Modern management of paediatric burns

Burn injuries pose a major threat to children in South Africa and remain a devastating injury, because of the resulting severe emotional and physical scarring and long psycho-social implications.

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Burns in children differ in multiple aspects from those in adults; the extent and depth of the burn injury are often more severe, the child's body proportions differ, resulting in greater evaporative water and heat loss, and fluid requirements are therefore generally greater. Importantly, many childhood burns are preventable.

The National Injury Mortality surveillance system indicates that burns are the leading cause of non-natural death in infants and children under 5 years and the fourth major cause of accidental death in the 5 - 9-year age group,[1] with more than 1 300 children dying annually from burns in South Africa (SA).

The majority of childhood burns in SA are treated by non-specialists, with referrals to burns units being reserved for the more severe cases. It is well documented in the literature that in some settings the majority of burn victims do not receive adequate first aid;[2] the majority of doctors treating burn wounds are unable to correctly measure the extent of the burn and almost half of treating doctors fail to prescribe adequate analgesia.[3] This article will focus on appropriate referral guidelines as well as deal with correct management of burns within a general hospital setting.

Importantly, many childhood burns are preventable.

Causes

About 90% of childhood burns are preventable. Informal housing, overcrowding and lack of electricity are underlying problems.[4]

The most frequent causes of burns in children are hot liquid scalds, flame burns, contact burns, electrical burns and chemical burns in descending order of frequency, with infants and toddlers being burned more frequently.[5]

Non-accidental injury (NAI)

Although the differentiation of accidental and non-accidental burn injury is not important from a wound treatment perspective, NAI has far-reaching social and legal consequences. Approximately 4% of burns are due to NAI. Suspicion of NAI may be raised when presentation is delayed, the history is vague, inconsistent or not compatible with the injury pattern, or there are other injuries or certain well-recognised patterns of injury (cigarette burns, bilateral glove or sock distribution scald on limbs).

Pathophysiology of the burn wound

The depth of a burn is determined by the amount of energy delivered to the site, the contact time and skin thickness. Jackson's 3-dimensional burn wound model describes 3 zones:

- a central zone of coagulation representing an area of irreversible tissue necrosis
- an area of stasis where sluggish circulation and release of inflammatory mediators will cause burn progression if resuscitation is inadequate
- a zone of hyperaemia which, after resolution of the hyperdynamic response, will return to normal.

The release of inflammatory mediators, mostly from the zone of hyperaemia, results in isotonic fluid shifts from the intravascular space to the burned area. These fluid losses are maximal from 3 to 12 hours post injury in small burns and up to 24 - 48 hours in larger burns.[6] In burns larger than 30% this fluid loss involves the whole body in a generalised systemic inflammatory response. Effective circulating fluid volume is decreased and hypovolaemia and shock may develop.

First aid

The patient and treating team must be free from all hazards including flame, electrical and chemical contact. Any hot fluid or smouldering or chemical-soaked clothes need to be removed, and all chemicals need to be washed away with copious amounts of water.

The second priority is to cool the burn with 'tap' water (12 - 18°) for 20 - 30 minutes. Ice or iced water may increase the depth of the burn.[7] Care must be taken not to induce hypothermia in larger burns – especially in children. Cooling the burn prevents the zone of coagulation spreading and can be effective up to 3 hours after the injury.

After the burn has been cooled it is covered with plastic wrap, gauze or a clean moist towel to reduce pain and wound contamination.

A space blanket or moisture-proof sheet is useful to reduce evaporative heat loss during transfer.

One of the principal aims of management is to determine which patients need referral to a specialist centre. Some determinants of this include airway problems, additional injuries, burn wound depth and extent and the age of the patient.

