Introduction

The Belgian Association of Burn Injuries (BABI) was founded 20 years ago, its goal being to increase co-operation between all burn centres, especially for the management of national burn disasters. Nowadays we have approximately 70 specialised burn beds in Belgium and approximately 1,000 patients are admitted each year in all 6 centres together (for a population of 10 million).

The mission of the BABI is fourfold: (i) top quality clinical care for severely burned patients, (ii) research, (iii) teaching and education, and (iv) the provision of information and services. The first goal (i) consists of the actual treatment of the burn wounds (conservative and surgical) and the systemic (intensive care) treatment of severely burned patients. This consists of fluid resuscitation and other important measures to stabilize the patient and prevent (and treat) the inflammatory cascade and (multi-) organ failure, caused by the general impact of the burns. Specialised psychological and social support for the patients and their relatives is also an important element of total burn care. The second goal (ii) can be illustrated by the last congress of the European Burn Association (EBA) held in Budapest (Sep. 07). It was attended by almost 60 Belgian participants. Only the United Kingdom had more representatives. Because of the large number of research projects in which Belgian burn centres are involved (1-8), we play a leading role in the development and introduction of some important new techniques and diagnostic tools (1, 4, 6). For example, the Laser Doppler Imaging (LDI-scan), to estimate burn depth by visualisation of the blood flow, has already been introduced in several Belgian centres (9-10). Most of the Belgian burn centres also have extensive experience with permanent dermal substitutes like Integra®. Other commercially available dermal substitutes are being developed and evaluated, such as the permanent dermal substitute GlyaDerm® (a Belgian-Dutch product), which is currently being tested in an international multi-centre study. Several of the new temporary skin substitutes have already been introduced in the Belgian centres. The third goal (iii) is the teaching of students, nurses and health care professionals, including lectures for general practitioners and post-graduate courses for surgeons. Finally, (iv) the BABI also provides information and services as illustrated by the national prevention campaigns and the ‘National Disaster Plan’. When this disaster plan is launched, close co-operation with the other emergency services can provide effective distribution of large numbers of severely burned patients, first in the actual burn centres, but if necessary also in other intensive care units. For this purpose, the available burn beds (in each centre) are registered on a daily basis. Moreover, there is close co-operation between the BABI and the burn centres in neighbouring countries and an international circuit of assistance can easily be set up if necessary.
This article will focus on the surgical treatment of burn wounds. Because of the above-mentioned rapid evolution in burn care, involving several new techniques, we thought it would be interesting to compare the different surgical approaches in the Belgian burn units, in order to draw up a consensus document.

Materials and methods

A questionnaire was sent to the surgeons of each burn unit. In Ghent, Brussels and Liege, plastic surgeons are responsible for the surgical treatment of burns. In the other three centres (Antwerp, Charleroi and Leuven) specialised general surgeons perform the operations, whereas plastic surgeons are only involved for special indications. The questionnaire covered the whole treatment of severely burned patients: emergency treatment, diagnostic techniques, burn surgery and post-healing treatment (scars, contractures). Some non-surgical issues (e.g. wound dressings, use of antibiotics) were also discussed because of their high impact on the total healing process. The whole questionnaire was completed individually by each surgeon. Following this, an investigator (NB) independently visited all burn centres to complete and clarify the answers. Later, the resulting summary was composed, resulting in this complete overview and consensus document of Belgian burn surgery.

Results

Emergency treatment

Some specific burns require immediate surgical intervention: circular burns, chemical burns and electrical burns. The multiple-trauma patient also needs fast intervention, but the treatment of the burn wounds is usually postponed until after stabilization of the patient and treatment of the most life threatening events (severe blood loss, ventilation). Therefore, the consensus in each burn centre is that other emergencies need priority, but that burns should be treated as soon as possible.

Deep circular or near-circular burns of the extremities, thorax and neck often need an escharotomy or even a fasciotomy. Escharotomies are surgical incisions in the leather-like crust of the deep burns, and are indicated because extensive burns cause a generalised oedema, which might compromise blood flow and damage nerves because of increasing pressure within this rigid crust (compartment syndrome). By making these incisions, pressure in the underlying tissues will diminish, and further damage can be prevented. A fasciotomy is a similar surgical technique, but the incisions are also performed at a deeper level, into the fascia of the muscles. The exact indications for escharotomies and fasciotomies seem to vary between the centres: when the distal pulse (Doppler) has disappeared completely, these incisions are definitely needed, but several burn surgeons do not wait that long and perform an escharotomy upon admission of patients with third degree circular burns. When the thorax is deeply burned and ventilation is compromised, a lateral escharotomy can also be indicated, sometimes even extended to the abdomen. Some centres even perform an escharotomy if only the front of the thorax is deeply burned. The biggest drawback of an escharotomy is the remaining (mutilating) scar of the incisions, especially when the incisions are made too deep. Therefore, the decision to perform an escharotomy should be made deliberately, on an individual basis, and should by preference be performed by specialised burn surgeons.

