Burns in children

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Key points

Burns are a common cause of injury in children, who may subsequently require multiple operative procedures.

Initial management is directed towards the ABC of basic life support and an assessment of the site, depth, and extent of the burn injury.

Anaesthetists may be involved by providing resuscitation, analgesia, sedation, anaesthesia, or intensive care.

Major burns in children are rare and the chances of survival are increasing.

Minor burns can cause major disability and morbidity.

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Burns make a significant contribution to paediatric hospital admissions; in 1 year, around 50,000 such patients attended accident and emergency departments and of these approximately 6400 attend a burns unit.[1] Most burns occur at home, usually in the kitchen and bathroom. The aetiology changes with age; younger children suffer more scalds, older children more flame burns.

Outwardly, burns treatment for children is similar to that for adults, but there are significant physical, psychological, and social differences. Paediatric surgical services are no longer an appendage to those for adults, and the burns team must be able to manage these different needs. A given injury inflicts a greater burn on a child. Children have thinner skin, lose proportionately more fluid, are more prone to hypothermia, and mount a greater systemic inflammatory response. Their youthfulness does make possible early, aggressive surgery and they demonstrate extraordinary ability to adapt to injury and survive extensive burns that are fatal to most adults. The focus of this article is the immediate and day-to-day management of children requiring admission to hospital for burns. The prolonged management of massive burns and inhalation injury is beyond the scope of this paper.

Local pathophysiology

Burns are usually caused by contact with a source of heat; in infants and children, temperatures as low as 40°C can rapidly inflict a significant injury. At the area of contact, there is coagulation of tissues surrounded by capillary stasis, aggravating the extent of cell injury by hypoxaemia. The depth to which dermal elements are destroyed affects their ability to regenerate from deeper elements; destruction of all dermal cells, including sweat glands and hair follicles, results in permanent loss of skin.

Classification

Although not always easy to assess in the first few hours, the site, depth, and extent of burns are critical factors in management, healing, and outcome. Essentially, specialist services are required for full-thickness burns exceeding 5% of body surface area (BSA), partial thickness exceeding 10% inhalation burns or burns to the airway, face, hands, feet, and perineum. Any concern of non-accidental injury or lack of care at home for the child necessitates admission to hospital.

Depth of burn

The depth of a burn is usually judged clinically; burns in children may have a different appearance to that in adults. The true depth is not immediately obvious and burns are rarely homogenous throughout. They may be:

Superficial: limited to the epidermis, resulting in a painful erythematous burn rarely requiring hospital treatment, usually healing within 5 days. These burns are not included in estimates for fluid resuscitation.
Partial thickness: these are significant burns, counted in burn size estimates. They are subclassified into superficial and deep, although the distinction is often difficult. Superficial is similar to the above, but damage extends to the dermis, causing blistering. Adequate living dermal elements remain to allow healing by re-epithelialization within 10 days. Deeper partial thickness burns are a management quandary: some heal without surgery and some require immediate excision and grafting to achieve healing within a suitable time frame.
Full thickness: the dermis is destroyed, leaving a well-demarcated burn, which may initially appear dark red, later dull yellow. They are insensate and will only heal with skin grafting.
Burns to underlying structures: below the dermis, burns can destroy muscle, periosteum, and bone; such injuries are covered by tissue with its own blood supply, for example, a free tissue transfer.

Extent of burn

To aid estimation of the extent of burns, separate paediatric charts are used which take

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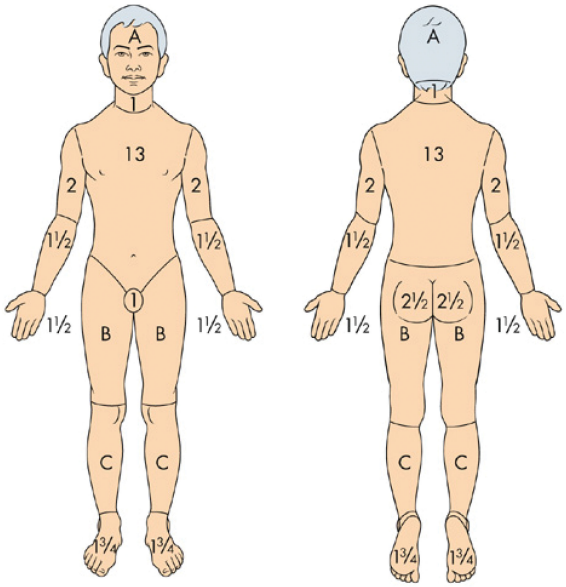