Evaluation by medical professionals

The ABCs of resuscitation with the principles of the primary and secondary survey need to be followed. Fire burns often have an inhalational and airway component. Hot fluid burns to the face may include oral or pharyngeal burns resulting in tissue swelling and airway compromise. Children are especially prone due to their narrower airway, and any mucosal swelling or fluid accumulation causes a comparatively larger reduction in airway diameter. In addition there is a high incidence of occult upper airway obstruction caused by enlarged adenoids and tonsils, laryngomalacia, and reactive airways in children. Intubation is preferred (with an uncuffed tube in children under 10 years) before airway closure rather than in the emergency setting once the airway has been lost. Stridor is a late sign.

Any bleeding wounds and concurrent fractures need to be addressed prior to the burn wound itself. Completion of the primary survey should result in a patient with a secured airway and restored circulatory volume.

If there is any doubt regarding assessment, resuscitation or management, a burns unit should be contacted telephonically for advice.

Assessment of burn depth

Children have a relatively thinner dermis, so for any given thermal insult the infant will sustain a deeper burn than the adult. Burns are clinically classified according to their depth, but most will not be homogeneous (Fig. 1).

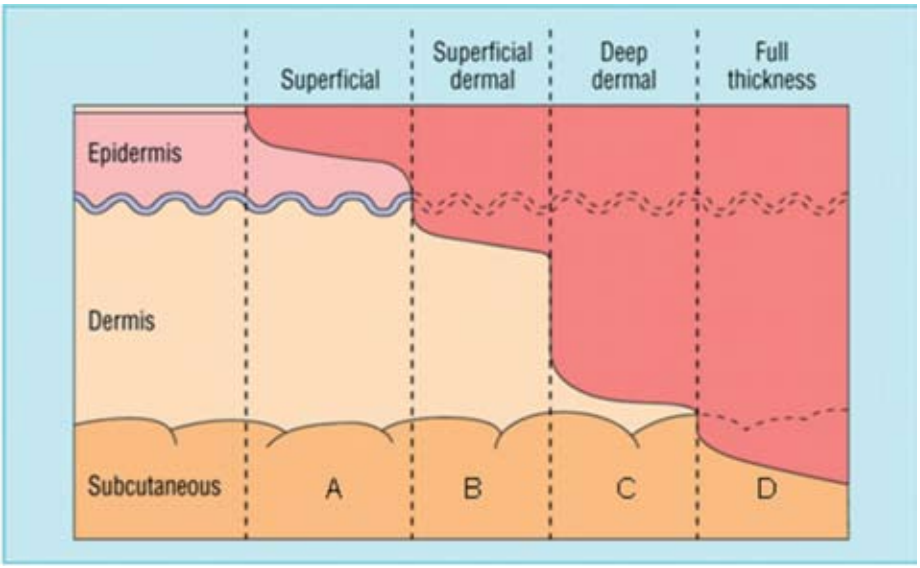

Fig. 1. Burn depth (adapted from Hettiaratchy S, et al.[12]*). Partial thickness: A = superficial (the burn affects the epidermis but not the dermis); B = superficial dermal (the burn extends into the upper layers of the dermis and is associated with blistering); C = deep dermal (the burn extends into the deeper layers of the dermis but not through the entire dermis). Full thickness: D = burns extend through all skin layers into the subcutaneous tissues.*

Assessment of depth, though difficult to the untrained eye, is important for planning treatment, as superficial burns will heal spontaneously while deep burns need surgical intervention (Table I). In some instances even the most experienced clinician will initially not be able to classify burn wound depth. A process of evolution of the wound occurs and in 3 - 4 post-burn days the depth can be more accurately established. These wounds are classified initially as 'indeterminate' depth.

It may be possible to treat partial-thickness burns in a general hospital, but all full-thickness burns exceeding 5% or those in special areas (hands, face, perineum) should be referred.

Body surface area involved

There are two commonly used methods to calculate the total body surface area (TBSA) involved:

Palmar surface: the surface area of the patient's hand (including fingers) is about 1% of total body surface area. This method is commonly used in small burns.

