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Burns and frostbites

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Part 1. Burns

The large one

Definition

Burns are traumatic injuries of the skin or other tissues primarily caused by thermal or other acute exposures.

Burns occur when some or all of the cells in the skin or other tissues are destroyed by heat, electrical discharge, friction, chemicals, or radiation.

Burns are acute wounds caused by an isolated, non-recurring insult, and healing ideally progresses rapidly through an orderly series of steps

Mechanism

- **Heat.** The depth of the thermal injury is related to contact temperature, duration of contact of the external heat source, and the thickness of the skin. Because the thermal conductivity of skin is low, most thermal burns are superficial. The most common thermal burns are associated with flames, hot liquids, hot solid objects, and steam.
- **Chemicals.** Injury is caused by a wide range of caustic reactions, including alteration of pH, disruption of cellular membranes, and direct toxic effects on metabolic processes. In addition to the duration of exposure, the nature of the agent will determine injury severity. Contact with acid causes coagulation necrosis of the tissue, while alkaline burns generate liquefaction necrosis. Systemic absorption of some chemicals is life-threatening, and local damage can include the full thickness of skin and underlying tissues.
- **Electrical discharge.** Electrical energy is transformed into heat as the current passes through poorly conducting body tissues. The magnitude of the injury depends on the pathway of the current, the resistance to the current flow through the tissues, and the strength and duration of the current flow.
- **Radiation.** Radio frequency energy or ionizing radiation can cause damage to skin and tissues. The most common type of radiation burn is the sunburn. Radiation burns are most commonly seen today following therapeutic radiation therapy and are also seen in patients who receive excessive radiation from diagnostic procedures. Radiation burns can be seen in individuals who work in the nuclear industry. Radiation burns are often associated with cancer due to the ability of ionizing radiation to interact with and damage DNA. The clinical results of ionizing radiation depend on the dose, time of exposure, and type of particle that determines the depth of exposure. Depending on the photon energy, radiation can cause very deep internal burns.
- **Friction.** Injury from friction can occur due to a combination of mechanical disruption of tissues as well as heat generated by friction.

Thermal burn



Hyperemia and bubble

Thermal burn



Bubble and erosion

Chemical burn (acids)



Hydrochloric acid



Hydrochloric acid



Hydrofluoric acid

Chemical burn (alkaline)



Sodium hydroxide



Alkaline burn with cement



Crude oil

Chemical burn (other)



Heracleum



Chemical burn (other)



Liquid nitrogen

Electrical burn



High voltage

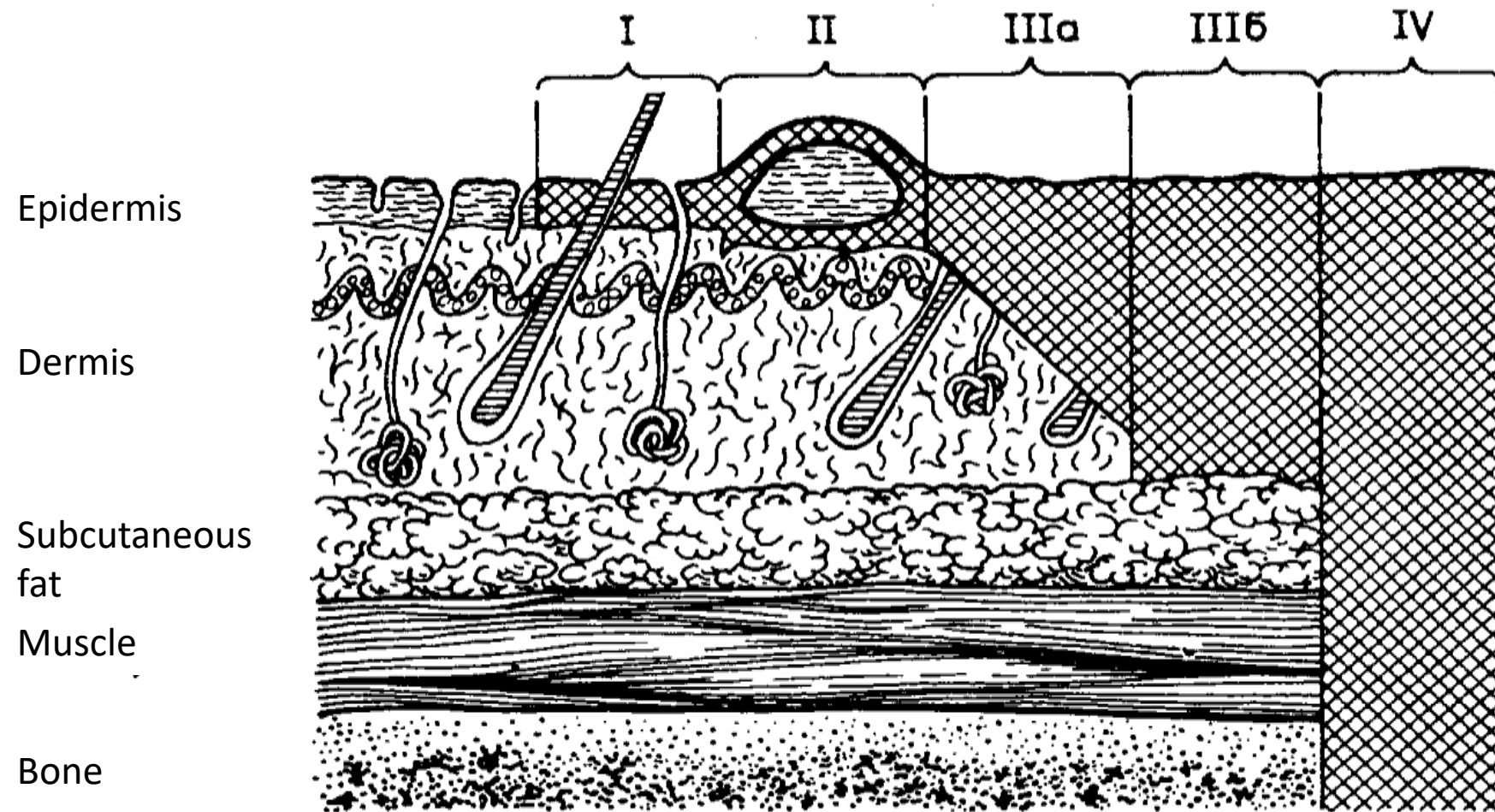
Sun burn



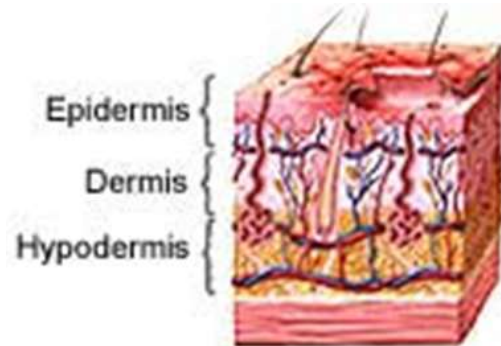
Radiation burn



Classification by depth (old fashioned)



Classification by depth (old fashioned)



First degree
burn



Second degree
burn



Third degree
burn



ADAM.



4



5



6

Classification by depth (novel)

Skin layers	Burn depth	Depth	Appearance	Sensation	Healing time
Epidermis		Superficial (epidermal)	Dry, red Blanches with pressure	Painful	3 to 6 days
Dermis		Superficial partial-thickness	Blisters Moist, red, weeping Blanches with pressure	Painful to temperature and air and touch	7 to 21 days
Subcutaneous fat		Deep partial-thickness	Blisters (easily unroofed) Wet or waxy dry Variable color (patchy to cheesy white to red) Blanching with pressure may be sluggish	Painful to pressure only	>21 days, usually requires surgical treatment
Muscle		Full-thickness	Waxy white to leathery gray to charred and black Dry and inelastic No blanching with pressure	Deep pressure only	Rare, unless surgically treated
		Deeper injury (ie, fourth degree)	Extends into fascia and/or muscle	Deep pressure	Never, unless surgically treated

Superficial/epidermal burn (Degree 1)



- Superficial or epidermal burns involve only the epidermal layer of skin.
- They do not blister but are painful, dry, red, and blanch with pressure.
- Over the next two to three days the pain and erythema subside, and by approximately day 4, the injured epithelium peels away from the newly healed epidermis.
- Such injuries are generally healed in 6 days without scarring.
- This process is commonly seen with sunburns.

Superficial partial thickness burn (Degree 2)



- The burns characteristically form blisters within 24 hours between the epidermis and dermis.
- They are painful, red, and weeping and blanch with pressure.
- Burns that initially appear to be only epidermal in depth may be determined to be partial thickness 12 to 24 hours later.
- These burns generally heal in 7 to 21 days; scarring is unusual, although pigment changes may occur.
- A layer of fibrinous exudates and necrotic debris may accumulate on the surface, which may predispose the burn wound to heavy bacterial colonization and delayed healing.
- These burns typically heal without functional impairment or hypertrophic scarring.

Deep partial thickness burn (Degree 3a)



- The burns extend into the deeper dermis and are characteristically different from superficial partial-thickness burns.
- Deep burns damage hair follicles and glandular tissue.
- They are painful to pressure only, almost always blister (easily unroofed), are wet or waxy dry, and have variable mottled colorization from patchy cheesy white to red.
- They do not blanch with pressure.
- If infection is prevented and wounds are allowed to heal spontaneously without grafting, they will heal in 2-9 weeks.
- These burns invariably cause hypertrophic scarring.
- If they involve a joint, joint dysfunction is expected even with aggressive physical therapy.
- A deep partial-thickness burn that fails to heal in 2 weeks is functionally and cosmetically equivalent to a full-thickness burn.
- Differentiation from full-thickness burns is often difficult.

Full-thickness burn (Degree 3b)



- The burns extend through and destroy all layers of the dermis and often injure the underlying subcutaneous tissue. Burn eschar, the dead and denatured dermis, is usually intact. The eschar can compromise the viability of a limb or torso if circumferential.
- Usually anesthetic or hypo-aesthetic. Skin appearance can vary from waxy white to leathery gray to charred and black. The skin is dry and inelastic and does not blanch with pressure. Hairs can easily be pulled from hair follicles. Vesicles and blisters do not develop.
- Pale full-thickness burns may simulate normal skin except that the skin does not blanch with pressure. Features that differentiate partial-thickness from full-thickness burns may take some time to develop.
- The eschar eventually separates from the underlying tissue and reveals an unhealed bed of granulation tissue. Without surgery, these wounds heal by wound contracture with epithelialization around the wound edges. Scarring is severe with contractures; complete spontaneous healing is not possible.

