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Thermal Injuries in Children: A Literature-Based Overview

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ABSTRACT

Burns are a significant cause of morbidity and mortality in children. While the majority of pediatric burns are not life-threatening, they can have a significant impact on a child's physical and psychological health. They pose a major social and financial burden, particularly in developing countries. The management of pediatric patients with thermal injuries requires a complex and multifaceted approach.

Pediatric burns constitute approximately 40-50% of all reported cases of severe burns. The most common etiologies of pediatric burns include scalds, contact burns, flames, and chemicals. From 80% to 90% of burns occurred at home and were accidental. Despite advancements in

treatment, severe burns can lead to life-threatening complications, such as sepsis, multisystem organ failure, and hypermetabolic response or even death.

This article aims to provide a literature-based overview of pediatric burn trauma, outlining its unique characteristics, etiology, epidemiology, classification, and initial management.

Keywords: child, burns, emergencies, emergency treatment

INTRODUCTION

Injuries are the leading cause of pediatric mortality. Following motor vehicle accidents, suffocation, and drowning, burns are a major mechanism of pediatric injury [1]. According to the World Health Organization (WHO), an estimated 180,000 deaths occur annually due to burns, highlighting the severity of this issue [2]. For example, in Germany, approximately 30,000 children experience burn injuries each year, with 2,000 requiring treatment in specialized pediatric burn centers [3]. While in 2017, around 84 000 children ages 0–14 years were treated for a burn in the United States [1,4]. While most pediatric burns are not life-threatening, they can significantly impact a child's physical, emotional, and social development [5–9]. They can also cause lifelong stigma like scars and other physical defects [3]. Importantly, the majority of burns are preventable through accident prevention strategies. Examples of such strategies include educational programs, smoke detector installation, and hot water temperature regulation in homes [7,10–12]. Thermal injuries are more prevalent in low- and middle-income countries with lower socioeconomic status [7,13–15]. Burns pose a significant social and financial burden, particularly in LMICs. An estimated 90% of global burn incidents occur in these regions, with approximately half concentrated in South or Southeast Asia [16,17].

The aim of this article is to provide an overview of pediatric burn trauma, outlining its unique characteristics and its complications, recommendations for initial management and follow-up care.

DEFINITION

A burn is an injury caused by exposure to heat, cold, electricity, chemicals, radiation, or friction. Burns can cause a wide range of tissue damage, leading to varying degrees of severity and potential complications. Burns can involve various tissues, including skin, epidermis, muscles, bones, and blood vessels. Nerve damage caused by burns can result in significant pain. Burns

trigger a full spectrum of inflammatory response mechanisms. During the acute phase, these inflammatory mechanisms can have detrimental effects, such as capillary leakage, worsening of inhalation injuries, and the potential development of multisystem organ failure [18].

EPIDEMIOLOGY

In the study from 2016 the incidence of burns in children from Europe were analyzed [12]. It was proven that burns in children constitute from 40 to 50% of severe burns in the population [19–27]. However, a separate study from Turkey reported a higher proportion, with children comprising up to 75% of their severe burn cases [28]. This highlights the potential for regional variations in burn epidemiology. Burns are most prevalent in children under the age of 5, accounting for 50-80% of all pediatric burns. Additionally, boys appear to be more susceptible, with studies indicating a range of 60-65% of burns occurring in this demographic within the pediatric population [19,23,29–34].

ETIOLOGY

Pediatric burns most frequently result from scalds, contact burns, flames, and chemicals. Scalds are the leading cause, accounting for 60-75% of all hospitalized pediatric burns, followed by flame and contact burns. Emergency department presentations mirror this trend, with scalds constituting the most common type (35-80%), followed by contact burns (13-47%) and flame burns (2-5%). At high risk of scalds are especially children younger than 2 years [26,32,35–40].

The vast majority (80-90%) of burns are accidental and occur within the home environment [19,23,24,35,40–44]. Kitchens (75%) and bathrooms are the most common locations for these incidents. In the kitchen, burns are typically caused by contact with hot food or beverages. Bathroom burns often involve immersion injuries from hot bathwater [36,38,39,43]. Understanding the specific mechanisms of injury, such as the location and causative agent, is crucial for implementing appropriate treatment approaches.

ANATOMY

Due to their smaller stature and natural curiosity, children are more susceptible to burns on the head, face, arms, and legs. Kemp AM et al. investigated the primary location of scalds in a study involving 554 children under 5 years old and 155 children between 5 and 16 years old [45]. Their findings are detailed in Table 1.

