



REVIEW

Pathophysiology, classification, and management of burns

Oktoriadi Manao¹, Yeni Puspawati²

ABSTRACT

Burn injuries are common forms of trauma in clinical practice and remain a serious public health problem because they can cause tissue damage, permanent disability, and death. These injuries result from exposure to external agents such as heat, electricity, chemicals, radiation, or friction, which damage the epidermis and/or dermis and impair the skin's protective, thermoregulatory, sensory, and fluid-balance functions. This narrative literature review summarizes the anatomy and physiology of the skin, the definition, epidemiology, etiology, pathophysiology, classification according to burn depth and extent, wound healing, methods for estimating the total body surface area affected by burns, principles of initial management, complications, and prognosis. The methods used to estimate burn extent include the Rule of Nines, the Pediatric Rule of Nines, the palmar surface method, and the Lund and Browder chart. This review was conducted using a narrative literature review approach based on an examination of relevant scientific literature. A comprehensive understanding of burn injuries is essential for health care professionals, particularly medical students, to facilitate accurate diagnosis, severity assessment, and appropriate management. These competencies may help reduce complication and mortality rates and improve patients' quality of life.

Keywords: burn injury, classification, pathophysiology, management, complications

Introduction

Burn injuries are common forms of trauma encountered in clinical practice and remain a serious health problem because they can cause tissue damage, permanent disability, and death.¹ These injuries occur following exposure to external agents such as heat, electricity, chemicals, radiation, or friction, which damage the skin and underlying tissues. As the largest organ of the body, the skin performs essential functions, including protection, thermoregulation, sensory perception, and maintenance of fluid balance. Consequently, burn-related skin damage can produce local and systemic disturbances that may threaten the patient's life.^{2,3}

Burn injuries remain major global causes of morbidity, disability, and mortality, with the greatest burden in low- and middle-income countries (LMICs), despite declining standardized rates in many regions. Global Burden of Disease analyses estimated 8.38 million burn injuries in 2019, with age-standardized incidence, mortality, and DALY rates 22%, 43%, and 43% lower than in 1990, respectively.⁴ However, another analysis reported 248 million burn cases in 2021 and projected a 6.42% increase by 2050, while burn-related YLDs declined 43.34% from 1990 to 2021.⁵ Projections to 2036 similarly indicate increasing absolute cases despite decreasing age-standardized incidence.¹ Burns can occur in all age groups; however,

Affiliation

¹Medical Education Program, Universitas Prima Indonesia

²Department of Surgery, Universitas Prima Indonesia

Correspondence:

oktoriadiமானo@gmail.com

the highest incidence is observed among children younger than 10 years. Most pediatric burns occur in the home and result from exposure to hot liquids. Among adults, major risks include occupational accidents, chemical exposure, electrical injuries, and fires.⁵⁻⁸

Prompt and appropriate burn management is essential to prevent serious complications such as hypovolemic shock, infection, pneumonia, sepsis, and contractures, all of which can worsen the patient's prognosis.^{9,10} Advances in fluid resuscitation, surgical techniques, infection control, and nutritional support have significantly improved survival among patients with burn injuries over the past several decades.¹¹⁻¹³ Nevertheless, treatment outcomes continue to depend on a thorough understanding of burn classification, pathophysiology, burn extent, and appropriate management principles.¹⁴ Therefore, this literature review discusses the definition, epidemiology, etiology, classification, pathophysiology, wound healing, assessment of burn extent, management, complications, and prognosis of burn injuries.

Skin Anatomy and Physiology

The skin consists of two main layers: the epidermis and the dermis. The epidermis is the most superficial layer and serves as the primary barrier against environmental factors. It undergoes continuous cellular renewal through cell division in the basal lamina. Beneath the epidermis lies the dermis, which connects the skin to the subcutaneous fat and fascia. The dermis provides structural support and protection against trauma, and damage to this layer can result in deeper tissue injury.¹⁵ The skin over the nose and ears has distinct anatomical characteristics because it is attached to cartilage and separated from it by only a thin layer of subcutaneous fat. Consequently, burns in these areas may compromise the blood supply and cause deformity, particularly when accompanied by bacterial infection.^{15,16} Of the two skin layers, only the epidermis has the capacity for self-regeneration.^{17,18}

