- Environmental modification: adequate lighting, removal of throw rugs, handrails for stairs, ramps

REHABILITATION OF BURN INJURIES

BURNS—GENERAL INFORMATION

- A burn is the body's response to a thermal insult from an external agent such as heat , cold, chemicals, electricity, and radiation
- 85%–90% of burns are caused by heat
- 10%–15% of burns are from frostbite, chemical, and electrical damage
- 1.5 to 2.0 million people sustain burns each year in the U.S
- 60,000 to 80,000 of burn victims need hospitalization
- 5,000 people die each year from burns
- 35,000 to 50,000 people have temporary or permanent disability secondary to burns

Burns are the:
- Number 1 cause of accidental deaths in children under 2. The majority of burns in this age group occur as a result of abuse
- Number 2 in children under 4
- Number 3 in children under 19

Pathophysiology
- Normal skin figure (Table 11–12)

Cellular Response to Burns

Local reactions to burns include:
a) Exposed collagen causes platelet activation
b) Intense vasoconstriction secondary to epinephrine, prostaglandins, serotonin, and leukotrienes
c) Within a few hours—histamine release causing vasodilatation and increased capillary permeability allowing protein and albumin into the extravascular space followed by fluid causing severe edema
d) Late capillary permeability secondary to leukotrienes
e) Swelling and rupture of damaged cells
f) Platelet and leukocyte aggregation with clot formation from tissue thromboplastin, endotoxin, interleukin-1, and Hageman factor
g) Establishment of a hypermetabolic state

Systemic Response to Burns

- Loss of fluid into extravascular compartment resulting in hypovolemia and shock
- Hyperventilation with increased oxygen demand
- Inhalational injury causing decreased oxygenation and ARDS
- Initial decrease followed in several days by a significant increase in cardiac output
- Increase in blood viscosity
- Gastric dilation and ileus occurs in the first three days postburn
- Multi-organ system failure

CLASSIFICATION OF BURNS

Causative Agent

1. **Thermal**
   a) Heat—application creates a zone of coagulation, where tissue is destroyed and a zone of stasis, an area of decreased blood flow. This area may improve or get worse depending upon treatment
   b) Cold—damage occurs as a combination of actual freezing plus decreased blood flow and ischemia. Commonly, alcohol is involved in these injuries

2. **Electrical**—superficial damage may appear minimal; however, the deeper tissues (muscle and bone) may have severe injuries. The electrical current travels through the body following the path of least resistance. This turns out to be the nerves, arteries, veins, and bones. The current causes damage all along the course through the body. Because of its smaller cross-section area, there is a relatively greater resistance at the exit site, causing a greater build up of heat. This often leads to an explosive release of built up energy and significantly more extensive damage at the exit wound than entrance. Injury observed in conjunction with electrical burns includes:
   a) Radiculopathy from hyperextension caused by tonic/clonic contractions during electrocution.
   b) Peripheral neuropathy caused by direct injury from the current
   c) Cognitive impairment
   d) Spinal cord injury
   e) Formation of heterotropic bone around joints and in residual limbs
   f) Cardiopulmonary arrest
   g) Will be at risk of developing early onset of cataracts and hearing loss, both amenable to usual treatments

3. **Chemical burns**—from either acid or alkali exposure. These burns are typically underestimated and will frequently appear to be mild in severity. However, inappropriate or insufficient removal of the causative agent allows the injury to progress

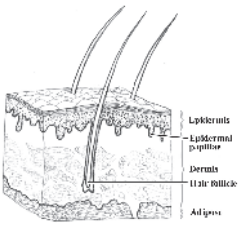
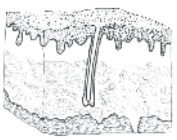
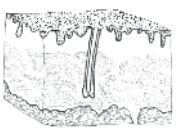
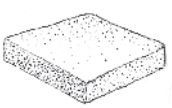
4. **Radiation**—risk and severity of burn will depend upon duration and intensity of exposure. Response will vary from mild erythema to blistering and skin sloughing over a period of hours to days. If exposure is high enough, treatment can only be palliative

