, it is very important that the three triangular flaps to be transferred into the release incisions on the contracted side are harvested from the healthy side (Figure 2). The tetrahedral effect ensures that length and depth will be gained, making this combined flap very suited for the correction of a burn contracture, in particular those with a fold that has an affected and a non-affected side.

Several designs exist, but in this chapter the design by Hirshowitz is discussed in further detail. The design by Hirshowitz is formed by two mirrored Z-plasties, where an extra incision allows the possibility of a Y-V advancement. The procedure is very well suited for the correction of contractures in folds, for example a burn contracture of an axilla, elbow crease, webspace of the hand, finger, or knee fold (Figure 2).

Considerations

Combined flap designs require specific three-dimensional (3D) features in order to be feasible. In general, most of them cannot be performed in a flat plane (two dimensions) because the tissue that has to be recruited from the sides simply cannot reach the required position for the plasty. Combined flaps work best when the contracture has formed in a fold or crease, creating extra tissue in the third dimension. In practice, often one side of this fold is badly scarred, while the other side has good quality skin, therefore proper design is of utmost importance. For instance, five-flap plasties are doomed to fail if the triangular flaps are projected onto the scarred side, and the rectangular flaps onto the healthy side, and this cannot be stressed enough!

PROCEDURE

Preparations

Surgical instruments

- Surgical pen.
- Ruler (it may be helpful to measure the length of the limbs of the Z-plasties and/ or Y-V advancement to make sure they are the same length).
- Scalpel (usually with a #10 or #15 blade, depending on the size of the plasty).
- Dissecting forceps (such as Adson or other tissue forceps).
- Hand held retractors (such as single toothed skin hooks for small five-flap plasties, or Senn retractors for larger plasties).
- Scissors (such as Metzenbaum or Iris).
- Mono- or bi-polar electrocautery, when available.
- Needle holders.
- Sutures (usually a non-absorbable, monofilament suture will suffice, though larger plasties under a lot of tension may sometimes require an absorbable suture in the dermal plane).

Figure 2 Jumping man, knee contracture, healthy side



Markings of flap design

- Before marking the flap, it is essential to determine the line of maximum tension (the direction of the contracture). This can be done by extending the affected joint or body part. It is also important to determine which side of the contracture contains the most damaged skin and which side contains the healthy skin.

- After the assessment of the affected area, the surgeon can mark the design of the five-flap plasty. The arms of the jumping man are usually not drawn at the start, but instead after the two lateral triangular flaps have been mobilized. 1

- The line between the two rectangular flaps and the three triangular flaps should be in line with the contracture (perpendicular to the axis of rotation of the joint). 2

- The two rectangular flaps (with the releasing incisions) should be located on the side with the most affected, contracted tissue. 3

- The three triangular flaps should be located on the side with the most healthy, unaffected tissue. 4

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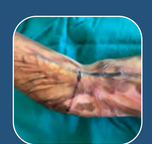


Anesthesia

- Depending on the localization of the contracture, the estimated size and extent of the surgery, and patient characteristics, a five-flap plasty can be performed under local (WALANT), regional, or general anesthesia.
  For example, a small five-flap plasty to release a webspace contracture in an adult will be performed under local anesthesia, whilst a large five-flap plasty on an elbow burn contracture in a child should be performed under general anesthesia.

- When using local anesthetic, it is recommended to anesthetize first and then to disinfect and drape. This ensures that the anesthetic has sufficient time to work properly. Even when the procedure is performed under general or regional anesthesia, it is advised to infiltrate the operative site with local anesthetic and adrenaline/epinephrine. This will greatly reduce the bleeding during the operation, make the dissection easier, and provide postoperative pain relief. Allow 30 minutes for the adrenaline/epinephrine to have the optimal effect and use a long-lasting local anesthetic agent for optimal postoperative pain relief.

