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PEDIATRIC BURNS: UNIQUE CHARACTERISTICS, CHALLENGES, AND MANAGEMENT STRATEGIES

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SUMMARY

Introduction: Pediatric burns are a frequent cause of morbidity and mortality, necessitating tailored care due to children's specific physiological needs. This paper explores the epidemiological trends, severity assessment, and management strategies for pediatric burns. **Methods:** A retrospective review was conducted, analyzing the cases of 1,347 children treated for burns at the National Burn Center, CHU Ibn Rochd, between 2018 and 2022. **Results:** Most pediatric burns are accidental, commonly occurring at home due to hot liquids. Infants under 2 years old are especially prone to severe complications. Effective management requires early resuscitation, accurate assessment of burn depth and area, along with targeted pain control and nutritional support. **Conclusion:** Advances in pediatric burn care have led to significant reductions in mortality, yet functional, aesthetic, and psychological sequelae remain challenges. Focused efforts on accident prevention and specialized care provision are essential for improved outcomes.

INTRODUCTION

A burn is defined as a primary injury to the skin, mucous membranes, and/or underlying tissues caused by thermal, chemical, electrical agents, or radiation. Initially, burns cause local damage. However, when they cover a significant surface area (over 20% of body surface area in adults and 10% in children), there is a major impact on vital functions, potentially endangering the patient's life.[1-2] Pediatric burns are a significant cause of morbidity and mortality from accidental injuries. They remain a frequent emergency in our daily practice.

The child's young age, coupled with a lack of awareness of risk and sometimes parental negligence, increases vulnerability.[3] The objective of this study is to identify the specific characteristics of burned children.

Epidemiology

The epidemiology of burns in Morocco is poorly documented due to the absence of systematic data collection and the diversity of sectors involved in burn care. Over a 4-year period, from January 2018 to January 2022, the National Burn Center at CHU Ibn Rochd treated 1,347 burned children, with an average of 337 cases per year. Males are more often affected, with a sex ratio of 1.17, and a peak incidence among children aged 0 to 2 years, who represented over 50.7%.

Peaks inpatient admissions were observed during school holidays, the month of Ramadan, and the Achoura festival. Burns occurred accidentally in 99% of cases due to children's carelessness or parental neglect. They were most often caused by hot liquids in 78% (tea, hot water, HARIRA, traditional baths), followed by flame burns (14%), usually occurring during group accidents linked to improper handling of small gas bottles, hot solid contact burns (6.3%), electrical burns (<1%), and chemical burns (<1%). Most burns occurred at home, in the kitchen or bathroom.

In the literature, the most common burn sites are the head, chest, and upper limbs.[4] This was also true for the cases treated in our facility between 2018 and 2022, where 31% of patients had burns on the hands, 26% on the upper limbs, and 20% on the trunk. This is likely due to the child's height relative to a table and the common mechanism of scald burns, which tend to cause extensive but shallow injuries.

Severity of Burns in Children

The assessment of severity is based on several parameters that determine the need for hospitalization and the appropriate care setting: intensive care or conventional hospitalization units. Severity is assessed according to the following factors:

Age is inversely related to burn mortality in children. Infants under 2 years old have a mortality rate twice that of older children when burns are extensive.[5] This finding is consistent with numerous studies on anesthetic risk in children.

The surface area of the burn is a critical parameter as it determines fluid loss. In infants, burns covering more than 10% of the body surface can lead to severe hypovolemia if fluid and electrolyte replenishment is not properly managed.[6] This assessment is more accurate using the Lund and Browder chart for children (Table 1).[7]

Table 1: Evaluation of Burned Surface Area According to the Lund and Browder.

Surface area (%)	< 1 year	1 year	5 years	10 years	15 years
Head	19	17	13	11	9
Neck	1	1	1	1	1
Trunk	13	13	13	13	13
Upper limb	9	9	9	9	9
Genital area	1	1	1	1	1
Buttocks	2.5	2.5	2.5	2.5	2.5
Thigh	5.5	6.5	8	8.5	9
Leg	5	5	5.5	6	6.5
Foot	3.5	3.5	3.5	3.5	3.5

Evaluating burn depth is crucial as it determines the potential for spontaneous healing, the expected healing time, and the need for preventive treatment of hypertrophic scarring.[8]

This assessment is particularly challenging for second-degree burns, which evolve over the first 3 to 4 days, with a risk of deepening due to local edema, hypovolemia, and super infection (Figure 1). Thus, regular re-evaluation of the lesions is necessary. Among diagnostic aids for depth assessment, only laser Doppler imaging has proven effective with sensitivity and specificity rates of 90% and 96%, respectively, but it remains costly, complex, and difficult to apply in clinical practice.[9]