Depth of Burn (Table 11–12) (Figure 11–11)

Older Terminology
a) First degree; outer layers of epidermis injured, erythema, but no blistering
b) Second degree; involves epidermis into dermis but basal layer remains, blistering
c) Third degree; all epidermis and dermis destroyed; only white eschar remains
d) Fourth degree; muscle, nerve and bone damaged

Newer terminology
a) Superficial partial thickness; epidermis and upper part of dermis injured
b) Deep partial thickness; epidermis and large upper portion of dermis injured
c) Full thickness; all layers destroyed

TABLE 11–12. Degree of Burns

NORMAL SKIN	Epidermis and Dermis Intact	
FIRST DEGREE	Only the outer layers of epidermis are injured, sparing deeper layers. Erythematous, but no blistering.	
SECOND DEGREE Superficial partial thickness	Involves epidermis, but most of basal layer remains; blistering	
SECOND DEGREE Deep partial thickness	Involves the dermis; only the basal layer lining skin appendages remains; blistering.	
THIRD DEGREE Full thickness	Total destruction of epidermis and dermis.	

The degree of burn describes the depth of injury. Most injuries are of varying depths. (O'Young, 1997)

Size of burn

Rule of nines (Figure 11–12)
The Rule of 9's is an approximate way of estimating Adult Total Body Surface Area (BSA).

- Head = 9% BSA
- Each upper extremity = 9% BSA
- Each lower extremity = 18% BSA
- Anterior trunk = 18% BSA
- Posterior trunk = 18% BSA
- Perineum = 1% BSA

American Burn Association Classification

1. Minor
   a) < 15% BSA partial thickness (10% in child)
   b) < 2% BSA full thickness (not involving eyes, ears, face or perineum)
2. Moderate (most should be hospitalized)
   a) 15% to 20% BSA (10% to 20% in child)
   b) 2% to 10% BSA full thickness (not involving eyes, ears, face or perineum.)

FIGURE 11–12. Rule of Nines.

3. Major (all should be hospitalized)
   a) > 25% BSA partial thickness (20% in child)
   b) ≥ 10% BSA full thickness
   c) All burns to eyes, ears, face or perineum.
   d) All electrical
   e) All inhalation
   f) All burns with fracture or major tissue trauma
   g) All with poor risk secondary to age or illness

FACTORS AFFECTING OUTCOME

1. **Age—**infants, children, and the elderly have a poorer rate of survival
2. **Total Body Surface Area**—the greater the area of involvement the worse the prognosis
3. **Depth of Burn**—as the total BSA that is full thickness increases the prognosis decreases
4. **Other Associated Injuries**—prognosis decreases as the number of concurrent injuries increases

PATIENT MANAGEMENT

Initial Treatment

Always begin any emergency assessment with an evaluation of the ABCs, airway , breathing, circulation. Special considerations include:

- Resuscitation with fluids, use Brooke, Evans, Baxter or Parkland formulas as a guide
- Parkland formula (4cc/kg body weight/% burned). One-half (1/2) of the total should be given in first 8 hours. The remaining amount is divided equally over the next 16 hours
- Escharotomy: an incision of burned tissue to relieve pressure from edema and hopefully avoid neurovascular compromise and amputation
- Nasogastric (NG) tube for abdominal decompression and foley catheter for volume management
- Tetanus toxoid
- Cleaning all wounds with sterile saline
- Application of topical antimicrobials. Systemic antibiotics should await specific indications and be culture driven
- Rapid and extensive debridement and grafting. The goal is to cover as much open area as possible in as short a period of time as possible. Nothing else will prevent complications, decrease pain, and promote rapid recovery as well as coverage of wounds

