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FOCUS ON: BURNS AND PLASTICS

Anaesthesia for patients with burns injuries

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Summary The safe management of complex burns injuries requires an understanding of the obligatory pathophysiological changes and current treatment options. The anaesthetic team must have, collectively, specialist skills in resuscitation, airway management, critical care procedures and care of small children and access to expert advice in the management of non-burns co-morbidity. The experience of treating relatively small numbers of these patients for prolonged periods of time is unusual in anaesthetic practice. Flexibility is required to tailor anaesthetic practices to fit with overall patient management objectives. Communication skills are necessary for multidisciplinary team membership and in dealings with patients, relatives and managerial authorities.

Regular commitment to burns anaesthesia is required to acquire and consolidate expertise in this group of patients. Issues include altered drug effects, monitoring, blood conservation techniques and choices in fluid therapy and environmental and metabolic control.

The contribution of anaesthetic personnel to the management of burns patients continues to evolve. Traditional roles in resuscitation and preparation for transfer, critical care, pain management, and anaesthesia for burns surgery remain important but anaesthetic input is required to influence the future direction of acute burns care services, and to ensure that the training and development needs of current and future specialist personnel are met.

INTRODUCTION

Although a specialist commitment to anaesthesia for burns patients is the province of a few, all anaesthetic personnel should be competent to systematically assess burns injuries and manage their transfer to specialist burns facilities. The causes and thus the presentation of burns injuries are diverse, and include flame burns, scalds, electrical and chemical burns. Minor burns are common—in the UK 1% of the population sustains a burn injury each year, 10% of whom require hospital admission. Of these only around one in 10 have sustained a life-threatening injury, but the appropriate early management of the burn wound and its systemic consequences is a key factor in reducing morbidity.

The burns case mix is not representative of the general population. Patients at the extremes of age are more vulnerable to injury, as are those with pre-existing morbidities such as epilepsy and alcoholism. There is an association with psychiatric illness, and others, including children, suffer non-accidental injuries.

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ASSESSMENT

The initial hospital assessment of a major burn should follow (advanced trauma life support) ATLS (advanced trauma life support) guidelines with a primary survey concentrating on the support of the airway, gas exchange and circulation. The secondary survey examines for associated trauma sustained during the accident or whilst trying to escape from the scene. Focusing on the burns injury requires:

- An estimation of percentage surface area involvement.
- Assessment of depth of burned areas.
- Determination of the evidence for inhalational injury.
- Vascular or respiratory compromise secondary to circumferential burns should be identified, and escharotomy considered.
- The cornea should always be examined before facial swelling makes assessment difficult.
- All patients with a history of exposure to smoke in an enclosed space should be considered at risk of inhalation injury, even if the initial signs and symptoms are unimpressive. Systemic toxicity secondary

to the inhalation of toxic gases such as carbon monoxide must be recognized and treated. If the history is unclear, then blood should be retained for toxicological analysis.
- The presence of associated injuries complicates management, and influences priority setting and referral decisions.

Major burns injuries (over 20% burn surface area in adults) require prompt resuscitation to treat the predictable pathophysiological consequences.[1]

- Fluid shifts from the circulation are maximal in the first 8 h following injury but continue for 24 h.
- There is generalized tissue oedema proportional to the extent of the burn surface area.
- Cardiac output is initially depressed
- Systemic vascular resistance is high.

The goal of resuscitation is to restore filling pressures and oxygen delivery as effectively as possible. Resuscitation fluids are transfused to correct hypovolaemia, initially directed by proscriptive formulae, most commonly the crystalloid-based Parkland regime. An accurate patient weight is required. Calculating fluid prescriptions in children needs adjustments from formulae to account for maintenance requirements.

