MANAGEMENT OF PAEDIATRIC BURNS

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Summary. Almost one-third of all burn centre admissions involve children under the age of ten years. Caring for the burned child continues to demand the close attention of a multidisciplinary team to the patient's many needs. Paediatric burns impose enormous economic burdens on families and on society as a whole. Scald burns secondary to household accidents predominate in most series, constituting 70% of all thermal injuries in infants, toddlers, and pre-school children. Most of these injuries are potentially preventable. Children with 5% TBSA third-degree burns or more than 10% TBSA second- and third-degree burns need to be hospitalized for proper resuscitation and burn wound management. Children with burn injuries involving the face, hands, or genital areas also require hospitalization. The goal of the resuscitation of hospitalized burn victims is to restore circulating blood volume and to minimize the early stress response. This is accomplished with adequate fluid replacement, correction of hypoxia and ventilatory disturbances, prevention of hypothermia, and adequate control of pain and anxiety. Minor burns can be treated at home with topical ointments. The recently introduced MEBO (Moist Exposed Burn Ointment) seems to be highly promising in this regard. Burn wounds should be encouraged to heal in the shortest possible period by a judicious combination of topical therapy, eschar excision, and skin grafting.

Introduction

Burn injuries pose a major threat to the health of children. A severe non-fatal burn injury caused by thermal, electrical, chemical, or radiation injury remains the most devastating injury the human body can survive, not only because of the excruciating pain that usually accompanies the initial stages following injury but also in view of the severe emotional and physical scarring that may last a lifetime. Recently published data reveal that almost one-third of all burn centre admissions involve children under the age of 10 years. Despite the improvement in survival rates in recent years, caring for the burned child continues to demand close attention to the patient's many needs. Paediatric burns also impose enormous economic burdens on families and on society as a whole. Burn injuries are second only to motor vehicle accidents as the leading cause of death in children aged 1 to 4 yr and the third most frequent cause of injury and death among all children from birth up to the age of 19 yr. The peak incidence for thermal injury in children is in the second year of life. In most series, burn injuries are commonest among boys. Seventy-eight per cent of infants and toddlers sustain thermal injury as a result of their own actions, 20% are innocent bystanders, and 2% are victims of child abuse. The aetiology of burn injuries varies as the child progresses through the stages of normal development. Scald burns predominate in most series, constituting 70% of all thermal injuries in infants, toddlers, and pre-school children. Scalds commonly occur at home and mainly affect the upper part of the body. Spills outnumber immersions by more than 2 to 1. More than half of scald burns occur in the kitchen, primarily due to hot liquid spills; the remainder occur in the bathroom and other locations in the home. Infants can be scalded while being bathed or, less frequently, when drinking liquids overheated in microwave ovens. Toddlers become increasingly mobile and are at increasing risk from spilled hot foods and drinks, hot tap water, household electrical current, caustic chemicals, and hot surfaces such as irons and stoves. Flame burns predominate among older children 2 and are the commonest form of thermal injury between the ages of 5 and 13 yr. Pre-school children can be burned while experimenting with matches, lighters, and stoves. Typical burns in pre-adolescent boys involve matches and gasoline. Although often difficult to distinguish with certainty, abuse due to negligence and child abuse by burning account for approximately 5% of admissions to burn units.

Material and methods
Over the 20-yr period 1975-1995, 810 burn patients were admitted to our medical centre. Many more patients were treated on an ambulatory basis and several others had to be transferred to other hospitals because of lack of space, but almost all the critically burned patients presenting to our emergency room were admitted to the hospital. These patients were entered into the hospital computer system in accordance with the Ninth Revision of the International Classification of Diseases. A retrospective analysis of the computer records was performed.

Results

Admitted paediatric burn patients (from birth to the age of 18 yr) accounted for 43% of all admitted burn patients. Fifty-nine per cent were male and 41% female, which is identical to the male preponderance among burn victims in all age groups. Seventy-one per cent of paediatric patients were in the first decade age bracket, with a mortality rate of 11%. Forty-two per cent were less than 4 yr old and 12% were under one year. The peak incidence of burns in our series was in the first year of life, followed by the second and then the third. Fifty-seven per cent of paediatric burn patients aged less than 4 yr old were male and 43% were female. If burn patients from birth up to the age of one yr are excluded from the group of patients aged under 4 yr, the male preponderance becomes even more pronounced, accounting for 63% of cases. This may be due to the greater activity of boys than of girls.