Extension to deep tissues (Degree 4)



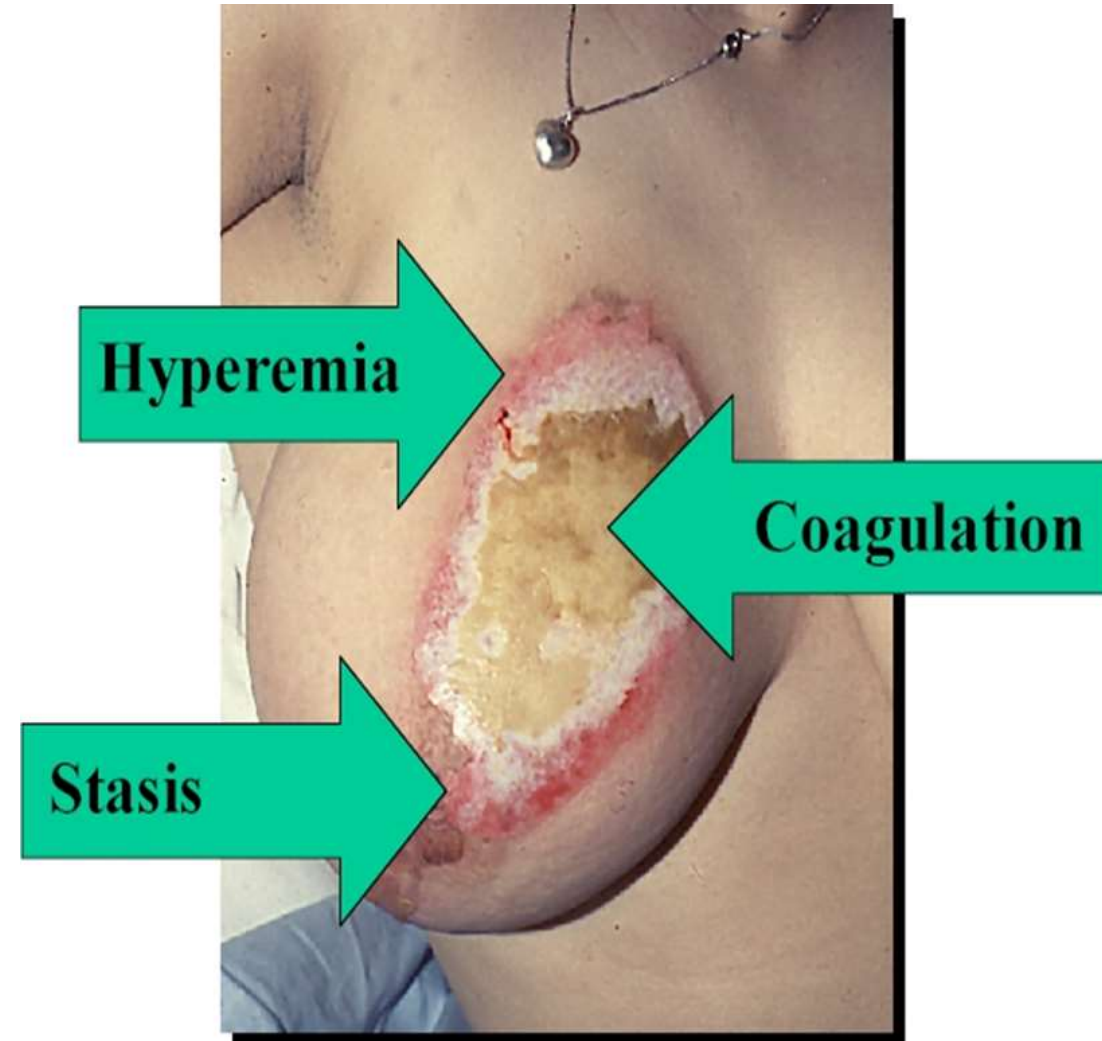
- The burns are deep and potentially life-threatening injuries that extend through the skin into underlying soft tissue and can involve muscle and/or bone.

Assessment of burn depth

- Burn wounds are not usually uniform in depth, and many have a mixture of deep and superficial components. A precise assessment of the depth of the burn wound may be difficult initially as burn wounds are dynamic and can progress as well as convert to deeper wounds, and as such may require several days for a final determination.
- Thin skin, particularly on the volar surfaces of the forearms, medial thighs, perineum, and ears, sustains deeper burn injuries than suggested by initial appearance. It is best to assume there are no shallow burns in these areas. Children under the age of 5 and adults over the age of 55 are also more susceptible to deeper burns because of thinner skin.

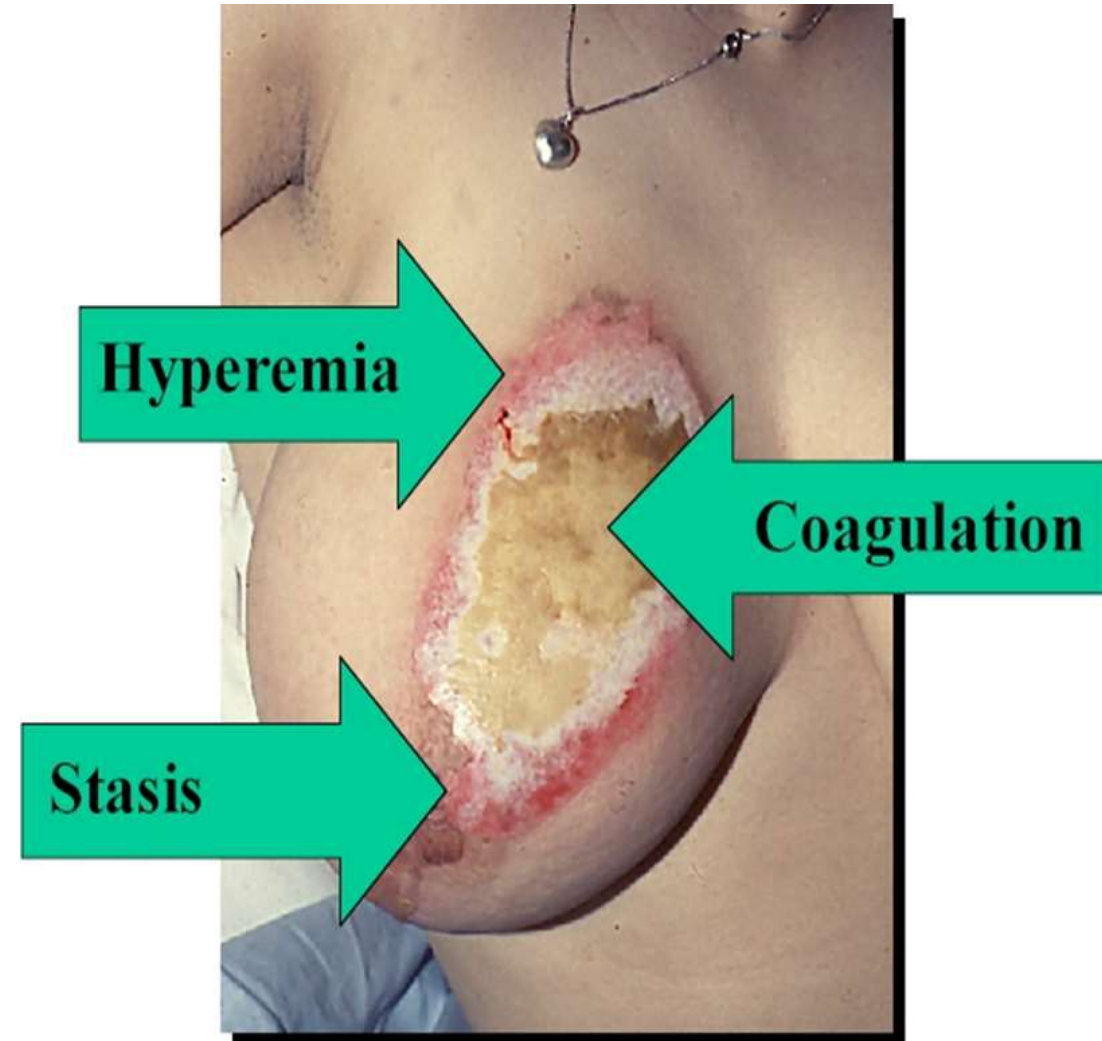
Assessment of burn depth

- Clinical assessment is the most common technique to assess the depth of a burn wound; however, it is accurate in only 60-75% of the cases, even when carried out by an experienced burn surgeon.
- Making assessments of burn depth is difficult because there are both spatial and temporal changes in perfusion in actual burn patients as most burn patients have burns of various depths caused by their injury.



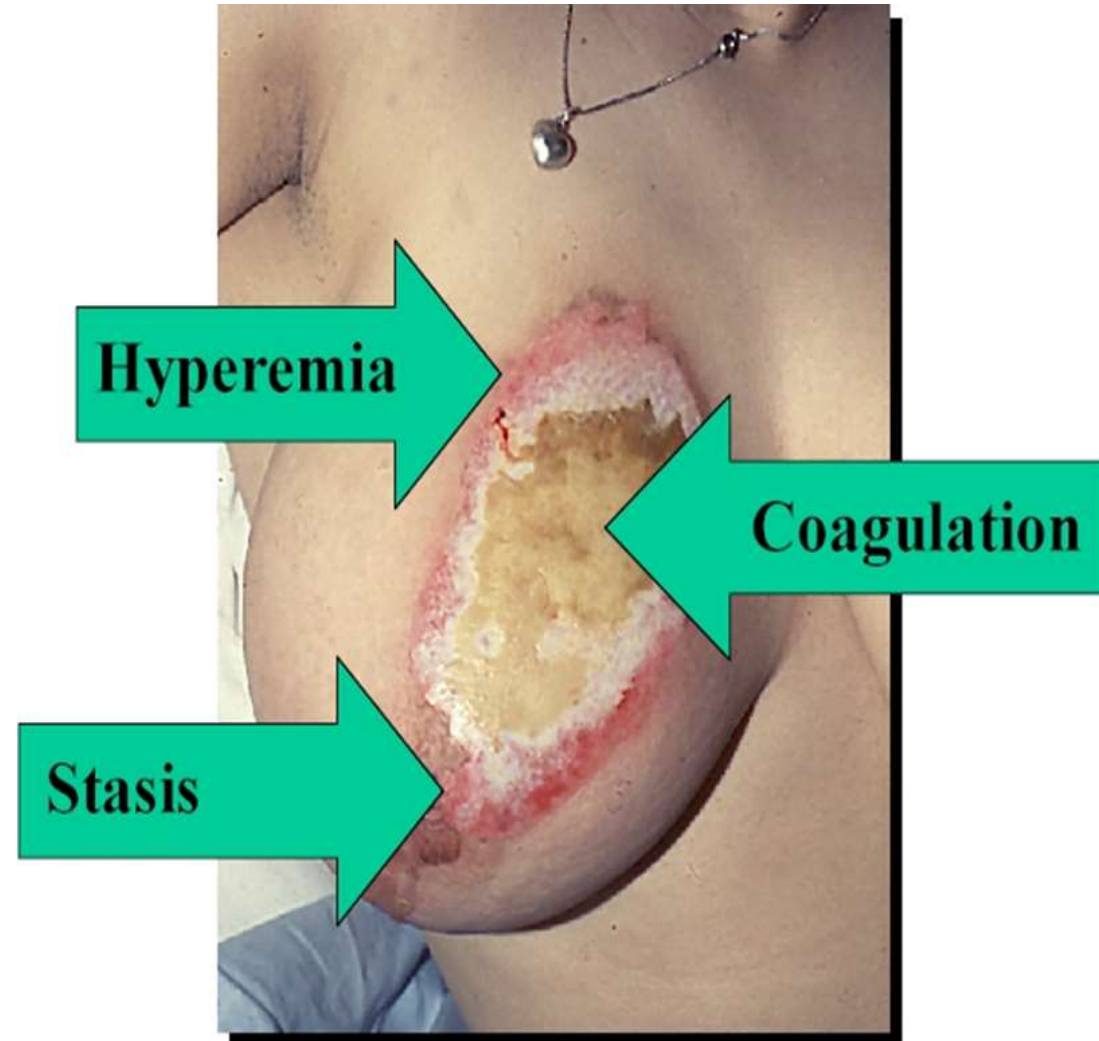
Assessment of burn depth

- Pain
- Hair extraction
- Laser Doppler
- Indocyanine green
- Thermography
- Dermoscop
- Hyperspectral imaging

