Chapter

40

Burns in Children

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Introduction

Burns are a common injury throughout the world and are mostly preventable. A moment of inattention by a guardian, or an older child playing with fire, can lead to a lifetime of burn care. Children have a higher incidence of burns than adults, although most burns are small. Burns over 10% require formal fluid resuscitation to mitigate the effects of systemic oedema and burn shock. Definitive treatment involves non-operative techniques, such as application of dressings or, for larger or deeper injuries, operations to debride the wound and apply skin grafts. Each burn generates background, breakthrough and procedural pain that must be managed effectively. Small burns may be complicated by infection, larger burns by multiple organ failure. The outcomes are generally good, and children can survive and thrive even after very large injuries. Anaesthetists are involved in all aspects of burn care once a child reaches hospital, and they are an essential part of the multidisciplinary burn care team. The aim of this team is to deliver faster healing and better pain control and to prevent complications. This chapter will describe current burn care for children in the United Kingdom.

Definition and Epidemiology

A 'burn' is defined as an area of coagulative necrosis of tissue. Burns involve the destruction of one or more layers of the skin and/or subdermal structures. Burns are a very common injury in all age groups; fortunately, large burns requiring hospital admission are not. In 2019, 7,061 children with burns presented to specialist burn services in the United Kingdom, according to the Children's Burns Trust, UK.

As with many victims of trauma, patients with significant burn injury are over-represented in areas of deprivation, and there are often coexisting social and psychological factors at play. This is particularly important in children, where it is estimated around 10% of admissions have safeguarding concerns.

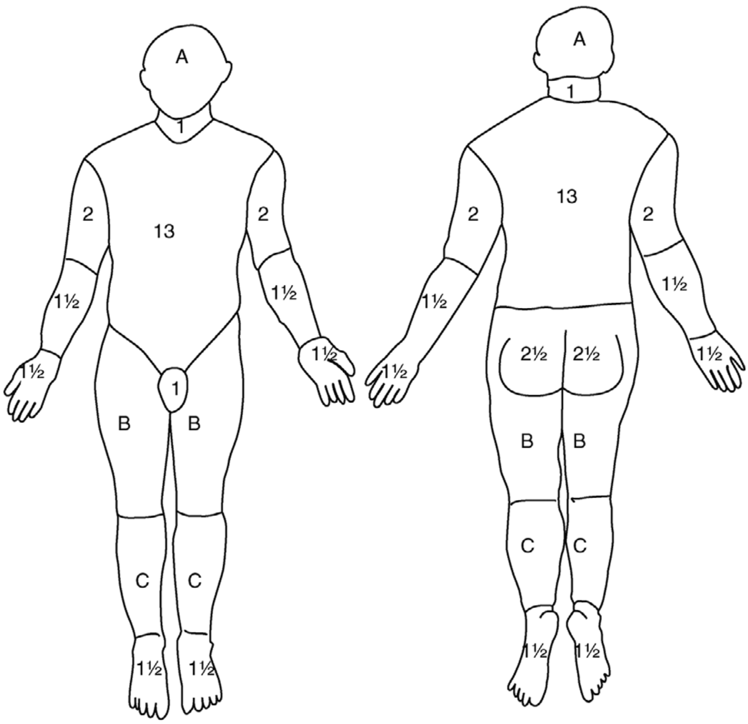
Classification and Aetiology

Burns are classified in terms of size (percentage of body surface area), depth and aetiology.

Accurate estimation of burn size is important to guide fluid resuscitation and prognosis. Children are particularly difficult to assess due to their changing body surface area proportions as they grow. Useful tools include the Lund and Browder chart for estimating larger burns (Figure 40.1) or the 'rule of one' for smaller burns. This uses the patient's palm area, which stays relatively constant at 1% of total body surface area (TBSA) throughout life. Novel smartphone apps are available for this use, some being validated for research. Burn erythema is *not* included in size estimations.

Depth estimation is used to guide clinical treatment and prognosis. This is a 'dynamic' process. Superficial burns may convert to deeper ones later, particularly if resuscitation is inadequate or wound infection happens. The degree of burn depth injury is a function of thickness of skin (infants have thin skin) and the 'dose' of energy imparted by the burn incident. The dose of energy is in turn a function of temperature and time exposed. An adult would need their skin exposed to a temperature of 70°C for only one second to sustain a deep burn. The energy dose resulting in a deep burn in an infant would be significantly less than this. Since 2010, all areas of the United Kingdom are required to limit bathing outlet temperatures in new homes to 48°C, following a successful campaign by the British Burn Association and Children's Burns Trust.

