Chapter 2

Comprehensive Management of Burn Injuries: Integration of Plastic Surgery in Burn Wound Care

Nelimar Cruz-Centeno[1*]; Luis Alamo-Irrizarry[1]; Angel Rivera-Barrios[1]

University of Puerto Rico Medical Sciences Campus, Department of Surgery, San Juan, PR, 00921.

[*]***Correspondence to: Nelimar Cruz-Centeno,*** *University of Puerto Rico Medical Sciences Campus, Department of Surgery, San Juan, PR, 00921.*

Email: nelimar.cruz@upr.edu

Role of Plastic Surgery in the Burn Patient

Burn injuries are a common and serious problem that can result in significant physical and emotional trauma. They can be caused by a variety of factors, including thermal, chemical, electrical, and radiation sources [1]. Depending on the severity of the injury, burns can lead to a range of complications, including scarring, infection, loss of function, and even death. Plastic surgery plays a critical role in the treatment of burn injuries, as it can help to improve function, restore appearance, and prevent significant scarring, contractures, and deformities, which can lead to impaired mobility, functional limitations, and psychological distress. Plastic surgeons can address these issues through a variety of techniques, including scar management, skin grafting, flap reconstruction, and reconstructive burn surgery. In this chapter, we discuss the different degrees of burns, indications for resuscitation, criteria for transfer to a burn center, and reconstructive management strategies to improve patient outcomes.

Burn Classification

Burn classification is a system used to categorize burn injuries based on their depth and severity. This system helps healthcare providers determine the appropriate treatment and predict potential complications. The depth and severity of a burn injury can have a significant impact on the course of treatment, and accurate classification is crucial for determining the most effective approach.

For example, superficial burns (first-degree burns) typically heal on their own within a few days with simple wound care and pain management. On the other hand, partial-thickness (second-degree) and full-thickness (third-degree) burns require more extensive treatment such as wound care, surgery, and sometimes skin grafting. An accurate classification helps health-care providers to determine the level of care and follow-up required, as well as the patient's overall treatment plan and goals.

Burns are classified as follows [2]:

1. First-degree burn: involves only the outer layer of skin (epidermis) and causes redness, pain, and swelling. These do not form blisters or scars [3].

2. Second-degree burn: involves the epidermis and the dermis, causing blisters, severe pain, and swelling.

3. Third-degree burn: involves all layers of the skin extending through the full dermis. Third-degree burns can cause the skin to appear dry, charred, or white and may be relatively painless due to nerve damage.

4. Fourth-degree burn: extends through all layers of the skin and involves the underlying muscle and bone.

In some cases, burn injuries may appear to be superficial (first-degree burns) initially but then progress to deeper partial-thickness or full-thickness burns over time. This can happen because the initial assessment of a burn injury may not reveal the full extent of the damage, especially if there is swelling or the burn area is covered by clothing or other materials.

As the burn injury progresses, it may become more apparent that the damage extends beyond the superficial layer of skin. Signs that a burn injury may be deeper or more extensive than originally thought include blistering, skin peeling, or a change in skin color from red to white or black.

Treatment based on burn classification

First Degree Burns

Treatment for first-degree burns is aimed at relieving pain and promoting healing of the affected area. In most cases, first-degree burns can be treated at home with simple measures. The initial step is to remove the source of the burn and cool the affected area under cool running water for at least 10 to 15 minutes. Cover the burn with a sterile, non-adhesive dressing and take over-the-counter pain relievers such as acetaminophen or ibuprofen to reduce pain and inflammation. Applying soothing creams like aloe vera can also help relieve pain and promote healing. In most cases, first-degree burns heal on their own within a week or two without complications.

Second Degree Burns

Second-degree burns are classified into two types: superficial partial-thickness and deep partial-thickness burns. Superficial partial-thickness burns (also known as second-degree superficial burns) involve damage to the epidermis and the upper dermis [2,3]. Deep partial-thickness burns (also known as second-degree deep burns) involve damage to the deeper layers of the dermis [2,3].

Superficial partial-thickness typically appears red and moist and may be painful. Blisters may also form, but the skin usually remains intact. Superficial partial-thickness burns typically heal within two to three weeks with minimal scarring.

Deep partial-thickness burns may appear white or pale and may be less painful than superficial partial-thickness burns because the nerve endings in the affected area may have been damaged. Blisters may also form, but the skin may be thinner and may peel away more easily. Deep partial-thickness burns may take up to 8 weeks to heal and may require skin grafting to prevent scarring [3].

