

Paediatric burns anaesthesia: the things that make a difference

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Abstract:

Anaesthesia and pain management for paediatric burns continues to challenge and frustrate healthcare professionals in this field of medicine. This review aims to provide some practical management strategies to enable the improved care of burned children. The pathophysiology of burns, toxic shock syndrome, inhalational injuries and perioperative care of paediatric burns is addressed.

Keywords: paediatric, burns, pathophysiology, anaesthesia, analgesia, inhalational injuries

Introduction

Burn injury is the major cause of death from trauma in children under four years of age in South Africa.¹ Survival after thermal injury depends on the age of the patient, the site, depth and percentage of the total body surface area (TBSA) burned, as well as the presence or absence of inhalational injury.² When age groups, from neonates to adolescents, are considered, younger patients are the most likely to survive, although there is higher mortality in neonates.¹ Most burns are caused by a thermal injury, e.g. scalds or flame, or cold, e.g. frostbite. Electrical, radiation or chemical injury is less common.³ Factors which impact on survival include burn shock and resuscitation, the presence of inhalational injury, and the rapidity of wound closure and burn hypermetabolism.⁴ Toxic shock syndrome (TSS) should be considered in any burned child who is more ill relative to the extent of the burn injury. TSS classically occurs in a child who is younger than two years of age, within two days of a burn injury of less than 10% TBSA.⁵

Advances in resuscitation, wound coverage, aggressive infection treatments, inhalational injury and understanding and management of burn-induced hypermetabolism have impacted on improved outcomes for burn survivors, but the answer lies in the prevention of burns. Protocolised and specialised critical care and specialised burn centres, especially for the management of children who have been burned, has improved outcomes in some centres, but is not available in all countries.⁴

Anaesthetists and other healthcare professionals may be involved in the care of burn children in a variety of situations, e.g. during acute resuscitation, for pain management, when changing dressings, during general anaesthesia for debridement and grafting, and in the intensive care unit (ICU). They will find it a challenging, gratifying, horrifying and sometimes heartbreaking experience. At a later stage, reconstructive and plastic surgery may be necessary, when, due to scarring and keloid formation, airway compromise and vascular access may cause difficulties. The emotional component of their previous experience is very evident at this time, and this may make the perioperative period difficult for everyone involved in their care.

Burn classification

Previously, the depth of the burn injury was classified as first, second, third and fourth degree, but this has been replaced by a simpler classification, based on the anatomical layers of the skin (Table 1). Most burns are a combination of superficial and deep, and are best assessed after 2–3 days. This also determines the type of pain experienced, i.e. acute nociceptive inflammatory pain, neuropathic pain, or no pain at that site for deep burns.

Preoperative management

Highlights of resuscitation

Some children need to be urgently transferred to theatre directly from the emergency room. Resuscitation should aim to achieve a balance between over- and under-resuscitation, and thus intend to maintain organ perfusion during the shock state to restore intravascular volume. Inotropes may be necessary to support the myocardium, even if only for a short period. Airway evaluation and management at this time is crucial to short- and long-term survival.

Prolonged starvation has considerable detrimental effects in the child who has been burned, namely hunger, thirst and loss of essential calories for extended periods, as well as patient irritability. During this starvation period, many nurses will not administer medications, including analgesics, so the child is in increasing pain as the day wears on. Clear fluids should be administered up until two hours before surgery. Nasogastric tube (NGT) feeds should be as for any other food, but nasojejunal tube (NJT) feeds must be individualised. If there is radiological proof that the NJT is in the jejunum and not the stomach, feeds may be continued until two hours preoperatively. Intraoperative feeding remains controversial.

Anxiety usually increases with each visit to theatre, and good psychological preparation is crucial to a successful anaesthetic. Patient choices for premedication, the type of induction or regional anaesthesia techniques must be identified. The application of EMLA™ cream may be difficult, but should always

be considered. Optimum preparation of the child for surgery includes medical play when explaining what is required for his or her visit to theatre and at induction of anaesthesia. This also helps to prepare the parents for the role that they will be expected to play. The skills of child life specialists or play therapists may be enrolled to facilitate this.