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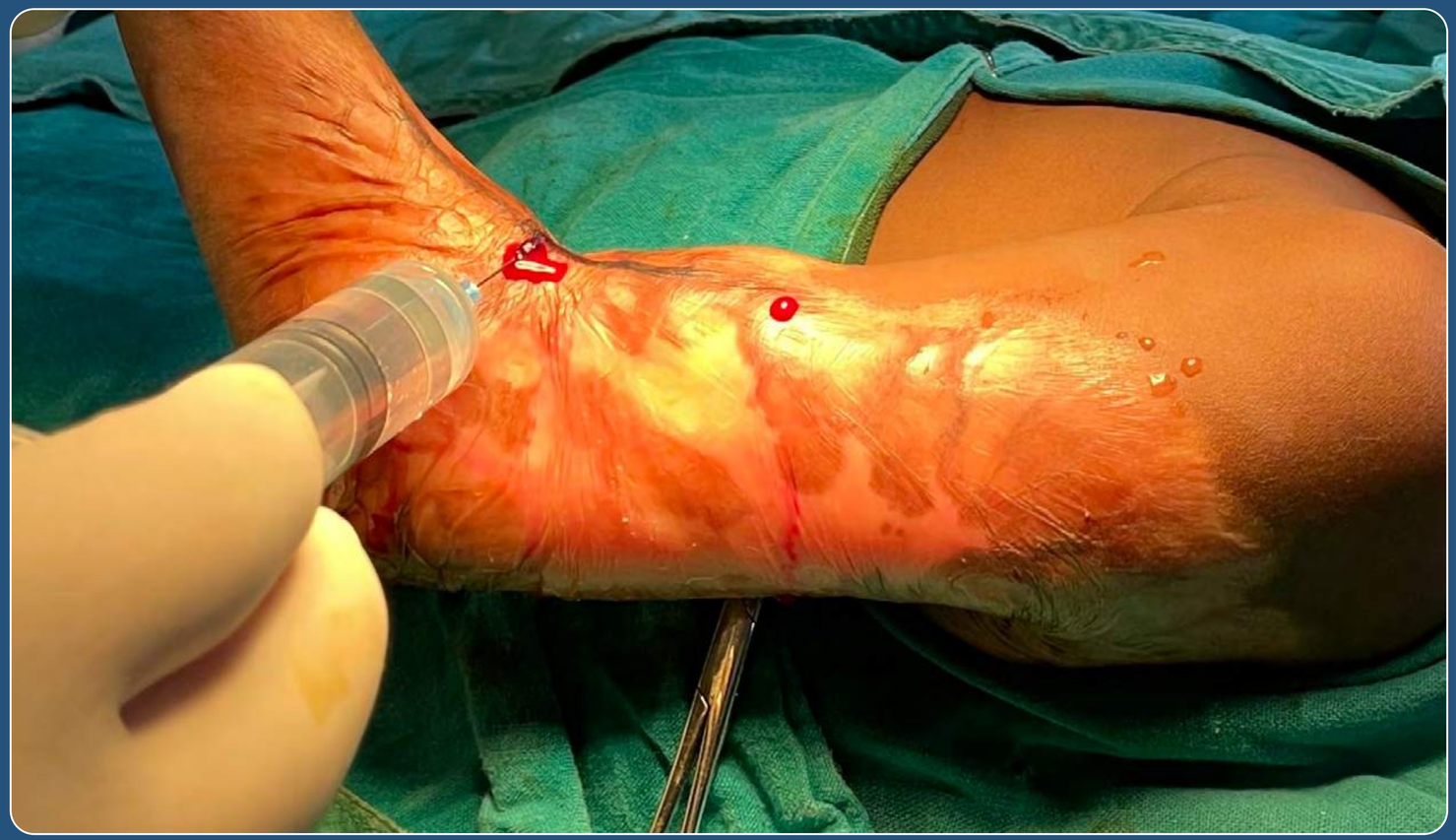

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Positioning
The positioning of the patient is dependent on the localization of the burn contracture.