The first step in managing a second-degree burn is to assess the extent of the burn and determine the total body surface area affected. Morbidity and mortality increase as the surface area of the burn increases [3]. The size of the burn can be estimated using the "rule of nines" also known as the Wallace rule of 9s **(Figure 1)** [4]. This information helps in determining the appropriate treatment plan and the need for referral to a specialized burn center. Some second-degree burns require aggressive fluid resuscitation depending on the total body surface area affected. Criteria for fluid resuscitation and transfer to specialized burn centers are discussed in detail later in this chapter.

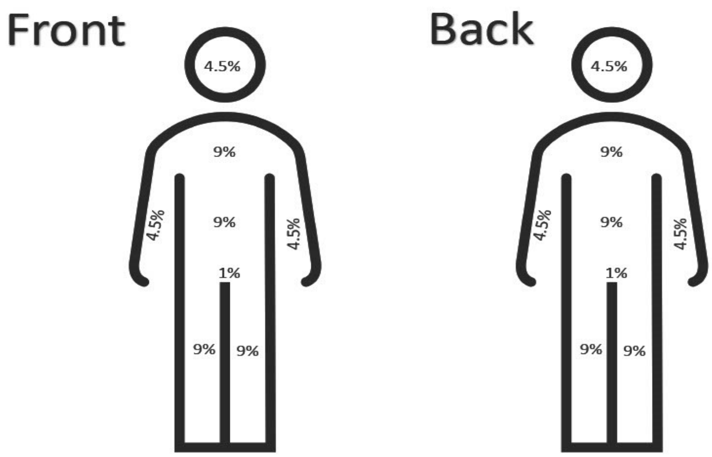

Figure 1: Wallace's rule of 9s to calculate total body surface area in adult burn patients.

The use of topical agents such as silver sulfadiazine, mafenide acetate, or collagenase may also be indicated to promote wound healing and reduce the risk of scarring. Indications and side effects are listed in **Table 1**. Silver nitrate should be avoided in the face due to the risk of staining and mafenide acetate is particularly useful to treat eschar formation [5].

Table 1: Topical ointments for burn injuries, their use, mechanism of action, and side effects.

Topical Ointment	Use	Indication	Mechanism of Action	Side Effects
Silver Sulfadiazine	Topical antimicrobial	Second and third-degree burns	Inhibits bacterial growth	Skin irritation, allergic reactions, delayed wound healing, blood abnormalities, kidney dysfunction
Mafenide Acetate	Topical antimicrobial	Second and third-degree burns	Inhibits bacterial growth	Skin irritation, allergic reactions, metabolic acidosis, electrolyte imbalances, kidney dysfunction
Bacitracin	Topical antibiotic	Minor burns, cuts, and wounds	Inhibits bacterial cell wall synthesis	Allergic reactions, skin irritation, rash
Silver Nitrate	Topical antimicrobial	First-degree burns, chemical burns	Denatures bacterial proteins	Skin irritation, staining of clothing and skin, electrolyte imbalances, kidney dysfunction

Regular monitoring of the burn wound and close follow-up with a healthcare provider is important to assess healing progress, identify signs of infection, and manage pain. Physical therapy and rehabilitation may also be necessary to restore function and mobility to affected areas.

Third and Fourth-Degree burns

Third-degree and fourth-degree burns are severe injuries that involve a combination of surgical intervention, wound care, and rehabilitation to promote healing and maximize recovery. These usually burn with contracture formation and take a long time to heal [3].

Initial treatment involves stabilizing the patient and preventing further injury. This may include administering fluids and medications to support vital functions, monitoring for signs of shock, and protecting the airway.

Once the patient is stabilized, the focus shifts to managing the burn wound. In most cases, these burns require surgical intervention to remove the damaged tissue and promote healing. After debridement, the wound may be covered with a skin graft or a flap procedure, which involves taking healthy tissue from another area of the body and transplanting it onto the burn wound. This helps to promote healing and reduce the risk of infection.

Complications may include infection, sepsis, organ failure, scarring, contractures, and limb loss. The outcome and prognosis for patients with these injuries depend on several factors, including the extent of tissue damage, the patient's overall health, and the effectiveness of the treatment. Long-term outcomes may include functional impairment, disfigurement, and chronic pain.