Burn depth is generally estimated according to the wound appearance (Figure 40.2). Laser



Area	Age					
	<1	1	5	10	15	Adult
A - ½ of head	9½	8½	6½	5½	4½	3½
B - ½ of one thigh	2¾	3¼	4	4½	4½	9¾
C - ½ of one leg	2½	2½	2¾	3	3¼	3½

Depth of burn		
	Superficial	Deep
	Shade on figure	*Diagonal lines on figure*
Region	%	%
Head		
Neck		
Anterior trunk		
Posterior trunk		
Right arm		
Left arm		
Buttocks		
Genitalia		
Right leg		
Left leg		
Total		

Figure 40.1 Lund and Browder chart for estimating the size of burn. The numbers on the figure represent percentage of total body surface area. The letters reflect age-specific areas (see the associated table). The Depth of Burn table allows differentiation between superficial and deep burns.

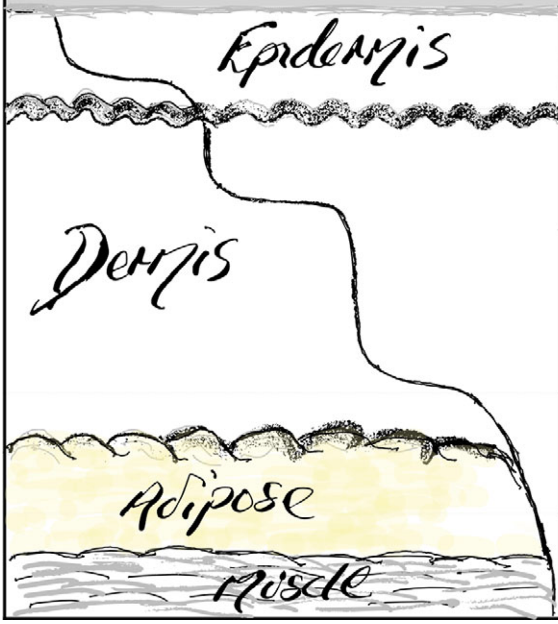
doppler technology, which measures dermal blood flow, can also be used if visual estimation of burn depth is equivocal. Generally, the deeper the burn, the longer the healing time and the higher the morbidity.

In the United Kingdom, the aetiology of most paediatric burns are thermal scald injuries. A common presentation to a specialist burns service is the '10% scald in a 10-month, 10 kg toddler' resulting from spilt hot drinks. Scalds from unprotected cooking liquids at ground level are common in the developing world.

The six most common causes of burns or skin loss presenting to specialist secondary burn services are:

- Thermal (scald, flame, contact, cold)
- Electrical injury
- Chemical (acid/alkali) injury
- Radiation
- Friction
- Medical skin loss (toxic epidermal necrolysis, staphylococcal scalded skin syndrome)

These all have differences in terms of clinical course and treatment.



Depth of burn	Appearance, signs & symptoms	Expected recovery time with no intervention
	Superficial Erythema – blanches to touch. Dry & non-blistering. Painful.	**Not included in burn size calculation.** 3–4 days.
	Superficial Dermal Pink – blanches to touch & brisk capillary refill. Wet & blistering. Very Painful.	Heals in around 7–14 days with dressings. Scarring unlikely.
	Deep Dermal Darker red – mixed capillary staining. Sluggish blanching to touch (if any) and sluggish capillary refill. Painful but less than more superficial wounds.	Heals > 21 days. Scarring likely. Often requires excision and skin graft.
	Full Thickness Tough white/grey eschar. No blanching to touch. Anaesthetic but 'dull' pain can still be present.	Will not heal without surgical intervention.
	Subdermal Involving muscles & bone. As per full thickness wound. Evidence of myoglobinuria.	Will not heal without surgical intervention.

Figure 40.2 Depth of burn – diagnostic features and clinical course of healing.

Depth of Burn-Diagnostic Features and Clinical Course of Healing: Pathophysiology of Burn Injury

The skin is the largest organ system in the human body and is involved in the protective and immunological response to infection as well as many other physiological processes. Damage from burn results in the release of pro-inflammatory molecules (cytokines, chemokines, etc.), causing a local inflammatory response and, in the case of larger burns, a systemic inflammatory response involving non-burned tissues. The degree of the systemic response tends to be proportional to burn size and depth; however, there is notable interindividual variation. In larger burns, there is a widespread marked increase in microvascular permeability, leading to oedema and intravascular volume depletion. Careful fluid replacement is required to maintain vital organ perfusion and minimise burn depth conversion whilst minimising oedema. The acute systemic response tends to be at its peak around four hours after the burn and tails off 36–48 hours after injury. Hypovolaemia and hypotension are *not* generally a feature immediately following an isolated burn injury – other possible causes should be investigated.