Wound Healing

Phases

1. Inflammatory Phase—response to injury with influx of neutrophils and macrophages
2. Proliferative Phase—with new matrix is laid with fibroblasts and in-growth of capillaries
3. Maturation Phase—resolution of inflammation in which collagen is laid down to form the scar.
4. Epithelialization—reestablishment of the basement membrane and epidermis
5. Wound Contraction—the open margins are brought together by fibroblasts
6. Wound Contracture—shrinkage of the scar through collagen remodeling. This causes functional restriction of motion

Treatment (Table 11–13)

Wounds are more likely to have hypertrophic scarring if they take longer than two weeks to heal. To reduce this, early debridement and skin grafting with good local wound care is required

- **Wound Dressings**—First use topical antibiotics (ie. Silvadene® or Bactroban®) then biological or synthetic dressings
- **Biological Dressings**—temporary cover for a burn wound to protect wound and decrease fluid loss from the site, decrease pain, and inhibits bacterial growth. May use autographs—split thickness (STSG) or full thickness (FTSG) skin grafts taken from donor sites on the patient; homographs—skin from the same species but not the patient (human cadavers or fetal membranes); and xenografts—skin from other species (pigs in the U.S. or frogs in Brazil). Homographs and xenografts are temporary coverings because the body will ultimately reject the foreign protein. They are utilized when too much BSA is involved and there is not enough uninjured skin to use for graphs, or until donor sites can be reharvested. Until then they provide the same benefits as STSG or FTSG.
- **Synthetic Dressings**—Much effort has gone into the development of synthetic membranes such as Biobrane®—a bi-laminate dressing that can be used temporarily to cover wounds until STSG are available
- **Cultured Epithelial Autocytes (CEA)**—CEA is skin that is cloned from a small 2.5 cm square piece of the patient's own skin. From that, literally yards of skin can be grown fairly rapidly. It is the patient's own skin so risk of rejection is minimized. Problems include: fragility (making application technically very difficult), lack of a basement membrane (it is only the epidermal layer meaning it cannot cover irregular surfaces well and easily slides off even after several days), and horrendous expense
- **Debridement**—removal of eschar to expose viable tissue and prepare the wound bed for coverage
  - **Mechanical**—wet to moist dressings, or hydro therapy to soften eschar
  - **Hydrotherapy**—consists of daily cleansing of wounds. Immersion tanks are not used secondary to the risk of cross contamination
  - **Enzymatic**—digest necrotic tissue without harming viable tissue. May be painful, increase body temperature, or cause bleeding. Can increase fluid loss therefore, should only be done 20% or less of BSA
- **Surgical debridement**
  - Tangential excision—1–10 days post burn, removing thin layers until normal viable tissue is exposed. May have significant bleeding. With early debridement and grafting, it has been shown to decrease hospital stay, mortality, and sepsis. (Helm, 1998).
- **Skin Grafting**—covering a wound with healthy skin
  - Used if wound is not expected to heal within 18–21 days
  - Allows early wound closure which reduces pain
  - Autologous
  - Full thickness. Utilizes all layers of epidermis and dermis. Will not contract as it matures. Obviously cannot be used to cover anything but small areas that are burned as available tissue is rapidly used up
  - Split thickness. Is meshed at the time of harvest giving largest possible area of coverage. Will contract as it heals
  - Homologous (cadaver) split skin (temporary)
  - Xenograft donor from another species (temporary)
  - Immobilize the joint above and below the graft for a minimum of 3 to 5 days to encourage healing
  - Minimize positional dependent edema to prevent graft loss