Sterilization and dressings
Make sure that the entire site is disinfected and that the sterile drapes do not restrict movement, so that the affected body part can move freely during the procedure. This can help improve exposure and allows immediate assessment of the effect of the contracture release.

Surgery
Contractures are characterized by problematic amounts of skin tension. Due to this tension, the skin on the side of the contracture has a tendency to shrink and the tetrahedral effect of combined flaps is challenging to predict. Therefore, it is advised to dissect the releasing incisions and the interposition flaps in stepwise fashion. Doing so provides the opportunity to alter the design if necessary.

1. Start with the incision in the direction of the contracture (the shoulders of the jumping man). 6

2. Continue with the releasing incisions (the head of the jumping man) through all fibrotic scar tissue and subsequently make the incisions forming both legs of the jumping man. 7 8

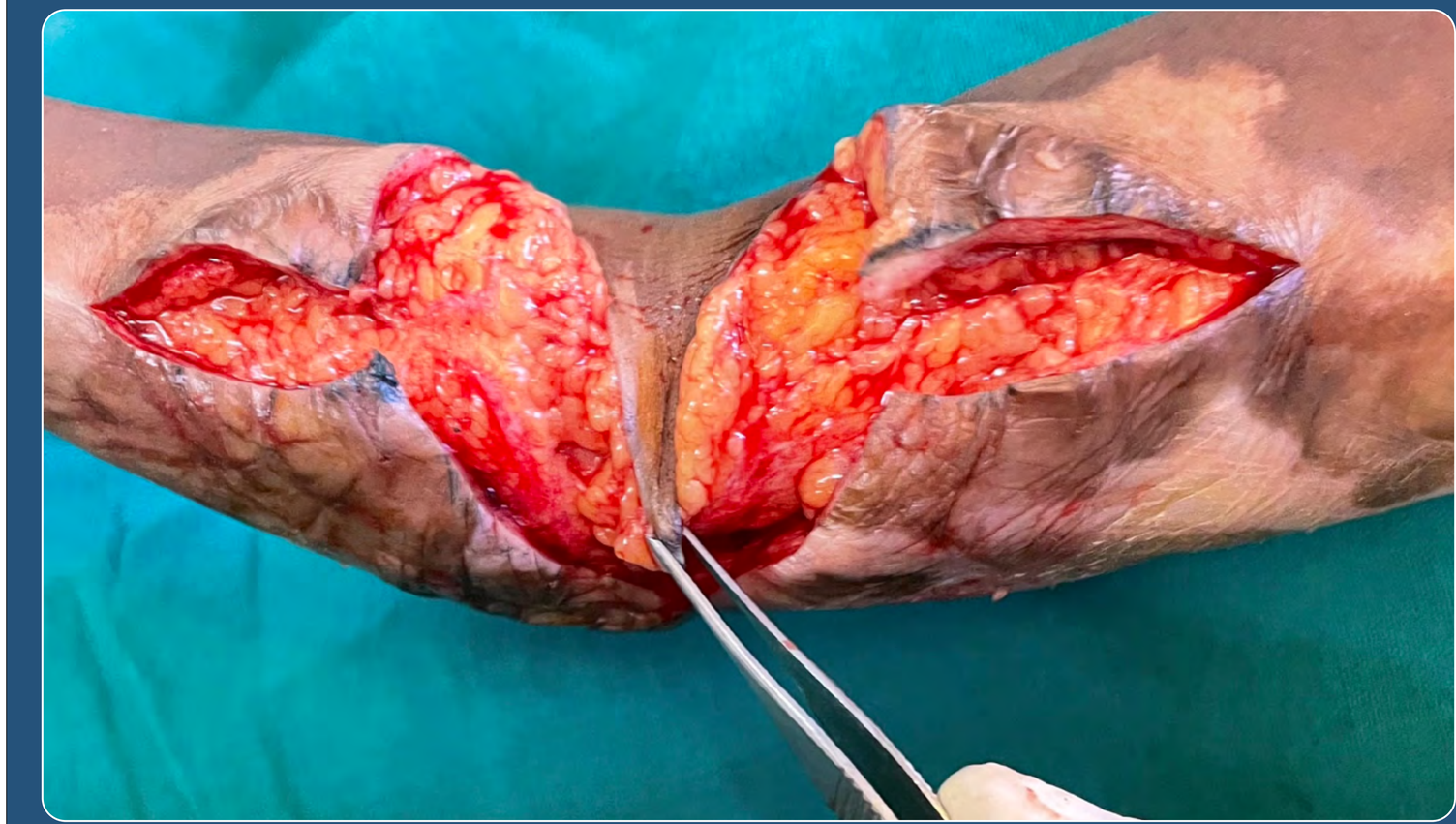
6

3. Then, raise the central triangular flap in between the legs of the jumping man. In an ideal situation, the Y-V advancement reaches the tip of the V almost at the level of the pivot point of the joint. 9

4. After the central triangular flap has been lifted, the two lateral triangular flaps on the healthier side of the contracture can be raised. By turning the lateral triangular flaps to their new position on the more affected side, the best position of for the lateral incisions of the rectangular flaps ('the arms of the jumping man') become clear and can be adjusted if necessary. 10 11 12

5. In a well-designed five-flap plasty, the flaps will almost fall into place by themselves. Make sure that all dissected flaps are the same thickness all over, or slightly thicker at the base. The dissection can be within the subcutaneous tissue if this layer is extensive, but often a supra-fascial plane is preferred to ensure maximum blood supply to the flaps. 13

6. Check for active bleeding and coagulate if necessary. Be cautious when coagulating on the skin flap as this could damage the vascularization. 14



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7. When suturing the five-flap plasty, it is recommended to start by putting the tips of the three triangular flaps in their new position. Subcutaneous sutures can be used to minimize tension on the skin. 15 16

