Major Burns Part 2: Anaesthesia, Intensive Care and Pain Management

Dr Christopher McGovern MRCEM FRCA FFICM is a specialty trainee in anaesthesia and intensive care medicine and a clinical research fellow at the University of Glasgow.

Dr Kathryn Puxty MD MRCP FRCA FFICM is a consultant in anaesthesia and intensive care at Glasgow Royal Infirmary. She is an honorary clinical associate professor at the University of Glasgow and a CSO career research fellow.

Dr Lia Paton BMedSci(Hons) FRCA FFICM is a consultant in anaesthesia and intensive care and lead clinician for burns intensive care at Glasgow Royal Infirmary, a tertiary referral centre for burns in Scotland. She is also chair of the Care of Burns in Scotland (COBIS) data group.

Corresponding author. paton.lia@ggc.scot.nhs.uk

Key Points

- Involvement of the multidisciplinary burns team is vital for the care of patients with major burns.
- Thermoregulation, blood loss and coagulopathy are key considerations in anaesthesia for burn surgery.
- Fluid resuscitation should be titrated to urine output, haemodynamic and laboratory parameters.
- Administration of human albumin solution in addition to crystalloid may reduce fluid requirements.
- The hypermetabolic response can be ameliorated by early excision, appropriate nutrition and specific pharmacotherapy.

Learning Objectives

By reading this article you should be able to:

- Describe the main challenges of caring for a patient with major burns in the operating theatre or intensive care unit.
- Describe the ways in which intravenous fluid therapy may be optimised, so as to avoid under-and over-resuscitation.
- Outline how to recognise and manage infectious complications in patients with major burns.

- Outline pharmacological and non-pharmacological techniques to mitigate the hypermetabolic response to burn injury.

As a result of improvements in the care of patients with major burns, increasing numbers of patients are surviving more severe injuries.[1] Many will require a protracted stay in intensive care, numerous operative interventions and comprehensive rehabilitation. Engagement of a multidisciplinary burns team is necessary to help maximise quality of life for survivors who may have profound physiological, psychological, functional and social problems..

The initial assessment and treatment of patients with major burns is covered in part 1. This article will focus on the ongoing care of adult patient with a major burn of over 15% total body surface area (TBSA) in both the operating theatre and the intensive care unit. Previous articles provide specific information on the management of smoke inhalation injury and major burns in paediatric patients.[2,3]

A – Anaesthesia and burn surgery

Since the 1940s it has been recognised that early excision of burn eschar improves mortality.[4] This is likely due to removal of necrotic tissue which can both fuel the intense inflammatory response and act as a culture medium for pathogens. Patients often undergo surgical excision of burnt tissue in the first day

or two after the injury. Some patients with full thickness burns will require more immediate decompressive surgery such as escharotomy or fasciotomy. However, many will undergo multiple subsequent operations including temporising cadaveric autografts, xenografts (such as pig skin) or synthetic dermal substitutes until skin coverage with autografts is possible utilising unburned patient donor skin.

Longer term elective procedures are largely performed with the aim of restoring function and cosmesis.

B –Location of surgery

Burns surgery should be carried out in a dedicated burns theatre, ideally in close proximity to intensive care facilities. Theatre personnel should have appropriate training, experience and access to specialist equipment. It is vital that the theatre can be appropriately warmed in order to reduce heat loss. Procedures such as dressing changes may be carried out under sedation led by an anaesthetist, with all the necessary resources to convert to general anaesthesia, should this be required.

B – Preoperative assessment

Assessment of a patient for burn surgery should include knowledge of the extent of the burn, associated injuries and details of the planned surgery including positioning and estimated blood loss. Coagulopathy may be present, driven by endothelial injury and the inflammatory cascade, often exacerbated by secondary infection. Its extent can vary from

subclinical changes to fulminant disseminated intravascular coagulation (DIC). Therefore, the need for blood products should be anticipated early.

Given the extensive volume of i.v. fluids often required and the potential for associated renal injury, a thorough assessment of volume status and electrolyte abnormalities should also be made. Nutritional support should be continued throughout the operative period in patients who are mechanically ventilated preoperatively and fasting times kept to a minimum in those requiring airway intervention.