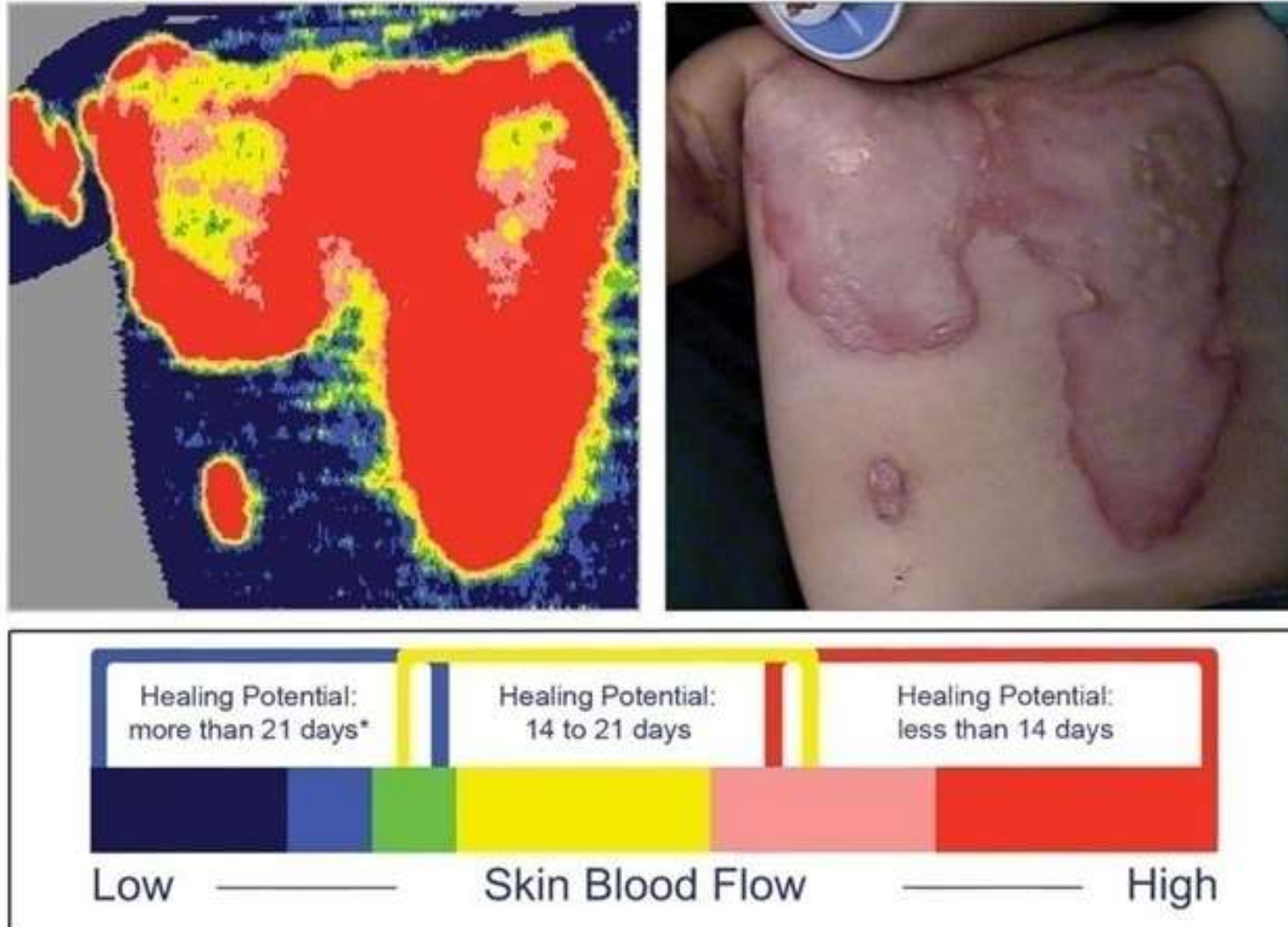


Assessment of burn depth

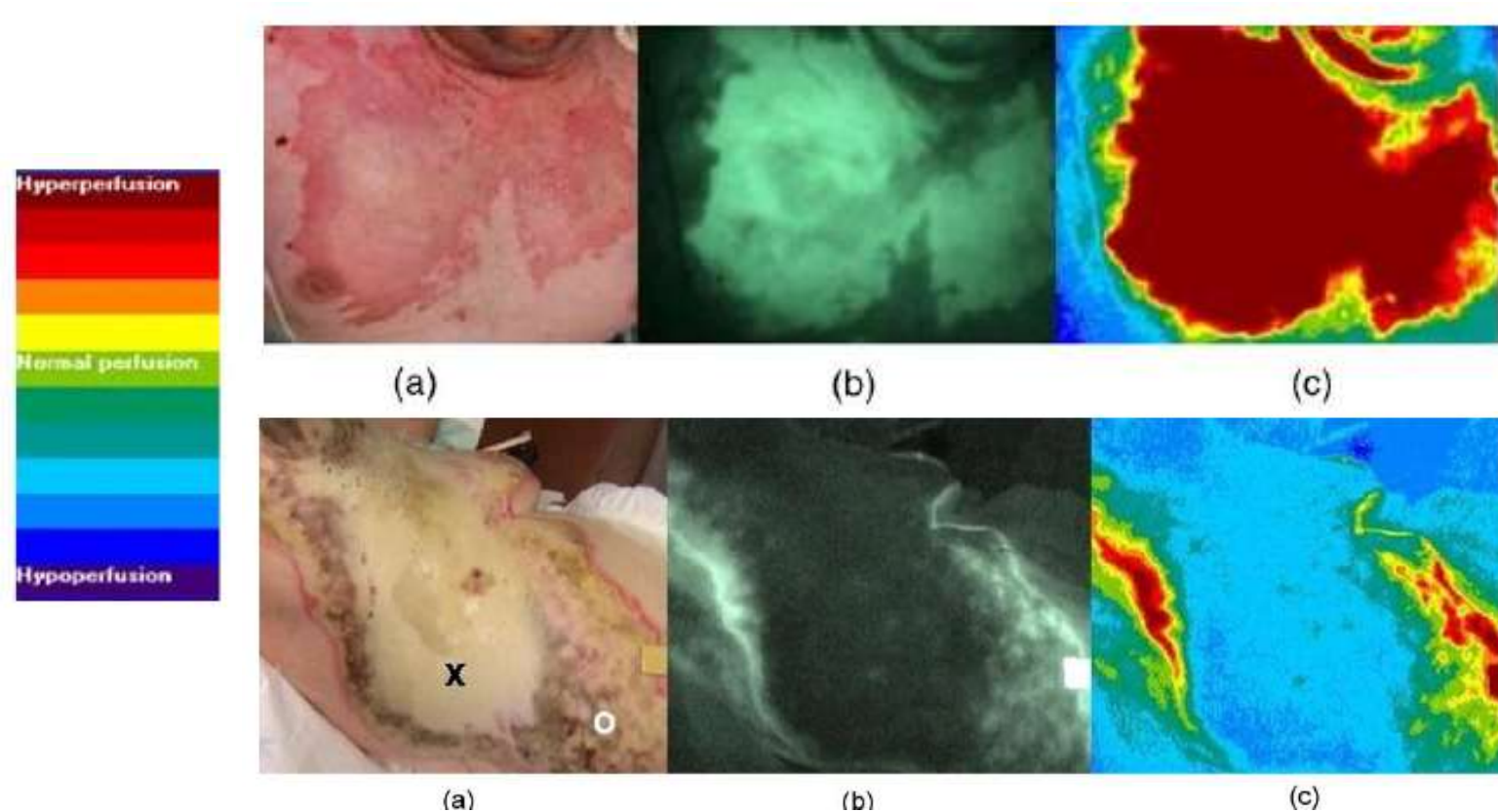
- **Laser Doppler** analysis assays the velocity of blood cells in the superficial dermis. This is reported as an index and correlated with blood perfusion.
- **Thermography** also provides an index of perfusion based on the temperature of the tissue. This provides two-dimensional images of perfusion in large areas.
- **Indocyanine green** is a dye that can be injected intravenously and can be imaged by the application of ultraviolet light showing both an arterial and venous phase.
- A number of **dermoscopy** techniques have also been reported to correlate nicely with burn depth.
- **Hyperspectral imaging** uses multiple light frequencies to image deoxy and oxyhemoglobin in tissues and has been shown in animal models to accurately correlate with burn depth.



Assessment of burn depth by Laser Doppler



Assessment of burn depth by Indocyanine green

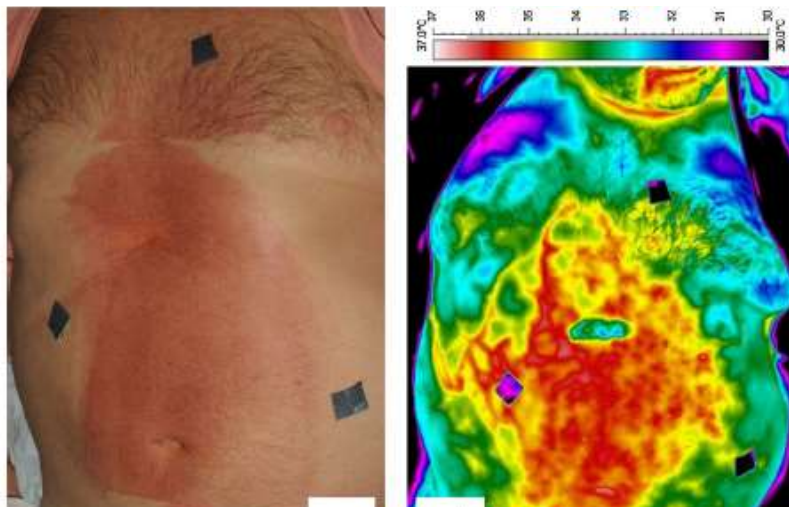


- **Superficial partial thickness burns** are characterized by areas of relatively bright and homogenous fluorescence, quick uptake, constant and high steady state distribution and quick clearance, indicating patency of the small vessels of the sub-papillary and dermal plexus. Those kinds of burns do not require any operative procedure.
- **Deep partial thickness burns**, which should be operated on as early as possible, appear as darker areas yielding mottled fluorescence, with slower uptake, constant but less steady state distribution, indicating partial patency of the dermal plexus.
- **Full thickness burns**, which also require surgical intervention and skin grafts, are areas showing only large and discrete vessels or no signs of fluorescence otherwise, indicating little or no remaining blood flow in the dermis.