Physiologically, the skin performs several important functions, including protection against physical, mechanical, chemical, and thermal insults, as well as infection. It absorbs lipid-soluble substances and facilitates respiratory gas exchange.¹⁹ The skin also excretes metabolic waste products through the sweat and sebaceous glands, detects heat, cold, pressure, and pain, and regulates body temperature through sweating and changes in cutaneous blood flow. In addition, it synthesizes vitamin D following sunlight exposure, produces the pigment melanin through melanocytes, and supports keratinization, the maturation of epidermal cells into hard, durable cells.¹⁵ An understanding of skin anatomy and physiology provides a foundation for evaluating the effects of tissue damage caused by burns.^{19,20}

Definition of Burns

A burn is an injury to the skin and underlying tissues caused by exposure to external agents, including heat, cold, electricity, chemicals, radiation, ultraviolet light, and friction.^{5,21} The extent of tissue damage varies from minor injuries limited to the epidermis to severe injuries involving the full thickness of the skin and deeper tissues.²² Previous literatures stated that burns are a distinct form of trauma because they can be assessed according to the percentage of total body surface area affected and the depth of tissue damage.^{21,23} Burns may cause not only localized tissue injury but also systemic disturbances affecting multiple organs, particularly when they are extensive or severe. They can result in loss of the skin's protective function, impaired fluid and electrolyte balance, an increased risk of infection, and complex metabolic alterations. Consequently, burns require prompt and appropriate management.^{23,24}

Epidemiology

Burn injuries remain a significant global public health problem and can affect individuals of all ages. Incidence varies according to age, sex, living environment, and other risk factors.^{1,25} In the United States, approximately 3,194 burn-related deaths were recorded in 2014 among a total population of 318,857,056.²⁶ Although burn injuries occur relatively frequently, their mortality rate is comparatively low relative to that of other types of trauma. The highest incidence was observed among children younger than 10 years, decreased among individuals aged 11 to 20 years, and increased again among adults aged 21 to 60 years.^{1,27} Most pediatric cases occur in the home, particularly in kitchens and bathrooms, with hot liquids being the most common cause.²⁸

Health surveys conducted in Australia and New Zealand reported that approximately 220,000 people, or nearly 1% of the population, sustain burn injuries each year and require medical care. Approximately 10% of these individuals require hospitalization, and another 10% sustain severe, life-threatening burns. More

than 50% experience limitations in activities of daily living.²⁹ Burn injuries have diverse causes, including flames, hot liquids (scalds), contact with hot objects, chemicals, electricity, lightning, and fireworks. Scalds are the most common cause of burns among children, whereas flame-related burns are more common among adults.^{21,30} Approximately 20% to 25% of serious burn cases are associated with occupational accidents, particularly in industrial and restaurant settings. Other vulnerable groups include people with disabilities, older adults, and military personnel, who face increased risks because of physical limitations, comorbidities, or exposure to hazardous environments. These factors may also affect length of hospital stay and mortality.^{31,32}

Pathophysiology

The pathophysiology of burn injuries involves a series of local and systemic changes resulting from tissue damage caused by heat, electricity, chemicals, radiation, or other agents. Damage to the epidermis and dermis triggers a complex inflammatory response characterized by the release of mediators such as histamine, prostaglandins, cytokines, and growth factors.^{21,33,34} These mediators increase capillary permeability and cause vasodilation, resulting in the movement of fluid from the intravascular space into the interstitial space. Consequently, edema and fluid loss develop, and extensive burns may lead to hypovolemic shock.^{33,34} At the tissue level, cellular necrosis affects keratinocytes, melanocytes, Langerhans cells, and dermal components. Melanocyte dysfunction may cause permanent changes in pigmentation, whereas damage to collagen and supporting tissue may impair healing and result in scar formation.^{21,35}

According to Jackson's concept of burn wound zones, a burn injury consists of three zones: the zone of coagulation, the zone of stasis, and the zone of hyperemia. The zone of coagulation is the central area of permanent tissue damage caused by direct exposure to heat. The surrounding zone of stasis is characterized by reduced tissue perfusion and may progress to necrosis if not managed appropriately. The outermost zone, the zone of hyperemia, has adequate perfusion and generally heals spontaneously.^{36–39} In electrical burns, current passing through the body generates heat that damages the skin, muscles, nerves, and blood vessels. The extent of injury is influenced by the current magnitude, tissue resistance, and duration of contact. Deep tissue damage is often more extensive than suggested by the appearance of the skin surface.^{40,41} Chemical burns result from reactions between tissue and corrosive substances, such as acids or alkalis, that continue as long as the chemical remains in contact with the skin; therefore, immediate decontamination is essential. In inhalation injuries, the inhalation of smoke or toxic gases damages the airway and pulmonary mucosa, potentially causing airway edema, impaired gas exchange, pulmonary inflammation, and acute respiratory failure. Inhalation injury is also a major contributor to increased morbidity and mortality among patients with severe burns. Overall, if not managed appropriately, these processes may progress to serious complications, including shock, infection, sepsis, and multiorgan failure.^{42–44}