Area in diagram	Age in years 0	1	5	10	15
A = ½ of head	9½	8½	6½	5½	4½
B = ½ of one thigh	2¾	3¼	4	4¼	4¼
C = ½ of one lower leg	2½	2½	2¾	3	3¼

Fig. 1 Chart for calculation of percentage of BSA burn in children.[2]

account of the varying proportions of body surface area (BSA), compared with adults (Fig. 1).[2]

General pathophysiology

According to the depth and extent of burns, dermal injury initiates a stress response with release of inflammatory mediators, pyrexia, catabolism, hyperglycaemia, increased capillary permeability, and a progressively hyperdynamic circulation. Catabolism can be marked, even with small burns, and close attention to nutritional intake is a management priority. The enteral route is the best, with early resort to nasogastric feeding when input cannot be adequately maintained. The hyperglycaemic response in larger burns is such that insulin can be required to control blood sugar, this intervention may also inhibit structural protein breakdown and promote healing. Other measures to control physiological changes such as growth hormone, adrenergic receptor blockade, or anabolic steroids are difficult to evaluate across the broad spectrum of burns; their use in children remains contentious.[3]

The anaesthetist's role

The anaesthetist's roles include resuscitation, analgesia, sedation, anaesthesia, and intensive care. Some considerations in the overall care of these patients are:

- Adequate, early fluid resuscitation to maintain organ perfusion and control the extent of the burn injury itself.
- Children suffer higher evaporative heat and fluid losses.
- Analogous to the benefit of early fixation of fractures, excision, and cover of non-viable skin reduces morbidity, mortality, and the extent of inflammatory response.[4]
- Adequate, pain management is an obligation and may help to alleviate psychological sequelae.

Resuscitation and initial assessment

Initial management of burns includes the same concerns towards life-support as any trauma patient. The 'ABC' approach organizes diagnosis and treatment and can incorporate the essentials identified above: namely site, depth, and extent. Background history should include events leading up to the injury, other injuries, conscious state, smoke inhalation or thermal injury of the upper airway, medical problems, vaccination status, and allergies. Burn centres distribute their own proforma to aid effective discussion, documentation, and initial management of referrals. All burns require immediate cooling to halt the burning process; prolonged cooling of burns >15% BSA risks hypothermia in children. Once described, the burn should be covered with a sterile non-adherent dressing. Nearly all burns are extremely painful, potent analgesia should be made available early in the management and titration of opioids to effect is the best approach.

Airway

Thermal and chemical assault to the airway causes local oedema, the effects of fluid resuscitation worsen this and the small diameter airway of the child is vulnerable to any narrowing. If in doubt, an uncut tracheal tube should be sited sooner rather than too late.

Breathing

Adequate ventilation and oxygenation must be ensured. Thoracic and abdominal escharotomy will relieve impairment of thoracic and diaphragmatic excursion. All patients must be given oxygen and pulse oximetry continually monitored. Smoke inhalation and carbon monoxide poisoning necessitate high inspired oxygen concentrations. The effects of circulating inflammatory mediators can reduce lung compliance in the absence of overt inhalation injury.

Circulation

There is loss of circulating volume into the burnt and unburnt areas. Oral replacement is acceptable for burns up to 10% BSA in children; above this there will be worsening general capillary leak necessitating prompt i.v. fluid resuscitation by formula. Although in common use, those based on body weight are likely to be inaccurate for children, in whom there is not a linear relationship between weight and BSA. Whatever is used, the volume dictated is an estimate, usually for the first 24 h and maintenance requirements must be added to this amount (Table 1). Burns oedema is maximal in the first 18–30 h. Thereafter, fluid needs are increasingly judged by endpoints such as capillary refill, mental state, and urine output. Glucose and electrolytes must be monitored: a few

Table 1 Fluid resuscitation for burns in children

Parkland formula
For the first 24 h after the burn, give 4 ml kg^{-1} per % BSA burn Hartmann's solution, half of this volume in 8 h post-burn, the other half in the next 16 h.
Maintenance
Use, for example, Hartmann's solution: 4 ml kg^{-1} h^{-1} for the first 10 kg body weight 2 ml kg^{-1} h^{-1} for the next 10 kg body weight 1 ml kg^{-1} h^{-1} for each kg body weight above 20 kg (Glucose containing i.v. fluids are not generally indicated though may be required for infants when early feeding cannot be established. The composition of resuscitation and maintenance fluids is the subject of current debate).
Blood samples
Baseline samples to monitor FBC and U + E, group and save or cross-match for early surgery or escharotomies. Check U + E daily for any child on i.v. fluid replacement.
Urine output
Catheterize early and monitor fastidiously, aim for 1 ml kg^{-1} h^{-1}.

children need i.v. glucose; all need early enteral feeding. The crystalloid/colloid controversy rages in burn care. Neither has been shown to be superior for children. Judicious use of both and careful observation of fluid and electrolyte balance are more important than which regimen is used.[5, 6]

Initial assessment of burn

This should be carried out using the tools described previously. Photography is useful in recording the extent and depth of the burn. Areas of partial and full thickness burn should be mapped and the total percentage of BSA burns calculated.