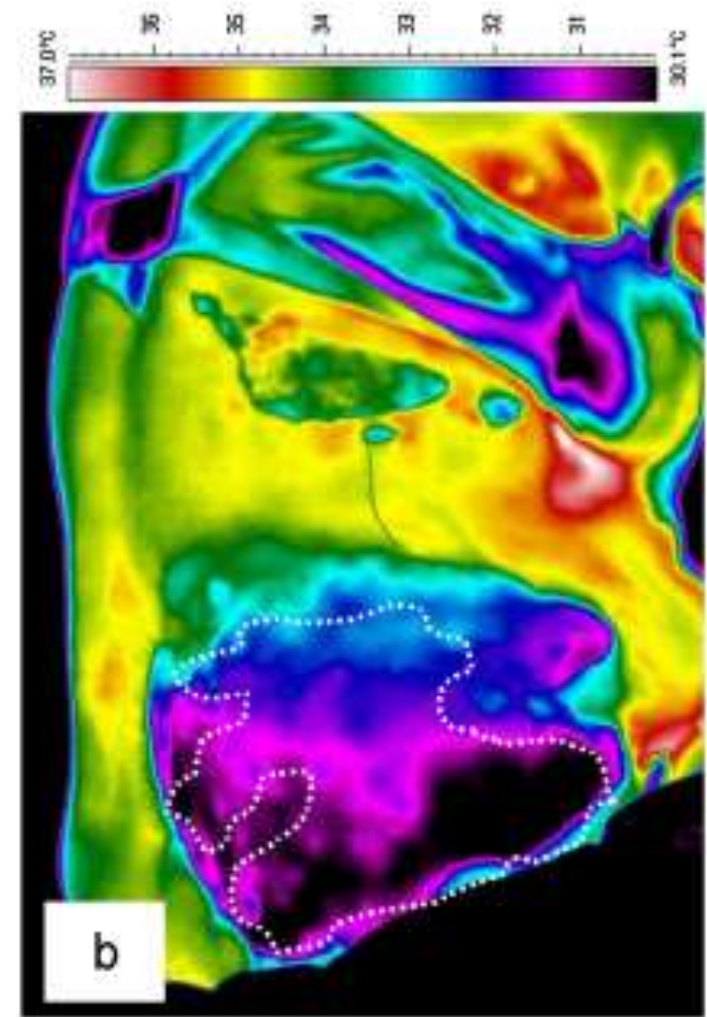
Assessment of burn depth by thermography



Full-thickness burn (3b)



Superficial partial thickness burn (2)



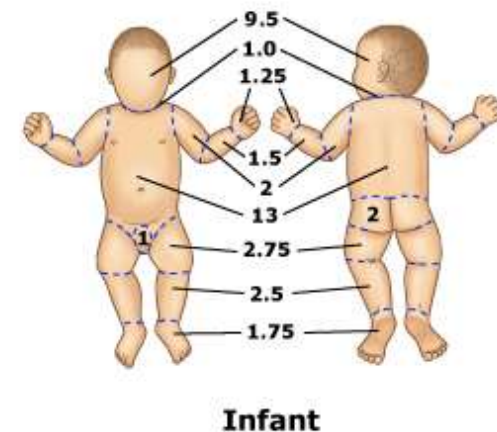
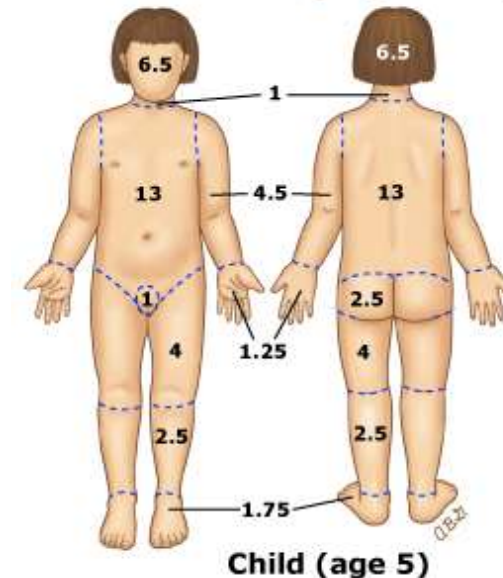
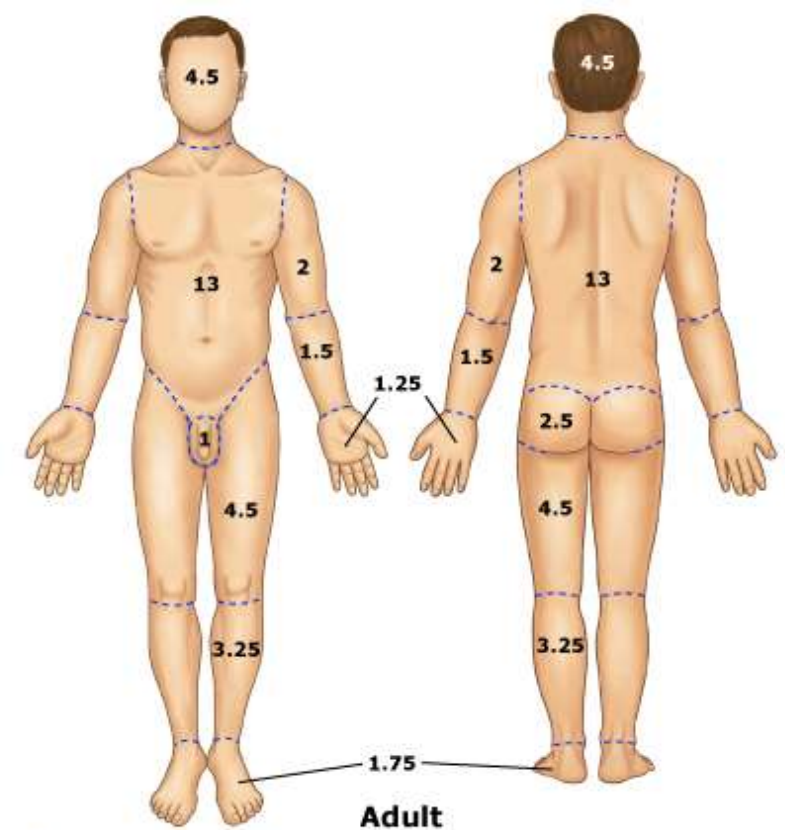
Full-thickness burn (3b)

Extent of burn injury

- Prognosis of burn disease
- Indication for the treatment in burn center and ICU
- Extent of burns is estimated and expressed as the total percentage of body surface area (ie, TBSA).
- Superficial (first-degree) burns are not included in percentage TBSA burn assessment.

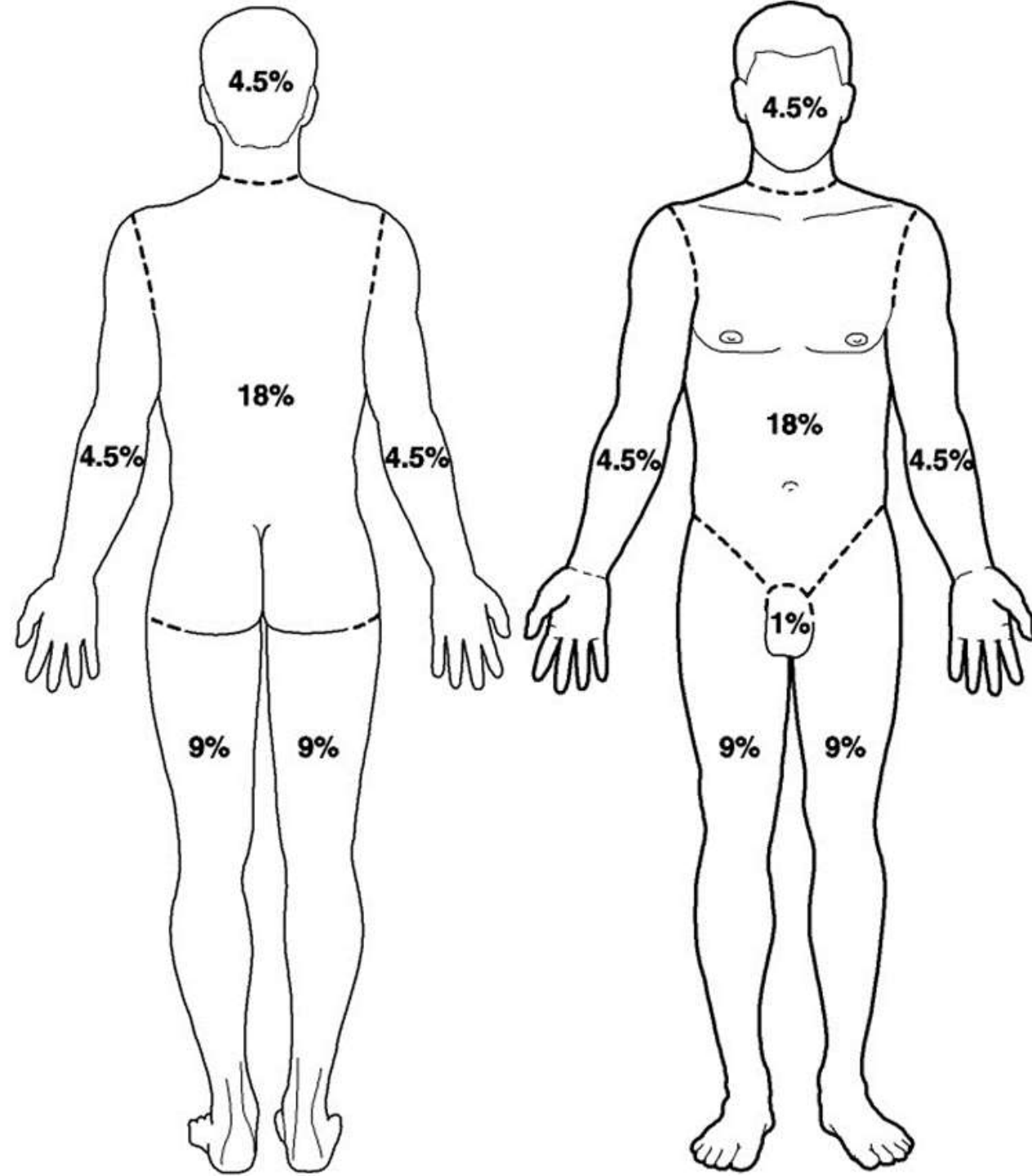
Lund-Browder chart

- Is the most accurate method for estimating TBSA for both adults and children.
- Children have proportionally larger heads and smaller lower extremities, so the percentage TBSA is more accurately estimated using the Lund-Browder chart.



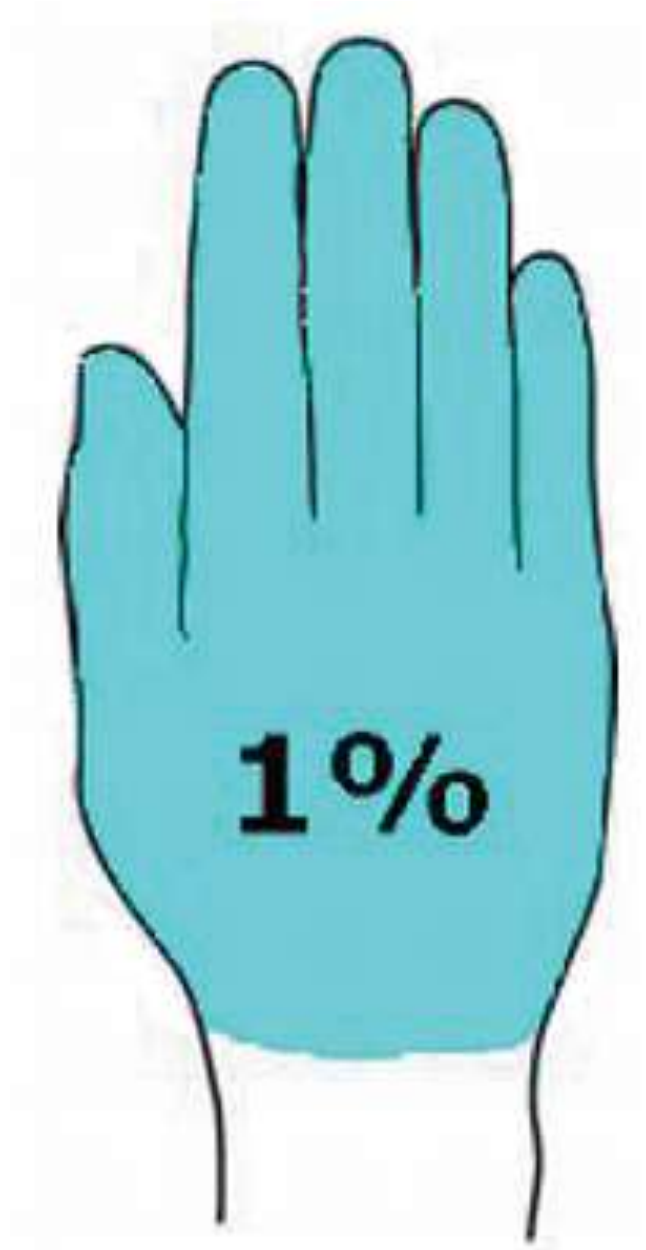
Rule of Nines

- The head represents 9% TBSA
- Each arm represents 9% TBSA
- Each leg represents 18% TBSA
- The anterior and posterior trunk each represent 18% TBSA



Palm method

- Small or patchy burns can be approximated by using the surface area of the patient's palm.
- The palm of the patient's hand, excluding the fingers, is approximately 0.5% of total body surface area,
- The entire palmar surface including fingers is 1% in children and adults



Overall severity of burn injury

- **Minor or mild burn injury** — Minor or mild burns are those that can be treated in a physician's office or in an emergency department as an outpatient.
- **Moderate burn injury** — Moderate burns would be those that require admission to a hospital but not to a burn center. These include superficial burns or deeper burns of limited extent.
- **Severe burn injury** — Severe burn injury can be defined as burns that should be referred to, and treated at, a designated burn center.