Traditionally, assessment of the adequacy of resuscitation has depended on simple parameters including heart rate, blood pressure and urine output. It is increasingly recognized that this approach fails to detect patients with significant regional hypoperfusion, and emphasizes the importance of expedite transfer from the casualty facility to a specialist centre bed where appropriate haemodynamic monitoring can be arranged. Trend monitoring of flow-based parameters is increasingly practiced. Tools such as oesophageal Doppler monitoring can be used to guide target-based resuscitation. Other less invasive measures of cardiac filling and cardiac output including a transpulmonary double-indicator dilution technique that computes intrathoracic blood volume have been reported.[2]

Anaesthetic involvement must be sought early for airway assessment, help in securing venous access and liaison in the arrangements for patient transfer.

Airway assessment

Initially, thermal injury to the upper airway causes oedema and potential respiratory obstruction. The combination of facial burns, soot around the nose and mouth, and a clear history of entrapment in a closed space dictates active airway management. Inspiratory noise, agitation and tachypnoea combine to indicate impending respiratory obstruction.

Inhalation injury develops as a dynamic process; airway oedema generally increases over 12–24 h. Smoke inhalation causes progressive cough and dyspnoea and the production of copious secretions. A low threshold for tracheal intubation and diagnostic fibre-optic bronchoscopy is recommended. The early institution of a regime of nebulized bicarbonate solution has proven to be beneficial in mobilizing secretions and reducing the incidence of mucous plugging. Other recommended regimes include nebulized heparin and or *N*-acetyl cysteine.[3]

Patients with significant carboxyhaemoglobin levels (over 30%) require high inspired oxygen concentrations to reduce the half-life of COHb. The benefit of hyperbaric oxygen treatment is questionable given the logistic difficulties of managing major burns injuries in hyperbaric facilities.

Venous access

Securing central venous access before generalized tissue oedema obscures landmarks is preferable. ATLS teaching has reduced the incidence of fluid under-resuscitation; over-enthusiastic volume loading should be avoided.

Preparation for transfer

The adequacy of transfer equipment and drugs should be checked. Guidelines for transfer management are widely available.[4] All intravascular lines should be firmly secured prior to departure. Contingency plans for airway management *en route* should be agreed. Emergency intubation whilst in motion is hardly a preferred option, and inevitably a number of patients will undergo tracheal intubation and ventilation primarily for transfer. This can cause difficulties in regions where burns intensive care resources are scarce, but is preferable to a wait and hope policy. Prolonged transfers accentuate the requirement to accurately measure and deliver resuscitation fluid volumes. Monitoring appropriate to the patient condition should be available, with a facility to record and print data on arrival.

Written information accompanying the patient should include a history of the burn and any associated injuries, initial examination details and treatment of the patient since the burn injury, including airway management, fluid volumes, urine output. If initial surgical escharotomies were performed these should be charted.

It is widely acknowledged that patients with serious burn injuries are best managed in specialist burn units. Early assessment and active intervention to manage the burn wounds can limit the systemic consequences of the injury and speed functional recovery. High standards of resuscitation, surgery and critical care are required, and early involvement of experienced staff is necessary. There are many aspects to be considered to achieve successful outcome in burns injuries; the contribution of anaesthetic members of the burns team remains of high

importance for a substantial part of the patient's hospital experience.
Areas of influence include:

- Anaesthesia for burns surgery.
- Acute pain management.
- Critical care.
  Airway, ventilation, haemodynamics
  Technical—line changes,
  postpyloric feeding tubes.
  Nutrition and metabolic management
  Infection control—diagnosis of ventilator-associated pneumonia.
- Communication.
  Patient, surgeons, nurses, therapists, relatives
- Chronic pain, sleep issues.

ANAESTHESIA FOR BURNS SURGERY

The burns theatre environment can be something of an acquired taste. The case mix, staff and patient dynamics are complex and the technical aspects are demanding. Repeated exposure to patients undergoing multiple surgical episodes demands patience and attention to detail to discern relevant changes in condition.

A dedicated burns theatre facility must be adequately stocked and resourced. Theatre anaesthetic equipment and transport monitoring should be compatible with that used in the critical care rooms. Stock control in theatre will be influenced by infection control procedures, minimizing store of equipment in theatres. Single use patient items are preferred and didactic cleaning schedules are needed between cases. Inevitably, the turnover of patients is reduced. The temptation to share resource with general theatre facilities must also consider infection control issues. The location and staffing of post-anaesthetic recovery facilities may be problematical, particularly for small children.