A compensatory anti-inflammatory response and hypermetabolic syndrome often occurs 48–72 hours post-injury, resulting in an immune dysfunction, raised basal metabolic rate and hyperdynamic circulation for some 18 months after large burns.

Inhalation Injury

Smoke inhalation is common when exposed to fires occurring in enclosed spaces, such as in housefires, and is the leading cause of mortality in these situations. Smoke is composed of soot particles and chemicals, both inorganic and organic, which cause direct damage to the airways. In addition, systemic toxins such as carbon monoxide and hydrogen cyanide are produced from the burning of materials in a relatively hypoxic atmosphere. The fractional inspired oxygen (FiO_2) in housefires is estimated to be around 0.12.

Smoke inhalation tends to cause thermal injury above the glottis, leading to oedema and threatening the patency of the airway. This swelling often gets worse with time and after formal fluid resuscitation has started. Below the glottis, chemicals can cause airway inflammation, bronchospasm, epithelial damage, pulmonary oedema and acute pulmonary hypertension, leading to an acute respiratory distress syndrome.

The carbon monoxide molecule has a very high affinity for haemoglobin and myoglobin. It causes a 'left shift' in the haemoglobin oxygen dissociation curve leading to tissue hypoxia. Systemic effects are experienced at haemoglobin carbon monoxide (HbCO) saturation levels over 15%. Over 50%, there is a very high mortality risk. Specific treatment involves the administration of supplemental oxygen therapy at high concentration until the HbCO is under 10%. At the time of writing, routine use of hyperbaric oxygen therapy is not recommended for acute carbon monoxide poisoning. Standard pulse oximeters do not specifically detect carboxyhaemoglobin, and significant poisoning can occur with normal oxygen saturation (SpO_2) readings. If poisoning is suspected, an arterial blood gas sample should be obtained to confirm this.

Hydrogen cyanide is released from burning synthetic materials often contained in furniture. It is a potent mitochondrial toxin that interferes with aerobic metabolism and leads to a profound lactic acidaemia and dysfunction of organ systems with high oxygen requirements. The brain and heart are often affected, presenting as unconsciousness and an early shock state respectively. In addition to supportive measures, specific antidotes should be given as early as possible (preferably pre-hospital), particularly if any of the aforementioned features are present. A commonly used antidote in the United Kingdom is high-dose intravenous hydroxocobalamin, such as Cyanokit®, at 70 mg kg^{-1} (a maximum of 5 g) over 15 minutes. A second dose can be given depending on severity of poisoning and stability.

Referral Criteria

Children, particularly infants, can become unwell, even following small burns. There are nationally and locally agreed guidelines governing the referral of patients to specialist burns services.

The UK national burn care referral guidance of 2012 has the following minimum thresholds for referral to specialist burns services:

- *All* burns over 2% TBSA.
- *All* full thickness burns.
- *All* circumferential burns.
- Any burn not healed in two weeks.
- Any burn with a suspicion of non-accidental injury should be referred to a burn unit/centre for expert assessment within 24 hours.

In addition, the following factors should prompt a discussion with a consultant in a specialised burn care service and consideration given to referral:

- All burns to hands, feet, face, perineum or genitalia.
- Any chemical, electrical or friction burn.
- Any cold injury.
- Any unwell/febrile child with a burn.
- Any concerns regarding burn injuries and comorbidities that may affect treatment or healing of the burn.
- If there is any suspicion of toxic shock syndrome (TSS), then refer early.

Management of Burn Injury in Children

The management of burn injury in children can conveniently be classified into:

- Emergency burn care and resuscitation
- Acute burn care (including critical care, surgery and rehabilitation)
- Post-burn reconstruction

Anaesthetists are integral to all aspects of management as part of the wider multidisciplinary team.

Emergency Burn Care and Resuscitation

Pre-hospital first aid and extraction should involve a 'safe approach', particularly at house fires or if an electrical injury is suspected. The burning process should be stopped as soon as possible (the stop-drop-roll campaign describes actions to take if clothes catch fire).

The benefits from cooling a burn wound with clean cool water are described up to three hours following injury by arresting damaging enzymatic processes. Cooling should be carried out using water under 20°C for at least 20 minutes following removal of clothing (unless these have melted on to the wound). Care needs to be taken to avoid hypothermia with large burns.

Emergency care and initial assessment of large burns are best carried out in an emergency department or major trauma centre prior to transfer to the burn service. Burns are a classic 'distracting' injury. To avoid missing coexisting injuries, a careful systematic assessment of the patient should be carried out according to established trauma principles described in previous chapters.