8. Monofilament sutures are advised for the skin. In small children or difficult anatomical locations absorbable sutures can be convenient, avoiding the need for removal. 17

9. Depending on the size and location, a small drain can be placed. 18 19

Dressing and fixation

In most cases, a simple dressing with dry gauzes can be applied as a first layer. If the flaps have the tendency to move away from the underlying tissue layer (this is called 'tenting'), an elastic bandage or even a tie-over dressing can be applied. Joints that have been affected by a contracture have the tendency to return to their contracted position and this must be avoided. Therefore, fixation of the affected joint in a position opposing the contracture is advised until the wounds have healed. A Plaster of Paris slab splint is an adequate way to achieve this, and K-wires are a very useful alternative in the hands, fingers, and toes, where plaster may be less effective, especially in young children

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Postoperative care

After surgery, it is recommended that the dressing is changed after 3-5 days, or earlier if there is a risk of infection. Sutures should be removed after 2-3 weeks if they are non-absorbable. If K-wires are used, it is recommended that they are removed after 3-4 weeks due to the risk of infection. Splinting can be continued for a longer period, until there is no further risk of recurrence. If the affected joint is not fixed for long enough in the position opposing the contracture, there is a high risk of recurrence of the contracture.

Physiotherapy
Active movement and exercises to maintain the gained ROM should be started as soon as wound healing permits. The availability of physical therapy makes a big difference. If physical therapy is not available, the importance of exercises should be emphasized to the patient and adequate instructions need to be provided. Splinting can be continued between exercises and during the night. Splinting during the night is sometimes continued for months, even after full healing of the wounds and return to normal use of the affected limb. Splinting works well when the skin quality is good, but is less effective in stretching remaining scar tissue and in these cases, additional surgery to add extra tissue where needed may be more effective, followed again by appropriate positioning after the additional procedure.