This photo (reproduced with parental consent) illustrates much that is typical of paediatric burns. Children of this age do not have a well developed withdrawal reflex and increase the extent of injury by maintaining contact. This skin of the palm, as elsewhere in a two year old, is thinner than that of adults and the result has been a full thickness burn in a critical area. The photo shows excellent take of meshed split skin graft from the buttock. The child is having the first change of dressing as a day case under general anaesthesia. To retain function of the hand, physiotherapy and creation of a hand splint were carried out under the same anaesthetic and will be an important part of future management. By this stage of treatment, pain was well controlled on regular paracetamol and NSAID.

General anaesthesia and perioperative care

Those problems alluded to in resuscitation remain pertinent in successive surgeries; before starting the anaesthetic, it is always wise to ascertain the surgeon's plan. There are no agent(s) of proven superiority for burns anaesthesia. Analgesia is a priority, and rapidly eliminated anaesthetic agents such as desflurane allow early return to normal activity, notably feeding. The airway must be adequately secured almost invariably by tracheal intubation, with positive pressure ventilation. Perioperative i.v. fluid administration is the subject of a recent editorial, and both type and volume for any surgery is contentious.[7] Notwithstanding this, some estimate has to be made of preoperative losses, maintenance and evaporative loss, using current guidelines. High concentrations of sodium chloride or dextrose should probably be avoided, Hartmann's solution is better. Burns, and to a lesser extent donor sites, can bleed profusely and steadily; tourniquets and topical or infiltrated epinephrine help, as will treatment of acquired coagulopathy. Hawk-like observation of swabs, wounds, suction bottle, and dressings is mandatory.

I.V. induction is smoother, but if airway control is a concern or venous access difficult, inhalation induction is used. The size of cannula should be chosen with the potential for blood and blood product transfusion in mind. As with the tracheal tube, i.v. lines cannot be too secure. Multiple surgical sites require frequent changes in position and exposure necessitates active warming, including raising theatre temperature, heated mattresses, overhead heaters, and covering exposed areas wherever possible. Monitoring can be difficult with lack of sites for probes, cuffs, and electrodes. Oximeter ear probes work well in many sites, and electrodes can be sited away from the chest or attached to surgical clips. Urinary catheterization is an invaluable aid to fluid balance and a useful source of central temperature monitoring.

The effects of some drugs are altered by burns. An increase in the number of acetylcholine receptors on skeletal muscle causes resistance to non-depolarizing neuromuscular blocking agents and potentially fatal hyperkalaemia after succinylcholine, which should therefore be avoided. Changes in plasma proteins may also affect drug actions; essentially, all drugs should be given in accordance with their measured effects rather than by recommended dose.

Analgesia for burns

Significant postoperative pain should always be anticipated and treated with multimodal analgesia combining, where possible, paracetamol, non-steroidal anti-inflammatory drugs (NSAIDs),

local anaesthesia and opioids. Clear guidelines and established protocols advocating measurement of pain with titration of analgesia have been shown to improve management.[8] Occasionally, analgesia can be provided by regional blocks, but the site of burn and local or systemic infection limits this practice. Local anaesthetic solution can be applied directly to skin donor sites.

In general, pain from burns can be acute, background, procedure-related, and develop into chronic pain. As the burn heals, other sources of discomfort such as itching and inability to sweat are additional, or may substitute for the initial pain. Burns produce pain by direct injury of nerve endings and specialized receptors in the skin, with both primary and secondary (outside the zone of injury) hyperalgesia. Beyond simple analgesics, opioids are the mainstay. They are potent, effective, easy to administer and can be titrated to effect; their acute side-effects, such as respiratory depression, are well known. Other unwanted side-effects, tolerance, dependence, and hyperalgesia emerge, particularly with the large doses required.

NSAIDs act to reduce pain and inflammation and may modify the systemic inflammatory response; side-effects such as renal impairment can limit their use. The more selective COX-2 antagonists have not been adequately evaluated in children with burns, but may reduce the extent of hyperalgesia.[8] Ketamine is widely used in burns care, though not usually as a primary analgesic because of the high incidence of agitation and delirium. Used in lower doses, a non-racemic formulation, and co-administered with benzodiazepines or opioids may allow a wider role for this drug. Novel drugs for use with children include antidepressants and anticonvulsants; the role of gabapentin in particular seems to be expanding into both acute and chronic pain management, possibly helping to prevent progression of the former to the latter.