Rule of nines (Fig. 2): This is a good, quick way to estimate medium to large burns in patients older than 10 years. The body is divided into areas of 9%. It is not accurate in children due to their different body proportions. The child figure represents an infant up to 1 year. For every year thereafter the head decreases in relative size by approximately 1% and each leg gains 0.5%. The Lund and Browder charts can also be used for children.

The majority of childhood burns in SA are treated by non-specialists, with referrals to burns units being reserved for the more severe cases.

Table I. Characteristics of burn wounds at different depths

Depth	History	Aetiology	Sensation	Appearance	Healing
Superficial	Momentary exposure Lower temperatures for longer duration	Sunburn Hot metal Hot liquid	Painful	Red, moist, oedematous, soft, blanches and rapidly refills, superficial blisters	±7 days
Superficial dermal, deep dermal	Exposure of limited duration or lower temperature	Scalds, flash burn without contact, weak chemical	Painful and sensitive to air/temp changes	Mottled red to pale, blanches and refills slowly, blisters, oedema, serous exudate, moist	14 - 21 days
Full thickness	Long duration or exposure to high temperature	Immersion, flame, electrical, chemical	Painless to touch and pinprick, may hurt at deep pressure	No blanching, pale, white, charred, hard, dry, leathery, hair absent	No spontaneous healing

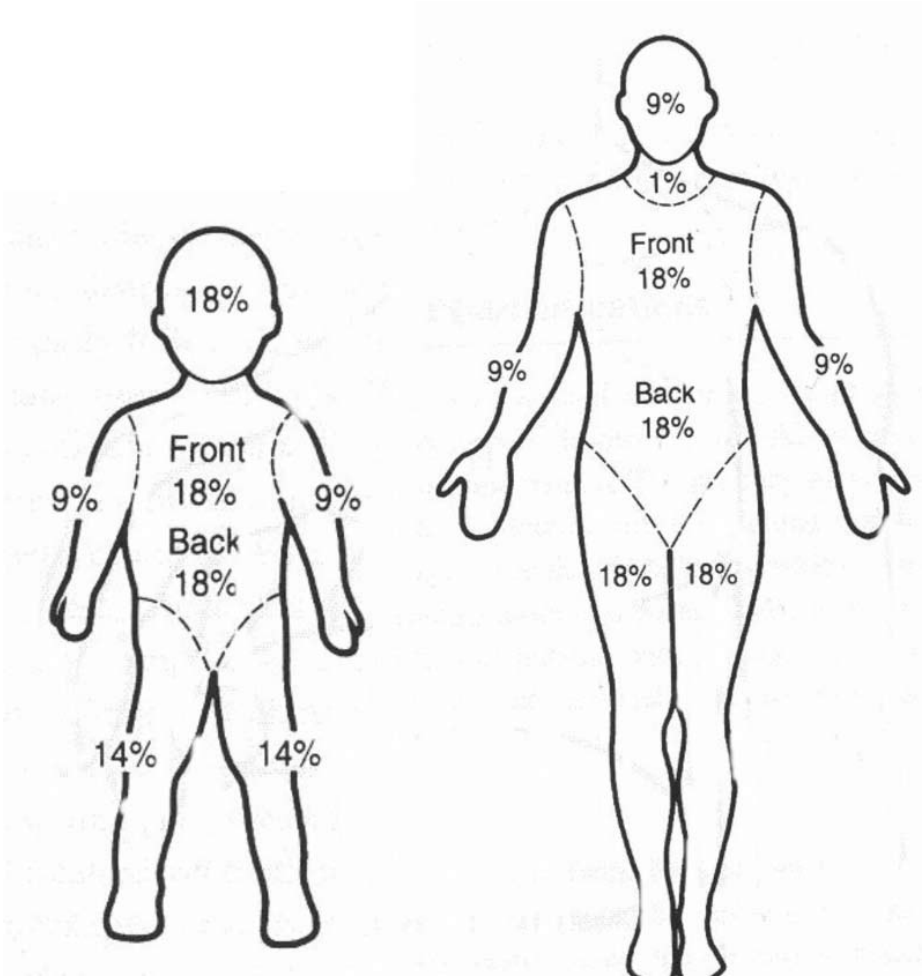

Fig. 2. Rule of nine in adult and child.