Fluid Resuscitation

Fluid resuscitation is a critical aspect of the initial management of burn patients. Burn injuries can cause significant fluid loss and result in a state of hypovolemia and shock. The extent of the fluid loss depends on the degree and extent of the burn injury, with larger and more severe burns resulting in greater fluid losses. Without appropriate fluid resuscitation, burn patients are at risk of developing severe complications such as renal failure, cardiovascular collapse, and death. Therefore, prompt, and appropriate fluid resuscitation is essential to optimize the outcomes of burn patients and has consistently been shown to decrease morbidity and mortality in victims of severe burns [4]. In this discussion, we will explore the principles and strategies of fluid resuscitation in burn patients in detail.

Patients with severe burns may require resuscitation with fluid and electrolytes to prevent shock. Fluid resuscitation should be initiated early in the management of burn patients, ideally within the first 6 hours of injury. Crystalloid solutions, such as lactated Ringer's (LR) or normal saline (NS), are the preferred fluids for the initial resuscitation of burn patients.

The Parkland formula is used to calculate fluid requirements in the first 24 hours. The formula 4mL x % total body surface area (TBSA) burned x body weight (kg) is used to resuscitate patients with electrical burn injuries. For other types of burns, the modified Brooke formula (2mL x % TBSA x body weight) is used, as recommended by the American Burn Association. Only those areas with deep partial-thickness burns or full-thickness burns are included to determine the TBSA [5]. Half of the calculated fluid volume is given in the first 8 hours from the time of the injury, and the remaining half is given over the next 16 hours. The rate of fluid infusion is adjusted based on the patient’s urine output, blood pressure, and clinical response.

Indications for resuscitation include [4]:

- Partial-thickness or full-thickness burns greater than 20% of total body surface area (TBSA)

- Inhalation injury

- Patients with associated injuries or comorbidities that increase the risk of shock or fluid imbalance

A target urine output of 0.5-1 ml/kg/hour in adults is recommended [4]. If urine output is inadequate, fluid infusion rates should be increased until the target urine output is achieved.

Transfer to a Burn Center

When it comes to the management of burn injuries, it is important to recognize the critical role of burn centers in providing specialized care to patients with severe burns. Burn centers are equipped with the necessary resources, expertise, and multidisciplinary teams to deliver optimal care and improve outcomes for burn patients. However, not all burn injuries require transfer to a burn center, and it is important to establish clear criteria for identifying those patients who would benefit from this level of care. In this regard, there are various factors that should be considered when determining whether a burn patient should be transferred to a burn center. These factors range from the size and depth of the burn injury to the presence of comorbidities and other complicating factors. In this discussion, we will explore the criteria for transfer to a burn center and highlight the importance of timely and appropriate referrals to optimize outcomes for burn patients.

Burn injuries can range from minor to severe, and while many can be treated in outpatient settings or in general hospitals, some patients require specialized care that can only be provided in burn centers. Burn centers are specialized facilities that are equipped to handle the unique challenges of burn injuries, such as fluid resuscitation, wound management, and infection control.

The following are some general criteria for transfer to a burn center [2]:

- Partial thickness burns involving more than 10% of TBSA

- Full-thickness burns

- Burns involving the face, hands, feet, genitalia, perineum, or major joints

- Electrical burns, including lightning injury

- Chemical burns

- Inhalation injury

- Burn injury in patients with pre-existing medical conditions that could complicate management, prolong recovery, or affect mortality

In general, burn patients who meet any of the above criteria should be transferred to a burn center as soon as possible. Timely transfer to a burn center can reduce morbidity and mortality, decrease the length of hospital stay, and improve outcomes [6]. In summary, identifying the criteria for transfer to a burn center is important to ensure timely and appropriate care for burn patients.

Debridement, Skin Grafts, and Flaps

Debridement

Debridement and skin grafting are crucial aspects of the treatment of burn injuries, particularly from a plastic surgery perspective. In severe burns, the skin may be destroyed or damaged beyond repair, and the wound may not heal on its own. Therefore, surgical intervention, such as debridement and skin grafting, is necessary to aid in the wound's healing process and prevent complications such as infection, scarring, and contractures. This discussion will focus on the techniques of debridement and skin grafting and flaps in the treatment of burn injuries.

Skin debridement in burn patients is generally indicated when there is necrotic tissue or eschar present, which can impede the wound's healing process and increase the risk of infection. Debridement is typically performed in the operating room under general anesthesia or deep sedation. The most common method of debridement in burn patients is sharp debridement, which involves using a scalpel or scissors to remove necrotic tissue and eschar.