Evaluation of results
It is recommended that patients are re-evaluated by their doctor until the scars have healed, ideally at least after six weeks, three months, six months, and one year. It is advisable to measure and document the ROM preoperatively and to monitor the development of ROM postoperatively. It should be explained to the patient that the ROM can continue to improve for months, provided they do their exercises. One year post-procedure, the final measurement can be made and the result can be evaluated by both patient and doctor.

Management of complications

As burn scars are very fibrotic and therefore often poorly vascularized, complications in wound healing are common. Wound breakdown, necrosis, and infection are the most common complications. This is particularly true when wounds are closed under skin tension. When a local flap such as a jumping man does not provide enough tissue to close the wound without tension, it is advised to either add a skin graft or accept that the joint cannot be fully extended (yet).

Antibiotic treatment can be initiated when indicated for infection. Small areas of necrosis and minor wound breakdown can be treated conservatively by cleaning the wound and applying anti-bacterial dressings. The small defects will heal by secondary intention and quite often, the end result will still be adequate in terms of contracture release and no further treatment is required. Larger breakdowns with extended necrosis should be surgically debrided. If the defects are substantial (for instance a complete triangle has become necrotic), it is advised to treat this area with a skin graft as soon as the wound bed allows, and to continue splinting.

Basics of Burn Care 2

Examples

1.

Head & neck >

2.

Trunk >

3.

Upper extremity >

4.

Lower extremity >

Photo by J. van Kesteren

Head and neck

Preview

Eye and mouth

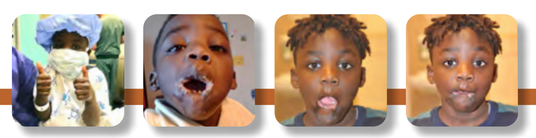
Eye and mouth

This example shows the treatment of a 4-year-old boy, after a burn injury to the face that occurred four years prior. Deep burn wounds of the face can be very destructive leading not only to disfiguring scarring, but also contractures causing loss of function of the mobile anatomical structures of the eyes and mouth. This young patient was treated at Haydom Lutheran Hospital in Tanzania.

- **MEDICAL HISTORY**
- **PHYSICAL EXAMINATION**
- **SURGERY**
- **POSTOPERATIVE CARE**
- **OUTCOME**
- **LESSONS LEARNED**

Preview

Mouth



Eye and mouth

The patient in this example is a boy from Nigeria who was adopted by a couple from the Netherlands. Over the past few years, he has been treated by reconstructive surgeons for severe microstomia with extensive scarring in and around the mouth. Between the ages of two and six, five surgical procedures were performed to improve the function of the mouth.

The aim of this example is to demonstrate that phasing treatment in a challenging reconstructive case can lead to a good outcome. In staging the procedure, less risk was taken, thus avoiding damage to the remaining oral musculature.

- MEDICAL HISTORY
- PHYSICAL EXAMINATION
- SURGERY
- POSTOPERATIVE CARE
- OUTCOME
- LESSONS LEARNED

Preview

Neck

Neck

Contractures in the neck can have a large impact on a patient's daily life. Most burns that cause these contractures are unintentional accidents, but intentional "acid attacks" are a relatively common cause of these contractures in some settings. In this example, we detail the treatment after an unintentional burn injury. Two years after sustaining large burn injuries to the face, neck, trunk, both arms, and left hand, this patient received surgical treatment for a contracture of the neck.