The following details are valuable when booking patients for theatre:

- **Patient demographics:** These should include the name, folder number, age, weight, consent and starting haemoglobin.
- **Surgical factors:** These refer to the type of burn and extent, i.e. percentage of TBSA for surgery (area for debridement plus donor site) and site for operation. All of this impacts on anaesthetic decisions intraoperatively, e.g. the placement of monitoring and venous lines.
- **Order of patients on the list:** The youngest should be first, and septic patients last.

Blood requirements

Depending on the starting haemoglobin, the extent of the injury and the planned surgery, blood may be required intraoperatively. A blood cross-match is necessary in any patient where transfusion is anticipated. An operative field involving 30% TBSA (debridement plus donor area) may require a blood volume available equivalent to an estimated blood volume for that particular child. If blood-sparing techniques (clysis, the application of adrenaline swabs, fast surgery and cautery) are used, the volume needed may be less.

Assessment and tests

The preoperative evaluation of the child requires an empathetic, compassionate but goal-directed approach.^{7,8}

History

Important facts include (using the acronym of "AMPLE"):

- **A Allergies**

- **Anaesthetics:** Previous anaesthetics, problems, tolerance or tachyphylaxis.
- **Analgesics:** Background and breakthrough pain.
- Awareness.
- **M Medications:** Acute (analgesics, sedatives and antibiotics) or chronic (e.g. for asthma and epilepsy). Were inotropes necessary? In many units, beta blockers are used to attenuate the hypermetabolic response. This should be factored into the anaesthetic technique.
- **P Pre-existing disease:** Surgical and/or medical.
- **L Last meal:** Most of these operations are elective, but a note should be made of the time of the last feed, when/if to stop the NJT or NGT feed, and when to allow the last clear fluid to be given orally. Clear fluids, preferably glucose containing (ideally an isotonic drink, or grape or apple juice), should be administered to these patients up until two hours prior to surgery.
- **E Events of the injury:** It is necessary to document what happened, when the accident occurred, the time and type of burn, any associated injuries, first aid management and any inhalational component. Non-accidental injury must be excluded, and a note made of whether or not tetanus immunisation was provided.

Examination

Despite the dressings, the patient must be examined as completely as possible, using the principles of advanced life support courses, i.e. Table 2 and A, B, C, D, E, F, G.^{7,8}

- **Airway:** Examine the mouth, teeth, jaw, face, head, neck, eyelashes and eyebrows, as well as nasal hair. Inhalational burns involve the mouth, pharynx, larynx and lower airway. Beware of contractures and keloids causing a potentially difficult airway. Plan the method of airway control that will be used intraoperatively. In the case of a potentially difficult airway, ensure that any additional equipment, such as a difficult airway trolley, is available and in working order. This

Table 1: Burn classification

| Depth | History | Aetiology | Sensation | Appearance | Healing |
|--|---|---|---|--|----------------------------------|
| <i>Superficial:</i> Epidermis | Momentary exposure | <ul style="list-style-type: none"> • Sunburn • Momentary hot fluid | Sharp, uniform pain | <ul style="list-style-type: none"> • Blanches red to pink • Oedematous • Soft, flaking and peeling | ± 7 days |
| <i>Partial thickness:</i> Epidermis plus dermis | Exposure of limited duration to lower temperature agents (40–55 °C) | <ul style="list-style-type: none"> • Scalds • Flash burns without contact • Weak chemicals | Dull or hyperactive pain Sensitivity to air or temperature changes | <ul style="list-style-type: none"> • Mottled and red • Blanches • Red or pink blisters • Oedema • Serous exudate • Thin eschar | 14–21 days |
| <i>Full thickness:</i> No dermis remaining | Long duration of exposure to high temperatures | <ul style="list-style-type: none"> • Immersion • Flame • Electrical • Chemical | Painless to touch and pin prick May hurt at deep pressure | <ul style="list-style-type: none"> • No blanching • Pale white or tan • Charred, hard, dry and leathery • Hair is absent • Thick eschar | Granulates and requires grafting |
| Underlying structures | Prolonged duration of exposure to extreme heat | <ul style="list-style-type: none"> • Electrical • Flame • Chemical | Usually painless | <ul style="list-style-type: none"> • Charred • Skeletonised | Requires extensive debridement |