Certain body parts, such as the face and hands, require special consideration when it comes to debridement. In general, the face should be debrided only, if necessary, as the risk of scarring and disfigurement is higher in this area. The hands should also be debrided with caution, as scarring and contractures can lead to functional impairment. In some cases, hand therapy and splinting may be necessary to prevent these complications.

Skin Grafts

Skin grafts involve taking a thin layer of skin from an unburned area of the body and transplanting it onto the burn wound. Indications for skin grafting in burn injuries include [7]:

• Deep second-degree burns

• Third-degree burns

• Non-healing wounds

• Large wounds not amenable to primary or secondary closure

• Burns that affect important functional or cosmetic areas, such as the face or hands

There are several types of skin grafts used in the management of burn injuries. The choice of graft depends on the location, extent, and severity of the burn, as well as the patient's overall health and available resources. Split-thickness grafts involve removing a thin layer of skin involving the epidermis and part of the dermis from a donor site to the intended burn wound for adequate coverage. These are further classified as thin, medium, or thick, depending on the thickness and the amount of dermis included [8]. In contrast, full-thickness grafts involve removing the epidermis and the whole dermis and transplanting it to the burn wound. Due to the differences in the composition of these grafts, their utility is limited and usually very intentionally used, depending on the wound location and extent.

Primary contraction, which is experienced immediately after graft harvesting, is related to the amount of dermis and elastin fibers within the dermis of the graft. Therefore, full-thickness grafts experience more primary contraction than split-thickness skin grafts [9]. Secondary contraction occurs during graft healing and is inversely related to the graft dermal component, making it more prevalent in split-thickness skin grafts[9]. This becomes extremely important when choosing grafts for areas such as joints, where mobility can be impaired due to these effects. The extent of the wound to cover is also a determining factor when considering graft options. Split-thickness skin grafts offer an advantage when there is need for large amounts of graft coverage for the following reasons: (1) the donor site heals by secondary intention with little morbidity or complications (2) split-thickness skin grafts can be meshed, increasing the amount of coverage per graft harvested [8,9]. In contrast, full-thickness skin grafts donor sites will not heal by secondary intention and often need primary closures or more complex closure techniques, making it difficult for large amounts of graft to be harvested while maintaining an aesthetic result.

Complications associated with skin grafts include infection, rejection, and graft failure. Causes of graft failure are often shear forces, fluid buildup underneath the graft (hematoma or seroma formation), or poor wound vascularity [7]. Grafts are therefore usually immobilized in the postoperative period by compressive dressings for 1 week. In recent years negative-pressure dressing techniques have become more popular for skin graft fixation, addressing both fluid accumulation and shear forces, two of the most common causes of graft failure. Infection can be managed with antibiotics, while rejection and graft failure may require additional surgeries or alternative treatment options.

Artificial skin grafts, also known as dermal substitutes, have been developed to address the limitations of traditional skin grafts. These substitutes are made of biocompatible materials that are designed to mimic the structure and function of natural skin. One of the main advantages of artificial skin grafts is that they can be produced in large quantities and do not require a donor site. They also provide a scaffold for new tissue growth, promote healing, and reduce scarring [10].

There are two main types of artificial skin grafts: cellular and acellular. Cellular grafts contain living cells, such as fibroblasts and keratinocytes, which are seeded onto a scaffold and then implanted into the wound bed. Acellular grafts, on the other hand, do not contain living cells but instead use a scaffold made of extracellular matrix proteins, such as collagen or hyaluronic acid. The surgical technique for implanting artificial skin grafts involves debriding the wound bed and preparing it for the graft. The graft is then placed over the wound and secured with sutures or staples. A dressing is applied to protect the graft and promote healing.

Tissue Flaps

Flaps are an important tool for reconstructive surgery in burn patients. A flap is a piece of tissue that is moved from one area of the body to another, along with its blood supply, to reconstruct a defect caused by burn injury. Flaps can be used in burn patients when the injury involves significant loss of tissue or when a skin graft alone may not provide adequate coverage. Flaps can be used for various purposes, including reconstructing the face, hands, or other areas of the body that require complex reconstruction.

There are different types of flaps and these are classified based on their content, their proximity to the defect, and their blood supply. For example, a flap containing skin and subcutaneous tissue would be termed a cutaneous flap and is one of the simplest forms of flap reconstruction. Similarly, fasciocutaneous and myocutaneous flaps are appropriately named

Table 2: T=Fasciocutaneous flap classification based on their pattern of vascularization.