Psychological management must not be overlooked. Children do not see pain and illness in the same way as adults, and their psychological responses differ. Techniques such as play therapy, hypnosis, and distraction are all valuable and add to the benefits of drug treatment without increasing the burden of side-effects.

Sedation/analgesia

Dressing changes, with or without showering or bathing, are a frequent accompaniment to the early phase of burns treatment. Where possible, they are conducted without general anaesthesia, reducing risk, infrastructure need, and interruption to feeding and home life. No single recipe exists for success; the various approaches taken are likely to be honed to local requirements and work well in the hands of those used to them. The exact agent and mode of administration is influenced by available staff and facilities.

There is considerable experience in the use of nurse-led day-stay techniques with primarily oral medication, such as opioids[9] or ketamine.[10] With poor nutritional status, repeated use of nitrous oxide should be avoided. Any care pathway must have flexibility, with general anaesthesia available for some cases; adequate debridement and dressing with general anaesthesia is better than several inadequate attempts without it.

Medical complications of burns

Major burn complications are unusual outside the intensive care setting. Renal failure usually follows inadequate resuscitation from large burns, although it can occur with a small electrical burn and underlying muscle damage. The most common complication is failure or delay in healing of the burn or donor site, which may relate to local infection, underlying catabolism, or both. Infection can occur in the wound itself, donor sites, or in association with invasive vascular lines or catheters.[11] Toxic shock syndrome (TSS) is a rare but serious complication mostly seen in children. It is caused by overwhelming infection by toxin-producing bacteria, usually *Staphylococcus aureus*, and should not be confused with scalded skin syndrome, a cutaneous manifestation of staphylococcal infection, not related to burn injury as the name may suggest. TSS is difficult to diagnose and often presents early in treatment of small burns which may not appear infected. Features include:

- Pyrexia $>39^{\circ}C$,
- Rash,
- Shock,
- Diarrhoea, vomiting, or both,
- Irritability, and
- Leucopoenia.

Treatment includes immediate hospitalization, fluid resuscitation, and i.v. antibiotics.[12]

Child protection

Child abuse by thermal injury is uncommon; representing around 2% of paediatric burns admissions. Neglect leading to burns is more common and may often be overlooked.[13] Concerns about the level of care available to the child or aetiology of the burn should lead to admission. Burn injuries to children impose a huge emotional burden on the family, with feelings of guilt, anger, and worry for the future; false implications of neglect or abuse add to this. Any healthcare worker, including the anaesthetist, must be aware of their Trust's policy for child protection and have an obligation to document and report concerns to a responsible individual. Trusts should have guidelines in place to ensure the safety of all children admitted to hospital, monitor injured children known to be at risk, and identify concerns arising from any injury or pattern of such. As a result of high profile cases, the regulations governing child protection are evolving with an increased emphasis on widespread responsibility and inter-agency communication. Maintenance of professional skills should include knowledge of these processes.

The future

Most burns in children are preventable; this will continue to be addressed by both raising individual awareness of hazards and extending legislation. Statutory regulation provides invaluable protection, particularly to those less able to fend for themselves. Example of this range from fire and smoke resistance inherent in

building construction to controls over the temperature of water exiting domestic hot water taps. Gains in the surgical management of burns result from improved diagnosis and treatment. Laser Doppler studies of blood flow within the burn allow more accurate early discrimination of burn depth, identifying those burns that heal rapidly without surgery and those needing an early surgical approach. Traditional conservative treatment entails frequent changes of dressing; novel biological dressings such as Biobrane, a layered nylon collagen and silicone sheet, are applied directly to the burn and shed once dermis is regenerated beneath. Extensive excision of more serious burns outpaces availability of autologous skin. To allow surgery to proceed, alternatives including cadaveric allograft, porcine xenograft or bovine collagen matrix provide temporary cover and may improve conditions for subsequent grafting. Another option particularly suitable for paediatric scalds is to apply the patient's own keratinocytes after their *in vitro* culture.

Advances in treatment of major burns, early debridement, better intensive care, and management of inhalation injury are responsible for a marked improvement in survival from more severe burns. Developments in anaesthesia has allowed these changes, and opportunities exist to take forward our practice in line with surgical developments across the spectrum of paediatric burns.

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Please see multiple choice questions 5–8