Burn Classification

Burn classification is used to determine injury severity, guide management, and predict prognosis. Burns can be classified according to the depth of tissue involvement and the extent of injury.^{45,46} Superficial burns, also called epidermal burns, involve only the epidermis and are typically caused by sun exposure or minor trauma. They are characterized by erythema and pain without blistering and heal without scarring.^{46,47} Superficial partial-thickness burns involve the epidermis and the superficial portion of the dermis. They are characterized by blistering, pink and moist skin, and severe pain. Healing generally occurs within 1 to 3 weeks, with minimal scarring.^{48,49} Mid-dermal burns involve the deeper dermis and therefore require a longer healing period. Clinical features include blistering, edema, capillary thrombosis, and damage to the dermal plexus.^{45,47,50} Deep full-thickness burns involve the entire thickness of the skin and may extend into the subcutaneous tissue. The affected skin may appear pale white, brown, or black; feel dry; and be relatively painless because of nerve-ending destruction. Skin grafting is generally required.^{38,45,47}

Burns are also classified by severity. Minor burns involve less than 15% of the total body surface area (TBSA) in adults or less than 10% TBSA in children, with less than 3% full-thickness involvement and no involvement of special areas, such as the face, hands, feet, genitalia, or perineum. Moderate burns involve 15% to 25% TBSA in adults or 10% to 15% TBSA in children, with a small proportion of full-thickness involvement. These burns may also be accompanied by other trauma or comorbidities. Major burns involve more than 25% TBSA in adults or more than 15% TBSA in children; burns involving critical areas, such as the face, head, hands, feet, genitalia, or perineum; or burns associated with inhalation injury, electrical injury,

or chemical exposure.^{51,52} In addition to depth and extent, the Jackson burn wound model divides burns into three zones. The zone of coagulation is the area of irreversible tissue damage. The zone of stasis is the area of reduced perfusion that is at risk of progressing to necrosis. The zone of hyperemia is the area of increased perfusion that generally recovers completely.^{39,53}

Burn Wound Healing

Burn wound healing is a complex biological process involving cytokines, growth factors, platelets, leukocytes, the extracellular matrix, and parenchymal cells. These components act sequentially through four primary phases.^{9,54,55} The hemostasis phase begins immediately after injury and is characterized by vasoconstriction and platelet aggregation, which form a blood clot and release growth factors such as platelet-derived growth factor (PDGF) and epidermal growth factor (EGF).^{56–58} The inflammation phase occurs primarily during the first 24 to 72 hours. Neutrophils and macrophages migrate to the wound to remove necrotic tissue and microorganisms. This phase is characterized by erythema, warmth, pain, and edema.⁹ The proliferation phase occurs over several days to weeks. Fibroblasts produce collagen and form granulation tissue, accompanied by neovascularization and re-epithelialization of the wound surface.^{59,60} The remodeling or maturation phase occurs over months to years and involves collagen reorganization and strengthening of the scar tissue. However, the final tensile strength of the tissue does not reach 100% of that of normal skin.^{59,61} The healing process may be impaired by infection, repeated trauma, ischemia, malnutrition, diabetes mellitus, and other chronic diseases. These factors may interrupt healing during any phase, resulting in chronic wounds and impairing collagen formation, angiogenesis, and tissue regeneration.⁶²

Burn Size Assessment

Assessing burn size is essential for determining injury severity, calculating fluid-resuscitation requirements, developing a treatment plan, and estimating prognosis. Burn size is generally expressed as a percentage of the total body surface area (TBSA).⁶³ Common assessment methods include the Wallace Rule of Nines, the pediatric Rule of Nines, the palmar surface method, and the Lund and Browder chart. The Wallace Rule of Nines divides the adult body into regions representing 9% or multiples of 9% of the body surface area. This method is commonly used because it is simple and rapid, particularly in emergency settings.^{64,65}

Table 1. Estimated adult burn size according to the Wallace Rule of Nines

Body region	Percentage (%)
Head and neck	9%
Right arm	9%
Left arm	9%
Anterior trunk	18%
Posterior trunk	18%
Right leg	18%
Left leg	18%
Perineum and genitalia	1%