The history should be carefully tailored to alert personnel to the possibility of coexisting injury (e.g. housefire, road traffic accident, blast, electrical injury, fall/jump). However, most burn injuries presenting to hospital are isolated.

Burn-Related Aspects to the Primary Survey

Airway and Cervical Spine Control

- History: fire in an enclosed space, trapped casualties, extricated unconscious, presence of explosion, other fatalities involved.
- Signs: intra-oral burns and soot present, deep peri-oral or neck burns, facial/neck oedema
- Symptoms: voice changes, stridor, dysphagia, tachypnoea or respiratory distress

If any of these features is present, there should be a low index of suspicion for significant inhalation injury and an ensuing threatened airway. Consideration should be given to securing the airway *early* with a cuffed and uncut tracheal tube.

> Note: it is very unusual for a child with a facial- or upper-body scald injury to require intubation to secure the airway. In the rare cases when this is required, there is often evidence of boiling fluid ingestion (intra-oral scalding) or deep burn to the front of the neck resulting in direct transmission of heat, damaging the glottic structures underneath.

If there is a history of a significant exposure to smoke, particularly in an enclosed environment and evidence of tissue hypoxia (high lactate) or early organ dysfunction (e.g. shock, unconsciousness), then consideration should be given to the possibility of systemic poisoning with carbon monoxide and/or hydrogen cyanide. Specific treatment should be given as previously described. There is no rapid turnover blood test to diagnose cyanide poisoning, and therefore clinical and biochemical surrogates are used to make the diagnosis.

Breathing and Ventilation

Extensive full thickness burns to the anterior trunk may form a restrictive eschar (tight coagulated dermis) impeding ventilation. Releasing escharotomies can improve matters; however, these need to be adequate and carefully done under anaesthetic to avoid damage to underlying structures. Cutting diathermy should always be used, as catastrophic bleeding can occur.

Circulation and Haemorrhage Control

Shock Due to a Cutaneous Burn Does Not Occur Immediately

If a child has evidence of shock early in presentation, then alternative causes such as haemorrhage or poisoning should be investigated and treated.

Reliable intravenous access should be placed for any burn over 10%. This can be difficult if burns are extensive. Intraosseous access can be life-saving in this situation.

Disability and Neurological Status

A Reduced Conscious State Is Not Associated with Cutaneous Burns

If a child has a reduced state of consciousness, then alternative causes such as head injury and poisoning should be investigated and treated.

Exposure and Environmental Control

Clothing should be removed unless it has melted. Burn size and depth should be estimated and documented as described earlier. Burns should be covered with a loose, non-adherent covering such as paraffin gauze or clingfilm. Children with extensive burns lose temperature rapidly, and active warming should be instituted to prevent this.

Intravenous Fluids

Resuscitation fluids should be given according to established paediatric trauma guidelines if shock is present. Large cutaneous burns result in a systemic inflammatory response and temporary microvascular capillary leak syndrome that can eventually lead to severe hypovolaemia and 'cold' shock. The capillary leak tends to be at its peak around four hours after burn and tails off 36–48 hours after

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injury. Different fluid resuscitation formulae based on burn size have been described to compensate for the first 24 hours of capillary leak. The most commonly used worldwide is the Parkland formula using Hartmann's solution, Ringer's lactate or other 'balanced' salt solution (2–4 ml kg^{-1} % $burn^{-1}$ over 24 hours).

All formulae are estimates and make no allowance for different burn depth or interindividual variation in systemic response. Under-resuscitation and over-resuscitation can both lead to morbidity and mortality, therefore infusion rates should be titrated according to response using markers such as urine output.

Young children have a large basal fluid requirement. It is easy to under-resuscitate if this is not taken into account or over-resuscitate if this is added to the full Parkland volume. In our institution, we recommend the following:

Start formal burn fluid resuscitation in burns over 10% TBSA (not including erythema) using Hartmann's solution, calculated from the time of burn.

For children <30 kg:

- 1 ml kg^{-1} % $burn^{-1}$ given as a constant infusion in the first eight hours post-burn
- 1 ml kg^{-1} % $burn^{-1}$ given as a constant infusion in the following 16 hours
- Plus maintenance fluid given according to Holliday–Segar formula (this may require a balanced glucose-containing solution if very young)

For children >30 kg:

- 2 ml kg^{-1} % $burn^{-1}$ given as a constant infusion in the first eight hours post-burn
- 2 ml kg^{-1} % $burn^{-1}$ given as a constant infusion in the following 16 hours
- No maintenance fluid

Urine output aim is 0.5–1 ml kg^{-1} h^{-1} or up to 2 ml kg^{-1} h^{-1} if there is evidence of myoglobinuria. Infusion rate should be titrated accordingly. Low urine output should not be aggressively 'chased' with fluid boluses if the child is otherwise well. A urinary catheter is recommended for burns over 20% TBSA.