Electrical burns sometimes need fasciotomies as well and, in most cases, a second look operation is indicated because of ongoing necrosis of the deeper tissues. In chemical burns, early debridement of the burn wound can be necessary to avoid further tissue damage by the chemical agents still present on the skin. The most dangerous chemicals commonly seen in the Belgian burn units are HF and NaOH. Burns with HF need urgent administration of calcium gluconate (intra-arterial, intravenously and/or locally) because HF binds to cellular calcium, leading to extended tissue damage and severe hypocalcaemia. NaOH also needs special attention and immediate excision because of the severe long lasting damage and tissue necrosis occurring after contact with high quantities or highly concentrated NaOH.

Surgical indications for admission to a burn unit

In the initial stage, burns are often underestimated and, therefore, it is not always clear which patients need to be referred to a specialised burn unit. The systemic effects of burns should be anticipated and treated: inflammatory reaction, temperature and fluid loss, oedema, increased metabolism, tissue necrosis and a high risk of infection. The indication for transfer can be either patient-specific or burn-related. The more vulnerable patients (young children, the elderly and/or immunocompromised patients) and patients with chronic illnesses, concomitant diseases or associated trauma (inhalation injury, fractures etc.) are more prone to burn-related problems (healing problems, infections) and therefore need specialised care. All third degree burns and all 2nd-3rd degree burns of at least 10% of the body surface need to be admitted to a burn unit. Burns of the face (eyes), hands, feet, perineum and joints also require the specialised care of a burn centre because of the high level of aesthetic or functional importance (3). As mentioned before, deep (near-) circular burns always need evaluation by burn surgeons. Chemical and electrical burns (and lightning injuries) also need specialised care.
Finally, referral to a burn unit is necessary if no healing of the burn wound occurs within 2-3 weeks post-burn.

Prior to the surgical treatment

After admission to a burn unit, the patient is thoroughly bathed and dirt and loose skin are removed. Afterwards, an adequate assessment of the severity of the burn is performed with an accurate estimation of burn depth and total burned surface area (TBSA) (2, 11), especially to calculate the amount of fluid needed for resuscitation. Laser Doppler Imaging is a very useful tool for estimating the precise depth of the burn by measuring blood flow in the burned tissue and has been shown to be much more accurate than clinical assessment only (9, 10). The LDI-scan is usually performed between 48-72 h post-burn, and is used to determine where surgery is needed. All burns can be divided into these four categories: ‘first degree’ burns (only epidermis), ‘superficial partial thickness’ or ‘superficial second degree’ burns (epidermis and superficial part of dermis), ‘deep partial thickness’ or ‘deep second degree’ burns (epidermis and most of the dermis) and finally, ‘full thickness’ or ‘third degree’ burns (epidermis and whole dermis). ‘Fourth degree’ burns are a subdivision of the third degree burns, with severe damage of the subcutaneous tissue (fat, muscles or even bone), but this distinction is not always made.

Severely burned patients require ‘intensive-care’ treatment because of their need for (extensive) fluid resuscitation and because of the major inflammatory reaction (leading to severe infections and multi-organ problems). Burn patients are very prone to infection and need a good cleansing and disinfection with antiseptic agents (isobetadine, silver dressings), on a daily basis or after several days (according to the degree of contamination and the type of dressing). Therefore, advanced bathing installations are available in all Belgian burn centres. Antibiotics are not recommended before signs of infection and, if needed, are preferably guided by an antibiogram. Some burn centres postpone the surgical treatment until stabilization and/or extubation. Most centres however, prefer an early surgical approach (within 3-5 days post-burn), and even earlier when the burns are definitely deep 3rd degree. Concomitant trauma and chronic illnesses can also have a high impact on morbidity and mortality (11).

Excision and coverage

There is some discussion about the timing of the first debridement. Early debridement has been shown to have a positive effect on the bacterial load, leading to less infection and shorter healing time (12). On day five after the burns, there is a shift from Gram-positive bacteria (tending to remain superficial and localised) to Gram-negative bacteria, increasing the risk of invasive systemic infection. Therefore it is considered best to surgically remove the debris as soon as possible, because this necrosed tissue is the ideal place for bacterial growth. Some surgeons plead for debridement during the first 24 h, but a delay of 48-72 h is becoming more popular (internationally), especially because of the better evaluation of burn depth after 2-3 days (LDI-scan), preventing unnecessary surgery. If surgery needs to be delayed, anti-septic treatment is even more essential.