Table II. Suggested formulas for fluid calculation

Fluid calculation for the first 24 hours:

- 3 ml x (total burn surface area (%)) x (body weight (kg))
  50% given in first 8 hours
  50% given in next 16 hours
- Children receive maintenance fluid in addition, at hourly rate of
  4 ml/kg for first 10 kg of body weight *plus*
  2 ml/kg for second 10 kg of body weight *plus*
  1 ml/kg for >20 kg of body weight

Fluid calculation for the second 24 hours:

- 1.5 x (total burn surface area (%)) x (body weight (kg))
  Total divided by 24 for an hourly rate
- Maintenance fluid in addition as above

Fluid requirements

A burn is a dynamic wound. Its depth will change depending on the efficacy of resuscitation which, if required, should begin as early as possible, generally within 2 hours of the burn, and not be delayed until arrival in a definitive burns facility. Children under 2 with >5% and any patient with >10% BSA burns will require intravenous fluid therapy.

If the patient is shocked a bolus of Ringer's lactate at 20 ml/kg should be infused immediately and repeated if necessary. Fluid therapy thereafter consists of 2 components – replacement of ongoing losses and maintenance requirements. Formulas to calculate required fluids are shown in Table II. These resuscitation formulas should be used as a guide to fluid administration. Ultimately the fluid infused needs to be altered according to urine output, pulse rate, blood pressure, respiration and sensorium. There is little overt warning of imminent circulatory collapse in a child until late in the progression of the pathophysiology of shock. Urine output should be 0.5 - 1 ml/kg/hour in the adult and 1 - 1.5 ml/kg/hour in the child. The main aim of resuscitation is to maintain tissue perfusion to the zone of stasis and so prevent the burn deepening.

The Parkland formula calculates the amount of fluid required in the first 24 hours. The starting point for resuscitation is the time of injury, not the time of admission. Any fluid already given should be deducted from the calculated requirement.

Inhalational injuries require additional fluid. Children require maintenance fluid, with 5% dextrose in addition to resuscitation fluid. Use modified Ringer's lactate (Hartmann's solution) for ongoing losses, and paediatric maintenance fluid for maintenance.

Ice or iced water may increase the depth of the burn.

Referral criteria

Table III lists criteria for transfer to a burns unit. Prior to transfer all patients need an established airway, adequate intravenous access and fluid resuscitation in progress, burn wounds covered, preferably with sterile, waterproof dressing or melaleuca alternifolia hydrogel (Burnshield®), potential hypothermia addressed, and adequate analgesia in the form of an opiate. On transfer, make sure as much information as possible pertaining to the burn size distribution and depth is documented, preferably in diagrammatic form, and be sure to include written particulars of dressings, medications, and fluid management prescribed and given.

Escharotomies

Deep dermal or full-thickness burns are inelastic. Fluid resuscitation leads to burn wound oedema and increases in tissue pressure, which impair circulation. Circumferential full-thickness burns on a limb require escharotomy to enable adequate peripheral perfusion and to prevent limb loss. Deep circumferential burns to the chest limit chest excursion and impair ventilation and escharotomies need to be performed to allow chest expansion separate to abdominal wall movement (Fig. 3).[8] Any escharotomies required should ideally be performed prior to transfer, as those performed earlier tend to have an increased rate of limb salvage.