Analgesia

Burns are extremely painful including, contrary to popular belief, full thickness burns. Strong analgesia using intravenous opioids is often required. Diamorphine or fentanyl are effective alternatives that can be given intranasally for rapid but short-action analgesia. Ketamine is a valuable analgesic but should only be administered by practitioners skilled in its use. Non-steroidal anti-inflammatory drugs (NSAIDs) are effective but are associated with gastrointestinal bleeding and acute kidney injury; they should not be used in children with 'resuscitation-sized' burns. One of the most effective analgesic interventions is the application of wound coverage, which should be done following inspection.

Burn-Related Aspects to the Secondary Survey

A 'head-to-toe' examination should take place with special focus on the limbs and presence of circumferential eschar causing compartment syndrome. Releasing limb escharotomies may be required. As with chest escharotomies, these should be carried out under anaesthesia by an experienced clinician using a cutting diathermy.

Burns are tetanus-prone injuries. Immunisation status should be ascertained. Booster vaccine and human tetanus immunoglobulin may be indicated. Prophylactic antimicrobial therapy is not usually indicated unless surgical procedures such as escharotomy take place.

Transfer to a specialist burn service is not often time critical and should only take place once the patient is comfortable and stable. A paediatric critical care transport service will often transfer children with large burn injuries.

Electrical Injury

Children of all ages are at risk of electrical injury due to accidents at home or misadventure. High-voltage electrical injuries are associated with large burns and extensive tissue damage (rhabdomyolysis and compartment syndrome). Domestic supplies are associated with direct myocardial injury and arrythmias. If there is a history of loss of consciousness or electrocardiogram (ECG) changes (the most common arrythmia being atrial fibrillation), the child should be monitored for 24 hours post-injury even if tissue injury is not apparent.

Chemical Burns

Chemical burns are often associated with the workplace or an assault. As such, they are rare in children. Accidental ingestion of a corrosive substance does occasionally happen; these cases should be referred urgently to a paediatric general surgeon, as internal aero-digestive complications can be fatal despite minimal cutaneous burn.

If cutaneous chemical burns do occur, they should be liberally irrigated with saline or water until the measured pH is within physiological limits. If available, amphoteric aqueous washing solutions such as Diphoterine® are highly effective against corrosive and irritant chemicals and can be used on both skin and eyes.

Acute Burn Care (Including Critical Care, Surgery and Rehabilitation)

Burn care is a surgical specialty involving both operative and non-operative interventions, supported by a large multidisciplinary team. Anaesthetists are key members of this team, providing specialist knowledge and skills in the areas of anaesthesia, sedation, critical care and pain management throughout the child's journey.

The broad surgical aims are:

- Accurate assessment of burn size and depth and development of a treatment plan. Immediate surgery (e.g. escharotomy) should be performed as soon as possible. Planned treatment may be operative or non-operative (dressings).
- Excision of deeply burned devitalised tissue. Early 'total' burn excision within 48 hours of injury has been shown to have a significant positive effect in terms of recovery and morbidity.
- Wound closure with the patient's own skin (autograft). In large burns with limited donor site, this is done in a staged fashion over a number of weeks involving multiple operative procedures. In the intervening time, temporary wound closure with biological dressings or processed cadaveric skin (allograft) is frequently used. These provide a protective layer and, in the case of allograft, release local growth factors which prepare the wound for later autograft.
- Post-burn reconstruction. Often takes place following discharge to correct functional and cosmetic defects that reveal themselves as the child ages, often due to scar contraction. Children sustaining major burn injury may be under the care of the burns team for many years.

Anaesthesia for Paediatric Burn Surgery

Burn centres in the United Kingdom are mandated to have a burns operating theatre available, preferably within the ICU. This minimises the infective risk associated with patient transfer and allows for better planning and coordination of surgical care. A large proportion of patients requiring burn surgery are children, often around one year of age, therefore it is vital the whole anaesthetic team are comfortable anaesthetising this age group. The majority of children are ASA 1–2 having a 'standard' anaesthetic for a single operation on a small area of burn – either sterile application of dressing or autograft (split skin graft). In the case of the latter, a painful donor site is created, often on the child's lateral thigh. These operations involve periods of intense stimulation, such as application of antiseptic solutions to raw areas or the taking of donor skin. In addition, surgical preparation often involves turning the patient, potentially dislodging a supraglottic airway. Securing the airway with a tracheal tube should be considered for these procedures. Short course, narrow spectrum, prophylactic dose antibiotics are administered. Pain is controlled using multimodal analgesics. Locoregional analgesic techniques can provide an invaluable way to treat wound and donor site pain. Young children will often need to return to theatre for dressing changes or staple removal, and hence psychological preparation is crucial.