Discussion

Adequate management of a paediatric burn injury requires initial accurate estimation of the percentage TBSA burned. It is common knowledge that both pre-hospital personnel and burn team members may significantly misjudge the extent of paediatric burns when compared with actual measurements. The Berkow body surface area chart and the rule of nines used to estimate TBSA with second- and third-degree burn injury in adults are not applicable to paediatric patients. The Lund and Browder modification, which divides the body into small portions to maximize accuracy and takes into account childhood differences in body proportions, is used in most burn centres. The initial assessment of the burned child must be expeditious and methodical in the identification of problems and establishment of treatment priorities. The emergency care of paediatric burns also includes a rapid assessment of the circumstances of the injury with regard to abuse and neglect, as in some instances protection of the child may become as important as medical care for the burn injury. Also, an awareness of the essential differences in the management of young burn victims and modifications of the treatment plan used for older patients are necessary if problems are to be avoided. It must be clear that children cannot be regarded as small adults. The primary determinant of survival in patients with burn injury has historically been the size and depth of the burn wound, followed by patient age under 4 yr. Young children do not tolerate thermal injury as well as adults. Many reports have suggested that children under 4 yr have a diminished probability of surviving as compared with the expected survival of young adults with equivalent burn injuries. Very often, children require formal fluid resuscitation for smaller burns, and more fluid per kg per percentage burn than adults. Mortality among patients with moderate burns is much higher in infants than in older patients. The mortality rate among children aged less than 4 yr with large TBSA burns is significantly higher than it is among older children. Mortality secondary to massive burns is slightly higher for patients aged under 13 yr than it is among older children. In large burns, the age of transition to a mortality that is equivalent to that of adult controls is approximately 48 months. Minor and moderate burns in adults, in accordance with the American Burn Association's classification of burns, are classified as moderate and major burns, respectively, in children. The guidelines contained in the curriculum of the Advanced Burn Life Support Course state that children with second- and third-degree burns in more than 10% TBSA should be hospitalized and undergo formal fluid resuscitation. Children with 5% TBSA third-degree burns must be admitted as well. Involvement of certain anatomical areas requiring special nursing care, such as the face, hands, and genital areas, in addition to certain social circumstances or medical conditions and associated trauma, may necessitate the hospitalization of paediatric burn patients with less than the arbitrary 10% TBSA burn cut-off point. The fact that young children do not tolerate thermal injury as well as adults, especially children under the age of 2 yr, should induce the medical team to pay more attention to the potential gravity of relatively small burns in these young patients. Presumably, the increased concern for paediatric burns is due to the markedly increased ratio of body surface area to body mass, as also to children's limited physiological reserves. Also, in the first three years of life, metabolic and systemic disturbances are greater than in older children. Other reasons cited for the higher paediatric burn mortality rate include the immature immune system and increased fluid requirements, which place children at higher risk of sepsis and hypovolaemic shock after a burn injury. In small burns of less than 2-3%, cold water soaks applied to second-degree burn areas within 10 to 15 min of the injury can reduce the extent of tissue damage and
reduce pain. Cold soaks should be applied only long enough to achieve pain relief or tissue euthenisation. The wrapping of patients with larger burns in wet sheets or the application of ice should be avoided since the resultant hypothermia leads to serious arrhythmia and compromises the response to resuscitation. When the patient arrives in the emergency unit, as is the case in all traumatic injuries, the first priorities are to secure a patent airway, when required, and to guarantee adequate ventilation. Inhalation injury is frequently associated with large burns; it is an important early predictor of mortality and is the commonest cause of death during the first hour post-burn. The causes of inhalation injury include asphyxia due to oxygen deprivation and to the inhalation of toxic gases such as carbon monoxide and hydrogen cyanide, chemical injury to the lungs caused by inhalation of toxic smoke, oedema and airway obstruction due to actual thermal burn (usually restricted to the upper airways, except when hot water vapour is inhaled), and restriction of respiratory movements caused by constricting cutaneous chest burns. Inhalation injury must be documented at the time of admission through physical examination and inspection of the oropharynx. Ninety per cent of patients with inhalation injury have significant head and neck burns. The singeing of the nasal vibrissae is common in facial burns but is not a reliable indicator of inhalation injury. The presence of signs of airway oedema and the clinical progression of such signs with a PEEP of less than 70 mm Hg are indications for endotracheal intubation. Fiberoptic bronchoscopy is considered the gold standard for the diagnosis and management of inhalation injury. This procedure may however be risky in small children