The percentage of deeply burned surface area which can be operated on during one operation is limited mostly to 10 to 15% per surgical session. In some cases, if the patient is stable and can manage the blood loss, larger excisions can be performed. For the same reason, the frequency of operations is usually limited to 1-2 operations a week.

Excision is mostly performed tangentially with a dermatome. The Versajet, a new apparatus for more precise debridement of deep 2nd degree burns, has already made its entry into some Belgian centres (13, 14). Avulsion, or the complete removal of the entire epidermis, dermis and subcutaneous layer, is rarely indicated, because of the unacceptable aesthetic outcome and the extensive loss of healthy tissue.

Coverage of debrided burn wounds is mostly performed with split thickness skin grafts (STSG), consisting of epidermis and a very thin layer of dermis, preferably harvested from the thighs (15). Those STSG’s are mostly meshed and enlarged from 1/1 to a maximum of 1/9, to drain the wound fluids and to cover larger surfaces. The disadvantages of large meshes are the slower healing and the resulting unaesthetic scars, thereby excluding its use on the face and the dorsum of the hands. Another skin expansion technique is the Meek-Wall technique, where the autologous skin graft is cut into small squares, put on a carrier and then evenly expanded (16, 17). The healing starts from the centre squares and not from the border of the meshes, resulting in a faster epithelialisation and less hypertrophic scars. When not enough skin is present and the burns are extensive and deep, the wound bed can be prepared with cadaver or donor skin, as a temporary coverage for 1-2 weeks. Healing of donor sites (where STSG’s are harvested) is comparable to the healing of abrasions and can be covered with several dressings, such as vaseline-gauzes (e.g. Jelonet®), polyurethane dressings, hydrofibre dressings (e.g. Aquacel®) and alginates (e.g. Kaltostat®). These dressings can also be used for the conservative treatment of the more superficial burns.

The healing of burn wounds (and donor sites) can be stimulated by using cultured autologous keratinocytes (4, 5). Hereby, a small skin biopsy is taken from healthy skin and cultured for 2-3 weeks to obtain suffi-
cient cells. Because of the long cultivation time (and the high costs) this technique is limited to severely burned patients with a large burned surface area. These cell cultures can be used alone or in combination with a widely meshed STSG or donor skin. Heterologous keratinocytes can also be used and are readily available. These allogenic keratinocytes will stimulate healing but will not be incorporated in the final healed epidermis (5).

Another option to cover a defect is the full thickness skin graft (FTSG), which consists of epidermis and the complete dermis. This technique can only be used for smaller areas and is especially indicated in zones with high functional or aesthetic importance. There will be less contractures and hypertrophic scarring, resulting in a more supple skin. For example, debrided eyelids are often covered with an FTSG from behind the ears. Zones of flexion (e.g. neck, axilla, elbow, palm of the hand), which are very prone to contractions, also give better results with FTSG. The donor sites of the FTSGs (e.g. lower abdomen) are closed primarily, or exceptionally, covered with an STSG.

Ideally, full thickness skin defects should be reconstructed with a complete dermal layer covered with an epidermis. Therefore, another option to close skin defects is with so-called permanent skin-substitutes (dermal or total skin). Especially the dermal substitutes, such as Integra®, Matriderm®, Renoskin® and GlyaDerm®, are gaining ground and the quality of this ‘new skin’ is improving (18-20). Modern temporary skin substitutes, for example Biobrane, are gaining ground in Belgian burn care. However, classic temporary coverage with donor skin is still the gold standard. Xenografts and amnion are no longer used in Belgium. Recently, negative pressure therapy has also been introduced in the management of burn wounds: healing is improved by reducing oedema and bacterial colonisation, and restoring local vascularisation (21). It can also be helpful for the fixation of skin grafts on difficult surfaces.