Burn center referral criteria

- Partial-thickness burns greater than 10% of TBSA
- Burns that involve the face, hands, feet, genitalia, perineum, or major joints
- Degree 3 burns in any age group
- Electrical burns, including lightning injury
- Chemical burns
- Inhalation injury
- Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
- Any patient with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk for morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient may be stabilized initially in a trauma center before being transferred to a burn unit. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
- Burned children in hospitals without qualified personnel or equipment for the care of children
- Burn injury in patients who will require special social, emotional, or rehabilitative intervention

Minor burns

- Partial-thickness burns **<10%** TBSA in patients 10-50 years old
- Partial-thickness burns **<5%** TBSA in patients <10 or >50 years old
- Full-thickness burns **<2%** TBSA in any patient without other injury
- Isolated injury (ie, no suspicion of inhalation or high-voltage injury)
- Does not involve face, hands, perineum, or feet
- Does not cross major joints
- Is not circumferential

Not need to be referred to the burn center
Treated as outpatients

Treatment of minor burns

- Cooling
- Pain management
- Cleaning
- Debridement
- Blisters
- Chemoprophylaxis
- Dressings



Cooling

- Remove clothing, jewelry (eg, rings), and nonadherent debris.
- Cool with room-temperature or cool tap water to provide some pain relief and limit tissue injury until pain diminishes but not longer than **5 minutes** to avoid macerating the wound.
- Cover the wound with wet gauze or towels, which can decrease pain without immersing the wound and may be kept on the wound for as long as **30 minutes**, until dressings are applied.
- Applying water or saline-soaked gauze, cooled to around 12°C (55°F), is one effective means of cooling.
- **Direct application of ice or iced water should be avoided as this can increase pain and burn depth.**

Pain management

- Acetaminophen and nonsteroidal antiinflammatory drugs (NSAIDs), alone or in combination with opioids, are often sufficient for analgesia.
- Analgesics should be administered around the clock, giving additional "rescue" medication before dressing changes and increased physical activity.
- Applying gauze soaked in cool water to a wound for up to 30 minutes is a suitable technique for reducing pain soon after the burn is sustained.

Cleaning

- Washing minor burn wounds using only mild soap and tap water.
- Patients should be instructed to wash their burns daily with mild soap and water during dressing changes.
- Chlorhexidine wash (without alcohol) is also effective for cleaning burn wounds.
- **Skin disinfectants (eg, povidone-iodine) can inhibit the healing process.**

Debridement

- Sloughed or necrotic skin, including **ruptured** blisters, should be debrided before applying a dressing.
- Necrotic blister skin remnants may increase the risk of infection and limit the contact of topical antimicrobial agents to the burn wound.
- Extensive debridement is rarely necessary and may often be deferred until the initial follow-up visit.

Blisters

- Ruptured blisters should be debrided.
- Needle aspiration of intact blisters should be avoided, as this increases the risk of infection.
- However, the management of clean, intact burn blisters remains a subject of debate.
- Blisters lasting for several weeks without resorption indicate a possible underlying deep partial- or full-thickness burn, necessitating referral to a burn center or surgeon with expertise managing burns.

Chemoprophylaxis

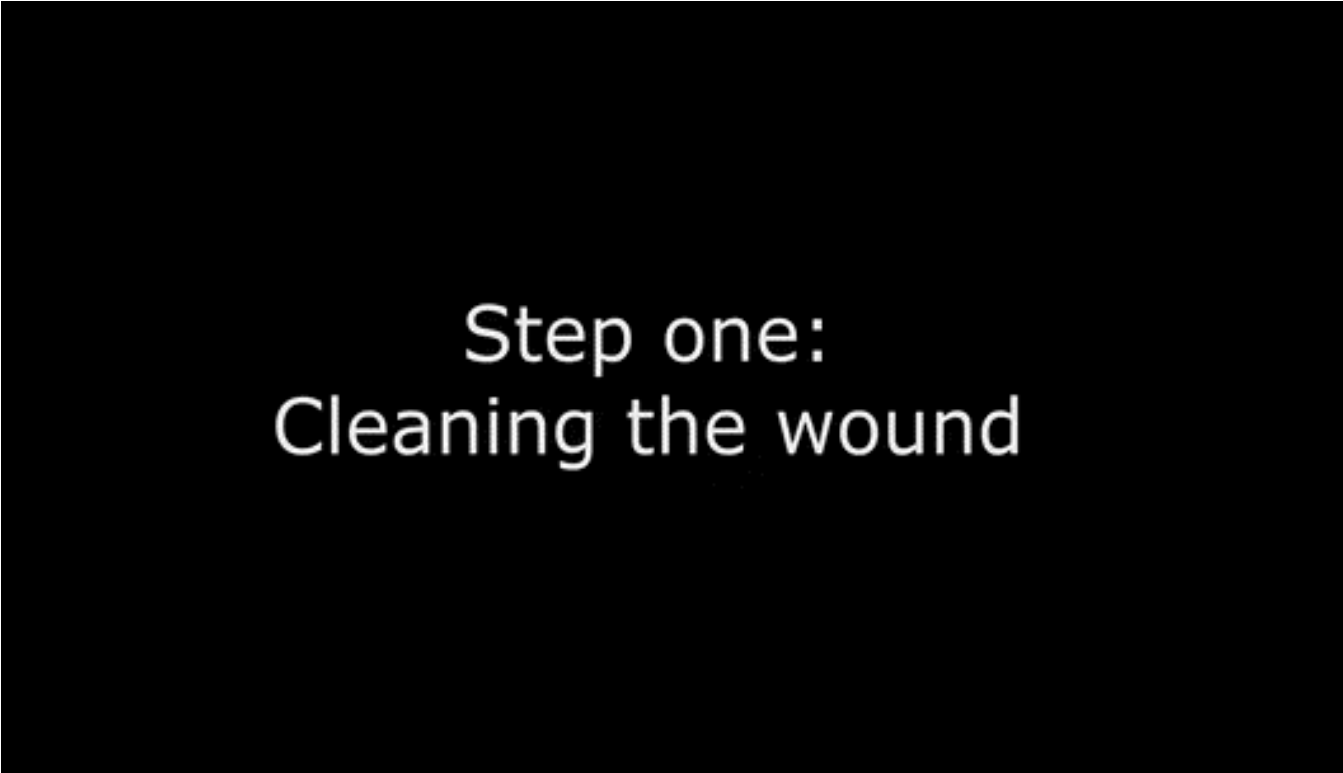
- Superficial (eg, sunburns) and superficial partial-thickness burns rarely develop such infections - **do not require** a topical antimicrobial agent.
 - Application of nonperfumed moisturizing cream is typically all that is required for superficial burns.
- Partial- or full-thickness burns require a topical antibiotic:
 - Aloe vera
 - Bacitracin
 - Silver sulfadiazine
 - Dressings with antimicrobial properties
- **Systemic prophylactic antibiotics are NOT indicated to prevent infection in patients with any acute burn, regardless of size or location.**
- There is **no role for topical steroids** in the initial treatment of minor burns, as this may increase the risk of infection and impair healing.
- Tetanus immunization should be updated, particularly for any burns deeper than superficial-thickness.

Dressings

- Superficial burns do not require dressings.
- Partial- and full-thickness burns are generally dressed, but some relatively minor burns may be treated without dressings:
 - It is often preferable to manage smaller burns of the face or hand (not involving fingers) without dressings; treatment consists of gentle cleansing with a mild soap followed by the application of a topical agent.
- Burn debridement and dressing changes are painful procedures, and adequate pain control is essential.

Basic dressing

- Basic gauze dressing provides adequate burn coverage. It is placed after the application of topical antibiotic and consists of a first layer of nonadherent gauze placed over the burn, a second layer of fluffed dry gauze, and an outer layer of an elastic gauze roll.



Step one:
Cleaning the wound

Biologic and synthetic dressings

- Generally, not used in the ED or primary care clinic, biologic and synthetic dressings can be used to treat partial-thickness burns.
- Their use in both adults and children reduces the frequency of dressing changes and may reduce pain, help prevent infection, and promote healing.

Dressing changes

- Recommended frequencies for dressing changes depend on the type of dressing used and range from twice daily to weekly.
- No firm recommendations can be made.
- Topical antibiotic ointment and nonadherent gauze dressings should be changed once daily.
- It appears best to change dressings whenever they become soaked with excessive exudate or other fluids.

Epithelization and scarring

- Patients should be referred to a burn center promptly at the first sign of hypertrophic scarring or if the wound misses the following epithelialization milestones:
 - 10 to 14 days in blacks and young children
 - 14 to 21 days in all ages, other races



Tiny opalescent "islands" of epithelium (skin buds) are apparent in this photograph of a deep partial thickness thermal burn of the arm in the early stages of epithelialization

Moderate and severe burns

Treatment in the hospital (not always the special burn center):

- No fulfilling the criteria of minor burn
- and/or:
 - Associated with multiple trauma;
 - Involvement of the face, hands, perineum, or feet; crosses a major joint; or circumferential burn
 - Comorbid illness
 - Questionable patient reliability
 - Noncompliance
 - Suspected or known abuse

Treatment of moderate burns

- Pain management
 - Acetaminophen and NSAIDs
 - Opioids
 - Anxiolytics
 - Patient-controlled analgesia
 - General IV anesthetics during dressing changes and manipulations
 - Local anesthetics are contraindicated (increased absorption!)
- Systemic antibiotics:
 - Are not recommended for patients with small-to-moderate-percent TBSA superficial partial-thickness burns.
 - For superficial partial-thickness burns that involve >40% TBSA, it is unclear if there is any benefit to antimicrobial prophylaxis.
- Tetanus immunization
- Local burn care



Local burn care

- Local burn wound care aims to protect the wound surface, maintain a moist environment, promote burn wound healing, and limit burn wound progression while minimizing discomfort for the patient. It is important to note that topical antimicrobials are used in conjunction with appropriate basic wound care.
- Burn wound surfaces are prone to rapid bacterial colonization with the potential for invasive infection. Measures to reduce the likelihood of infection include good infection control practices, topical antimicrobial therapy, and burn wound debridement/excision, when needed.
- Closed dressing management is often advocated to minimize cross-contamination by pathogens (eg, methicillin-resistant *Staphylococcus aureus*) that can cause burn wound infection, delayed wound healing, and loss of skin grafts.
- Wounds that become infected require systemic antimicrobial therapy, in addition to the chosen regimen for local wound care.