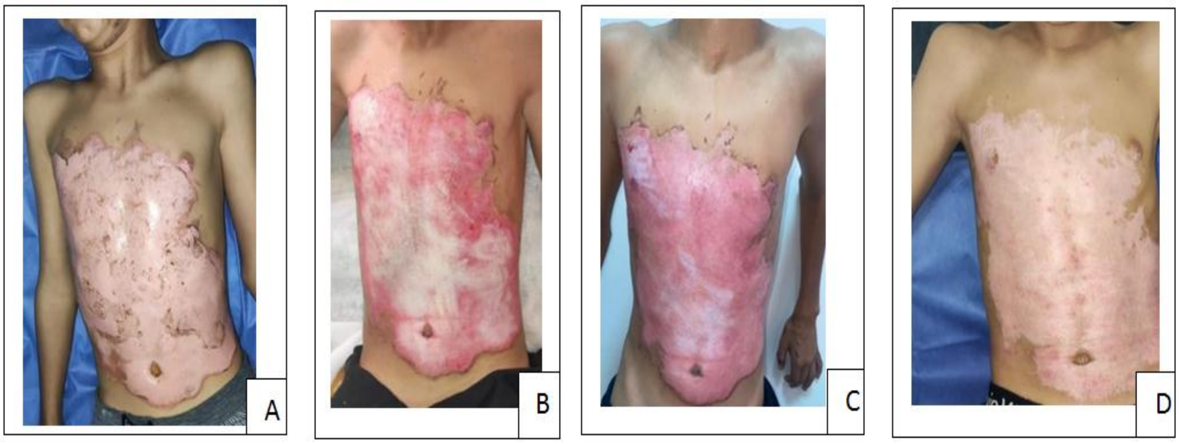

Figure 1: Evolution of Burn Depth in the Acute Phase A: Burn at 6 hours post-injury B: Burn at 48 hours. C: Burn at 7 days. D: Burn at 15 days.

Beyond the immediate risks, some burns, due to their depth and **location,** present critical challenges for life, function, and aesthetics. Edema associated with deep cervicofacial burns can pose a life-threatening risk by obstructing the airways, potentially leading to asphyxiation within hours. In cases of facial burns, it is also essential to assess for ocular involvement before the onset of eyelid edema. Burns to the perineum and external genital organs carry a risk of infection due to fecal contamination, necessitating early insertion of a urinary catheter, and sometimes, a colostomy may be considered.

Deep, circumferential burns of the limbs can result in a tourniquet effect, causing ischemia and sometimes requiring decompressive incisions to relieve tension. Functional prognosis is at risk in cases of burns to the neck, hands, and flexion creases.

The precise circumstances of the burn incident are crucial to determine: a flame burn in an enclosed space or during an explosion should prompt investigation for respiratory injuries caused by smoke inhalation, which may also be accompanied by carbon monoxide (CO) or hydrogen cyanide (CN) poisoning. Smoke inhalation is the leading cause of mortality in burn patients, both in children and adults.[10] Electrical or chemical burns tend to be deep and progressive, necessitating hospitalization (Figure 2).

Figure 2: Chemical Burn of the Face A: Burn at 5 hours post-injury. B: Burn at 48 hours. C: Burn at 4 days.

In practice, in children, a burn is considered severe if the burned body surface area (BSA) is greater than 10%, third-degree BSA is greater than 5%, if the child is under 1 year of age, if there are severe comorbidities, evidence of smoke inhalation syndrome, particular deep locations (face, hands, feet, perineum, flexion creases), circumferential burns, or electrical or chemical burns.[11]

Resuscitation

Initial resuscitation is crucial in managing burn injuries and must begin before hospital admission. Pre-hospital care at the accident site involves a series of actions, often performed before the arrival of a medical team: removing the patient from the causative agent or preventing further exposure, removing non-adherent burned clothing and metal objects that can retain heat. Cooling thermal burns with water at around 15°C can have positive effects: preventing deepening up to 45 minutes post-accident, modulating histamine release, reducing edema and pain. However, the risk of iatrogenic hypothermia, or even vasoconstriction and ischemia due to excessive cooling, is high in children. It is recommended to cool burn injuries in children when less than 20% of the body surface area (BSA) is affected, but to avoid cooling when more than 40% of the BSA is burned; in such cases, preventing secondary hypothermia by using an isothermal cover during care is essential.[12]