Table 2: Summary of possible pathophysiological changes occurring during a burn injury^{1,2}

| | Early or acute (24-48 hours) | Late (> 48 hours) |
|-------------------------|--|---|
| Airway | <i>Upper:</i> Obstruction, oedema, hoarseness and stridor <i>Lower:</i> Smoke inhalation, chemical pneumonitis, wheezing, respiratory distress syndrome, pneumonia and pulmonary oedema | <ul style="list-style-type: none"> Ongoing acute responses <i>Scarring of the face and airway:</i> Limited mouth opening and chin extension Lung fibrosis and restrictive lung disease |
| Breathing and pulmonary | Hypoxia, carbon monoxide poisoning and cyanide toxicity | Circumferential chest wall restriction, infection and tracheal stenosis |
| Circulation | Hypovolaemia, decreasing cardiac output, increasing systemic vascular resistance and ischaemic reperfusion injury | Increasing cardiac output, hypertension and tachycardia |
| Disability | Confusion, cerebral oedema and increasing intracranial pressure <i>Pain:</i> Acute and nociceptive | <i>Burn encephalopathy:</i> Seizures, hallucinations, personality disorders, coma and delirium <i>Causes:</i> Hypoxia, sepsis, hyponatraemia and cortical vein thrombosis <i>Pain:</i> Acute, chronic and neuropathic |
| Drugs | <i>Suxemethonium:</i> Hyperkalaemia after \pm 12 hours after injury. Avoid use after 12 hours after injury | <i>Suxemethonium:</i> Hyperkalaemia <i>Non-depolarising muscle relaxants:</i> Resistance to effects <i>Opioids:</i> Tolerance |
| Endocrine (AQ7) | <ul style="list-style-type: none"> Release of stress hormones Decreasing T3 and T4 | <ul style="list-style-type: none"> Hypermetabolic response (3–5 days post burn) proportional to total body surface area burned. Lasts up to 9–12 months Increasing basal metabolic rate, temperature and catabolism All electrolytes may be affected |
| Electrolyte imbalance | Hypoparathyroidism leading to hypocalcaemia, hypomagnesaemia, hypophosphataemia, hyponatraemia and hypernatraemia | |
| Fluids | <ul style="list-style-type: none"> <i>“Fluid creep”:</i> Oedema after over-resuscitation⁶ Oedema is directly proportional to fluid administration Abdominal compartment syndrome | <ul style="list-style-type: none"> May require blood products Monitor clinically and biochemically. |
| Glucose | Insulin resistance | Hyperglycaemia |
| Gastrointestinal tract | <ul style="list-style-type: none"> Gastric stasis, ulcerations and small bowel ischaemia Endotoxaemia <i>Early enteral feeding:</i> “Use the gut or lose it” (ileus and haemodynamic shock are contraindications) Ischaemic bowel syndrome Abdominal compartment syndrome | <ul style="list-style-type: none"> Acalculous cholecystitis Bowel ischaemia, endotoxaemia and abdominal compartment syndrome |
| Haematological | Initial haemoconcentration, then haemodilution (from resuscitation, blood loss and erythrocyte damage from heat) | <ul style="list-style-type: none"> Hypercoagulable state Disseminated intravascular coagulation with sepsis |
| Hepatic | Thrombocytopenia <i>Hepatic injury:</i> Decreasing alanine aminotransferase, aspartate aminotransferase and tumour-bearing rats | <ul style="list-style-type: none"> Increasing albumin and transferrin Increasing acute phase proteins |
| Itching | Uncommon early | <ul style="list-style-type: none"> Caused by drugs (e.g. morphine) or nerve and tissue regeneration. Short- and long-term problem |
| Immunology | <i>Inflammatory mediators:</i> Local and systemic release, causing capillary leak | |
| Kidneys | <ul style="list-style-type: none"> Decreasing glomerular filtration rate and myoglobinuria Maintain urine output 0.5–1 ml/kg/hour | Increasing glomerular filtration rate and tubular dysfunction |
| Pain | Acute severe pain | Chronic pain, neuropathic pain and phantom limb pain |
| Psychological impact | Post-traumatic stress disorder | Post-traumatic stress disorder, despair, suicidal tendencies and depression |
| Skin | Infection, fluid and heat loss | Loss from graft failure contributes to ongoing infection, and heat and fluid loss |
| Sepsis | Major cause of morbidity | |