and cannot be performed unless adequate burn resuscitation is underway. As patients with inhalation injury can decompen sate rapidly, endotracheal intubation and supportive ventilation with PEEP should be initiated early, in addition to hyperventilation with 100% oxygen, which shortens the half-life of carbon monoxide elimination from 4 h to 40 min. The treatment of children with inhalation injury is largely symptomatic. Prophylactic antibiotic therapy has no value in the prevention of later pulmonary infections and the prophylactic administration of steroids has no advantageous effect on the course of the injury - on the contrary, it may increase infectious complications. Children often suffer from associated injuries, as for example when desperate parents try to save their children from flames by dropping them from an apartment window. Subsequently, after adequate ventilation has been achieved, concomitant blunt or penetrating trauma must not be overlooked. Prevention of haemodynamic collapse is the next priority. Intravenous access should be established promptly by inserting a large-bore venous cannula, ideally through unburned skin. An indwelling urethral catheter must be placed to monitor urine output and a nasogastric tube must be inserted and placed for continuous suction in all patients with post-injury ileus in order to prevent emesis and aspiration. Decompressive escharotomy of circumferential burns of the chest, abdomen, and extremities must be performed without delay at the bedside by incising insensitive eschar, without anaesthesia, in order to release the restriction. Fluid imbalance is usually a result of incorrect estimation of the burn area and inadequate evaluation of fluid requirements. Children require more fluid for burn shock resuscitation than adults with similar thermal injury. The rates of heat exchange and imperceptible water losses relative to size and weight in children are considerably greater than in adults. Children have a high rate of water exchange relative to total body water and require larger urine volumes for excretion of waste products than adults. Although overtransfusion is usually well tolerated in children, it is better to follow well-established resuscitation guidelines. Isotonic solutions should be administered initially at a rate of 20 ml/kg/h until calculations of appropriate replacement can be made. Lactated Ringer’s solution is initiated at a rate of 250 ml/h in children aged 5 to 15 yr. While pulmonary artery catheters may be desirable to monitor patients with large or complicated burns, children normally have good myocardial function so that standard vital signs, urine output, and central venous pressure are often sufficient to guide resuscitation. Urine output alone is not a reliable indicator of hydration. Oliguria occurs as a result of several factors, but the excessive secretion of antidiuretic hormone - a common occurrence in burn patients - is of great importance. Hourly urine volumes tend to vary without any apparent reason and can be misleading. An average urine output over an 8-h period expressed in relation to body surface area seems to be more adequate than the 30 ml per h advocated by Monaco or the 50 ml per h advocated by Reiss et al., or even the higher volumes preferred by others. A volume of 200 to 400 ml of urine per square metre of body surface per 8 h for the first 24 h and slightly higher volumes for the second 24 h are the guidelines established by Carvajal. Evaluation of the extent and depth of the burn injury is the basis for adequate estimation of fluid requirements for successful resuscitation. Some controversy, however, still exists as to the quantity and composition of fluids required and appropriate guidelines for monitoring hydration. Overzealous attempts at restoring blood volume, though less lethal than shock, may cause excessive burn oedema, with serious morbidity. The goal of fluid resuscitation is to restore and maintain perfusion and tissue oxygen delivery at optimal levels in order to
protect the zone of ischaemia in burned tissues without overloading the circulation. The Parkland formula or the modified Brooke formula, which use single fluid requirement calculations per percentage burn injury, may be adequate for children over 10 years of age but they tend to underhydrate younger children. Better estimates of fluid requirements for young children are made by calculating burn-related requirements and maintenance requirements separately. The physiological goal is the maintenance of urine output at 1 ml/kg/h. Carvajal has developed a programme of fluid replacement based on TBSA obtained from standard surface area normograms after careful measurement of the patient's height and weight. In this programme isotonic glucose-containing solution with added albumin is used for the first 24 h. In infants aged less than one year, the concentration of sodium is reduced in order to prevent hypernatraemia. No potassium is added during the first 12 to 24 h post-burn or until normal kidney function has been demonstrated. Although the addition of colloid to the initial resuscitating solutions remains controversial, it has been demonstrated that, except for a transient histaminemediated increase in vascular permeability that occurs immediately after burn injury, the oedema observed in unburned tissues is mostly due to the burn patient's severe hypoproteinaemic state rather than to altered protein permeability. Early colloid infusion has been shown to minimize oedema in unburned tissues and to increase blood volume better than crystalloids. Hypertonic solutions have been used in adults to limit the total amount of fluid administered and to limit oedema. The risks of hypernatraemia make this alternative less attractive in children. Once adequate resuscitation has been initiated, attention can be turned to