TABLE 11–13. Assessment and Treatment of Burn Injuries

Depth of Injury	Healing Time	Pain	Wound Outcome	Treatment Modalities
Superficial epidermis (First degree)	• 1–5 days	• Painful for 1–3 days, Ibuprofen or acetaminophen gives adequate analgesia	• No sequelae	• Elevation decreases pain of limb • Keep wound clean • Aloe or other moisturizer reduces dry skin and itching • If needed (usually in electrical injuries) therapy to prevent PTSD
Superficial dermis (Second degree/ superficial partial thickness)	• 14 days	• Painful for 5–14 days • Acetaminophen with codeine or oxycodone gives adequate analgesia for wound care, exercise and sleep	• Possible pigment changes	• Wound care • Active exercise • Protective garments • Sunscreen • Therapy to prevent PTSD
Deep reticular dermis (Second degree/deep partial thickness)	• 21 days for spontaneous healing • If grafted after 10–14 days, less scar formation will be noted, with improved functional outcome; less pain, and shortened hospital stay	• Very painful until closure • Methadone or oral morphine continuously for baseline pain control • Parenteral or instant-release oral morphine and/or oxazepam and midazolam for dressing changes and stretching exercises	• Probable pigment changes • Reduced skin durability • Severe scarring • Sensory changes • Apocrine changes • Edema in dependent limbs	• Wound care • Anti-inflammatories, analgesics, antipruritics • Active exercise • Elevated positioning/orthotics • External vascular support garments • Moisturization and lubrication • Daily living skills • Psychological therapy • Therapy to prevent PTSD
Subcutaneous tissue (Third degree/ full thickness)	• Graft needed, or if smaller, undermine to approximate with primary closure • Variable healing time	• Nonpainful initially due to destruction of nerve endings • Pain medication as above • Carbamazepine, phenytoin, or amitriptyline	• Same as above • Additional sweating loss • Possible loss of finger or toenails • Possible additional sensory loss • Alopecia over grafts • Areas of cultured epithelial autograft show permanent fragility, loss of temperature control, dry blistering skin with changed sensation	• Same as above • Post-op positioning/immobilization • Possible need for NSAIDs or other etidronate disodium to prevent heterotopic ossification (controversial early treatment) • Therapy to prevent PTSD • Very slow weaning from analgesics and anxiolytics • Vibration for pruritus
Muscle, tendon, bone (4th degree) (Old term in disfavor and rarely used)	• Amputation or reconstructive surgery, such as flaps, needed • Healing time variable	• Nonpainful initially due to destruction of nerve ending • Chronic pain treatment for neuromas and phantom limb pain and later bone spicules	• Variable • Early amputation with closure using non-injured tissue shortens hospital stay, decreases pain, and improves prosthesis fit	• Same as above • Deep tendon massage • Adapted equipment • Prosthetic fitting if indicated

Ibuprofen has the dual action of inflammation reduction at injury site and pain reception reduced at the CNS level.
PTSD = post traumatic stress disorder; NSAIDs = nonsteroidal antiinflammatory drugs
Rivers EA, Fisher SV. Burn Rehabilitation. In: O'Young B, Young, MA: Stiens, SA. PM&R Secrets. Philadelphia: Hanley & Belfus, 1997.

TABLE 11–14. Consequences of Burn Injury by Depth of Burn

	Absent or Impaired Morphology	Wound Consequences
Epidermis	Stratum basale Stratum spinosum Stratum granulosum Stratum lucidum Stratum corneum Melanocytes	Source for proliferating cells Decrease protection Increased water loss Water loss, microorganism growth, entry of noxious agents Repeated sunburn
Dermis (does not regenerate)	Altered collagen Increased collagen Aging collagen	Decreased tensile strength Scarring Altered surgical response
Nerves	Affected Absent	Pruritus/paresthesisas Decreased sensation, trauma, and burn risk
Vascular system	Impaired Absent Fragility	Impaired (especially venous return) No healing (depends on area) Re-injury risk
Basement membrane zone	Basal decidua and densa Rete pegs and dermal papillae	Blisters Blisters, fragility
Epidermal appendages	Sweat ducts Sebaceous glands Hair follicle	Impaired thermoregulation Loss of duct, sweat, and oil glands Loss of hair root, resultant alopecia
Fingernail bed	Basal cells for proliferation absent	Malformed or absent nail

Campbell MK, Covey MH, eds. Topics in Acute Care and Trauma Rehabilitation. Frederick, MD: Aspen, 1987.