The practical conduct of burns anaesthesia requires flexibility. Surgical episodes have to be seen in the context of overall patient management. Momentum has to be maintained in the recovery process with targets set and progress judged. This philosophy will inform attitudes to fasting times, timing of surgery, sedation, weaning and mobilization.

Surgery

Modern surgical management strategies are directed at accurately assessing the depth of the burns wound, excising necrotic tissue to limit infection and the extent of the hypermetabolic response, and achieving wound closure, with the ultimate goal of maximizing functional and cosmetic recovery.[5]

Surgery is indicated for full thickness injuries or when the wound is unlikely to heal within a few weeks. Slower healing wounds risk hypertrophic scar and contracture formation. Tangential excision is commonly practiced—this is the debridement of progressive amounts of burns tissue until viable tissue is reached.[6] This contrasts with the historical approach in which burns surgeons waited for eschar to slough off, and then grafted skin onto granulating tissue. Advances in surgical, anaesthetic and critical care have made it possible to excise larger areas of deep burns earlier, and close the wound with autologous or cadaveric skin, or a growing range of skin substitutes. The introduction of prompt burn excision with early grafting is believed to result in less scar formation and accelerates functional recovery. Hospital stay is decreased for small burns, but it is more difficult to clearly demonstrate reduced length of in-patient stay for larger burns.

The timing of surgery for burns wound can be classified as:

- Immediate—escharotomy, or injuries associated with the accident.
- Early—tangential excision and grafting within 72 h.
- Intermediate—tangential excision and grafting beyond 72 h.
- Late—post-burn reconstruction.

In moderate size burns (less than 30%), wound closure can be achieved in one procedure using partial thickness skin grafts from unburned donor sites. In larger burns partial thickness skin grafts are expanded by 3:1 or more, and cover is augmented by cadaver allograft which may remain adherent for more than 10 days before immune rejection ensues.

In very large burns where donor sites are limited, alternative approaches include staged excision of the burns wound with reharvesting of autologous skin donor areas or the use of artificial skin substitutes to provide temporary cover.

Patients requiring later reconstructive burns surgery need careful assessment. The extent of the surgery may not reflect anaesthetic difficulties in venous access and airway management, so adequate time must be allocated. Patients may travel large distances to maintain continuity with a particular unit, making day-case arrangements difficult.

Blood conservation techniques

Debridement of major burns has the potential for significant blood loss, and it is prudent to confirm that adequate cross-matched blood and blood products is available before induction of anaesthesia. Surgical timing and technique influences bleeding, and vigilance is necessary to assess losses, especially when multiple surgical teams work at different sites on the patient. Blood loss has been estimated to range from 200 to 300 ml for each percent of the body surface area excised and grafted.[7,8] Major blood loss can be sudden and surgery may need to be suspended while hypovolaemia is corrected.

Naturally, prevention is better than cure, and strategies to keep blood loss to a minimum are an important part of surgical technique. Tourniquets should be used for all extremity burns. Subcutaneous infiltration of the operative site using saline with adrenaline 1:1 000 000 solution 'to tumescence' is highly effective.[9] A delay of 10–15 min before excision enhances the vasoconstrictive effect. The technique appears to be safe with few and only transient haemodynamic complications.[10] There is a surgical learning curve as there is a qualitative change in the tissue surface at excision, but graft take rates appear not to be compromised. Other techniques shown to be useful are the use of temporary pressure dressings, topical thrombin sprays, and topical adrenaline soaks.

Blood transfusion practices are influenced by risk–benefit analyses of red cell transfusion and the availability of alternative plasma volume expanders.