T3: triiodothyronine, T4: thyroxine

equipment should also be available at the time of extubation. Inhalational injury in burn survivors is associated with a 20% increase in mortality. Pneumonia independently increases mortality by 40%, and, together with an inhalational injury, leads to a 60% increase in deaths.⁹

- **Breathing:** It is important to look, listen and feel. This includes breath sounds, adventitious sounds, carbonaceous sputum, pneumonia, chest splinting from tight dressings or

circumferential burns. Check that diaphragmatic movement is adequate. Beware of dressings that are too tight and which may limit respiratory excursions and the ability to cough.

- **Circulation:** Assess capillary perfusion, skin colour, the peripheral pulse, blood pressure, heart rate, level of consciousness and urine output. Check for vascular access possibilities. Peripheral venous access is often limited in burn patients who have been in hospital for some time. Central

vascular access may be the only option for the perioperative period, even if this involves going through burned tissue. In an emergency, the intraosseous route may be lifesaving.

- **Disability or drugs:** Assess level of consciousness, pain and sedation. Use "AVPU": alert, responds to voice, responds to pain, or unresponsive. Check pupils and posture. Document all medications, and assess how these will impact on the anaesthetic and vice versa. Specifically note the use of analgesics, sedatives, anxiolytic agents, antidepressant drugs and beta blockers.
- **Expose and examine:** Undertake a routine systematic examination, as far as possible, without removing the dressings. Be sensitive to the patient's privacy.
- **Fluids:** What, how much, which route? Nutrition, e.g. enteral feeding via the NJT or NGT routes, or total parenteral nutrition (TPN).
- **Glucose level:** Record the glucose level, if available. It should be checked in any patient who is confused, has a depressed level of consciousness, or who is on TPN.

Exclude the possibility of other injuries, especially if the accident occurred in an enclosed space.

Investigations and requests

A recent haemoglobin level is essential. A platelet count and clotting profile should be available with respect to the septic, ill patient. An arterial blood gas investigation is seldom required in routine burn surgery, but is necessary in the ICU patient, who will usually have an arterial line from which to take a blood sample. (These are very painful procedures, so there should be a very good indication for requesting one in a patient without an arterial line.)

Acid base status, electrolytes and lactate, together with urine output, reflect the adequacy of resuscitation.

Radiographs of the chest and abdomen may be necessary. The child with clinical features of pneumonia, who is tachypnoeic with increased oxygen requirements, requires a chest X-ray prior to surgery. If there is any doubt about the position of the nasojunal tube and if the *nil per os* status is in doubt, an abdominal X-ray is necessary, or the patient should be starved for six hours. A lateral cervical spine radiograph, chest X-ray and pelvic X-ray should be available with respect to any burn child who has been involved in a multi-trauma accident.

Premedication

Attention to pain, anxiety, amnesia, and sedation is required. During transportation to the theatre, in the operating suite, and in the ward postoperatively, everything possible should be done to minimise the psychological and physical pain. Awareness of previous bad experiences and increased requirements for anaesthetic drugs should be factored into the premedication and planned anaesthetic technique. Once the decision is made as to what is required in the premedication (analgesia, sedation, amnesia, and/or anxiolysis), options include the following:

- **Analgesia:** Paracetamol, morphine, tilidine hydrochloride (Valoron™), clonidine, oxycodone, hydrocodone, ketamine and gabapentin.