Local burn care

- Cleansing and debridement (debrided wounds have a greater tendency to heal in a timely fashion as compared with nondebrided wounds):
 - mild soap and water
 - mechanical techniques (eg, brushing, scraping, curetting, and cutting)
 - proteolytic enzymes (eg, collagenase, bromelain)
- Burn blisters
- Burn wound dressings and topical therapy

Proteolytic enzymes (chemical debridement)

Agent	Enzyme source	Advantages	Disadvantages	• Precautions
Collagenase	Strain of <i>Clostridium histolyticum</i>	• Approved by the US FDA for the debridement of chronic wounds and burns • Selective for collagen • Generally pain-free delivery • May be combined with a variety of other topical dressings	• Effectiveness compared with other forms of debridement may be questionable • Prescription based on wound area • High cost • Relatively slow acting	• Moist wound environment required for activation • Topical silver dressings significantly inhibit collagenase activity
Papain	Papaya	• Provides relatively "aggressive" enzymatic debridement • Generally pain-free delivery • May be combined with a variety of other topical dressings	• Not readily available in the United States • Nonselective (ie, will cleave any protein containing cysteine) • Relatively slow acting	• Agent is often combined with a chlorophyll complex that causes green wound discoloration following application • Need to avoid adjacent healthy tissues
Bromelain	Pineapple	• Relatively rapid acting • Selective for nonviable tissue	• Removal from base of wound required after several hours • Inhibits platelet function but is reversible	• Evidence of efficacy is based on acute wounds or burns, not chronic wounds

Burn blisters (in the hospital)

Intent to remove

- Large and expanding blisters may exert pressure onto the underlying wound surface.
- Large blisters can impair range of motion or movement (eg, hand, fingers, foot, toe).
- Intact blisters can hinder the accurate assessment of burn depth.
- The risk of infection is increased in intact blisters.
- Components of blister fluid are harmful to wound healing.

Intent to save

- Blisters form a natural barrier against infection.
- Blister fluid provides wound healing benefits.
- A wound may become desiccated in the absence of adequate dressings and topical antimicrobial agents.

Burn wound topical therapy

Antimicrobial agents	Clinical indications	Effectiveness	Contraindications	Adverse effects
Silver sulfadiazine (1% cream) with or without cerium	Small, medium, and large surface area burns	Decreased colonization of wounds Alleviates pain Broad spectrum No evidence to support improved wound healing or reduction in bacterial wound infections	Burns near eyes Pregnancy Breastfeeding Newborns <2 months Allergic to sulfonamides Signs of reepithelialization	Skin hypersensitivity Neutropenia (usually transient) Leukopenia (usually transient) Methemoglobinemia
Silver containing dressings (Atrauman Ag)	Small, medium, and large surface area burns	Stronger antimicrobial activity, longer duration of action than silver sulfadiazine, some evidence for reduced wound infection rates	Burns near eyes Pregnancy Allergic to silver	Systemic silver uptake, temporary staining of the skin, argyrosis-argyria
Bacitracin ointment 500 units/gram	Small surface area burns (face, ears, perineum, graft sites, alternative if allergic to sulfonamides)	Ease of application and of removal Painless Frequent dressing changes	Bacterial resistance Signs of reepithelialization	Yeast colonization Skin hypersensitivity
Combination antibiotic ointment (eg, bacitracin, neomycin, and polymyxin B)	Small surface area burns (face, ears, perineum, graft sites, alternative if allergic to sulfonamides)	Ease of application and of removal Painless Frequent dressing changes	Bacterial resistance Allergic reaction Signs of reepithelialization	Yeast colonization Skin hypersensitivity Ototoxicity and nephrotoxicity with neomycin-containing ointments (eg, Neosporin)

Antimicrobial agents	Clinical indications	Effectiveness	Contraindications	Adverse effects
Mupirocin ointment/cream 2%	Small, medium surface area burns (face, ears, perineum, graft sites, alternative if allergic to sulfonamides)	Gram-positive coverage includes methicillin-resistant <i>Staphylococcus aureus</i> (MRSA) Ease of application and of removal Painless Frequent dressing changes	Bacterial resistance Allergic reaction Signs of reepithelialization	Yeast colonization Skin hypersensitivity
Mafenide (8.5% cream, 5% solution)	Ears Nose Dense bacterial proliferation	Excellent eschar penetration Penetrates cartilage Gram-negative coverage includes <i>Pseudomonas</i>	Burns >40% total body surface area Allergic to sulfonamides	Metabolic acidosis (inhibits carbonic anhydrase) Painful Inhibits epithelial regeneration
Chlorhexidine	Only superficial burns	Does not interfere with reepithelialization Can be used with silver sulfadiazine Generally used as a cleansing agent	Deep burns Caution in neonates – rare association with cutaneous burns	Skin hypersensitivity
Povidone-iodine	Small, medium surface area burns	Only when no other agent is available	Children under 2 years Pregnancy Breastfeeding Thyroid disorders Signs of reepithelialization	Cytotoxicity (toxic to fibroblasts, reduces cell proliferation), painful, skin hypersensitivities, chemical burn, iodine toxicity, renal failure, acidosis, anaphylaxis
Acetic acid	Antiseptic, topical agent often used in a diluted form as an adjunct in the setting of <i>Pseudomonas aeruginosa</i>	Gram-negative bacteria including <i>P. aeruginosa</i>	Superficial burns have been described from misuse	High concentrations inhibit epithelialization, inhibit PMNs and fibroblasts

Burn wound topical therapy

Type	Actions	Indications/use	Precautions/contraindications
Alginates/ Carboxy- methylcellulose	•Absorb fluid. •Promote autolytic debridement. •Moisture control. •Conformability to wound bed.	•Moderate to high exuding wounds. •Special cavity presentations in the form of rope or ribbon. •Combined presentation with silver for antimicrobial activity.	•Do not use on dry/necrotic wounds. •Use with caution on friable tissue (may cause bleeding). •Do not pack cavity wounds tightly.
Foams	•Absorb fluid. •Moisture control. •Conformability to wound bed.	•Moderate to high exuding wounds. •Special cavity presentations in the form of strips or ribbon. •Low-adherent versions available for patients with fragile skin. •Combined presentation with silver or polyhexamethylene biguanide for antimicrobial activity.	•Do not use on dry/necrotic wounds or those with minimal exudate.
Honey	•Rehydrate wound bed. •Promote autolytic debridement. •Antimicrobial action.	•Sloughy, low to moderate exuding wounds. •Critically colonized wounds or clinical signs of infection.	•May cause "drawing" pain (osmotic effect). •Known sensitivity.
Hydrocolloids	•Absorb fluid. •Promote autolytic debridement.	•Clean, low to moderate exuding wounds. •Combined presentation with silver for antimicrobial activity.	•Do not use on dry/necrotic wounds or high exuding wounds. •May encourage overgranulation. •May cause maceration.
Hydrogels	•Rehydrate wound bed. •Moisture control. •Promote autolytic debridement. •Cooling.	•Dry/low to moderate exuding wounds. •Combined presentation with silver for antimicrobial activity.	•Do not use on highly exuding wounds or where anaerobic infection is suspected. •May cause maceration.

Type	Actions	Indications/use	Precautions/contraindications
Iodine	•Antimicrobial action.	•Critically colonized wounds or clinical signs of infection. •Low to high exuding wounds.	•Do not use on dry necrotic tissue. •Known sensitivity to iodine. •Short-term use recommended (risk of systemic absorption).
Low-adherent wound contact layer (silicone)	•Protect new tissue growth. •Atraumatic to periwound skin. •Conformable to body contours.	•Low to high exuding wounds. •Use as contact layer on superficial low exuding wounds.	•May dry out if left in place for too long. •Known sensitivity to silicone.
Polyhexa-methylene biguanide	•Antimicrobial action.	•Low to high exuding wounds. •Critically colonized wounds or clinical signs of infection. •May require secondary dressing.	•Do not use on dry/necrotic wounds. •Known sensitivity.
Odor control (eg, activated charcoal)	•Odor absorption.	•Malodorous wounds (due to excess exudate). •May require antimicrobial if due to increased bioburden.	•Do not use on dry wounds.
Protease modulating	•Active or passive control of wound protease levels.	•Clean wounds that are not progressing despite correction of underlying causes, exclusion of infection, and optimal wound care.	•Do not use on dry wounds or those with leathery eschar.
Silver	•Antimicrobial action.	•Critically colonized wounds or clinical signs of infection. •Low to high exuding wounds. •Combined presentation with foam and alginatesC for increased absorbency. Also in paste form.	•Some may cause discoloration. •Known sensitivity. •Discontinue after 2 weeks if no improvement and reevaluate.
Polyurethane film	•Moisture control. •Breathable bacterial barrier. •Transparent (allow visualization of wound).	•Primary dressing over superficial low exuding wounds. •Secondary dressing over alginate or hydrogel for rehydration of wound bed.	•Do not use on patients with fragile/compromised periwound skin. •Do not use on moderate to high exuding wounds.

Surgical treatment of burns

Indications

- Superficial – never
- Partial-thickness:
 - Superficial – never
 - Deep – always
- Full-thickness – always
- Deep – always (another

Type of surgery

- Escharotomy
- Early burn excision and coverage
- Skin grafting
- Burn scar revision

Escharotomy

- Indicated for deep partial- and full-thickness burns, mostly when associated with >20 percent TBSA burn.
- May be performed at the time of initial burn presentation, particularly among those with circumferential burns; however, escharotomy may be needed at a later time as tissue edema increases with fluid resuscitation.
- Severe tissue edema may compromise vascular flow, potentially leading to compartment syndromes related to the external compression.



Early burn excision and coverage

- Provide an appropriate wound bed for eventual autografting, prevent burn wound sepsis, simplify dressing changes, fasten healing, decrease mortality
- Better time: 24-72 hours (up to 5 days)
- Techniques:
 - Tangential excision sequential debridement of burned tissue until a layer of viable, vascularized tissue is encountered
 - Others (high-pressure water, enzymatic debridement).



Burn wound closure

- As soon as possible (better for 5 days) to avoid scarring:
 - For small TBSA follows excision in the same operative setting
 - For large TBSA the ideal timing is the same, but grafting is often delayed due to lack of donor sites.
- Direct wound closure
- Skin grafting
 - Split-thickness autografting
 - Full-thickness autografting
 - Use of skin substitutes
- Coverage with expanded tissue
- Tissue transfer (local flaps, pedicle flaps)

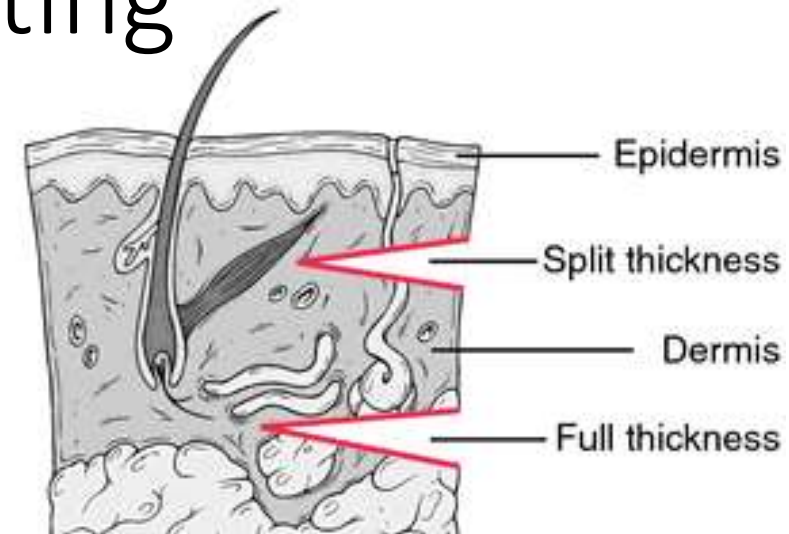
Direct wound closure

- Is the simplest procedure that can be used for small to moderately sized wounds with edges can be brought together without tension.
- Excess tension will lead to stretched, unsightly, and painful scars.
- Larger wounds can be closed in areas with sufficiently redundant tissue or in areas where the elasticity of the surrounding tissues allows for tension-free closure.