The pediatric Rule of Nines is a modification that accounts for differences in body proportions between children and adults. Children have a proportionally larger head and smaller legs than adults. Therefore, applying the adult Rule of Nines to children may produce less accurate estimates and affect fluid-resuscitation requirements.^{65,66} The palmar surface method uses the patient's palm, including the fingers, as a reference equivalent to approximately 1% TBSA. This method is useful for estimating small, irregular, or scattered burns.^{63,66,67} The Lund and Browder chart is generally considered the most accurate method because it accounts for age-related differences in body proportions using a detailed body diagram. It is particularly useful for assessing burns in children.^{66,68} Accurate assessment of burn size is important for determining injury severity, calculating fluid-resuscitation requirements, including those based on the Parkland formula, determining the need for referral to a burn center, estimating the risk of complications and mortality, and assessing the patient's overall prognosis.^{63–66}

Management

Burn management comprises a series of medical interventions aimed at minimizing local and systemic dysfunction in affected patients. Several key principles guide the initial management of burns.^{10,69} The first step is to stop the burning process by rolling the patient to extinguish flames and promptly removing burned clothing and jewelry. Clothing adherent to the skin should be cut away and left in place, except for synthetic materials that have melted and adhered to nonviable tissue. Cooling the burn with running water at approximately 15°C (range 8–25°C) helps reduce the inflammatory response, halt progression of injury in the zone of stasis, and provide analgesia.^{70,71}

The primary survey includes evaluation of the airway with cervical spine control, assessment of breathing and ventilation, evaluation of circulation with hemorrhage control, neurological assessment, exposure with environmental control, and collection of a focused history using the AMPLE framework (allergies, medications, past illnesses, last meal, and events leading to injury).^{72–74} This is followed by placement of large-bore intravenous access and initiation of fluid resuscitation according to a modified Parkland formula. First aid measures include administration of resuscitation fluids, analgesia, placement of a nasogastric tube, and appropriate adjunct investigations, such as imaging of the spine, chest, and pelvis as indicated.^{75–77}

The secondary survey involves a more detailed history, a comprehensive physical examination, laboratory evaluation, and radiographic studies when indicated. Gentle wound debridement, cultures of blood, urine, wound, and sputum, photographic documentation, and completion of a burn diagram to record the size and depth of injury are also performed.^{10,48} Circulatory assessment includes identification of signs of impaired perfusion in affected extremities, such as swelling, pain, pallor, and loss of pulses. Escharotomy may be indicated if these signs are present.^{78–80} All interventions should be performed carefully and in accordance with established guidelines to ensure effective management, meet patient needs, avoid complications, and promote healing.^{69,81,82}

Complications

Burn complications can affect wound healing and patient quality of life. Hypovolemic shock may result from substantial fluid loss into the burn area, impairing vital organ function and necessitating appropriate fluid resuscitation.^{83,84} Pneumonia is a particular concern in patients with inhalation injury or swallowing dysfunction who are at risk of aspiration.⁸⁵ Urinary tract infections may occur with prolonged use of Foley catheters and present with dysuria, abdominal pain, and fever.¹⁰ Cellulitis, an infection of the tissue surrounding the burn, is characterized by edema, erythema, induration, pain, and changes in wound color and odor.^{86,87} Burn wound infections may progress to sepsis and therefore require early detection and appropriate antibacterial therapy.^{88,89} Post-healing skin contractures can limit joint mobility and cause cosmetic deformity, often requiring intensive physiotherapy and, in some cases, surgical intervention.⁹⁰ Understanding these complications and ensuring multidisciplinary team involvement are essential to preventing and managing problems that arise during the course of burn recovery.

Prognosis

The prognosis of burns is generally determined by burn depth, which defines burn severity.⁹¹ The seriousness of a burn depends on its depth, extent, and anatomical location.⁹² In addition to injury severity, the patient's age and pre-injury health status are important factors that influence prognosis.⁹³

Conclusion

Burns are injuries to the skin caused by external stressors, including thermal trauma, ultraviolet radiation, ionizing radiation, electricity, chemicals, and friction. The diagnosis of burns is based on burn depth and extent, supported by adjunct investigations. Management begins with a primary survey, followed by a secondary survey and definitive treatment according to burn severity. Burn prognosis depends on burn depth, the percentage of body surface area involved, the presence of complications, and the timeliness of medical care. A comprehensive understanding of skin anatomy, pathophysiology, classification, burn size assessment, management, and complications is essential for healthcare providers to improve clinical outcomes and reduce burn-related morbidity and mortality.

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