the burn wound, which may be adversely affected by desiccation and infection. The burn wounds should be immediately covered with a clean sheet or dressing to prevent further contamination and to reduce pain in partialthickness burn areas. The patient is then covered with a clean blanket in order to preserve body heat and minimize the risk of hypothermia. Sixty-five per cent of paediatric burns heal spontaneously, without the need of skin grafting, with topical therapy alone. The most commonly used topical agents are 0.5% silver sulphadiazine, 0.5% silver nitrate, and mafenide acetate. All these agents limit bacterial proliferation but none of them sterilize the burn wound. Silver sulphadiazine offers particular advantages when used in small children. Its application is painless and it has a soothing effect; it can also restrict fluid and heat loss from the burn surface. It can however cause thrombocytopenia, leukopenia, and a spreading skin rash. Silver nitrate is not an effective antibacterial agent because of its poor penetration of the burn eschar; also, it can cause hyponatraemia, hypokalaemia, hypochloroaemia, and hypocalcaemia. Mafenide acetate penetrates the burn eschar effectively but its application can be painful and be associated with an allergic skin reaction. Mafenide is also a potent carbonic anhydrase inhibitor that leads to bicarbonate depletion, metabolic acidosis, and hyperventilation. Daily dressing changes are required after thorough cleansing. However, despite the use of surgical nets or elastic bandages to hold the dressings in place, maintaining such dressings intact in a young child is not easy, particularly over the face and hands. MEBO (Moist Exposed Burn Ointment) is the basis of MEBT (Moist Exposed Burn Therapy), popularized two decades ago by Xu Rongxiang of the Beijing Chinese Burn Centre. MEBO offers the advantages of a moist environment for wound healing that promotes rapid infectionfree re-epithelialization with less pain together with the advantages of the open treatment technique, avoiding cumbersome, bulky, and expensive dressings. It also remarkably reduces the volume of fluids needed for resuscitation. MEBO has been a USA patented formulation since 1995. Its active component is B-sitosterol in a base of beeswax, sesame oil, and other components. Clinical and experimental studies reported in the Chinese literature have demonstrated that MEBO markedly reduces evaporation from the wound surface. It has a dose-related inhibitory effect on smooth muscle cells and has no evident effect on the humoral and cellular immune defence mechanisms. Although MEBO has no demonstrable in vitro bacteriostatic and bactericidal activity (probably owing to its oily composition, which prevents adequate diffusion in a watery culture medium), it has been shown that in vivo it exerted similar action to silver sulphadiazine in the control of burn wound sepsis and systemic infection by P. aeruginosa. It has also been demonstrated experimentally that MEBO exhibited a statistically significant wound healing potential in rabbit corneal epithelium as compared to saline, homologous serum, vitamin A, and dexamethasone. Also, rabbit skin burns healed much faster and with better quality scars when treated with MEBO than similar burns treated with Vaseline, with demonstrable histological differences in repeated serial biopsies. In a recent study, we demonstrated a faster rate of healing and a superior cosmetic result when MEBO was applied to split-thickness skin graft donor sites as compared to similar sites treated with the conventional Sofra-tulle dressing. Although aggressive wound care and the use of topical chemotherapeutic agents have lowered the incidence of burn wound sepsis, the burn wound continues to constitute a dominant source for bacterial colonization and secondary dissemination to other
organs. The use of systemic antibiotics alone is ineffective in the treatment of invasive burn wound infections, and likewise prophylactic antibiotics have not been shown to decrease their incidence. Burn wound sepsis and multiple organ failure continue to be the major cause of death in massively burned patients. Recent improvements in patient survival following severe burns are largely attributed to the early excision of deep burn eschar and to biological wound coverage with autografts, homografts, and even heterografts and cultured keratinocytes. Whatever the topical preparation used, the only effective means of treating burn wound infection is surgical excision of the eschar. It is also worth noting that burn wound sepsis may convert a split-thickness superficial burn into a deeper burn, in the same way as desiccation or traumatic handling of the burn wound. The timing of burn wound excision has been a focus of controversy over the past few decades. Burns that are clearly full-thickness do not pose a management dilemma because they almost certainly require excision and grafting. With careful observation, the more superficial second-degree burns are allowed to epithelialize, whereas deeper second-degree burns - which may require more than three weeks to heal and which can potentially produce hypertrophic scarring and contractures are best excised and grafted. In children with large full-thickness or deep second-degree burns, excision is best initiated within the first week and must be limited to approximately 50-60% of the child’s total blood volume. Also, millilitre per millilitre replacement of blood loss is required intra-operatively in order to minimize haemodynamic fluctuations in these fragile young patients. The policy of allowing the eschar to detach spontaneously before any skin grafting procedure may be associated with fewer operative procedures and therefore fewer restrictions on the activity of young patients, fewer metabolic disturbances, and fewer blood