Recent attention has concentrated on determining objective indications for blood transfusion, with clinical experience suggesting that losses of up to 30% circulating volume can be replaced with crystalloid or colloid solutions alone.[11] Haemoglobin concentrations above 8 g/l are considered sufficient and there is no evidence that moderate anaemia impairs wound healing.[12,13]

The trend away from the use of albumin, fuelled by cost issues and controversy around a published meta-analysis of albumin in critical care patients has compounded the wide variation in fluid prescription practices in the post acute phase burns patient.[14] The use of hydroxyethyl starches has spread, with prolonged duration of effect and efficient volume expansion seen as desirable properties. However, a recent paper has raised the possibility that the use of hydroxyethyl starches may increase the risk of acute renal failure in patients with a septic profile.[15] Reports of chronic itch are also of concern in a patient group already at high risk of this complication.

The persisting high-volume fluid exchanges required in severe burns injury patients emphasize the need for studies to better determine optimal fluid regimes in the post acute phase. Manufacturers dosage recommendations for new colloid solutions are derived from general critical care population studies—their relevance in burns patients is conjectural.

Pharmacology

Abnormal drug effects are to be expected in burns patients.[16] The host response to severe burns injuries results in functional changes in organ systems controlling the distribution, transformation and excretion of drugs; receptor populations are altered, and losses may occur through the burn wound. Polypharmacy is usual, and the potential for interactions high. Experienced pharmacy staff have an important surveillance role.

The acute phase response to severe burns injuries results in early changes in plasma protein levels. Albumin levels fall and alpha-1 acid glycoprotein levels rise. Changes in the drug non-protein bound fraction can alter the pharmacological response.

In general, drug pharmacokinetics undergo a biphasic response in burns injury. The initial reduction in circulating blood volume, cardiac output and tissue perfusion, due to blood and fluid loss and increased vascular permeability, reduces renal and hepatic blood flow. This is restored following the development of the hypermetabolic phase, usually after 48 h. There may be, however, impairment in renal tubular and hepatic function, so increased drug clearance may not necessarily result.

The volume of distribution (V_d) of a drug may be altered by changes in protein binding and in extracellular fluid volume, resulting from fluid loss, exogenous fluid administration, and increased capillary permeability. Changes in loading dose may be required if the drug has a small volume of distribution or a narrow therapeutic range. Total plasma clearance must be considered when considering drug maintenance doses and dosage intervals.

A pharmacodynamic explanation has been proposed for the effects of burn injury on the efficacy of muscle relaxants. Burn injury causes proliferation of extrajunctional acetylcholine receptors (AchR) leading to resistance to non-depolarizing muscle relaxants (NDMR), and hypersensitivity to depolarizing muscle relaxants.[17] This effect may occur within a week of the injury, persist for up to a year, and is proportional to the total burns surface area.

Dose requirements for all anaesthetic agents are generally increased in the burns population with their hyperdynamic circulation and hypermetabolic state; MAC values are raised and the duration of action is decreased. Tolerance to the effects of sedative, analgesic and inotropic medication is commonly seen but the range of response for individual patients is unpredictable.

Feeding and fasting

Clinically, significant gastrointestinal dysmotility is common in the burns population but repeated interruptions to the feeding regime for surgical procedures delays recovery. Consideration should be given to the early institution of postpyloric feeding, and intubated patients can be fed throughout surgery. Anaesthetic techniques that permit early re-institution of feeding regimes postoperatively should be preferred, and the development of antagonists to opioid-induced gastrointestinal status may be of advantage.[18]

The importance of tight glycaemic control in critical care patients has recently been promoted.[19,20] Clear unit feeding protocols contribute to this by reducing the incidence of prolonged interruptions to enteral regimes.

Monitoring

During anaesthesia there is a continual requirement to monitor the patient's physiological state, to confirm correct equipment function, and to avoid patient awareness. Accepted recommendations state that the following monitoring devices are essential to the safe conduct of anaesthesia: pulse oximetry, non-invasive blood pressure monitor, ECG and capnography.[21] The extent to which the patient is assessed beyond the minimal standards of monitoring should be determined by the patient's medical condition and the proposed extent of surgery.
Specific issues in the burns patient include

- Difficulties in placement of monitoring equipment.