Severe burns induce early hypovolemic shock due to inflammation, capillary leakage, and microcirculatory alterations.[13] Therefore, it is critical to begin vascular fluid replacement promptly when the burn patient is an infant or young child.[14] Early initiation of rehydration (within 2 hours) is a key prognostic factor, reducing the risk of renal failure, sepsis, and death.[15] Prompt venous access is essential, as it can quickly become difficult, especially in young children who can become cold rapidly (inappropriate home cooling, such as immersing the child in a bath or shower). Following the Demling and Lalonde protocol (Peripheral vein access in non-burned areas > peripheral vein access in burned areas > central vein access in non-burned areas > central vein access in burned areas) is recommended.[16]

If central venous access is required, femoral access is the simplest approach in children. If the child is already in hypovolemic shock, intraosseous access may be an alternative to venous access, provided it is placed in a non-burned area.[17]

The fluid volume to be administered is calculated for children using the Carvajal formula, which considers the burned skin surface area and the total body surface area: during the first 24 hours, 2,000 mL/m² of total body surface area + 5,000 mL/m² of burned body surface area. Half of this volume should be infused in the first 8 hours, with the remaining half over the next 16 hours. The infused volumes must then be adjusted daily, based on elements from ongoing monitoring. Fluid replacement is provided using isotonic crystalloid solutions like Ringer's lactate, which remains the reference product.

However, the use of isotonic crystalloids has drawbacks: large infused volumes, increased burn-related edema, and accentuated hypoproteinemia.

Diluted human albumin solutions at 4% are most commonly used in children. As protein loss is highest in the first 8 hours, the oncotic power of this solution is temporary during the initial phase. Most authors recommend its use in combination with crystalloids. After the initial 8 hours, adding albumin (1g/kg) leads to early and sustained hemodynamic stabilization.

Hyponatremia is a common complication in pediatric patients beyond 48 hours post-burn. Children under 1 year of age may require sodium supplementation due to higher urinary sodium losses. Losses of calcium and magnesium should also be compensated.[18]

The insertion of a urinary catheter may be considered in the initial phase for severely burned patients and is essential in cases of perineal burns.

Respiratory tract injuries must be systematically assessed using bronchoscopy if respiratory distress is present, in cases of deep facial and neck burns, or in smoke inhalation incidents, which should be suspected if the burn occurred in an enclosed space, there are soot deposits in the upper airways, or there is dysphonia or cough with soot-stained expectoration, potentially necessitating intubation with ventilation.

In cases of intubation, weaning from mechanical ventilation should be a priority in severely burned children. The risk of infection of the lesions is high. In a French prospective survey on the epidemiology of infections in major burn patients[19], the lungs were the second most common infection site after the burn area. A reference study on mortality in severely burned children by Spies et al. demonstrated that the main prognostic factor is the duration of ventilation, with a cumulative ventilation duration of 28 days in deceased children compared to less than 10 days in survivors.[20] Altered consciousness should raise suspicion of CO or CN poisoning, requiring oxygenation upon admission, potentially accompanied by vitamin B12 administration.

Pain Management

Pain management and assessment are systematic, using validated scales tailored to the child's age (CHEOPS, DEGR, or visual analog scales).[21] Pain relief primarily relies on intravenous or rectal paracetamol at 15 mg/kg and titrated intravenous morphine at 0.05 mg/kg. Anti-inflammatory drugs are typically avoided during the initial phase. Painful local treatments are often performed under general anesthesia in children, commonly using a combination of morphine-ketamine and/or propofol, as well as alfentanil or sufentanil depending on the procedures.[22]

Infection Management

Infection is currently the leading cause of death in burn units, along with multiple organ failures.[23] Infections can be localized or systemic, with the lungs being a common target. Diagnosing infection is particularly challenging in burned children, who may exhibit a hyper-inflammatory state with elevated core temperature, high white blood cell counts, and increased inflammatory proteins even in the absence of infection. This febrile syndrome can be misleading and must be distinguished from true septic syndrome. The most frequently infected sites are the burn wound, the lungs, urine, and central venous catheters.

A positive diagnosis is based on clinical monitoring during dressing changes and isolating pathogens from a sample site (swab from the burn site, blood cultures, urinalysis, etc.). The main pathogens involved are Staphylococcus species, followed by Pseudomonas, and then Klebsiella, Proteus, and yeast species.[24] Multidrug-resistant pathogens, such as Imipenem- Resistant Acinetobacter Baumannii and Imipenem-Resistant Pseudomonas Aeruginosa, pose significant therapeutic challenges in our department.