transfusions. Conversely, the advantages of early excision and grafting are less risk of infection, less burn wound contracture, and shorter hospital stay, in addition to the resolution of the many physiological and metabolic changes that complicate burn injuries, the commonest of which is hyperpyrexia. Following burn injury, there is an increase in body temperature and in the zone of thermal neutrality, paralleled by inhibition of the heat-losing mechanisms, which in children leads to a rapid increase in heat storage. In most instances, hyperpyrexia is associated with marked peripheral vasoconstriction: it is not usually related to the presence of infection or to the extent of the burn wound. Small burns not requiring hospitalization constitute a significant portion of paediatric emergency unit practice, particularly in rural areas. The majority of these injuries are contact or scald burns that will normally heal within 7 to 10 days. Following adequate pain control with analgesics, such minor burns are usually managed with a multitude of topical ointment dressings. MEBO’s easy application, which can be readily taught to the family, together with the remarkable analgesia it provides, makes this ointment highly recommended in the management of small paediatric burns. Adequate control of pain and anxiety is essential to minimize the early stress response in burn injury. Narcotics are the commonest form of analgesic therapy in major burns. Although not explained by pharmacokinetic changes, the narcotic requirements in adult burn injuries are higher than usual, possibly on account of the severity of the pain. Pain control in paediatric burns, however, can be a real challenge. Small children are non-verbal in their expression of pain, and interpretation of pain severity by nursing and surgical staff is highly subjective. Analgesia in paediatric burn patients should therefore assure medication on a regular basis in order to provide adequate and continuous pain relief. In small burns, acetaminophen with codeine may be sufficient, particularly if supplemented in the first few days with parenteral narcotics. Ketamine is highly effective during dressing changes because it produces dissociative anaesthesia with a low risk of hypoxia, and morphine and fentanyl continue to be reliable parenteral agents in this regard. Methadone for 24-h analgesia is both safe and effective in children. Perhaps the most valuable benefit of MEBO is, in our judgement, its potent analgesic effect, which in a large percentage of patients obviates the need for analgesic agents. The acute phase of burn injury and initial resuscitation is followed by a hypermetabolic state that lasts until completion of wound healing. Although the complex metabolic response is not yet fully understood, its magnitude is proportional to the size and depth of the burn. Symptomatic and catecholamines play a role in this response, but it is unlikely that they either initiate or primarily sustain it. Endogenous processes accompanied by elevation of cortisol and glucagon become geared towards production of energy substrates by catabolism of fat and protein stores. Attention to the nutritional needs of a burned child is therefore an essential component of management. High caloric and nitrogen intake is crucial for survival. This prevents protein breakdown and promotes wound healing. Adult nutritional calculation formulas are not well suited to children. Calorie requirements are best estimated by the formula used at the Shriners Burn Center in Galveston, Texas. Infants require 2100 cal/m² surface area plus 1000 cal/m² TBSA. Older children require 1800 cal/m² surface area plus 1300 cal/m² TBSA; adolescents require 1500 cal/m² for both body and burn surface areas. It is necessary to add 1 to 2 g of protein per kg body weight to
the diet, in addition to supplementation of vitamins and trace minerals. Whenever it is feasible, particularly in children with less than 15-20% TBSA burns, nutrients should be administered by the enteral route. Tube feeding is best started on the first day of admission with rapid advancement towards intake goals. In children with more extensive burns or presenting associated inhalation injury, in whom prolonged paralytic ileus may be expected, parenteral nutrition may be contemplated. At the same time, the maintenance of normal functions and the prevention of the complications caused by prolonged immobility are the specific goals of rehabilitative treatment in children. This requires daily assessment of their ambulating ability and the range of motion of their joints by the physical and occupational therapists and by the play therapist, whose intervention is essential in order to overcome the extreme withdrawal and regression that are so frequent among pediatric burn victims. Family support and proper evaluation of the child's social environment must not be overlooked.

Conclusion

In brief, the goal of burn victim resuscitation is to restore circulating blood volume and to minimize the early stress response. This is accomplished with adequate fluid replacement, correction of hypoxia and ventilatory disturbances, prevention of hypothermia, and adequate control of pain and anxiety. Burn wounds must be encouraged to heal in the shortest possible time in order to limit inflammation and the formation of contractures by a judicious combination of topical agents and eschar excision and skin grafting. The care of the burned child requires a multidisciplinary team approach that embraces not only the medical aspects but also the child's rehabilitative needs, nutritional requirements, and social and environmental concerns. It must be also stressed that the majority of pediatric burns are scald burns affecting the very young occurring in the home. Such burns are preventable.

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