- **Sedation:** Trimeprazine (Vallergan™), droperidol, hydroxyzine, promethazine and clonidine.
- **Anxiolysis:** Midazolam, lorazepam, hydroxyzine, diazepam and clonidine.
- **Amnesia:** Benzodiazepines, ketamine and droperidol.

Intraoperative management

Preparation of theatre

Airway management: What is necessary for this patient? Guedel airway, laryngeal mask airway, nasopharyngeal airway, nasal cannulae with capnography, endotracheal tube (cuffed or uncuffed), special strapping required (cable ties or waterproof Elastoplast®), Magill forceps? Ventilate or spontaneous breathing?

- **Intravenous line:** Ringer's lactate (or equivalent), volume controller if child is < 10 kg, blood-giving set, three-way tap, extension (size depends on the age of the child and the extent of surgery), and T-piece extension to facilitate piggy-backing ketamine if not using a separate line.
- **Cannula:** For big cases, use the largest cannula possible. Two separate lines are advised for the administration of blood in one, and drugs [especially total intravenous anaesthesia (TIVA)] in the other.
- **Temperature control:** Warm the theatre to > 28 °C. Prepare to warm fluids, especially blood. Ensure the availability of thermometers to monitor the temperature of the patient and the environment. Especially in theatres that are not dedicated to burn surgery, warm fluid devices, overhead heating lamps, forced air warmers and plastic covering should be available.
- **Antibiotics:** Antibiotics are not used routinely, but for bacteraemia with debridement, use cephalosporins (cefazolin) 50 mg/kg/dose intravenously. Clindamycin 20 mg/kg is the preferred agent in penicillin-sensitive patients.

Anaesthetic choices

Anaesthetic choices include the following:

Conventional general anaesthetic: Intravenous or inhalational, balanced multimodal analgesia.

Ketamine

- **Induction:** 1–2 mg/kg/dose intravenously, 6–10 mg/kg/dose intramuscularly. Ketamine intramuscularly is painful, and should only be given once the child has been anaesthetised using an inhalational induction. It should be administered in the vastus lateralis muscle of the leg, not the deltoid. When venous access is impossible, intramuscular ketamine is sometimes the less traumatic option.
- **Infusion:** 4–12 mg/kg/hour (200 mg in 50 ml normal saline in a 50 ml syringe, and run at the child's weight. This will deliver 4 mg/kg/hour). Ketamine pharmacokinetics requires, after a 2 mg/kg loading dose, a decreasing infusion dose every 20 minutes from 11, 7, 5 and then 4 mg/kg/hour.¹⁰ This calculation aims at a target concentration of 3 mg/l. This has been simplified at the Red Cross War Memorial Children's Hospital to 12, 8 and

then 4 mg/kg/hour. (This translates to three times, two times and then at the bodyweight of the child, at a concentration of 4 mg/ml).

Midazolam

- Bolus: 0.1–0.2 mg/kg/dose intravenously. Infusion: 0.1–0.2 mg/kg/hour (5 mg in 50 ml normal saline in a 50 ml syringe, e.g. 0.1 mg/ml. Run at the child's body weight in kilograms).

Ketamine and midazolam can be mixed in the same syringe and when run at the child's body weight at the above concentrations, will provide 4 mg/kg/hour ketamine, and 0.1 mg/kg/hour of midazolam. Nitrous oxide and oxygen via nasal cannulae at 2–3 l/minute will supplement analgesia in ketamine TIVA. Nasal cannulae are available which provide oxygen and monitor end-tidal CO₂ simultaneously.

Alternative techniques

- Regional: Caudals and nerve blocks are very useful, but are often limited by the sites of the burn and by the surgical procedures. Local anaesthetic techniques in conjunction with a general anaesthetic are useful.
- Local: Infiltration with lignocaine or bupivacaine is frequently used in donor areas (see clysis).
- General anaesthesia: Conventional inhalational ± opioids.
- TIVA: Ketamine (see above), propofol ± fentanyl ± low-dose ketamine. Remifentanyl has been used, but beware of haemodynamic and respiratory consequences.