Table 1 Primary site affected by a scald in 554 children younger than 5 years old and 155 children 5–16 years (percentage of children with scald in each site) [Kemp A, et al. [45]]		
	Children less than 5 years % children (n=554)	Children more than 5 years % children (n=155)
Arm	19.3% (107)	16.1% (25)
Chest	17.3% (96)	11% (17)
Face	15.9% (88)	7.1% (11)
Neck/shoulder	11.2% (62)	7.7% (12)
Leg	10.2% (57)	19.4% (30)
Hand	7% (39)	15.5% (24)
Foot	6% (33)	5.2% (8)
Abdomen	5.2% (29)	9% (14)
Head	3.8% (21)	0.6% (1)
Buttock	1.3% (7)	2.6% (4)
Back	0.7% (4)	1.9% (3)
Groin	0.2% (1)	3.2% (5)
Unknown	1.8% (10)	0.6% (1)
Total	554	155

BURN CLASSIFICATION

Burn wound depths are universally classified into three degrees (I-III). able 2 provides a detailed description of the clinical characteristics associated with each degree of burn wound [18,46,47].

Table 2. Clinical characteristics of burn wounds of various degrees				
Degree	Layer of skin involved	Appearance	Pain	Healing time
I° Superficial	Only epidermis	Pink-to-red, moist, without blistering	Moderate to severe	5-10 days
IIa° Superficial partial	Superficial, papillary dermis	Blisters are common, red, moist, with intact epidermal appendages, and blanches with pressure.	Severe	2–3 weeks, minimal scarring
IIb° Deep partial	Deeper reticular dermis	Dry, white, non-blanching, loss of all epidermal appendages	Minimal	3–6 weeks, scaring is unavoidable
III° Deep	Full thickness of skin, in to the subcutaneous fat or deeper, nerves damages	Leathery, dry, white or red with thrombosed vessels	No	More than 8 weeks, does not heal by primary intention, requires skin graft

COMPLICATIONS

Despite significant advancements in burn treatment, severe burns can still lead to serious health complications and mortality [48–51]. Burn-related deaths can occur either immediately after the incident or weeks later due to complications [50,52]. These complications include sepsis, multisystem organ failure, and the hypermetabolic response, leading to an estimated 4,000 deaths annually from thermal injuries [50,52–54].

A 20-year retrospective review from Texas examining over 5,200 hospitalized pediatric burn patients revealed a mortality rate of 2.8% (145 deaths). Inhalation injury was present in 71% of

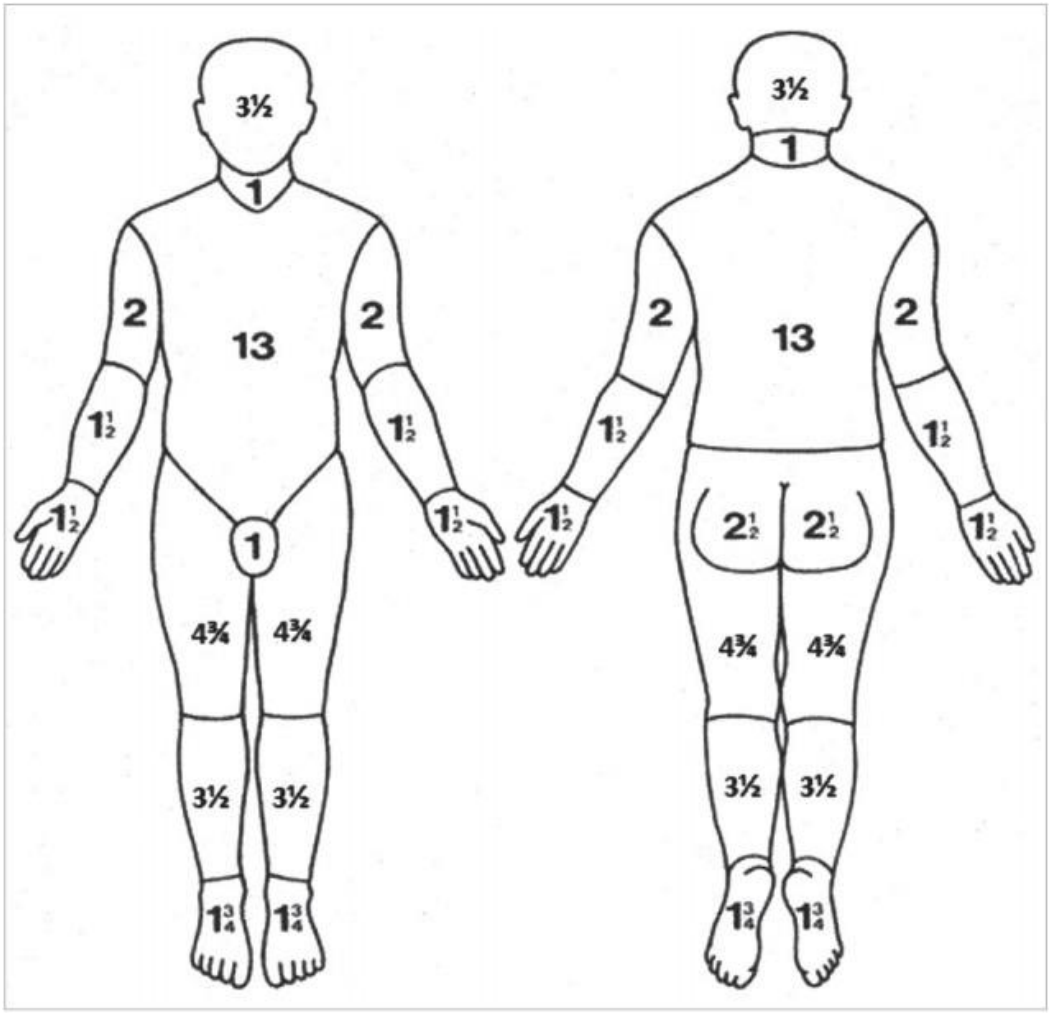
deceased patients, highlighting its significant role in mortality. Respiratory failure was the leading cause of death (29%), followed by brain injury (16%), shock (8%), and sepsis (47%). Sepsis, a frequent complication (47% of fatalities), was predominantly caused by multidrug-resistant organisms such as Pseudomonas aeruginosa, Acinetobacter baumannii, MRSA, Klebsiella pneumoniae, Enterococcus faecalis, and Enterobacter cloacae. Fungal and drug-sensitive bacterial infections were less common [52]. The study by Kraft et al. confirmed a positive correlation between burn surface area and the risk of developing burn-related sepsis [50]. Furthermore, multi-organ failure was identified in 51% of fatal cases, further emphasizing the complexity of complications following burn injuries [52].