Airway assessment should include clinical examination and a careful review of previous anaesthetics. Whilst mechanical ventilation may have already been established prior to transfer to the operating theatre, particular care is required to prevent accidental extubation, especially in patients with airway burns or inhalational injuries. Formation of a tracheostomy may be indicated for various reasons, particularly for patients with complex facial burns in order to maintain skin health around the mouth and nose. Additionally, whilst burns involving the face or neck may not present any airway difficulties initially, subsequent contractures may severely limit neck extension and mouth opening. Advanced techniques such as awake fibreoptic intubation may be indicated. A difficult airway trolley with equipment for front-of-neck access should be readily available in all circumstances.

- B – Intraoperative management

Monitoring can prove challenging. ECG electrodes sometimes require sutures or skin clips for reliable contact. Pulse oximetry and blood pressure cuff positioning may also be difficult and suitable sites for i.v. access and direct arterial monitoring may be limited.

Monitoring the patient's core temperature is mandatory. Methods to minimise heat loss include minimising exposure, using forced air warmers and heat lamps, humidifying anaesthetic gases, infusing warmed intravenous fluids and maintaining an ambient temperature in theatre of 28-33 ºC.

Care should be taken to assess a patients ventilatory requirements preoperatively and lung protective ventilation should be continued throughout the intra-operative period. Patients who have also suffered an inhalation injury may have increased oxygen and PEEP requirements, prompting care to avoid de-recruitment with the loss of PEEP during transfer to a transport or theatre ventilator.. The hypermetabolic response suffered by burns patients leads to increased oxygen consumption and carbon dioxide production, higher than expected oxygen concentrations and minute volumes may be required.

Blood loss can be as much as 3.4% of total blood volume for each per cent TBSA excised.[5] The risks are increased in infected burn tissue, deeper thickness burns and prolonged

operative time. Risks may be reduced by using limb tourniquets on extremity burns, topical adrenaline or compression bandages. The use of near patient coagulation studies such as thromboelastography may be superior to standard lab-based tests in detecting coagulation abnormalities and may be of value to direct blood product use intraoperatively.[6]

B – General vs regional anaesthesia

Many major burn injuries will require general anaesthesia for surgical interventions. However regional anaesthesia, either alone or in combination with general anaesthesia, may be suitable. Careful evaluation is required before performing neuraxial anaesthesia because of the potential for coagulopathy and infection in this patient group.

A - Intensive care management

B - Fluid management

Appropriate fluid resuscitation is critical in the first 24 to 48 hours following a burn injury. Under-resuscitation may lead to impaired tissue perfusion, end organ damage and extension of burn depth. However, excessive fluid administration is also harmful; risks include electrolyte disturbances such as hyponatraemia, exacerbation of tissue oedema, pulmonary and cerebral oedema and abdominal and limb compartment syndromes.

The Parkland formula, as covered in part 1 of this article, remains the most common tool used to calculate fluid requirements. Concerns have been raised that it may over-estimate the volume needed, prompting bodies such as the American Burn Association to recommend less than 4 ml kg^{-1} $TBSA^{-1}$.[7] However, we advocate starting with an infusion of 4 ml kg^{-1} $TBSA^{-1}$ and carrying out regular clinical reviews to permit escalation or de-escalation of fluid input based on individual patient physiology as opposed to rigidly adhering to any one formula.

- C - Goal directed fluid therapy

The most common and easy method of ensuring appropriate fluid resuscitation is by targeting an hourly urine output of 0.5-1 ml kg^{-1} ideal body weight. Failure to meet this target should prompt reassessment and adjustment of fluid delivery as detailed in Fig. 1.

However, an inadequate urine output is not always caused by volume depletion. Renal failure from acute tubular necrosis or rhabdomyolysis can result in oliguria, as can increased anti-diuretic hormone release in response to injury. Other causes such as vasoplegia, low cardiac output and abdominal compartment syndrome should also be considered. Conversely, urine volumes in excess of targeted values should prompt a reduction in fluid administration, mitigating against the

phenomenon of “fluid creep”, whereby more fluid than required is given.