Muscle relaxants in burns

Succinylcholine should be avoided in burn patients. The risk of hyperkalaemia with the use of succinylcholine is highest on days 10–50 after a burn injury, and the rise in potassium may be 3–5 mmol or more.¹¹ The use of succinylcholine with a difficult airway is contraindicated. In the long term, the time at which it is safe to use the drug remains speculative.

Non-depolarising muscle relaxants: Burn patients, especially those with a TBSA burn of > 30% TBSA, show a marked resistance to non-depolarising muscle relaxants (NMDRs). This is thought to be owing to either the proliferation of extrajunctional cholinergic receptors, or to an altered affinity for cholinergic receptors caused by acetylcholine or NMDRs. Because of decreased cholinesterase activity, drugs metabolised by serum cholinesterases have a prolonged action in burn patients.¹¹

Table 3: Diagnosis of an inhalational injury

History of the injury: Trapped in an enclosed space. Clinically, suspect inhalational injury with any of the following:

- Burns to the face, neck, eyes, upper trunk and nose
- Singed eyebrows and eyelashes, burned nose hairs, and soot in the sputum
- Hoarseness, stridor, respiratory distress and use of accessory muscles
- Change of voice and a brassy cough
- *Abnormal chest X-ray:* Patchy opacification, e.g. a "white out"
- Arterial blood gas indicating low PaO₂.
- Raised carboxyhaemoglobin levels.

PaO₂: partial pressure of oxygen in arterial blood

Airway control

Regardless of the method of airway control chosen, it is important to remain vigilant! Choices include the use of:

- *Nasal cannulae with a capnograph port:* This is ideal when using a ketamine infusion, and when not wanting to instrument the airway. Before placing the cannula, use oxymetazoline nose drops in each nostril and clear nasal secretions. The capnograph monitors both respiration and cardiac output.
- *Laryngeal mask airway (LMA):* Perform direct laryngoscopy prior to placing the LMA so that postnasal and pharyngeal secretions can be cleared. This is especially important when the nose and face have been burned. This is a useful technique when the burns are in the lower half of the body, and for COD. (AQ2) It is life-saving in patients with difficult airways.

Endotracheal tubes: Endotracheal tubes may be placed either orally or nasally. Stable securement may be very difficult and vigilance is required. A technique using cable ties has been described,¹² and is summarised here. After oral intubation with an endotracheal tube (ETT), take a NGT and pass it through one nostril to the nasopharynx. Under direct vision, use a Magill forceps to pull the tip of the NGT out of the mouth, thus looping it around the hard palate. Pull the NGT so that there is no slack at the two ends, and then align these ends with the ETT and tie them all together firmly with a cable tie. Tie firmly, but not too tightly, as this will crimp the ETT and decrease the internal diameter. To avoid this, cut the ETT at the desired length, replace the connector and use this connector to provide a stent at the cable tie.

Acute management of the burned airway

Inhalational injury increases mortality in burn survivors, but the reason for this is unclear.⁴ The need for bronchoscopic evaluation of the airway, using the criteria of grading the injury has been proposed,¹³ but is not always possible. Tables 3 and 4 list the diagnostic and main features of inhalational injury.

Table 4: Salient features of inhalational injury¹

- Stridor, a brassy cough and dysphonia
- Respiratory distress
- A common clinical error is to diagnose children with inhalational injury as having croup (laryngotracheobronchitis), tracheomalacia or tracheobronchitis
- Symptoms may be delayed for up to 48 hours after the injury
- Endotracheal intubation is necessary in > 50% of children with airway burns
- Endoscopy is performed to establish the diagnosis, assess the severity of the injury, and to decide on airway management when upper airway laryngoscopy is not adequate to provide evaluation of injury below the vocal cords
- Secondary pneumonia occurs in more than 50% of cases
- High-frequency, low-pressure ventilation is preferred to minimise barotraumas
- Additional fluids are required to maintain haemodynamic stability
- Inhalational injury increasing mortality by 50%, regardless of the surface area burned
- Aerosolised (nebulised) heparin loosens casts which form in the airways
- Prophylactic antibiotics and steroids are not indicated.