Acute surgery for large burns can challenge even the most experienced of anaesthetists. These tend to be repeated, lengthy operations on children who may have limited sites for vascular access and monitoring and potentially difficult airways. Many of these children are already receiving intensive care and often have evidence of organ dysfunction, systemic sepsis and burn hypermetabolic syndrome. It is vital that there is preoperative coordination and a clear plan for the procedure amongst critical care, anaesthesia and surgical colleagues. Length of procedure, perioperative antimicrobial cover, estimation of possible blood loss, adequacy of vascular access and postoperative care needs should be discussed in the planning stage.

Temperature Management and Feeding

Children with large burns are particularly prone to hypothermia during long operative procedures.

This is due to exposure and an increased surface area to weight ratio compared to adults. The ambient temperature of the operating room should be kept in the thermoneutral zone, which can be up to 32°C in infants. Active warming techniques, such as radiant heaters, may also be used in order to minimise heat loss and muscle catabolism from an already raised resting energy expenditure (REE) due to the burn hypermetabolic syndrome. It is common to enterally feed all patients with large burns intraoperatively, ideally through a post-pyloric feeding tube, in order to minimise calorie deficit. Ongoing dialogue between the anaesthetist and surgeon should take place. If the child becomes hypothermic, surgery should come to an end when it is safe to do so.

Blood loss during major burn surgery can be significant and is often hidden in pads and dressings. Infected wounds or delayed excision of deep wounds can result in up to three times the blood lost than if the excision is done early. An estimation of blood loss should be made pre-operatively and blood and blood products be made available. Surgical techniques, including the use of tourniquets, diathermy, epinephrine containing infiltration and topical phenylephrine soaks, are commonly used intraoperatively. Avoidance of hypothermia and acidaemia is vital, and the administration of tranexamic acid is helpful. Blood and blood product administration should be guided by patient laboratory results where possible. Over-transfusion is associated with poor outcome in both adults and children. A haemoglobin concentration of 70 g l^{-1} is adequate. A significant loss of blood can continue following surgery and should be carefully monitored and treated in the intensive care unit.

Burn-Related Pharmacology

Burns can have a significant effect on the pharmacokinetic handling and pharmacodynamic action of many drugs. In the acute stages, burn oedema can lead to an increase in volume of distribution for water-soluble ionised drugs. Plasma proteins are acutely diluted by resuscitation crystalloid. Hepatic and renal clearance may also be a decreased due to hypovolaemia. In practical terms, these factors do not tend to change drug dosing at this stage. Later, however, various pathophysiological changes associated with large burns do have an impact:

- Altered gastrointestinal absorption (hyperchlorhydria, gastroparesis, increased gut permeability)
- Catabolism leading to hypoalbuminaemia and decreased acid/neutral drug binding
- Increased acute phase response (α-acid glycoprotein) leading to increased binding of basic drugs
- Reduced plasma-esterase concentration
- Increased hepatic and renal clearance of many drugs
- Hepatic phase 1 reactions impaired
- Hepatic phase 2 reactions induced
- Drug receptor population numbers change (often increase)
- Cellular secondary signalling altered and quantal release of acetylcholine at the neuromuscular junction increased

In practical terms, these changes manifest as a rapid clearance of non-depolarising muscle relaxants (NMDRs) and some antibiotics (e.g. piperacillin-tazobactam). Resistance frequently develops to the effects of opioids and NMDRs.

Extensive deep burns in particular can lead to a proliferation of extrajunctional nicotinic acetylcholine receptors. Administration of suxamethonium chloride can lead to acute life-threatening hyperkalaemia, and its use is relatively contraindicated 24 hours after a burn injury and for up to 18 months afterwards.

Burn-Related Pain Management

> [Burn] pain is of a peculiar kind, resembling that from the continued application of fire to the part.
> Professor Jacob Bielow (1786–1879).