REHAB ISSUES

Contractures

Scars will grow and contract. They will continue to contract until they mature in one to one and a half years or unless they are met by an opposing force. This contracture is particularly damaging over joints. Hypertropic scarring is cosmetically and psychologically devastating even in the absence of mechanical limitation. Need 25mm of pressure to counteract the contraction of a scar.

Positioning to prevent contracture (Fig 11–13)

- Position patient in extension and abduction. Patients tend to contract in flexion and adduction to reduce stretching in the injured skin.
- Position to prevent dependent edema.
- Use of special beds i.e., Kin Air® and ROHO to limit pressure, breakdown, and facilitate positioning.

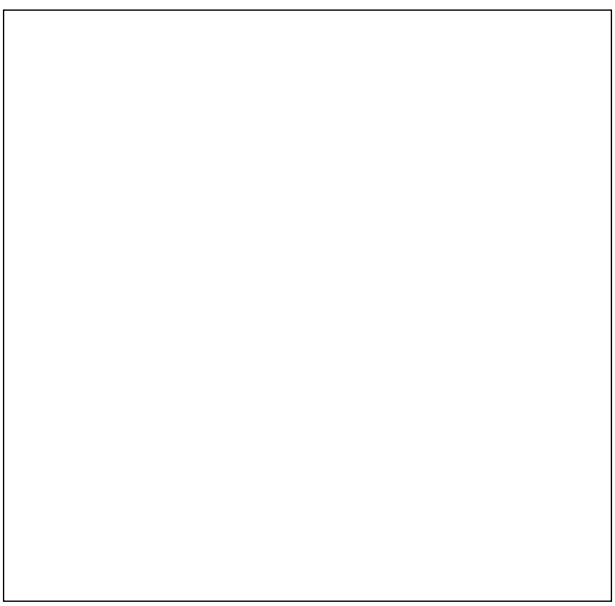


FIGURE 11–13. Anti-contracture Positioning—patient supine from ventral position.

Splinting

- Used with patients who are not compliant with positioning, or if there are exposed tendons or joints
- Splinting cannot be used without mobilization. A elbow that is frozen in full extension because it was splinted and never ranged is just as impaired as one that has contracted into full flexion because it was never splinted initially

Splints used:

Resting hand splint

1) For general hand burns to properly position patient
2) For hand burns with extensor tendons exposed

Dorsiflexion Lower Extremity

Knee-extension with foot dorsiflexion

Elbow extension

Transparent Face Mask—Made of silicon and used over healed grafts.

- Monitor skin easily
- Molded from the patient's own face for individual fit
- Protect contours of the face
- Prevents severe cosmetic deformities with even pressure across uneven surfaces, i.e., the nose
- Clear mask is more cosmetically and socially acceptable than a fabric mask
- Very hot, does not breathe and can cause maceration of the skin and even heat injury

Compression Garments

Used to help decrease hypertrophic scarring. It is thought that the pressure exerted on capillaries reduces blood flow; therefore, reducing the scar formation. These are worn 23 hours a day, only removed for washing. They are specifically measured to fit the burned areas: face masks, gloves, sleeves, jackets, or pants. They will need to be replaced frequently as they wear out and must be changed as the patient gains or loses weight.

Other Mechanisms to Control Hypertropic Scarring and Contractures

- Silastic gel has been found to reduce hypertrophic scar formation in the absence of pressure; however, the mechanism is not clear. It is used to line silicone masks and is applied over individual problem scar areas
- Steroids injected locally may reduce hypotrophic scarring
- Early mobilization is encouraged to maintain range of motion and prevent contractures. Balance splinting with mobilization
- Use assistive devices as needed for ambulation including Ankle Foot Orthosis (AFO)
- If torso is injured, maintain ROM with exercises
- Monitor for heterotopic ossification (HO)

Pain Control

Pain can be severe from burns, and adequate pain control is needed. Long-acting narcotics are used with short-acting for breakthrough pain. Dose may be high because metabolism of medications is higher in burn patients. Patient controlled analgesia (PCA) may be used to help the patient feel in more control. Consideration must be given to other causes of discomfort i.e. neuropathic pain, myofacial pain, pruritus, sleep deprivation and be treated aggressively and specifically. Mobilization must not be limited by pain.