Peripheral perfusion, serum lactate, acid-base balance and haematocrit should also be used to guide fluid therapy. The additional use of cardiac output monitoring to guide fluid delivery in patients with major burns has demonstrated improvements in cardiac output, oxygen delivery and organ dysfunction, but a mortality benefit has not been identified.[8]

- C – Choice of fluid

Balanced crystalloids such as Hartmann’s solution are the mainstay of fluid resuscitation in major burn injuries. Their use has been demonstrated to reduce the incidence of significant electrolyte disturbances such as hyperchloraemic metabolic acidosis.[9] The use of colloids such as human albumin solution in combination with crystalloids may reduce overall fluid volume requirements, mitigate against “fluid creep” and lessen the increases in intra-abdominal pressures compared to crystalloids alone.[8] We recommend the addition of 4.5% human albumin solution if fluid resuscitation volumes in the first 24 hours are projected to be greater than 6 ml kg^{-1} $\%TBSA^{-1}$ (Fig.1). This technique of “colloid rescue” should be continued until 48 hours post-burn.

B – Thermoregulation

Major burn injuries are associated with thermodysregulation, with an initial propensity to hypothermia driven by heat and

fluid loss from the burn wounds themselves. Steps to reduce heat loss during the initial stages of resuscitation are detailed in part 1. The principles of maintaining an adequate core temperature in the theatre environment, as already detailed, also apply to the intensive care environment.

Most patients with major burns will subsequently develop a raised core temperature. This reflects altering of the hypothalamic setpoint for thermoregulation by pyrogens such as interleukin-1 and tumour necrosis factor.[10,11] More profound hyperthermia, with temperatures exceeding 40 ºC, can occasionally occur and may lead to multi organ failure. Steps to address potentially harmful hyperthermia should be taken in patients with a core temperature above 39.5 ºC. Techniques include debulking dressings, giving antipyretics such as paracetamol, applying ice to non-burned areas, infusion of cooled intravenous fluid, and irrigating the bladder and stomach with cold fluid. More invasive approaches such as intravascular heat exchange catheters or extracorporeal circuits may also need to be considered.

B – Nutrition

An individual's basal metabolic rate can increase significantly following a burn injury, more than doubling in burns greater than 40% TBSA.[12] If not addressed, this can result in loss of lean body mass, immune compromise and impaired healing. A

direct correlation between loss of lean body mass and adverse events, including infectious complications and death, has been demonstrated.[13]

- C – Timing of nutritional support

Starting enteral nutrition in the hours immediately after injury has been shown to beneficially modulate stress hormones, improve gut integrity, reduce intensive care length of stay, improve wound healing and reduce wound infections.[13] The British Burn Association (BBA) national standards state:[14]

- Enteral nutrition should be started as soon as possible in major burns, ideally within 6-12 hours after the injury.
- Total body weight loss should not exceed 10% of the patient's weight at admission.

- C – Route of nutrition

As with most critically ill patients, the enteral route is preferred. Post-pyloric feeding may be required if gastric stasis is present and impairing calorie delivery. It may also help reduce aspiration risk, especially in patients requiring multiple interventions under general anaesthesia. Parenteral nutrition is rarely required, but when used, caution should be exercised because of the risks of infection, overfeeding and erratic blood glucose control.

- C – Caloric requirements

The aim of nutritional support is to meet the substantially increased caloric requirements while avoiding harmful overfeeding that can lead to hyperglycaemia, hypertriglyceridemia, hepatic steatosis, hypercapnoea and prolonged duration of mechanical ventilation.[13] Various methods have been used to assess caloric needs. The most accurate method is indirect calorimetry, but this remains mainly a research tool. In lieu of this, various formulae have been devised to guide clinicians (Table 1).[13,15] Such formulae may under- or over-estimate requirements at different times during a patient's admission. Given the complexities of providing optimum nutritional support, specialist input from a dietician within the burns team is essential.

- C - Macronutrients

The three main macronutrients, carbohydrates, proteins and lipids, provide substrates for ATP biosynthesis, wound repair, immune function and maintenance of lean body mass. Carbohydrates are generally the preferred energy source, preventing a reliance on muscle proteolysis. However, relying solely on carbohydrates to meet caloric needs would result in hyperglycaemia due to glucose delivery exceeding the rate at which it can be utilised. A relative insulin resistance, commonly observed in critically ill patients, may also exacerbate hyperglycaemia. Glucose should be limited to 55%

of total energy requirements and hyperglycaemia managed with supplemental insulin as required.[15]

Excessive lipid delivery can result in accumulation in the liver and impaired immune function.[13] Therefore, lipids should account for no more than 30% of energy delivered, although some centres would recommend a maximum of 15%.[13,15]

Given the potentially high sedation requirements of this patient group, the lipid content of propofol should also be accounted for.