Management

Follow the "ABC" of resuscitation. Maintain patency of the airway (it may be necessary to intubate early), oxygenate, stabilise the cervical spine, ventilate if necessary, and optimise haemodynamics. Swelling of the airway is worst from 8–24 hours after injury. Obstruction of the ETT with slough from damaged airways may be catastrophic.

Airway management under general anaesthetic may be necessary for the acute burn. Inhalational techniques are usually preferred, and even if the child is not starved, muscle relaxants are contraindicated. Beware of haemodynamic instability from inadequate resuscitation as the child will decompensate with induction and be difficult to resuscitate. Endoscopy of the upper and lower airway is ideal, but should not compromise the safety of the child.

Techniques to minimise blood loss

Techniques to minimise blood loss include the following:

- **Adrenaline:** Apply topically to decrease bleeding, using 30 mg adrenaline per litre of normal saline. Soak swabs and bandages for application to donor sites and debrided areas.
- **Clysis:** Mix 100 mg (two ampoules) bupivacaine with 2 mg adrenaline in one litre of either Ringer's lactate solution (more physiological pH) or normal saline. Of this, allow 20 ml/kg per patient for tumescence of the planned donor and/or operative site.¹⁴ This provides both a reduction in bleeding and pain relief.
- **Bipolar diathermy and fast, competent surgeons:** These minimise blood loss.

Fluids

For large cases, a pre-load of 10–20 ml/kg crystalloid (Ringer's lactate, Plasmalyte® B) should be considered. Have blood in theatre, or at least confirm before starting that blood has been cross-matched and is available. Clysis will reduce the perioperative blood requirements. Monitor blood loss and conduct regular haemoglobin measurements. Monitoring using a thromboelastogram is useful.

At the end of surgery, additional fluids may be necessary as the vasoconstrictor effects of ketamine wears off. Monitor oxygen saturation, heart rate, blood pressure, patient colour and capillary refill time. This is a dangerous stage of the surgery because much of the monitoring is removed while the dressings are put on. Keep some monitoring in place! Oximetry and capnography are the most useful.

Temperature control

Maintenance of normothermia is vital. Minimise and prevent heat loss by warming the theatre to > 28°C, warm all the fluids, cover where possible with plastic, use overhead heating lamps, monitor the temperature of both the patient and the theatre, cover the patient warmly at the end of surgery and provide warming in the recovery area (warm air convection devices and overhead heating).

Monitoring

Useful tips for monitoring include:

- **Electrocardiography:** Surgical staples and crocodile clips (stickers do not stay on).
- **Blood pressure cuff:** Place this where it is not going to interfere with surgery. It may be necessary to change the position as the procedure progresses.
- **Place the oximeter on the same limb as the drip:** Cover with a plastic bag and seal with waterproof Elastoplast®. This prevents the monitoring and drip from getting wet with washing and debridement.
- **Invasive monitoring:** Invasive monitoring may be the only option in the severely burned child. Stitch it securely in place. Communicate with the surgeon.
- **End-points of resuscitation or intraoperative management:** Include urine output, a mean arterial blood pressure > 65 mmHg, acid base status and serum lactate. Transoesophageal echocardiography and focused assessment transthoracic echocardiography are promising new technologies which are not yet in regular clinical use.

Indications for general anaesthetic for change of dressings

Indications for a general anaesthetic with respect to a change of the dressings are as follows:

- Large TBSA burn > 20%.
- Burns of the face, hands, feet and perineum.
- Mentally challenged children, with whom it is difficult to communicate.
- Large children who are difficult to manage in the ward.
- Removal of surgical staples (clips), especially on the hands, face, feet, neck and perineum.
- Any patient for whom the ward analgesic regimen is inadequate.
- Where joint and scar manipulation may be painful.
- Children with post-traumatic stress disorder.