Burn pain management can be challenging and requires specialist knowledge when treating children. Conceptually, management should be viewed in terms of background pain, breakthrough pain and procedural pain. Pain scores should be frequently assessed in order to guide therapy according to a 'step-ladder' approach. Opioids are the mainstay of pain management as part of a multimodal approach. Non-standard opioids such as methadone and oxycodone have been used successfully for difficult to manage pain under specialist supervision. Pharmacological adjuncts are commonly used in non-opioid responsive pain. Common adjuncts currently used in our institution are clonidine, gabapentin and low-dose oral ketamine. As mentioned previously, NSAIDs are relatively contraindicated in patients with large burns in the acute stages. Non-pharmacological techniques are also important. Input from specialist children's nurses, play therapists and psychological therapy is often invaluable.

Management of Painful Burn-Related Procedures

Children may undergo many painful procedures during the course of their inpatient stay ranging from physical therapy to extensive painful dressing changes and showers. Management options include short-acting analgesia, deep analgesia-sedation or general anaesthesia. Standards for monitoring and delivery of deep analgesia-sedation should be the same as for general anaesthesia. An example of a procedural pain management 'step ladder' from our institution is outlined in Table 40.1.

Burn-Related Itch Management

Itching (pruritis) is very common after burn injury. It can be severe and debilitating. It can present during all phases of wound healing, the early inflammatory phase (zero to four days), the proliferative phase (4–20 days) and the late remodelling phase (21 days to 18 months). Most institutions have protocols in place for management of burn itch involving the use of pharmacological and non-pharmacological therapies. Commonly used medications are potent antihistamines, which tend to work better in the inflammatory, and early proliferative phases and gabapentin, which works well in the proliferative and early remodelling phases. Chronic itch going beyond the early remodelling phase tends to be poorly responsive to systemic pharmacotherapy; in these cases, psychological therapy can be effective, particularly in adults. Small case series and randomised controlled trials using novel topical therapies (colloidal oatmeal), laser therapy, transcutaneous electrical nerve stimulation (TENS) and intradermal botulinum toxin have shown some promise, particularly in adults, though their efficacy has not been reproduced in children.

Table 40.1 An example procedural pain management 'step ladder'

Management technique	Suitability of technique
Oral/intranasal opioids	Nurse-led on ward
Entonox	Nurse-led on ward
Oral midazolam and ketamine	Nurse-led protocol in sedation area of ward
'Ketofol' (ketamine/propofol admixture)	Anaesthetist-led in the ICU/theatres
General anaesthesia	Anaesthetist-led in theatre

Critical Care Management of the Severely Burned Child

Intensive care for children with burns is a low-volume, high-intensity activity that requires careful coordination and close attention to detail. It should be delivered by a multidisciplinary team familiar with all aspects of burn care. A 'concertina of care' model works well, where facilities and staff can be expanded or contracted to meet the specific needs of the child.

Children who require tracheal intubation owing to airway oedema or respiratory insufficiency need adequate sedation and ventilation. Tracheal tubes should generally be uncut to allow for facial swelling, cuffed and fixed securely. This can be challenging in the presence of facial burns. Tracheal extubation can follow as oedema resolves. Elective tracheostomy is common in adults but less so in children due to an increased complication rate in comparison.

Children with suspected smoke inhalation injury should undergo diagnostic bronchoscopy and therapeutic bronchial lavage, if indicated, soon after admission. Frequent chest physiotherapy and 'inhalation injury' protocols consisting of nebulised drugs are commonly used. An alternating regimen of nebulised salbutamol, N-acetylcysteine and heparin used for five days has been shown to reduce complications following paediatric inhalation injury. Smoke inhalation injury, particularly if accompanied by a large cutaneous burn, may be complicated by acute respiratory distress syndrome necessitating prolonged respiratory support and lung-protective ventilation strategies.

Burn hypermetabolic syndrome is commonly seen in children with larger burns (>20% TBSA). The response appears to be driven by catecholamines, stress hormones and pro-inflammatory cytokines. The result is an elevated REE with augmented catabolism resulting in loss of lean body mass, bone density and the development of hepatic steatosis. Clinical manifestations are a hyperdynamic circulation, raised plateau temperature, hepatomegaly, weight loss, wound breakdown and infection. In addition to warming, physical therapy and feeding, propranolol and oxandrolone (a safe synthetic testosterone analogue) have been shown to maintain lean body mass, increase bone mineral content and prevent hepatomegaly in children with burns over 40%. Burn hypermetabolism can be evident up to three years following injury; the child's physical growth is often delayed as a result.

Sepsis is the main cause of organ failure and mortality in children with burns. Loss of physical barrier and injury-related immunosuppression leaves the child prone to systemic sepsis, often related to wound infection, vascular catheter sepsis and ventilator associated pneumonia. Gut dysfunction can also lead to bacterial translocation. Repeated exposure to antibiotics can eventually result in the emergence of multi-drug-resistant strains of bacteria, some being extremely difficult to treat. The diagnosis of sepsis is often challenging when the child has a hypermetabolic physiology and high plateau temperature. Careful evaluation of clinical, biochemical and haematological trends in addition to possible sources needs to be ongoing.