Protein plays a crucial role in wound repair and maintenance of lean body mass. Increasing protein intake to supra-physiological values does not prevent catabolism of existing protein stores but does prevent a negative nitrogen balance and improve protein synthesis. Protein should be delivered at 1.5-2 g kg^{-1} day^{-1} in adults. This often requires protein enriched feeds prescribed under the guidance of a dietetic team.[15]

- C - Micronutrients

Reserves of trace elements including copper, selenium, zinc and vitamins B, C, D and E may become depleted due to the intense inflammatory response, exudative losses and haemodilution resulting from intravenous fluid resuscitation.[16]

Micronutrients are essential for antioxidant defences, wound healing and immune function. Adequate supplementation often requires supra-physiological doses to be administered, often parenterally due to limitations in enteral absorption.[15] Early

replacement of these elements may reduce infectious complications, improve wound healing and reduce intensive care length of stay.[16]

B – Infection

The loss of skin, the primary barrier to infection, coupled with relative immunosuppression observed in patients with major burns lead to an increased risk of infectious complications. Infections are an important contributor to the high morbidity and mortality rates seen in this patient group, accounting for an estimated 42-65% of deaths after burn injury.[17]

- C – Burn wound colonisation and infection

Patients can become colonised with multiple, often resistant, organisms.[17] Such colonisation occurs with low bacterial concentrations on the surface of wounds, without surrounding erythema or cellulitis. In contrast, invasive wound infection is characterised by cellulitis of surrounding healthy tissue, extension of existing burn depth, eschar separation or necrosis. Patients may develop worsening pyrexia or raised inflammatory markers but this can be difficult to distinguish from the post-burns inflammatory response. Consequently, specific criteria for the diagnosis of sepsis in burns patients have been proposed:[18]

- Temperature > 39 or < 36.5 ºC
- Heart rate > 110 beats min^{-1}

- Respiratory rate > 25 Bpm (or minute ventilation > 12 litres min^{-1} if invasively ventilated)
- Thrombocytopenia < 100 $x10^9$ L^{-1} (> 3 days after initial resuscitation)
- Hyperglycaemia > 11.1 mmol L^{-1} or Insulin infusion requirement > 7 units hr^{-1}
- Intolerance of enteral feed

With such difficulty in relying on clinical signs and traditional biomarkers like C-reactive protein (CRP), other markers such as procalcitonin (PCT) may have better discriminatory capacity in diagnosing sepsis in burn injured patients.[19] There is also increasing interest in the use of genomic variants, cytokine profiles and epigenetic markers.[20]

Patients with infections should be treated with appropriate antibiotics, ideally as advised by medical microbiology and based on colonising organisms. Surgical debridement may be required. Patients with a delayed presentation or delayed excision of burn wounds are at highest risk of infective complications.

- C – Common pathogens

The most common pathogens, particularly early in the admission, are Gram positive bacteria such as Staphylococcus aureus, Streptococcus and Enterococcus species. Gram negative bacteria such as Pseudomonas aeruginosa can translocate from the gastrointestinal tract or the environment

and thrive in the moist environment of a burn wound. Infections due to Pseudomonas will have a typically green/yellow colour and foul smell which can lead to invasive infection with necrosis. Other Gram negative pathogens including Acinetobacter, Escherichia coli and Klebsiella can also cause invasive infections. Multi-resistant strains of pathogens including Pseudomonas aeruginosa, Acinetobacter species and vancomycin resistant Enterococcus (VRE) are an increasing concern. Recognised risk factors include the use of broad spectrum antibiotics, colonisation at admission, need for escharotomy, prolonged hospital or intensive care stay and multiple surgical procedures all recognised risk factors.[21] Fungal colonisation and invasive fungal infections are also significant problems. Fungal wound infection has been demonstrated to be independently associated with increased mortality.[22] Candida albicans is the most common pathogen, although Aspergillus and non-albicans Candida such as C. tropicalis and C. krusei are becoming more common.[21] Regular clinical review and sampling of wounds and other potential sources of colonisation and infection should guide when and which antimicrobial therapy is initiated.