Postoperative management

A detailed handover from theatre staff to ward personnel is vital for good patient care. Good pain control after surgery is non-negotiable. At this time, volume losses are ongoing from the blood and serum oozing from the operative sites. Haemodynamic monitoring and observation of blood loss is essential. Children are often cold after theatre and need to be actively warmed. Feeding and drinking should be re-introduced as soon as possible, and nausea and vomiting aggressively managed.

Pain management

To achieve good pain control, pain must be regularly and adequately assessed, and analgesia tailored to the individual patient's needs and psychological state.³ The pain experienced by a burn patient is not simple, as the pain from the nerve damage is combined with inflammatory pain, and these are in a constant state of flux. Adequate pain control during the initial

period of a burn injury and its healing may limit or even prevent the development of chronic pain.³

Pain for the burn survivor may be acute, chronic and neuropathic, and when loss of a limb has occurred, may include phantom limb pain. Because of both the physical and emotional nature of this pain, it is a difficult entity to treat. The main stumbling blocks are the following:

- Inadequate emotional support and reintegration back into society.
- Misconceptions about the side-effects of drugs and the possibility of addiction.
- Lack of understanding that good pain control is moral, ethical, humanitarian, and based on physiological reasons with science-based evidence.
- Inadequate resources at many levels of care, with poor caregiver concern about patient well-being.
- Itching forms a major component of pain and discomfort.¹⁵⁻¹⁷

Pain management should always include nonpharmacological strategies (distraction, psychotherapy, music therapy, play therapy, child life therapists, and art and music therapy), but these are beyond the scope of this discussion.

Options for treatment include the following, but are not limited to these (options are determined by available resources and clinician preferences):

- *Simple analgesics*: Paracetamol, nonsteroidal anti-inflammatory drugs (NSAIDs). Beware giving NSAIDs to patients who are inadequately resuscitated, or who run the risk of haemodynamic compromise.
- *Opioids*: Morphine, fentanyl, sufentnil, Valoron™ and codeine.
- *Adjuncts*: Clonidine and gabapentin¹⁵⁻¹⁷ (personal experience), and antidepressants.
- *Anaesthetics*: Ketamine, Entonox™ and local anaesthetics.
- Attention to neuropathic pain, anxiety and fear need to be addressed early and aggressively. Chronic pain, post-traumatic stress disorder and neuropathic pain are common in burn patients. Gabapentin has been very successful in managing both pain and itching in paediatric burns.^{16,17} To avoid a withdrawal state, analgesic and anxiolytic medications that are used in burn care need to be weaned; not stopped abruptly.

Reconstruction and rehabilitation

During their period of rehabilitation, many burn survivors will present for reconstructive surgery. Preoperative evaluation of these children should involve the same assessment as that given during the acute phase of their injury, with particular emphasis on airway and vascular access issues.

Their previous experiences in theatre may make them very fearful and agitated. The child should be asked for his or her preferences with regard to the anaesthetic induction technique.

It may be necessary to have a plan for the urgent release of keloids, which may make airway access impossible. These may be performed under local anaesthetic, and the use of a LMA may be life saving.¹⁸ Neuropathic pain with allodynia can be a major part of the child's life, and pain control should include medication options to provide adequate pain control for acute and neuropathic pain.

Conclusion

The role of changes in genome expression with burn injury is not yet clear. Critical adverse events in burns anaesthesia and surgery are common, and mainly relate to the airway and haemodynamic compromise. Vigilance and attention to detail are crucial for a successful outcome. With adequate preparation and planning of the patient, the anaesthetist, the anaesthetic technique, the theatre environment and the surgery, many potential and actual problems may be overcome.

In 1973, Gordon Bush, a paediatric anaesthetist, said: "Apart from all else, a humane, friendly, gentle and encouraging approach is essential in dealing with a burned child. The burns of today are the suffering of tomorrow and the scars of a lifetime".

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