Psychological Problems and Treatments for Burn Survivors

- Posttraumatic stress disorder (PTSD)
- Severe loss of personal identity with change in appearance. Little is more devastating than a change in our appearance
- Loss and change in position in the family and the community
- Financial and social stress
- Stress of constant pain
- Survivor guilt
- Depression
- Pre-existing psychological disorders
- Adjustment disorders
- Antidepressants
- Counseling
- Peer support of other burn survivors i.e., Phoenix Society
- Early reintegration into the community. Early and repeated emphasis upon return to vocational and avocational activity

Nutrition

Adequate calories must be given to maintain a positive nitrogen balance and promote muscle and skin repair. Healing will not take place without it, as the body is in a highly catabolic state. This may require as much as 2000 to 2200 calories and 15 gm of nitrogen per square meter of body surface per day. Additional vitamin C, vitamin A, zinc, copper, and manganese are important in wound care. The use of additional supplementation is essential. Once the acute phase has passed another problem may appear. Burned fat cells are not replaced. Overeating will cause weight gain into any area that has not lost cells and can lead to disfigurement secondary to relative obesity.

Exercise

- AROM (Active Range of Motion)
- Cardiovascular fitness
- Slow sustained stretching of the skin contractures:
  - Gentle application of superficial heat prior to stretch
  - Manual
  - Traction/weights
  - Serial casting/splinting
  - Paraffin
  - Massage/vibration

SPECIFIC PROBLEMS

Peripheral Neuropathy

- Present in 15–20% of burn patients with BSA of 20% or greater. (Helm, 1998)
- Etiology uncertain
- May have paresthesias, weakness
- Strength may recover well but usually easily fatigued

Multiple Mononeuropathy

Secondary to multiple crush syndrome caused by neurotoxins, metabolic or compression type injuries to nerves.

Bone and Joint Changes

- Decreased growth in children with burns near the epiphyseal plate
- Bone growth deformity after burn injury. Also must change the size of the compression garments frequently as children grow to prevent deformity. Particularly true with pressure to the mandible causing overbite

Osteophytes

- Found at the elbow and olecranon or coracoid process after burn injury

Heterotopic Ossification (HO)

- Ectopic bone deposition around joints and tendons
- Most common site of HO joint involvement in burns in elbow
- Reported in up to 23% of burn patients
- Recommend pain free active ROM

Scoliosis and Kyphosis

- Can be seen with burns of the chest or back
- May occur from protective posturing

Subluxations and Dislocations

- Seen with burns of the hands and feet, dorsal surface. During the healing process, skin pulls the joint into hyperextension, if chronic causes a subluxation
- Seen in MCP and MTP joints.
- Splint MCP in joint in flexion between 60 to 90 degrees, and exercise
- Use a surgical high-top shoe with a metatarsal bar 24 hours a day to prevent MTP subluxation

POSTACUTE PHASE

- Continue local wound care
- Prevention of new injury from mechanical irritants, the skin is now very sensitive.
- Lubricate skin several times a day
- Oral antihistamines and pressure garments (vascular support garments) for pruritus decrease edema, lessen hypertrophic scars, and speed wound healing. These garments should provide at least 25 mm Hg or more and be worn 23–24 hours per day to reduce hypertrophic scarring. (Helm, 1998)
- Provide protection from the sun as skin is susceptible to repeat burns. Use long sleeves, hats and sunscreen
- The skin will also be susceptible to topical irritants such as oil and gas and these should be avoided
- Extremes of heat should be avoided in full thickness burns as sweat glands are lost and the ability to cool the body through sweating is lost