Split-thickness autografting

- Includes the epidermis and varying amounts of dermis to provide epithelium cells, fibroblasts and collagen to the wound surface and improve healing
- Limited by burn area and donor's size
- Meshing can expand the size
- Allows to cover relatively large surface



Full-thickness autografting

- Includes the entire thickness of skin, both epidermis and dermis.
- The donor site is closed primarily.
- Used in areas of special anatomic and functional importance (eg, head, eyelids, perioral areas, neck, and hands)
- Better-appearing texture, pliability, elasticity, and color match and contract less compared with split-thickness skin grafts.



Flap reconstruction

- Flaps represent the gold standard of reconstruction by providing like tissue for like tissue in burn wound defects.
- The obvious limitation to their use in the burn patient is the availability of healthy, pliable, well-vascularized tissue.
- The selection of a reconstructive option is based on the relative importance of replacing each component of the defect.
- Careful design of flaps, taking into consideration the frequent presence of scarred tissue around the defect, is fundamental.



Tissue expansion

- Tissue expansion is a technique that gradually stretches an area of pliable skin (taking advantage of the principles of creep and stress relaxation) in preparation for its use as coverage of a burn defect or area of contracture release.
- Tissue expansion techniques are used in the reconstructive stage of scar management when the wounds are fully healed and the scars resulting from the original burn injury need to be addressed.

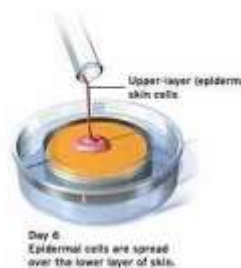
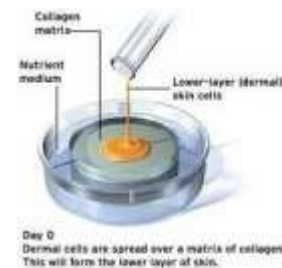


Temporary burn wound coverage

- **Biologic grafts:**
 - **Allografts (homografts)** – allogeneic skin grafts from human cadavers (fresh or cryopreserved). The application of an allograft over superficial partial-thickness wounds can minimize pain and facilitate reepithelialization.
 - **Xenografts (heterografts)** – xenogeneic skin grafts of unrelated species (animals, generally, pig), are used as temporary skin coverage, especially for large burn wounds. Porcine-derived xenografts do not vascularize but will adhere to a clean superficial wound, accelerate reepithelialization, and reduce pain.
 - **Human amnion** has been successfully used as a biologic dressing for partial-thickness wounds. It promotes reepithelialization of the burn wound; has antimicrobial properties; and reduces pain, fluid loss, and scar formation. An allograft consisting of sterilized, dehydrated human amnion/chorion membrane (dHACM) has also been used for burn patients. It contains growth factors that promote wound healing. Concerns regarding pathogenic transmission have limited its use.
- **Semibiologic skin substitutes** are temporary biosynthetic dressings that are meant to reduce the number of dressing changes and facilitate healing
- **Biobrane and Biobrane-like** - biosynthetic wound dressing.

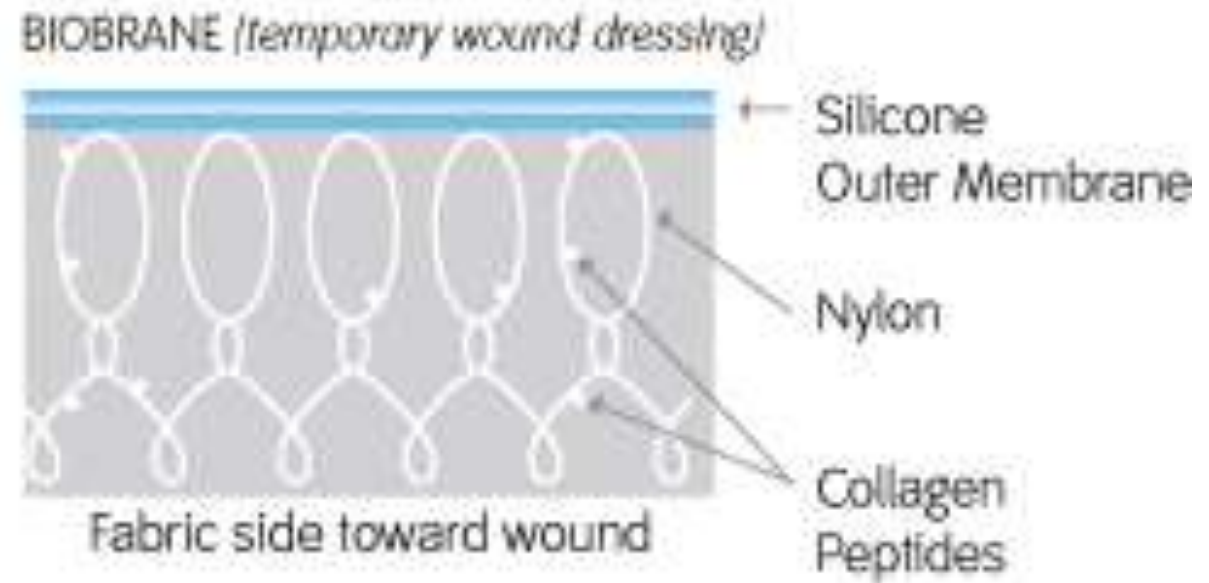
Semibiologic skin substitutes

- **Dermal replacement matrix (DRM)** is composed of a cross-linked bovine collagen and glycosaminoglycan dermal layer and a silicone epidermal layer.
- **Acellular dermal matrix** is an allograft (homograft) product created from skin from a deceased human donor that has been processed to remove the epidermis using a sequential decellularization process. These decellularized matrices fully integrate into the wound bed after application, replacing lost dermal tissue and providing a scaffold into which the recipient's cells can grow and become vascularized, ultimately regenerating into normal skin.
- **Bilayered living cellular construct:**
 - Dermal part – bovine type I collagen with human neonatal foreskin fibroblasts
 - Epidermal part – human keratinocytes



Biobrane

- Bilayer membrane contains a thin semipermeable silicone membrane bonded to a layer of nylon fabric mesh and coated with a monomolecular layer of type 1 porcine.
- The porcine collagen provides a hydrophilic coating for fibrin growth that promotes wound adherence.
- Biobrane has no inherent antimicrobial activity, but the membrane is porous, allowing absorption of topical antimicrobial agents and drainage of exudate.
- Biobrane is versatile and has additional properties of flexibility, elasticity, and transparency for wound observation.
- Biobrane can be left in place for up to 14 days, then removed in a warm bath or trimmed.
- Used for coverage of large surface area burns, including hands, feet, and joints and sometimes used on full-thickness excisions as a temporary covering to protect the excised wound site in a staged fashion prior to subsequent stage skin grafting.



Biobrane



Examples



Figure 3. A 16-year-old female patient with a full-thickness flame burn to the left upper limb. A: Exposed area suitable for grafts; B: coverage with split-thickness skin grafts placed transversely; C: appearance by postoperative day 45; D: appearance after 6 months, with no functional limitations

Examples



Figure 4. A 24-year-old male patient with a full-thickness chemical burn (sulfuric acid) to the left upper limb, involving creases. A: Initial appearance, with an adhered and hard eschar; B: formation of a uniform and non-hypertrophic granulation tissue. It was red and had no discharge following two escharectomies. It was covered temporarily with skin allografts; C: placement of split-thickness skin grafts transversely soon after surgery; D: appearance at postoperative month 1

Examples



Figure 5. A: Thirty-two-year-old female patient with a deep partial-thickness flame burn to both lower limbs, who underwent eschar removal by tangential excision; B: placement of split-thickness skin grafts transversely; C: results at postoperative year 1. No evidence of contracture, and both texture and color are adequate

Examples



Figure 6. A: Twenty-eight-year-old male patient with a full-thickness flame burn of 18% total body surface area to back and gluteal region; B: appearance following 3 escharectomies performed by electric dermatome, and temporary coverage with skin allografts; C: intraoperative appearance after placing split-thickness skin grafts transversely; D: results at postoperative month 12

Treatment of burn injury

- Immediate burn care and cooling
- Immobilization
- Pain management
- Airway management (attention to inhalation injury)
- Fluid resuscitation (essential)
- Blood transfusion (strict)
- Chemoprophylaxis (topical, systemic - in selected cases)
- Laboratory studies and monitoring (evaluation of carbon monoxide and cyanide)
- Symptomatic treatment

Fluid resuscitation

- Burn shock during the initial 24 to 48 hours following major burns is characterized by myocardial depression and increased capillary permeability resulting in large fluid shifts and depletion of intravascular volume.
- Rapid, aggressive fluid resuscitation to reconstitute intravascular volume and thereby maintain end-organ perfusion is crucial.
- Delays in fluid resuscitation and inadequate resuscitation are associated with increased mortality.
- Any patient with >15% total TBSA should receive formal fluid resuscitation.
- Patients with major burns should have two large-bore intravenous (IV) lines placed through unburned skin, if possible, and may require central venous access.

Fluid resuscitation

- Ringer's or Hartmann's solution
- Avoid hypertonic and colloid
- After maintaining diuresis of 0.5 mL/kg/ per hour switch to 5% dextrose (glucose) or 0.45% saline
- Fluid requirements:
 - Parkland-Baxter formula: 4 mL/kg x %TBSA (excluding superficial) - ½ volume for 8 hours and ½ volume for 16 hours
 - Modified Brooke formula: 2 mL/kg x %TBSA for 24 hours
 - Rule of Tens:
 - Estimate TBSA to the nearest 10 percent.
 - %TBSA x 10 – The result gives the initial fluid rate in mL/hour for adults weighing 40-80 kg.
 - For patients who weigh more than 80 kg, increase the rate by 100 mL/hour for every additional 10 kg of body weight

Calculator: Adult burn injury fluid resuscitation (Parkland crystalloid estimate)

```
Total_crystalloid_for_first_24_hours[mL] = 4 * Weight[kg] * Percent_burn_area_deeper_than_epidermis[Percent]  
Rate_first_8_hours[mL/hr] = Total_crystalloid_for_first_24_hours[mL] / 16  
Rate_next_16_hours[mL/hr] = Total_crystalloid_for_first_24_hours[mL] / 32
```

Input:

Weight: 70 kg

Percent burn area deeper than epidermis: 15 Percent

Results:

Total crystalloid for first 24 hours: 4200 mL

Rate first 8 hours: 263 mL/hr

Rate next 16 hours: 131 mL/hr

Reset form

Notes

- Fluid needs calculated according to the Parkland formula provide only a guide to baseline fluid requirements in patients with major burns. Superficial burns are not included in the calculation.
- Patients with burn shock require immediate, aggressive IV fluid resuscitation and their fluid needs can exceed those estimated by the Parkland formula.
- The fluid needs of burn patients vary widely. Use physiologic parameters (eg, blood pressure, pulse, urine output) to determine the adequacy of fluid resuscitation.
- Children with major burns have additional fluid needs.
- Burns deeper than the epidermis include full thickness, deep partial thickness, and superficial partial thickness burns.

References

1. Saffle JR. Practice guidelines for burn care. J Burn Care 2001; 22(Suppl):i.
2. Baxter CR, Shires GT. Physiological response to crystalloid resuscitation of severe burns. Ann N Y Acad Sci 1968; 150:874.