Analgesia

Burns are exceptionally painful. Analgesia not only diminishes the pain, but also serves to diminish the systemic inflammatory reaction by modulating the

Table III. Criteria for transfer to a burn centre

All burns in patients <1 year of age
1 - 2-year olds with >5% BSA burns
All ages >10% BSA burn
Full-thickness burns
Electrical burns
Chemical burns
Burns to face, flexures, perineum, hands, feet
Circumferential burns
Associated inhalational burn
Infected burns
Where child abuse is suspected
Concomitant trauma
Patients with pre-existing medical disorders
Where treatment requirements exceed the capabilities of the referring centre

sympathetic response and hence cytokine secretion. Analgesia should be tailored for the specific requirements, acute pain, procedural pain relief and chronic pain. In the acute setting, the following agents are suggested:

- morphine: 10 - 40 µg/kg/h infusion IVI
- tilidine HCl (Valoron®): 0.5 - 1 mg/kg/dose
- paracetamol: 20 mg/kg/dose.

One of the principal aims of management is to determine which patients need referral to a specialist centre.

Wound preparation

Ensure that the patient is stable and comfortable and complete wound cooling and washing if appropriate. Clothes and dressings should be removed and the area cleaned with a water-based disinfectant. Blisters larger than 2% BSA and loose skin should be removed while smaller blisters should be punctured.[9]

Wound covering

Patients with small superficial or partial-thickness wounds can be treated on an outpatient basis with a semi-permeable occlusive dressing which is left until healed, or a hydrocolloid dressing, and changed when indicated. Should these not be available, any of the agents in Table IV can be used, with more regular changes of dressings. These wounds should heal within 10 - 14 days.

The dressing used should:[10]

- create a moist environment to accelerate healing and reduce pain
- absorb excess exudate
- provide a barrier to the exterior to reduce infection
- fit to body contours
- be easy to apply.

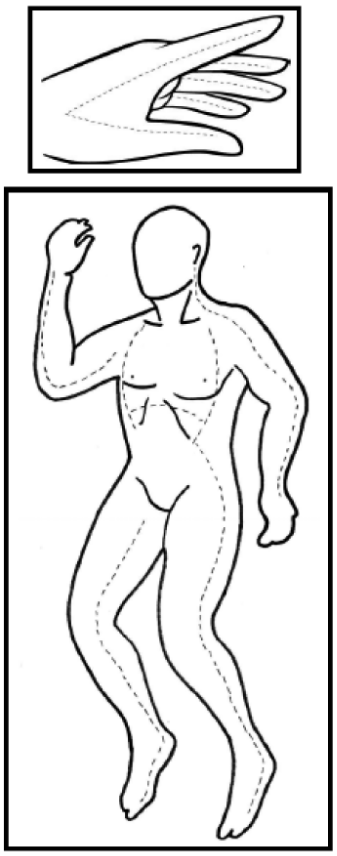

Fig. 3. Escharotomy sites.

Large or deep burns with any of the admission criteria listed in Table III require referral to a burns centre. A detailed description of surgical procedures is beyond the scope of this article, but

Table IV. Topical agents used to treat burns

Silver sulfadiazine (Flamazine®)
- excellent spectrum of activity
- low toxicity
- effective for 24 hours

Povidone-iodine (Betadine®)
- wide antibacterial spectrum
- inactivated by wound exudates
- half-life of 12 hours, needs to be applied twice daily

Mupirocin (Bactroban®)
- excellent broad-spectrum antimicrobial activity
- predominantly Gram-positive organisms and methicillin-resistant staphylococci (MRSA)
- ineffective against *Pseudomonas*
- apply daily

Chlorhexidine (Hibitane®)
- broad-spectrum antimicrobial action
- effective especially against *Pseudomonas*
- often combined with mupirocin to broaden the antibacterial spectrum
- change daily

Nanocrystalline silver (Acticoat®)
- liberates silver (AG°) at a concentration 10 times the MIC for more than 150 organisms
- apply topically
- remove every third to fourth day

involves combinations of decompression escharotomies if needed, tangential excision, fascial excision, delayed escharectomy and skin grafting.