Treatment is primarily preventive, relying on structural and organizational measures: reinforced hygiene practices, individual patient rooms, air treatment, and conducting care and interventions in dedicated areas. It focuses mainly on local antiseptic treatment of burns, with systemic antibiotics reserved for treating, rather than preventing, infections in children and adults alike. Early removal of invasive medical devices, such as tracheal tubes, central catheters, and urinary catheters, is also recommended as soon as the patient's condition allows.

Nutrition

Nutritional management has significantly improved the survival of severely burned patients in recent years. Fluid and protein losses are substantial and must be compensated with a hypercaloric and hyperproteic diet as soon as the burn surface area exceeds 15%. Enteral nutrition is preferred and can be initiated early to preserve intestinal mucosal integrity, prevent bacterial translocation, and improve intestinal blood flow and motility. There is no consensus on the specific quantitative and qualitative nutritional requirements for children. In intensive care, caloric needs are calculated using formulas, with the Hildreth formula being the most commonly used: 1800 kcal/m² of total body surface area + 2200 kcal/m² of burned body surface area. However, these estimates often result in overnutrition that is difficult to administer and generally poorly tolerated, making indirect calorimetry a more suitable approach.[32]

Indirect calorimetry is the gold standard for measuring energy expenditure, with an accuracy of up to 96% in measuring oxygen consumption (VO2) and carbon dioxide production (VCO2).[33] Portable metabolic monitors are available, allowing clinicians to accurately estimate the patient's energy requirements.[34] The fundamental principles of indirect calorimetry are based on the premise that the human body metabolizes nutrients using O2 and producing CO2. Basal metabolic rate is calculated from VO2 and VCO2 measurements as well as nitrogen production.[35]

In quantitative terms, carbohydrates are the primary energy source for burn patients. Protein intake is proportional to the extent and depth of the burn, following the Davies formula: 3 grams of nitrogen per kilogram + 1 gram of nitrogen per 1% of burned skin surface, maintaining a calorie-to-nitrogen ratio of 100 to 150 kcal per 1 gram of nitrogen. Vitamin A and C supplementation is recommended, as well as trace elements such as selenium, copper, and zinc.[25] In young children, hospitalization, changes in environment and dietary habits, and medical care can result in feeding refusal which, if not compensated for, can lead to severe malnutrition with hypoproteinemia. This condition can have consequences such as increased risk of infection, delayed wound healing, and a heightened risk of "burn lung"[26] To prevent stress ulcers, the administration of proton pump inhibitors is systematic at the beginning of hospitalization and/or when enteral feeding is poorly tolerated. Monitoring of weight is crucial, especially to ensure that weight loss does not exceed 10% of the pre-injury weight. Maintaining good nutritional status is essential to reduce the risk of infection, which can cause further deepening of burns, graft loss, delayed healing, and an increased risk of hypertrophic scarring.[27]

Local Treatment of Burns

The goals of burn treatment are to prevent infection and further deepening of the burns, as well as to achieve healing within 15 to 21 days to ensure good scar quality.[28] Local treatment of burns depends on the depth and location of the injuries. Superficial burns are typically treated with conservative local care aimed at preventing infection, which is the primary factor in the secondary deepening of lesions. The need for escharotomies or fasciotomies should be evaluated for any deep, circular, and/or electrical burn and performed early to prevent ischemia due to a tourniquet effect. Deep burns require aggressive local care and surgical treatment involving excision of necrotic tissues and definitive coverage through autografting. Excision and grafting are performed either early, before the 5th day, or after the debridement phase from the 15th day onward (Figure 3).

Figure 3: Deep burn of the trunk and left upper limb in a 15-month-old infant. A: Burn on day 4 before excision and grafting. B: After excision and grafting.

For children, excision is often performed tangentially using a dermatome.[29] This technique is hemorrhagic and should be performed on a hemodynamically stable, well-warmed patient.[30] Reducing blood loss is crucial, and this can be achieved by using adrenaline-infiltrated saline and antifibrinolytics to ensure hemostasis. Some small local flaps can be useful for covering small, deep tissue losses on the hands, particularly in cases of low-voltage electrical burns.[31]

CONCLUSION

Burns are a common and serious accident in children, causing significant mortality and, more importantly, substantial morbidity. Thanks to improved early management of this condition, the survival rates of burned children have undeniably improved in recent years.

However, the challenges of managing severe burns, their significant consequences in terms of pain, financial costs, functional and aesthetic sequelae, as well as their psychological and social impacts, necessitate the implementation of effective prevention measures.

Conflict of Interest

The authors declare no conflict of interest.

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