Trunk

2.1. Inframammary region >

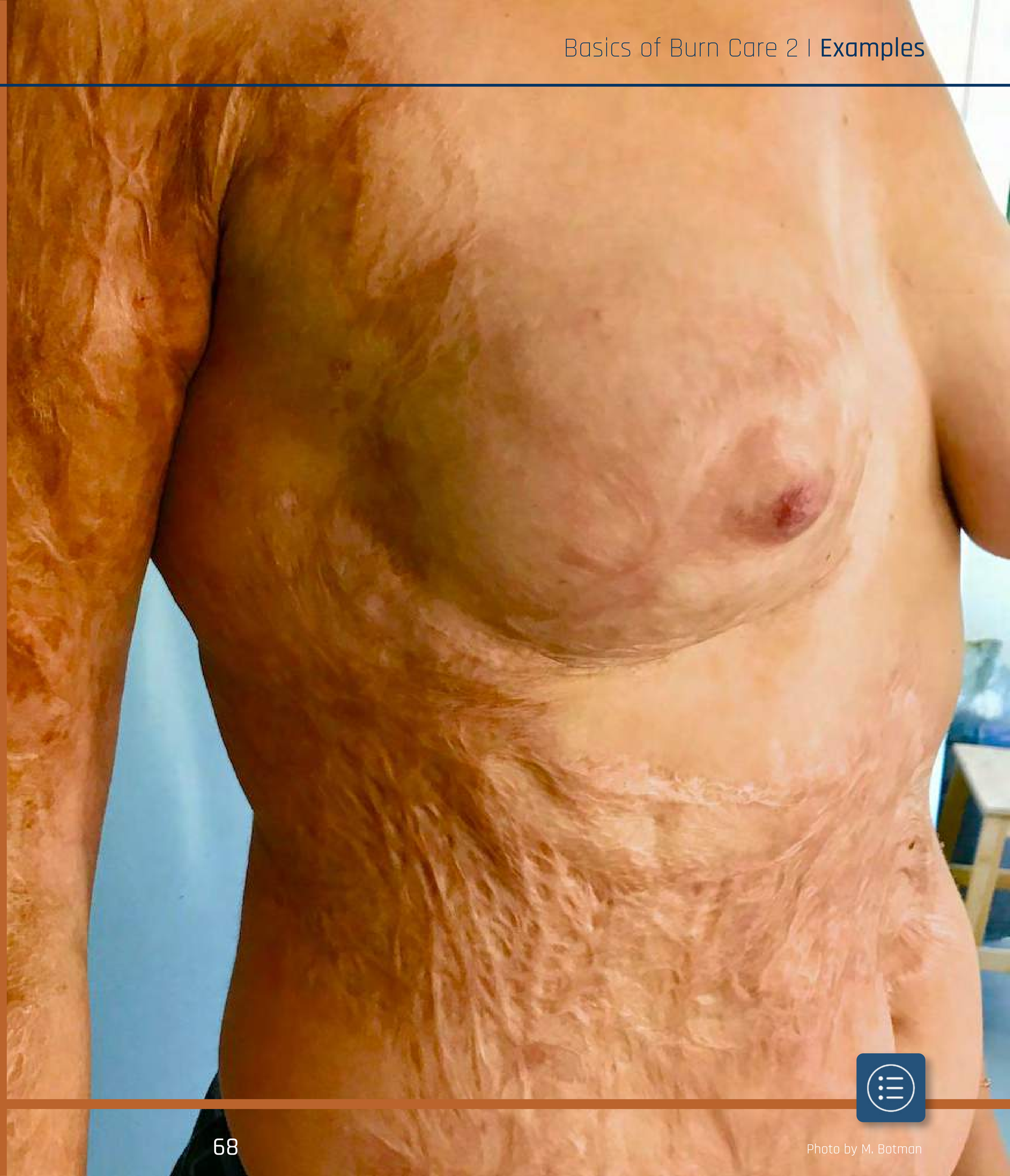


Photo by M. Botman

Preview

Inframammary region

Inframammary region

The 17 year-old patient in this example had sustained an extensive burn 14 years prior. When her breasts developed, the scar tissue on the right side of the chest became tight. The focus of this example is a scar in the inframammary region. She was treated at the Burn Center of the Red Cross Hospital in Beverwijk, the Netherlands.

Upper extremity

Photo by M. Botman

Preview

Axilla, elbow, wrist and fingers

Axilla, elbow, wrist and fingers

This example shows a girl with a severe contracture involving the axilla, elbow, and dorsal side of the wrist and fingers. Prior to presentation, two operations had been performed to improve the function.