Part 2. Frostbites

The small one

Definition

- Frostbite is a severe, localized cold-induced injury due to freezing of tissue.
- Nonfreezing cold injury (NFCI):
 - **Frostnip** refers to cold-induced, localized paresthesias that resolve with rewarming. There is no permanent tissue damage.
 - **Pernio, or chilblains**, is characterized by localized inflammatory lesions that can result from acute or repetitive exposure to damp cold above the freezing point. Lesions are edematous, often reddish or purple, and may be very painful or pruritic. Pernio is most common in young women, but both sexes and all age ranges may be affected. Permanent damage from pernio is uncommon, with symptoms and signs generally resolving within two to three weeks.
 - **Immersion foot** (or trench foot) involves injury to the sympathetic nerves and vasculature of the feet. It was first described in 1914 during World War I trench warfare. It results from prolonged exposure of the feet to a combination of dampness and cold. Tight-fitting boots exacerbate the condition. Feet and occasionally hands are red, edematous, can be numb or extremely painful, and, in severe cases, can be covered with hemorrhagic bullae.

Nonfreezing cold injury



Pernio



Immersion foot

Pathophysiology

- The tissue destruction of frostbite is due to both immediate cold-induced cell death and the more gradual development of reperfusion-related localized inflammatory processes and tissue ischemia.
- Following exposure to subfreezing temperatures, ice crystals form extracellularly.
- If freezing is rapid, ice crystals may also form inside cells.
- Fluid and electrolyte fluxes cause lysis of cell membranes with subsequent cell death.
- An inflammatory process ensues mediated by thromboxane A₂, prostaglandin F₂-α, bradykinins, and histamine. This leads to tissue ischemia and necrosis.
- The initial cellular damage and the subsequent inflammatory processes are made worse in the setting of thawing followed by refreezing of the affected area.

Classification

Old-fashioned

- First-degree frostbite is very superficial and is characterized by a central area of pallor and anesthesia of the skin surrounded by edema.
- Second-degree frostbite is recognized by large blisters containing clear fluid surrounded by edema and erythema, developing within 24 hours and extending to or nearly to the tips of digits. The blisters may form an eschar, but this later sloughs off, revealing healthy granulation tissue. There is no tissue loss.
- Third-degree frostbite differs from second-degree in that the injury is deeper and the blisters are smaller, hemorrhagic and more proximal. The skin forms a black eschar in one to several weeks.
- Fourth-degree frostbite, which extends to muscle and bone, involves complete tissue necrosis. Mummification occurs in 4 to 10 days.

Novel (frostbite of the hands and feet, based on the level at which skin lesions are noted after rapid rewarming in warm water)

- Grade 1 frostbite is characterized by no cyanosis on the extremity . This predicts no amputation and no sequelae.
- Grade 2 involves cyanosis isolated to the distal phalanx. This predicts only soft tissue amputation and fingernail or toenail sequelae.
- Grade 3 frostbite is characterized by intermediate and proximal phalangeal cyanosis. This predicts bone amputation of the digit and functional sequelae.
- Grade 4 frostbite involves cyanosis over the carpal or tarsal bones. This predicts bone amputation of the limb with functional sequelae.

Classification



First-degree



Second-degree



Third-degree



Fourth-degree



Grade 1



Grade 2



Grade 3



Grade 4

Imaging studies

- **Plain radiographs** are not useful initially except to screen for trauma-related fractures. Late (weeks to months) radiographic findings in frostbite include bony destruction and, in children, damage to growth plates. Frostbite arthritis often spares the thumbs, most likely because patients wrap them within clenched fists during the exposure.
- **Standard or digital subtraction angiography** can be used to identify patients suitable for thrombolytic therapy.
- **Fluorescence microangiography**, a technique that has been used to monitor wound healing, has been used to monitor progression of perfusion in frostbite.
- **Technetium (Tc)-99m scintigraphy** (ie, bone scan) can be used to identify candidates suitable for thrombolytic therapy. It is also used to predict the long-term viability of affected tissue, with the goal of allowing early debridement or amputation of dead or dying areas while preserving viable tissues. In candidates for treatment with tissue plasminogen activator (tPA), technetium scanning is used immediately after thawing. For patients who are not candidates for tPA, technetium scanning on day 2 following injury may avoid the need for the traditional several-week delay in surgical intervention while awaiting demarcation between viable and nonviable zones.
- **Single-photon emission computed tomography (SPECT)**, a nuclear bone scan processed similarly to a computed tomography (CT) scan, combined with conventional CT (SPECT/CT), may be able to identify non-salvageable tissue, allowing more accurate determination of the extent of tissue destruction and autoamputation than a conventional bone scan.
- **Magnetic resonance imaging (MRI)** and magnetic resonance angiography (MRA) may be superior to bone scans in establishing tissue viability. In case reports they have permitted visualization of occluded blood vessels and better demonstrated the line of demarcation between ischemic and nonischemic tissue. However, experience with MRI and MRA in this setting is limited

Prehospital care

- Get the patient to a warm environment as soon as possible. Whenever possible, pad or splint the affected area to minimize injury.
- Remove wet clothing.
- Avoid walking on frostbitten feet; this can increase tissue damage. If walking is necessary for evacuation, do not rewarm the feet before walking.
- Do not rewarm frostbitten tissue if there is a possibility of refreezing before reaching definitive care. This would result in worse tissue damage.
- If prehospital warming is attempted, options include placing the affected area in warm (not hot) water or warming it using body heat (eg, placing frostbitten fingers in the axillae).
- Do not rub frostbitten areas in an attempt to rewarm them; this can cause further tissue damage.
- Avoid the use of stoves or fires to rewarm frostbitten tissue. Such tissue may be insensate and burns can result

Hospital-based management

- Rewarming
- Thrombolysis for severe injury presenting within 24 hours
- Prostacyclin therapy for severe injury presenting within 48 hours
- Wound care
- Infection prophylaxis
- Surgery

Rewarming

- Rewarming is most effectively accomplished by immersing the affected area in water heated to 37 to 39°C (98.6 to 102.2°F), ideally in a whirlpool so a steady temperature can be maintained.
- Gentle active motion of the extremity while rewarming may help.
- Care should also be taken to avoid trauma to the injured area against the container walls during treatment.
- Higher temperatures do not warm the injured area appreciably faster and cause the warming process to be much more painful.
- Dry heat is difficult to regulate and is not recommended.
- Thawing is usually complete when the tissue is red or purple and soft to the touch. This usually takes 15 to 30 minutes.
- Rewarming of frostbitten tissue may be painful. Appropriate analgesia, generally opioids, should be administered.

Thrombolysis

- Because frostbite is associated with vascular thrombosis of affected tissue, administration of intravenous or intra-arterial tissue plasminogen activator (tPA; with intravenous or intra-arterial heparin, or subcutaneous enoxaparin) has been used for therapy.
- Although high-quality evidence is limited, in patients at high risk for life-altering amputation (eg, multiple digits in a limb, multiple limbs, proximal limb amputation), without contraindications to the use of tPA, who present within 24 hours of injury treatment with intravenous tPA plus subcutaneous low-molecular weight heparin (eg enoxaparin) or intravenous heparin may be suggested.
- The use of intra-arterial tPA with heparin is also reasonable in facilities capable of administering intra-arterial tPA.
- For IV administration of tPA:
 - Give a bolus dose of 0.15 mg/kg over 15 minutes, followed by a continuous IV infusion of 0.15 mg/kg per hour for six hours. The maximum total dose is 100 mg.
 - After tPA has been given, adjunct treatment can be started with IV heparin or subcutaneous (SC) enoxaparin. The dose of IV heparin is 500 to 1000 units/hour for six hours, or targeted to maintain the partial thromboplastin time (PTT) at twice the control value. Enoxaparin can be given at the therapeutic dose (1 mg/kg SC).
- For intra-arterial administration of tPA, we suggest the following regimen :
 - Give a bolus of 2 to 4 mg, followed by an infusion of 0.5 to 1 mg/hour via the femoral or brachial artery. Repeat angiograms are performed every 8 to 12 hours.
 - A few centers give an intra-arterial vasodilator, most commonly papaverine (150 mg), immediately before administering intra-arterial tPA .
 - If more than one extremity is affected, divide the total tPA dose between or among them. Treatment should be continued until perfusion is restored (as demonstrated by angiography or technetium-99m scanning) or a time limit of 72 hours is reached.

Prostacyclin

- Prostacyclin, a vasodilator, shows promise for the treatment of frostbite.
- Treatment with iloprost may be suggested, with or without tPA, for patients with severe frostbite (Grade 2-4) if given within 48 hours of the initial insult.
- Iloprost administration may be effective past 48 hours, perhaps up to 72 hours (eg, if a clear history or timeline cannot be established).
- When used without tPA, administration of iloprost does not require an intensive care setting, nor does it require radiologic intervention.
- Iloprost should be used alone when tPA is contraindicated, as in frostbite seen more than 24 hours after thawing or in cases associated with trauma.
- Iloprost is given by intravenous infusion at a dose 0.5 nanogram/kg per minute, increased every 30 minutes by 0.5 nanogram/kg per minute, to a maximum of 2 nanogram/kg per minute. If the patient develops headache or hypotension, the dose is decreased by 0.5 nanogram/kg per minute. The infusion is given for 6 hours/day for five days at the maximum tolerable rate, up to 2 nanogram/kg per minute

Wound care

- Maintain aseptic technique during wound treatment.
- Apply nonadherent gauze as the first dressing layer.
- Use sterile fluff dressing.
- Insert pledgets (eg, sterile cotton) between digits to prevent tissue maceration during demarcation.
- Avoid occlusive dressings.
- Protect lower extremity wounds with a cradle and upper extremity wounds with sterile sheets.
- Keep wounds open immediately following water bath or whirlpool treatment and allow them to dry before applying any dressing.
- Blisters – There is no clear consensus on management of frostbite-induced blisters. Some authors suggest that because of the high concentrations of inflammatory mediators in the blister fluid, all should be drained. Others take a more conservative approach. A reasonable compromise is to drain, debride, and bandage large nonhemorrhagic bullae that interfere with movement, such as those over joints. Hemorrhagic bullae of comparable size and location are drained by aspiration but are NOT debrided. Hemorrhagic bullae reflect more significant damage to the microvasculature. Other minor bullae should be left intact.
- Topical aloe, applied with dressing changes, and oral ibuprofen (adult dose 400 to 600 mg every 12 hours) or aspirin (adult dose 325 mg daily) may limit inflammation associated with frostbite by inhibiting thromboxane and prostaglandins, although supporting evidence is limited.

Infection prophylaxis

- Tetanus is a reported complication of frostbite. Tetanus prophylaxis is recommended .
- Prophylactic antibiotics are controversial, and little evidence exists to guide decision-making. Post-thaw daily or twice daily warm whirlpool treatments are standard therapy to help to reduce bacterial colonization of injured tissue, but infection can develop nevertheless.
- **Routine use of prophylactic antibiotics is not recommended.**
- Parenteral antibiotics should be given at the earliest sign of infection. Staphylococci, streptococci, and pseudomonas species should be covered.
- Topical antibiotics can cause maceration and should be avoided; if given, antibiotics should be administered intravenously.

Surgery

- Repeated tissue debridement,
- Escharotomy,
- Fasciotomy
- Delayed amputation

Example



Frostbite on both hands during Arctic storm, Qaanaaq. Second- or third-degree frostbite on both hands, with oedema and multiple bullae filled with clear fluid on day 1. The patient was treated conservatively with a silver sulfadiazine ointment and wound dressings daily for 21 d. He experienced no tissue loss but had significant cold hypersensitivity after 6 mo. Note the slight discoloration of the nails as the only objective finding at 6 mo follow-up.

Example



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