- C-Toxic shock syndromes

Toxin producing strains of Staphylococcus aureus can cause toxic shock syndrome (TSS). Streptococcal toxic shock syndrome (STSS), caused by Group A Streptococcus, has a

similar presentation. In addition to the non-specific clinical signs suggestive of infection described previously, patients with TSS or STSS may also exhibit a diffuse macular rash, vomiting and diarrhoea, thrombocytopaenia, lymphopaenia and deranged liver function tests. In addition to standard management of infections, antibiotics that directly reduce exotoxin production, such as clindamycin and linezolid, should be considered. The use of intravenous immunoglobulin has also been reported.[23]

B - Hypermetabolic and inflammatory response

Although these effects are most pronounced in the acute phase following burn injury, the inflammatory and immunosuppressive changes can last for several years after a burn injury has healed.[24] Changes include:

- Increased resting energy expenditure
- Increased serum and urine cortisol and catecholamines
- Increased cytokines including IL-6, IL-8 and G-CSF

These persisting metabolic, inflammatory and immune changes can result in an increased risk of developing problems later in life, as illustrated in Table 2.[25] Skin closure, nutritional support and analgesia are fundamental to mitigating this response. Several therapies have been proposed, some of which are discussed further.

- C - Beta-blockers

Beta-adrenergic blockade with drugs, such as propranolol, supress the catabolic effects of a burn by reducing energy expenditure, limiting insulin resistance, preventing muscle wasting and acting as anti-inflammatory agents. However, caution must be exercised in the use of adrenergic antagonists in the intensive care setting due to risk of cardiorespiratory instability. A recent systematic review failed to show benefit in terms of mortality, length of hospital stay or incidence of sepsis.[26] However, other studies have demonstrated improved wound healing and reduced muscle catabolism.[27]

- C – Oxandrolone

Oxandrolone is an androgen receptor agonist, stimulating protein synthesis and muscle growth with much less virilising activity compared to testosterone, making it more suitable for use in women and children. Oxandrolone has been used from around day 5 post-burn at a dose of 10 mg enterally twice daily in ≥ 30% TBSA burns to minimise weight loss, improve urinary nitrogen balance, increase muscle strength and reduce healing time. Some studies have shown benefits such as reduced intensive care and hospital length of stay, maintained lean body mass and improved whole body mass.[28] Adverse events include hepatic injury with increased liver transaminases, renal injury and skin complications like cellulitis.

A - Pain management

The pain experienced from a burn injury can be excruciating and is often difficult to manage. Some studies suggest higher pain scores during hospital admission are associated with poorer long term outcomes such as increased mental health problems.[29] Given the complexities and challenges of effective pain management, a specialist pain service should be an integral part of the burn team.[14]

B – Types of pain

Whilst the burn injury is usually the most significant source of pain, there are many other causes. These include pain from associated injuries, tracheal tubes, invasive lines and catheters, skin autograft donor sites, pressure areas and interventions including position changes will all impact pain severity. Clinicians should adopt a structured approach to acute burn pain management, addressing the three main types of pain:

- C – Background pain

Patients will experience a degree of persistent pain after a burn injury and multi-modal analgesia should be prescribed to maintain adequate control. Infusions should be titrated to a targeted effect, maximising clinical benefit while avoiding unwanted adverse effects. Multiple methods for pain assessment exist including the visual analogue scale (VAS), designed for cooperative and communicative patients, and the Critical Care Pain Observation Tool (CPOT) for use in the

intensive care unit.[30] Non-pharmacological measures such as appropriate dressings, comfortable positioning, cutaneous stimulation, acupuncture and techniques such as cognitive behavioural therapy and music therapy may also help alleviate this form of pain.

- C – Breakthrough pain

Breakthrough pain occurs on top of well controlled background pain, either as an exacerbation of background pain or originating from another source. This can be evoked, spontaneous, predictable or unpredictable. It can be managed with boluses of rapid acting agents, increases in the rate of opioid infusions or, if predictable, anticipatory doses of longer acting agents.

- C – Procedural pain

Procedural interventions include dressing changes and mobilisation. Analgesic interventions should be timed appropriately to gain the maximum benefit from the agent being used. Appropriate agents include opioid boluses, inhaled agents including nitrous oxide and methoxyflurane or analgo-sedative agents such as ketamine. Other non-pharmacological methods may be beneficial including hypnosis, virtual reality systems and other distraction techniques.