- **MEDICAL HISTORY**
- **PHYSICAL EXAMINATION**
- **SURGERY 1**
- **POSTOPERATIVE CARE**
- **SURGERY 2**
- **OUTCOME**
- **LESSONS LEARNED**

Preview

Axilla and elbow 1

Axilla and elbow 1

On the Chars, the river islands in northern Bangladesh, almost all stoves are made of clay and the people use wood as fuel. They hold their children in one hand and cook with the other. Even small accidents in front of a burning stove can causes serious burn injuries. The soil is very fertile on the Chars and the area is densely populated, but health care is very scarce. Friendship is an organization providing medical care on hospital ships that move from island to island to serve the population in need. They also provide reconstructive surgical care, such as burn contracture release, in a basic but effective small operating theatre on the hospital ships, with the help of visiting reconstructive surgeons.

- MEDICAL HISTORY
- PHYSICAL EXAMINATION
- SURGERY
- POSTOPERATIVE CARE
- OUTCOME
- LESSONS LEARNED

Preview

Axilla and elbow 2

Axilla and elbow 2

The patient in this example is the son of Maasai parents in central Tanzania. The burn wound he sustained to his left arm was deep, and without skin grafting took many months to heal. The healing process was complicated by malnutrition and anemia. Two years later, they came to Haydom hoping that something could be done to improve the function of the arm. The wound was healthy and there was an impaired range of motion in the axilla and elbow.

This example shows a variation on the design in the previous example with local flaps. This time, the surgeons choose a large Z-pasty combined with a jumping man instead of two jumping mans in a row.

MEDICAL HISTORY

PHYSICAL EXAMINATION

SURGERY

POSTOPERATIVE CARE

OUTCOME

LESSONS LEARNED

Preview

Axilla and elbow 3

Axilla and elbow 3

You may recognize this patient from the example of an acute burn wound of the shoulders and upper right arm in ‘Basics of Burn Care 1, Acute Burn Injuries’. Here, we show the treatment of the remaining contractures of the right axilla and elbow one year later in Haydom Lutheran Hospital, Tanzania.

Preview

Axilla 1

Axilla 1

The patient in this example presented at Haydom Lutheran Hospital in Tanzania with a severe broad contracture of the left axilla. Deep burns in the axilla commonly lead to adduction contractures. A deep burn on the anterior aspect of the shoulder can also cause rotational contractures (where external rotation is limited), as was the case for this patient. The boy presented in this example required two operations. The first procedure for the broad contracture needed skin grafts. At a later stage, a Z-plasty was performed to treat the less severe narrow band contracture that had developed after the first operation. We believe it is often indicated to perform additional surgeries in severe contractures. Good communication, aftercare, and follow-up are essential to obtain a good final result.

Preview

Axilla 2

Axilla 2

The girl shown here was treated at Haydom Lutheran hospital for a 39% TBSA full thickness burn of the back, shoulders and buttocks. The treatment of the acute burn was presented as an example in Basics of Burn Care 1: Acute burn injuries. She survived and the wounds healed, but she developed contractures of both axillae. This example shows how contractures with a narrow band (typically forming a fold with good quality skin on at least one side of the contracture) can be treated with local flaps without skin grafts.

Preview

Elbow, wrist and fingers

Elbow, wrist and fingers

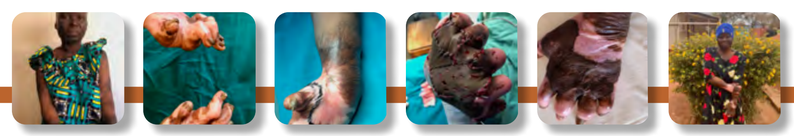
This example shows a patient with a contracture of the elbow, wrist and fingers.

This young girl was presented with a contracture with a clear fold, but the fold had scarred skin on both sides and the contracture was extending over three joints (elbow, wrist and MCP joints of the fingers). In addition to local flaps, additional FTGs were also needed to treat the contracture. This example also illustrates how partial flap and graft necrosis can be managed successfully.