The standard sites for placement of ECG electrodes are often unavailable, and it may be difficult to make the gel electrodes adhere to damaged skin. Options to overcome these difficulties include attaching the ECG leads to surgical staples or steel sutures placed in burned areas, or accepting the trace obtained by electrode placement at distant sites.

Even with all limbs burned it can be possible to place a blood pressure cuff and obtain a reliable reading. However, for all extensive procedures invasive measurement is indicated, with the benefits of pulse-contour analysis, and ease of blood sampling.

- Access to usual sites

Pulse oximetry may be unreliable in the presence of carboxyhaemoglobin or in shocked, vasoconstricted patients or those with peripheral burns. Attachment of probes to central sites, such as ear, nose, lip, or tongue may be helpful. Access to neck veins for central venous pressure monitoring may be precluded by burns wounds.

- Temperature monitoring

This is manadatory in all but the shortest procedures. The combination of lengthy procedures in cold operating theatres, large exposed areas of body surface, and administration of large volumes of fluids, can lead to marked intraoperative hypothermia.

Infants below 6 months are unable to shiver and prolonged hypothermia risks hypoxia and acidosis through adaptive brown fat metabolism. Infants and children have higher relative evaporative heat loss than adults.

The ambient theatre temperature should be warm, above 27°C, despite the discomfort this causes to the theatre team. Body areas not being operated on should be kept covered, and forced air warming devices used if practicable. A radiant heater near the patient can be particularly effective at reducing heat loss. Intravenous fluids should be warmed.

PAIN CONTROL

Burns pain is frequently poorly managed, with poor communication, drug side-effects and anxiety and depression being contributory factors.[22] Pain receptors in residual skin elements are stimulated, and the host response sensitizes receptors around the injury sites. Neuropathic pain develops secondary to nerve damage, abnormalities in nerve regeneration and central nervous system reprogramming.

In the acute stage, the assessment of pain in the critical care burns patient is difficult as the usual signs including hypertension, tachycardia, sweating and agitation are obscured. The pattern of burns depth or area provides few clues as to pain severity but effective analgesia is important to prevent the physiological, functional and psychological consequences of severe or protracted pain.

Opioid doses titrated to response remains the mainstay of therapy, and side-effects must be accepted and managed. Combination therapy with low-dose ketamine infusions, regular paracetamol and judicious use of non-steroidal inflammatory agents can be opioid sparing, though NSAID side-effects limit their use.

- Sodium and water retention.
- Inhibition of renal prostaglandin production.
- Inhibition of platelet aggregation.
- Small bowel villous atrophy.
- Extensively protein bound, so effects potentiated by hypoproteinaemia.

Antidepressant therapy should be started early and may be beneficial in improving sleep patterns.

Following discharge from critical care regular assessments of severity (those recorded by the professionals generally correlate poorly with the patient's own assessment) are needed, and distinction between background and procedural pain is important, as different strategies are needed for each.

Background pain may be present continually. At first, intravenous opioids by infusion or patient-controlled analgesia (PCA), will be needed to control pain. Once feeding has been established the enteral route can be used, with long acting oral opioids supplemented, as necessary, with shorter acting preparations for breakthrough pain.

Procedures, including surgery, dressing changes, and physiotherapy, may require more intense analgesia. Poor management can lead to a high degree of anticipatory anxiety for future procedures, lowering pain tolerance, so early failure is poorly tolerated. Bolus alfentanil doses and patient-controlled propofol techniques have been used successfully and recovery times are markedly shorter than conventional practice with oral opioid and benzodiazepine combinations. Regional anaesthetic techniques may be available, depending on the burns distribution but topical local anaesthetic application has proven disappointing in our hands, with variable effect.

Prolonged pain can develop co-incident to the healing process and tissue regeneration, associated with itching and tingling. The chronic pain state that emerges often has multiple, often unclear origins of pain, and can be frustratingly unresponsive to conventional regimes. Adjuvant therapies include clonidine, and anticonvulsants which are effective in the treatment of sympathetically maintained pain.[23] Psychological therapies to boost coping strategies and aid relaxation benefit many patients.

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