B – Pharmacological management

- C – Opioids

Opioids remain the mainstay of pain management in burn injuries. The choice of opioid and method of delivery will depend on local preferences and patient factors including renal function and conscious level. Patient Controlled Analgesia (PCA) is commonly used but relies on a conscious and alert patient. Patients with significant burn injuries often require large doses of opioids resulting in inevitable adverse effects such as ileus, respiratory depression, delirium, hypotension and potentially dependence. For these reasons, a multi-modal analgesic approach and advice from a pain specialist are both advised.

- C – Non-steroidal anti-inflammatory drugs

NSAIDs such as ibuprofen and diclofenac are infrequently used in critically ill patients due to the risk of gastrointestinal haemorrhage and renal impairment. Whilst they may be of benefit in selected patients, they should be used with caution.

- C – Ketamine

Ketamine is an N-Methyl D-Aspartate (NMDA) receptor antagonist with potent analgesic effects. Ketamine can be given as an infusion, often to reduce opioid requirements, or in sedative or anaesthetic doses for painful interventions. Ketamine may also have a role in preventing the development of neuropathic pain and has been shown to reduce secondary

hyperalgesia and “wind-up” phenomenon in healthy volunteers.[31]

- C – Gabapentinoids

Gabapentin and pregabalin have been used in the management of burn pain and pruritus, both acutely and in those who develop chronic symptoms. The evidence for benefit is mainly from observational studies, which demonstrated improved pain scores and reduced opioid consumption.[32] However, given the increasing evidence of harm from dependence, abuse and overdose, they should be used with caution, especially in patients with a history of alcohol or drug misuse.[33]

- C - Dexmedetomidine

Dexmedetomidine is a highly selective α-2 receptor agonist with both analgesic and sedative effects. It can be used in the intensive care unit as part of an analgo-sedative regimen, in combination general anaesthesia, as a sedative for painful procedures and also as an adjunct in patient controlled analgesia. Common side effects of dexmedetomidine are bradycardia and hypotension. As recent studies have highlighted the risk of pyrexia associated with dexmedetomidine use, caution is advised in the context of hypermetabolism post-burn.[34]

A – Psychological sequalae of burn injury

Survivors of burn injuries can be left with long lasting mental health problems such as depression, anxiety, suicidal ideation

and post-traumatic stress disorder (PTSD). Other consequences include cognitive impairment, physical limitations, chronic pain and pruritus. These sequalae are recognised in intensive care survivors as Post-Intensive Care Syndrome (PICS), although such effects are likely to be amplified in survivors of major burn injuries, regardless of whether or not they were managed in the intensive care unit. Patients with major burns often have a prolonged hospital admission, numerous invasive procedures, multiple risk factors for developing delirium and significant pain issues. Additionally, the event causing the burn injury is frequently distressing.

Psychological support staff should form part of the burn multi-disciplinary team. Routine psychological assessment is advised and robust care pathways should be in place in order to provide help and support to burn victims and their families. This should include access to support groups, charities, websites and opportunities for peer support.[14] Early psychosocial screening may help identify patients at the highest risk of developing problems post-injury, allowing prompt intervention to address the psychological, emotional and social challenges these patients may face.

A – Conclusion

Due to vast improvements in burn care in recent decades, clinicians are now responsible for managing patients who have suffered burn injuries of increasing severity and complexity.

The provision of high quality anaesthetic and intensive care is challenging. These patients often require numerous and complex surgical interventions. Areas that require special focus include airway management, management of blood and fluid loss, thermoregulation and overcoming monitoring difficulties. Patients who have suffered major burns are also at high risk of infection, excessive catabolism, significant pain and psychological distress, all of which have adverse long-term consequences. Managing this myriad of complex issues requires expert input from a wide multidisciplinary team.

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Declaration of interest

The authors declare that they have no conflict of interest.

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Legends for tables and figures

Fig 1. Adult burn fluid resuscitation protocol (adapted with permission from COBIS (Care of Burns in Scotland)).

Table 1. Formulae to calculate daily caloric requirements (Kcal day^{-1}) in burn injuries

Table 2. Long term effects of burn injuries.[25]