Split skin grafts are usually meshed 1:1.5. Sheet grafts should be used where possible for cosmetically sensitive areas, as well as for hand burns. In larger burns, where there is limited donor site available, temporary closure can be achieved by donor allograft or a temporary synthetic skin substitute. Cadaver allograft can also be used over a split skin graft meshed 1:3. This covering provides a physiological and mechanical barrier while healing takes place. Allograft is usually rejected within 2 - 3 weeks.

Hot water burns in children, if not definitely full thickness, are usually treated expectantly for a period of 14 - 21 days. By adopting a conservative approach, the extent of grafting and blood transfusion is reduced by 66%. All burns not healed within 3 weeks should be grafted.

Feeding

Children's high metabolic rate and growth needs result in less tolerance to nutritional deprivation. Enteral feeding on day 1 decreases stress hormone release, improves nitrogen balance, maintains gut mucosal integrity, lowers the incidence of diarrhoea and decreases hospital stay.[11] Patients with >20% TBSA require aggressive nutritional support to meet the calorie and protein requirements from day 1 to optimise wound healing and prevent infection. Feeds are often administered via nasogastric or nasojejunal tube. Total parenteral nutrition is not advised due to associated infections and metabolic and immunological complications.

Physical and occupational therapy

Therapists involved in the burns team maintain joint mobility and apply and construct splints, which are crucial to the long-term functional outcome of a patient. Early splinting of involved flexures in combination with pressure garments post healing and continual goal-directed physiotherapy help to prevent joint contractures and minimise scarring that may limit rehabilitation.

Post-wound care

Healed burn wounds need to be regularly moisturised by any commercially available lotion or cream. Symptoms of itching should be treated by moisturisers and occasionally oral medication. Sunscreen is vital to prevent further damage as well as increased pigmentation. Hypertrophic scars as well as any late blistering need to be referred.