ASSESSMENT

The management of pediatric patients with thermal injuries is multifaceted and requires a comprehensive approach. A thorough assessment, including evaluation of burn size, depth, and location, is essential for effective treatment planning [4]. Prompt assessment of pediatric burn patients is critical. Their higher body surface area (BSA) to body mass ratio makes them more susceptible to complications like hypovolemia, prolonged hospitalization, acute renal failure, and increased mortality with delayed resuscitation [55].

While the rule of nines is a simple method for estimating TBSA, it is most accurate for adult body proportions [4]. In children, it can overestimate burn size by up to 40% [56]. For more accurate TBSA estimation in children, the Lund and Browder charts (Figure 1) provide age-specific reference values [57]. Interestingly, studies by Rumpf, R. W. et al. have demonstrated that body mass ratio (BMI) does not significantly influence the accuracy of TBSA estimates using the Lund and Browder charts [58].

Figure 1. Lund and Browder rule. Modified from Wikipedia Contributors by Murari A. et al [57,59].



Despite its limitations in children, the rule of nines remains the most commonly used method for estimating TBSA in burn cases [55,60]. Table 3 presents a comparison of the clinical evaluation of burn wounds in children and adults using Wallace's modification of the rule of nines.

Table 3. Comparing clinical evaluation of burn wounds extend in children and adults- Wallace's rule of nine		
	Child	Adult
Head (front and back)	18%	9%
Back	18%	18%
Chest	18%	18%
Right arm and left arm	9% and 9%	9% and 9%
Right leg and left leg	13,5% and 13,5%	18% and 18%
Peritoneum	1%	1%
Total	100%	

Accurate burn depth assessment is essential for guiding appropriate treatment decisions. However, there is no single, universally accepted method for precisely determining burn depth. Physical examination remains the most widely used method, but its accuracy ranges from 71% to 89% [61,62]. Laser Doppler imaging offers improved accuracy (90-97%) but is limited by high cost and lengthy scan times [63]. Several emerging technologies, such as thermography, ultrasonography, photoacoustic techniques, nuclear magnetic resonance (NMR), and near-infrared spectroscopy, hold promise for early and accurate burn depth assessment. However, further research is needed to validate their efficacy for routine clinical use [64].

TREATMENT

Immediate cooling of the burn wound with cool running tap water for an unspecified duration helps alleviate pain and minimize tissue damage by reducing blistering, erythema (redness), and edema (swelling) in the affected area [65,66]. However, existing studies have not identified a specific cooling duration that demonstrably improves outcomes. Therefore, a set timeframe cannot be universally recommended [67]. It is crucial to exercise caution during cooling to avoid inducing hypothermia, a potentially life-threatening complication [65].