Type of flap	Definition	Examples
Type A	Pedicled fasciocutaneous flap dependent on multiple fasciocutaneous perforators at the base and oriented with the long axis of the flap in the predominant direction of the arterial plexus	Sural artery flap
Type B	Pedicled or free flap, depending on a single and consistent fasciocutaneous perforator feeding a plexus at the level of the deep fascia	Scapular flaps, supraclavicular flap
Type C	Flap where the support of the skin is dependent upon the fascial plexus that is supplied by multiple small perforators along its length	Radial forearm flap
Type D	Osteomyofasciocutaneous free tissue transfer. A flap where the fascial septum is taken in continuity with adjacent muscle and bone which derive their blood supply from the same artery	Free fibular flap

Blood supply to the flap can be random or axial. An axial flap contains an artery coursing along the longitudinal axis while a random flap is designed without a known vessel and relies on the subdermal plexus for blood supply [13].

Local flaps are designed to cover defects in the immediate vicinity of the burn injury. In burn patients, local flaps may be used to cover small or moderate-sized wounds, especially when there is not enough healthy tissue available for a skin graft. Common types of local flaps include rotation flaps, transposition flaps, advancement flaps, and island flaps. Rotation flaps are created by rotating tissue around a pivot point, while transposition flaps are moved from one site to another without rotation. Advancement flaps are designed to advance adjacent tissue into the defect, while island flaps involve the transfer of tissue from a nearby site with a known blood supply.

Other types of flaps that may be related to local flaps in burn patients include regional flaps, distant flaps, and free flaps. Regional flaps are similar to local flaps, but they involve using tissue from a larger nearby area. Distant flaps are designed to cover defects that cannot be addressed with local flaps. They are classified based on the blood supply to the flap, which can be pedicled or free. Pedicled flaps maintain their blood supply from their original site, while free flaps rely on microvascular anastomosis to restore blood supply at the recipient site. The use of pedicled flaps to reconstruct defects in areas of functional importance or with exposed structures can be limited by the presence of previously burned skin in the surrounding tissues [14]. Examples of distant flaps include the latissimus dorsi flap, radial forearm flap, and anterolateral thigh flap. The latissimus dorsi flap is a pedicled flap that is commonly used for back and shoulder reconstructions, while the radial forearm flap and anterolateral thigh flap are free flaps that are commonly used for hand and lower extremity reconstructions.

The choice of flap depends on the location and size of the defect, the availability of donor tissue, the quality of the surrounding tissue, and the patient's overall health. Complications after flap surgery can include flap necrosis, infection, and wound healing problems, which can be managed with appropriate wound care and surgical intervention if necessary.

Flap Compromise

The most important complication after a flap creation is decreased arterial perfusion or venous congestion which can lead to flap loss. In pedicled flaps, this can be secondary to kinking of the pedicle while in free flaps it can be the result of thrombosis of the anastomosis. Revision with return to the operating room is imperative for flap salvage.

Flap venous congestion can occur due to several reasons, such as the disconnection of longitudinal venous channels during flap elevation and compression of the venous system due to flap edema or tension in the insetting sutures. Venous congestion is more insidious than arterial insufficiency, and the onset can be gradual.

There are several methods available to improve the survival of flaps when venous congestion occurs. The surgeon may attempt to release any sutures that cause tension or kinking, or they may prick the flap with a needle to reduce the burden on the venous system. Removing a portion of the flap or the nail plate, and periodically applying heparin solution, can increase venous outflow. The use of medicinal leeches can help ensure ongoing flap outflow until venous microanastomoses form. Additionally, the surgeon may cannulate a vein with an angiocatheter and periodically drain the flap to augment outflow. These methods are critical for the success of flap surgery, and prompt intervention is necessary to prevent flap failure.

Conclusion

In conclusion, burns are complex and devastating injuries that require a multidisciplinary approach for optimal management. Plastic surgery plays a critical role in the treatment of burns, from wound debridement and skin grafting to reconstructive procedures using flaps. The choice of treatment depends on the degree and extent of the burn injury, and close monitoring of patients is essential to ensure timely intervention and prevent complications. With advances in technology and techniques, plastic surgery has made significant contributions to improving the outcomes of burn patients. Collaboration between burn centers and plastic surgeons is essential to provide the best possible care and help them achieve the best possible functional and aesthetic outcomes.

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