- MEDICAL HISTORY
- PHYSICAL EXAMINATION
- SURGERY
- POSTOPERATIVE CARE
- OUTCOME
- LESSONS LEARNED

Preview

Wrist and fingers dorsal side



Wrist and fingers dorsal side

This example shows severe contractures of both hands. Due to the fragile skin on the dorsal side of the hands, a common pattern after severe burns is a contracture causing extension of the wrist and MCP joints, and flexion of the PIP joints.

- MEDICAL HISTORY
- PHYSICAL EXAMINATION
- SURGERY 1
- POSTOPERATIVE CARE
- SURGERY 2
- OUTCOME
- LESSONS LEARNED

Preview

Wrist and fingers ulnar side

Wrist and fingers ulnar side

Burns on the dorsal side of the hand can lead to contractures, causing the wrist and MCP joints to be fixed in extension. In the experience of the doctors at Haydom Lutheran Hospital in Tanzania, in young children severe scald burns are the most common cause of contractures on the thin-skinned dorsal side of the hands. This example shows a child with a contracture on the ulnar side of the wrist and hand that was caused by an open fire in the house.

Preview

Fingers - palmar side

Fingers - palmar side

In this example from Tanzania, we present a young boy with flexion contractures of four fingers on the palmar surface of the hand, to show how to perform a release and coverage with local flaps and FTGs.

- MEDICAL HISTORY
- PHYSICAL EXAMINATION
- SURGERY
- POSTOPERATIVE CARE
- OUTCOME
- LESSONS LEARNED

Lower extremity

Photo by M. Botman

Preview

Hips

Hips

A 5 year-old girl had sustained an acute burn wound covering 36% TBSA, that was treated at Haydom Lutheran Hospital in Tanzania. She survived and was treated with three sessions of skin grafting (see examples Basics of Burn Care 1: acute burn injuries). Despite adequate surgical treatment, she developed contractures involving both hips and also affecting the genital area. She came back to the hospital one year later for contracture release.

- MEDICAL HISTORY
- PHYSICAL EXAMINATION
- SURGERY 1
- POSTOPERATIVE CARE
- SURGERY 2
- OUTCOME
- LESSONS LEARNED

Preview

Knee

Knee

This example shows the treatment of a severe contracture of the left knee, after a burn wound caused by an open fire in rural Tanzania. The girl survived the large burn wound, but the acute wound had to heal by itself as she was treated at a hospital where surgical burn care was not available. Her wounds healed slowly, and when she arrived at Haydom Lutheran Hospital six months after the injury occurred, the remaining broad contracture that she had developed was treated with a release, local flaps, and skin grafts.

Preview

Ankle and toes

Ankle and toes

This example shows the treatment of a post-burn contracture in an approximately 50 year-old man in Bangladesh. He presented to the doctors on one of Friendship's hospital ships in the northern part of the country, with a contracture of the ankle joint and toes. This example shows the treatment of this contracture with a combination of local flaps and a skin graft: a Z-plasty and a full thickness graft, followed by 6 weeks of immobilization with a plaster of Paris (POP) cast.

Addendum

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Principles

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Abstract

Full article

Full Article

Full article

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Principles

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Glossary

FTG	Full Thickness (skin)Graft
IP	Interphalangeal
ISBI	International Society for Burn Injuries
K-wires	Kirscher wires
LMIC	Low- and Middle-Income Country
MCP	MetaCarpal Phalangeal
MTP	MetaTarsal Phalangeal
POP	Plaster of Paris
POSAS	Patient and Observer Scar Assessment Scale
ROM	Range of Motion
SCC	Squamous Cell Carcinoma
SPF	Sun Protection Factor
SSG	Split Thickness (skin)Graft
TBSA	Total Body Surface Area
UV	Ultra Violet
WALANT	Wide Awake Local Anesthesia No Tourniquet
5-FU	5-FluoroUracil