Rehabilitation

Rehabilitation is an ongoing process continuing well beyond initial wound

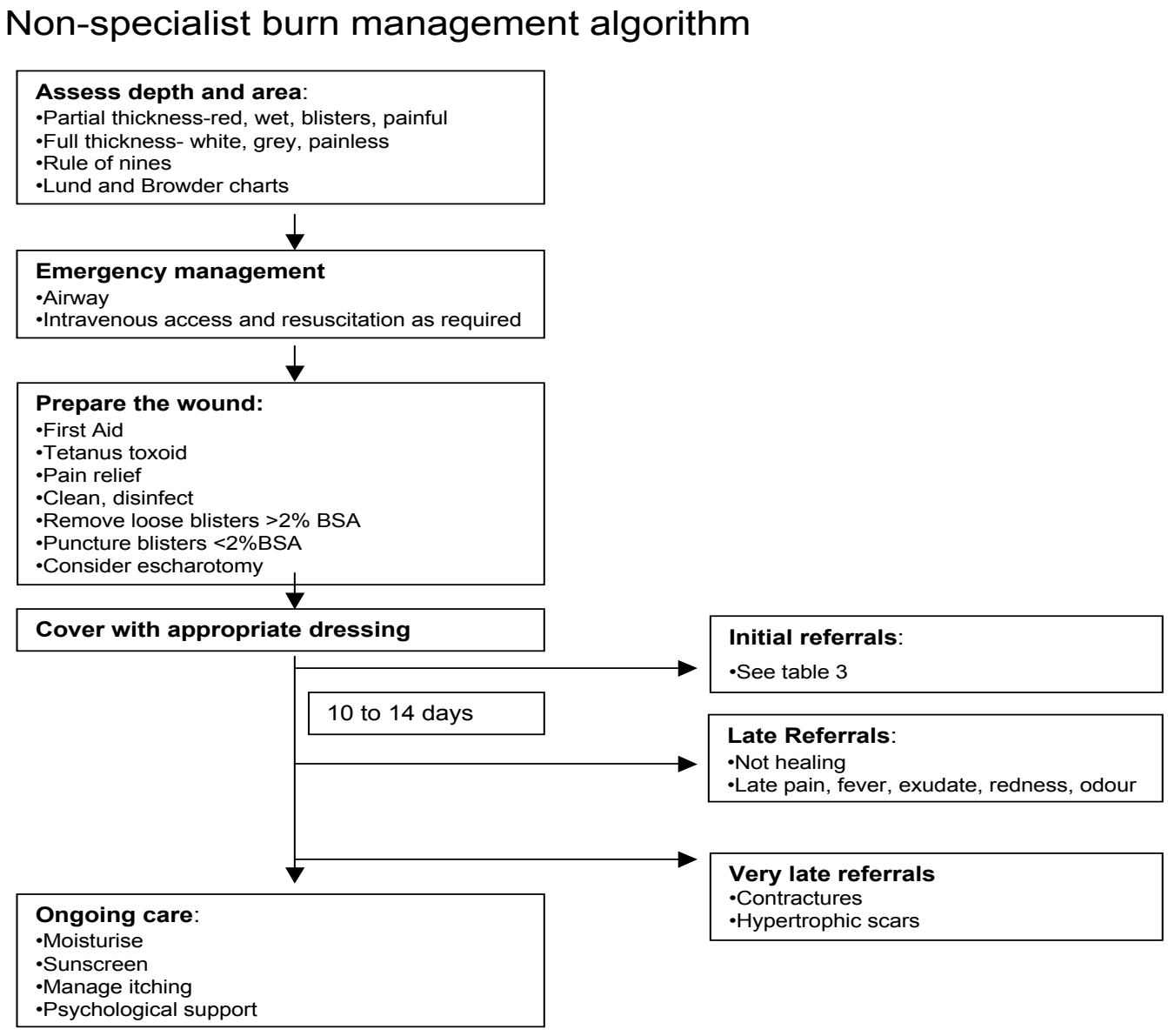

Fig. 4. Treatment algorithm for burns, adapted from Alsbjorn et al.[9]

closure, and involves a team of psychologists, physical and occupational therapists and reconstructive surgeons. Ultimately the goal is successful reintegration into society. The long-term emotional outcome of a paediatric burn is dependent on the whole family's emotional care. This emotional rehabilitation is essential and should start as soon as possible after the burn injury.

Conclusion

The management of burns in children and adults follows the same basic principles (Fig. 4). While smaller and more superficial burns can be adequately treated on an outpatient basis, the successful management of severe larger burns requires a dedicated multi-disciplinary team within the framework of a dedicated burns unit. If the principles of early resuscitation, adequate nutrition, maximum tissue preservation, early wound coverage, psychological and social support are adhered to there will ultimately be a successful outcome for patients with these potentially devastating injuries.

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In a nutshell

- Burns in children are often more severe than in adults.
- They are often preventable.
- The management of burns in children and adults follows the same basic principles.
- Small, superficial burns can be managed on an outpatient basis.
- Large, extensive burns require management by a dedicated burn unit.
- Children under 2 with >5% and any patient with >10% BSA burns will require intravenous fluid therapy.
- Adequate analgesia is essential.
- Children require enteral feeding from day 1 because of their high nutritional needs.
- Rehabilitation is an ongoing process, and involves a team of psychologists, physical and occupational therapists and reconstructive surgeons.

Single Suture

Skin cells deliver gene therapy

Patches of synthetic skin could deliver gene therapies to patients without using injections. A team led by John Vogel at the National Institutes of Health in Bethesda, Maryland, cultured fibroblasts and keratinocytes and introduced the gene for atrionatriuretic peptide into their genomes. This compound is released naturally by cells in the heart. It reduces blood pressure by dilating blood vessels and lowering blood volume. The team mixed the cells into a jelly-like matrix and applied the grafts to mice, which caused the animals' blood pressure to drop.

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