The American Burn Association Have Produced Sepsis Criteria

At least three of the following should be present:

- Temperature >39°C or <36.5°C
- Progressive tachycardia (>2 standard deviation [SD] above age-specific norms)
- Progressive tachypnoea (>2 SD above age-specific norms)
- Thrombocytopenia (three days after initial resuscitation)
- Hyperglycaemia or insulin resistance
- Inability to tolerate enteral feeds >24 hours (abdominal distention, feed intolerance, diarrhoea)

These indications should appear alongside infection, demonstrated by one of the following:

- Culture positive infection
- Pathological tissue source identified
- Clinical response to antimicrobial therapy

Staphylococcal Toxic Shock Syndrome

Special mention of burn-related TSS in children needs to be made. It is very common for children to have mild systemic illness following even a small burn injury. A small but significant proportion of young children will develop a fulminant TSS – a catastrophic systemic response. Some *Staphylococcus Aureus* isolates can produce a toxic shock syndrome toxin (TSST) which acts as a superantigen, causing a cytokine 'storm'. The degree of shock is unrelated to bacterial load and is associated with smaller burns presenting within a few days of injury. Children are particularly prone to this due to their immature immune systems. Diagnosis can be difficult. In addition to profound shock, children often present with the following:

- Pyrexia
- Diffuse macular rash
- Diarrhoea/vomiting (TSST is an enterotoxin)
- Lethargy/irritability
- Lymphopenia
- Hyponatraemia

In addition to resuscitation and supportive treatment, children should receive suitable anti-staphylococcal antibiotics (we use flucloxacillin, gentamicin and clindamycin). If this does not improve things rapidly, at the time of writing intravenous immunoglobulin (IVIG) is indicated for life-threatening staphylococcal TSS in the United Kingdom.

Rehabilitation and Psychological Support

Holistic burn care is multidisciplinary. Physical rehabilitation happens from day one. The main goal of pain management is allowing this to happen. Psychological support is integral and is vital for the child, their family and occasionally the burn unit staff. Children with burns often have many procedures and can develop anxiety states and phobias. Anaesthetists need to be receptive and responsive to the individual needs of the child and develop strategies to prevent and deal with these issues.

Safeguarding

Non-accidental injury (NAI) is thought to be involved with up to 10% of burns in children. Most involve unintentional neglect, but it is estimated that up to 1% may be intentional. Children with suspected NAI should be referred to the specialist burn service, irrespective of injury size. Delayed presentation or history inconsistent with the injury or degree of development should alert clinicians. Unusual or suspicious burn injury patterns and distribution should be recorded and discussed with the burn service involved.

Outcome

Burns of any size can be fatal. Risk factors for morbidity and mortality in children are:

- Age less than two years
- Burn larger than 60%
- Smoke inhalation
- Delay of more than one hour before intravenous fluid replacement is started

There are very few survivors with a 90% burn, but children have better outcomes for massive burns than adults. Burns as small as 1% can be fatal if complications such as TSS occur. Most children with small partial thickness burns can be expected to recover within two weeks with minimal scarring. Larger burns will take three to six months; they need long-term burn wound management and often heal with lumpy unstable scars. Generally, parents should be advised that their child will need to stay in hospital for one or two days for each percentage of burn.

An experienced multidisciplinary burns team should manage all children with massive burns. Strong family support has a positive benefit on recovery, but children will inevitably be left with physical and psychological disabilities. Despite suffering severe injuries, it has been shown that children who survive massive burns can have a quality of life that is comparable to that of non-burned children.

Key Points

- Burns are common in children, but large burn injuries are not.
- Formal fluid resuscitation is recommended in children with burns over 10%.
- Scald injuries are rarely airway threatening.
- Inhalational injuries are frequently airway threatening, and the risk increases over time, particularly when fluid resuscitation starts.
- Large burns are classic 'distracting' injuries – patients should undergo a full trauma evaluation.
- Hypotension and changes in conscious state are not features of an isolated burn injury. Beware of carbon monoxide or hydrogen cyanide poisoning from fires in enclosed spaces.
- Children with any safeguarding concerns should be referred to a specialist burn service.
- Sepsis is common and can be life threatening. It can present in patients with a small burn injury.
- Specialisation and improvements in burn care in recent decades have led to good treatment outcomes in burnt children.

Further Reading

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