Flap-surgery is the next step in the classic ‘reconstructive ladder’ for coverage of burn wounds. When important structures (joints, nerves, bare bone, etc.) are exposed, various flaps can be used to cover the defect: skin flap, fasciocutaneous flap, myocutaneous flap, etc. Flaps can be divided into two groups: pedicled flaps and free flaps. The first group remains attached to the donor area by its pedicle, which provides the blood supply and possibly its innervation. Pedicled flaps can be very simply created, such as by advancing the adjacent tissue to allow for primary closure, but these flaps can also be rotated or transposed to cover the defect. The donor site of those local flaps is closed primarily or covered with an STSG. The flaps of the second group, the free flaps, are completely extricated from the donor area by dissection of at least one artery and one vein, which can supply a sufficient blood flow to the whole flap. After transsection of the vascular pedicle at the donor area, the blood vessels will be anastomosed to blood vessels in the acceptor area by microsurgical techniques. The donor areas are closed primarily or covered with an STSG. This technique of the free flaps leads to optimal results, without hypertrophic scarring and contractures. In specific indications, a downgrading of the ‘reconstructive ladder’ can be obtained by using dermal substitutes (covered with STSG), resulting in a more simple coverage, which in some cases can avoid a more complex flap reconstruction.

Post-operative treatment

After the operation, several different dressings and bandages can be applied, varying according to the technique used for closure and the preferred products of each centre. The skin grafts are usually covered with a semi-permeable membrane and bandages soaked with isobetadine or furacine. As mentioned before, a good antisepsis and frequent control for signs of infection is obligatory. When the patient is in a bad general condition, healing will also be impaired and the number of operations necessary to obtain final closure might increase.

After care

The treatment of burns does not stop at the time of wound closure. Burn wounds, especially the deep burns, are very prone to hypertrophic scarring and contraction and therefore the prevention of unfavourable scars is of the utmost importance. The non-surgical scar treatment is well established and all Belgian centres promote multi-disciplinary scar-management, with splinting, physiotherapy, hydration, special custom-made pressure garments, and silicone inlays (6). Pressure therapy and splinting are applied before the closure of the wound and the treatment is usually continued until complete maturation of the burn scars. Another non-surgical option, in cases of small hypertrophic scars, is local infiltration with corticosteroid. Nevertheless, this technique is not used in all centres because of the possible generalised effects.

It takes at least one year and a half (or even 2 years or more in children) for complete maturation of scar tissue. Aesthetic surgical corrections are not recommended at an early stage unless functional problems such as contractures arise. Contractures are commonly seen at the flexion side of joints (axilla, elbow, neck, hands) and may need early surgical intervention to restore function by increasing the range of motion. This can be obtained with FTSG, dermal substitutes and flap surgery (e.g. Z- and V-Y-plasty).

If the non-surgical techniques are not sufficient to prevent the formation of disfiguring scars, surgical corrections can be indicated for aesthetic reasons. Excision
of the scar and primary closure is the easiest option. If the scar is too extended, this technique can be repeated (serial excision) or tissue-expanders can be used to enlarge the healthy surrounding skin (e.g. of a scalp defect). For this technique, extra saline is injected into the expansion prosthesis on a weekly basis, slowly enlarging the overlying healthy skin (7). Another option is coverage with full thickness skin grafts but, as already mentioned, the use is limited to small areas. Split thickness skin grafts are rarely used for scar revision. More challenging are the different flap-techniques, whereby tissue is transferred from the surrounding area or from further away (free flaps, pedicled flaps) (22). Because flaps or full thickness grafts are not always possible in severely burned patients, another option here is the use of dermal substitutes. Nevertheless, dermal substitutes are not often used in the reconstruction of scars, because of the high costs, difficulties in managing dermal substitutes and sometimes disappointing results.

**Discussion**

Comparison of the different surgical approaches to burn surgery in the Belgian burn centres revealed that, in all burn centres, the approach for superficial burns is conservative (but with variable products), while surgery is performed for full thickness burns (23). However, there is a wider variation in therapy for the burns in between, because the exact depth is not always clear from the beginning. A universally accepted rule is that burns should heal in less than 2-3 weeks; otherwise surgery is required to prevent hypertrophic scarring and contraction. A good estimation of healing time is not always easy. A re-evaluation of burn depth, and from this an estimation of healing time is usually made after 2-3 days (clinically or with LDI-scan). A possible explanation for the different approaches is that in three centres the patients are operated on by plastic surgeons and in the others by specialised general surgeons with occasional help from plastic surgeons. It seems that the general surgeons preferred to use more skin substitutes (temporary and permanent) and plastic surgeons more flaps.

To conclude, several approaches can be followed to obtain final closure of the burn wound. The ultimate goal is healing with an optimal functional and aesthetic outcome, but this often needs several (reconstructive) operations. However, the ‘ideal’ and best health-economic treatment for each patient and each burn has not yet been found. Nowadays, every burn unit has its own experience and expertise in burn care, keeping up with the most recent developments. A total multi-disciplinary approach to the burn patient, including psychological treatment and physiotherapy, is essential for success. It is hoped that we can continue this national co-operation between surgeons and other disciplines and keep sharing our experiences, leading to a further improvement in national burn care.

**References**