Effective pain management is crucial for improving a child's comfort and facilitating wound care. Treatment strategies should be tailored to the child's age and weight. According to Polish guidelines for acute pediatric pain management, recognizing the different phases of burn injury is important because it can affect drug absorption and influence analgesic selection. However, the fundamental principles of pain treatment remain similar to those for pain caused by other conditions [68].

Immediate initiation of fluid resuscitation is essential for patients with significant TBSA burns, typically exceeding 20% TBSA [4]. The Parkland formula, a widely used method for calculating the total volume of crystalloid fluids needed over the first 24 hours (4 mL/kg body weight/% TBSA burned), has limitations. Recent evidence suggests it may underestimate fluid requirements in patients with extensive or deeper burns, inhalation injury, delayed resuscitation, substance use, or electrical injuries, potentially leading to inadequate or inappropriate resuscitation [60,69]. Urine output, mean arterial pressure above 65mmHg, and normal base excess and lactate concentration are currently used to assess the effectiveness of fluid resuscitation. However, these markers may not always be entirely accurate, and there are no superior alternatives at present [69–71].

Wound care plays a critical role in promoting healing and minimizing the risk of infection. It involves gentle cleansing and application of appropriate dressings to create a moist environment that fosters epithelialization (skin cell growth). Treatment strategies vary depending on the burn depth. Superficial partial-thickness burns are typically managed with topical medications and regular dressing changes. Full-thickness burns and some deep partial-thickness burns may require surgical debridement (removal of non-viable tissue) followed by skin grafting to accelerate healing and minimize long-term complications such as scarring [4].

Recent randomized controlled trials have explored the efficacy of various dressings for treating superficial partial-thickness burns [4]. These studies suggest that antibiotic-impregnated non-adherent gauze may promote faster healing compared to silver-impregnated foam dressings when both are applied with a cast and changed twice weekly [72]. Furthermore, silver-impregnated foam dressings have been shown to accelerate healing compared to porcine xenografts [73].

Surgical excision, also known as debridement, may be necessary for full-thickness burns and some deep partial-thickness burns. This procedure removes non-viable tissue, promoting faster

healing and potentially reducing long-term scarring. Debridement is often followed by skin grafting, a surgical technique that replaces lost skin with healthy tissue, typically the patient's own skin (autograft). This promotes wound closure and improves functional recovery. Pediatric patients with extensive burns experience significant alterations in their immune and metabolic systems, making them more susceptible to complications such as infections and loss of lean muscle mass. Various skin grafting techniques can be employed, including split-thickness autografts and cultured epithelial autografts, depending on the specific needs of the patient [4].

Comprehensive follow-up care is essential for all burn patients. Regular appointments allow healthcare providers to monitor wound healing, assess scar formation, and identify and address any potential complications. Pediatric burn patients specifically benefit from a multidisciplinary rehabilitation program following their injury. This program plays a vital role in optimizing functional outcomes and promoting patient independence. Physical therapy evaluations and ongoing scar management strategies, including massage therapy and scar revision surgery when necessary, are crucial for minimizing functional limitations and improving cosmetic appearance. Psychological support, particularly during the initial weeks post-burn, is essential for both the child and their family. This support system helps address emotional and behavioral challenges associated with burn trauma [4–6,69].

CONCLUSION

Burns are a significant global public health concern, disproportionately affecting children, particularly in developing countries. They remain a major cause of pediatric morbidity and mortality, ranking as the fourth most common mechanism of injury. The successful management of pediatric thermal injuries necessitates a multifaceted approach due to the potential for complications such as multiorgan failure in nearly half of severely burned patients. While the rule of nines remains widely used, the Lund and Browder charts provide a more accurate method for estimating burn surface area in children. Understanding the unique characteristics of pediatric burns is critical for developing effective prevention and treatment programs, ultimately leading to improved patient care. Large-scale studies evaluating various treatment modalities, such as standard dressings, silver-impregnated foams, and xenografts, are crucial for establishing optimal management practices specifically for children with superficial partial-thickness burns.

DISCLOSURE

Author's contribution

Conceptualization: Natalia Wierzejska and Aneta Michalczewska; Methodology: Justyna Dobrzańska; Software: Agnieszka Nowak; Check: Zuzanna Chmielowiec and Agnieszka Fugas; Formal analysis: Karolina Smykiewicz and Alicja Partyka; Investigation: Mariola Dziedzic and Magdalena Pach; Resources: Aneta Michalczewska; Data curation: Alicja Partyka; Writing - rough preparation: Justyna Dobrzańska and Zuzanna Chmielowiec; Writing - review and editing, Natalia Wierzejska and Agnieszka Nowak; Visualization: Karolina Smykiewicz; Supervision: Magdalena Pach; Project administration: Mariola Dziedzic and Agnieszka Fugas; Receiving funding - no specific funding.

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