Chapter 10

REHABILITATION MANAGEMENT OF BURN CASUALTIES

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INTRODUCTION

Most burn casualties require evacuation from the theater of operations. Ideally, severely burned casualties will be evacuated rapidly to burn centers, such as the U.S. Army's Institute of Surgical Research at Fort Sam Houston, Texas. Actual battlefield conditions, including dehydration, decreased nutritional balance, fear, other psychological stressors, and extremes of climate may contribute to the severity of the burn wounds and also hinder the healing process. Fluid for wound cleansing, topical antimicrobials, effective analgesics, and bandages are not easily carried in a field pack. The mobile army surgical hospital is not appropriate to care for burn wounds, which heal in two to three weeks or which need grafting and rehabilitation.

This chapter will primarily address rehabilitation care of the casualty who is transferred back to a burn center in the continental United States. After a major burn injury, the casualty benefits from a comprehensive rehabilitation treatment plan to quickly recover the maximal possible preburn status of strength, endurance, active range-of-motion (AROM), coordination, and mental functioning. The rehabilitation plan will assist military personnel to achieve independent self-care and return to active duty as soon as the wounds are healed and durable. For optimal final outcome, the constant goal of the casualty, family, surgeon, and therapists must be achieving the soldier's preburn level of active function and return to duty, despite the burn injury.

The following presentation is divided into four sections, the first three introductory sections discuss (1) classification, (2) pathophysiology, and (3) medical surgical considerations of burns. The fourth section deals with the management and rehabilitation of burn casualties; and is divided into (*a*) the acute phase, (*b*) the immobilization phase, and (*c*) the maturation phase of wound healing.

CLASSIFICATION

Burns are classified by mechanism of causation: thermal, chemical, electrical, and radiation; the depth of injury; the location of injury; and associated other injuries.

Thermal Injuries

Heat injury accounts for 85% to 90% of civilian burn victims in the United States, with chemical and electrical making up the majority of the remainder. Flame burns are the most common casualties seen at a time of conflict and may be caused by petroleum products including napalm, jet fuel, or gasoline. Contact with hot liquids results in scald burns; grease burns are common among cooks, kitchen workers, and mechanics. Superheated steam burns with inhalation complications occur from ship or submarine boilers.

Cold injury has some of the characteristics of thermal injury and most commonly occurs when a distal part is exposed to low environmental temperatures. Volatile liquids can produce localized freezing injury to tissues, especially if the liquids are allowed to escape and change rapidly to a gaseous state. The severity of injury depends on the intensity and duration of exposure and the care taken to avoid damaging the cell nucleus while it is in crystal form. The depth of injury can rarely be determined before rewarming. Fortunately, the degree of gangrene is often less than initially feared. For this reason, unlike heat injuries, amputation is delayed until the extent of gangrene is certain. Unlike heat injury, after healing there is frequent permanent increase in vasoconstrictor tone resulting in hyperhidrosis and abnormal sensitivity to cold. Pain and paresthesia are common from residual neuritis. Long term joint chondral changes are common, especially in the small finger joints.

Chemical Burns

Most chemical burns are caused by acids, alkalis, or vesicants. Except for white phosphorus, most chemical burns should be immediately treated with copious water lavage for a minimum of 30 minutes; it is inappropriate to waste valuable time searching for a specific neutralizing agent. Neutralization generates heat and increases the depth of burn. Powdered chemicals should be brushed away prior to water lavage to decrease the quantity of exposure. Lavage is continued until skin pH has returned to neutral and pain has abated. Lavage of the eye is performed with an irrigating lens.

Chemical agents produce direct tissue damage by a variety of reactions. Acid burns tend to be superficial in depth whereas alkali burns tend to burrow into the tissues and cause more significant destruction. Acids cause coagulation necrosis (Fig-

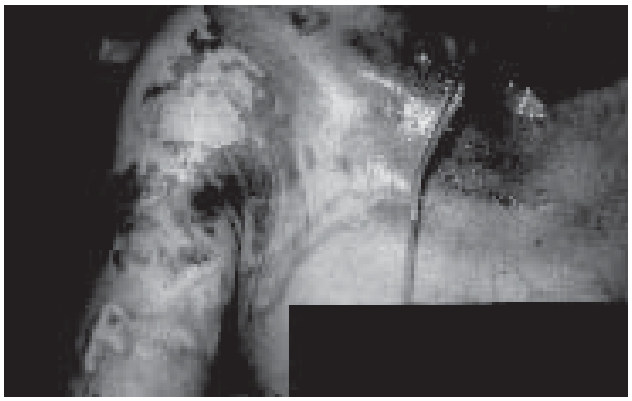


Fig. 10-1. Coagulation necrosis of shoulder, secondary to acid burn.

ure 10-1). Alkalis cause liquefaction necrosis. Once the initial care, neutralization, and removal of the offending agent are completed, the rehabilitative care is much the same as that for a thermal burn.

White phosphorus, which ignites on contact with air, is covered with water or saline until the wound can be debrided of all phosphorus. Hydrofluoric acid requires copious water lavage followed by topical calcium gluconate. Calcium gluconate injected into the area may decrease the severity of the injury. The use of intraarterial calcium gluconate for wounds of the hands and feet is beneficial.

Mustard is the vesicant most likely to be used in warfare. It is rapidly absorbed by the skin, conjunctiva, and mucous membranes, and within minutes, irreversibly combines with tissue proteins. Ophthalmic injuries are best treated with copious water irrigation. Skin is decontaminated with 0.5% hypochlorite. In general, the skin burns are superficial and heal without difficulties. Injuries to the mucosal linings are much more serious and disable the soldier for combat.

Fig. 10-2. Demonstration of electrical arc ("Jacob's Ladder" effect).

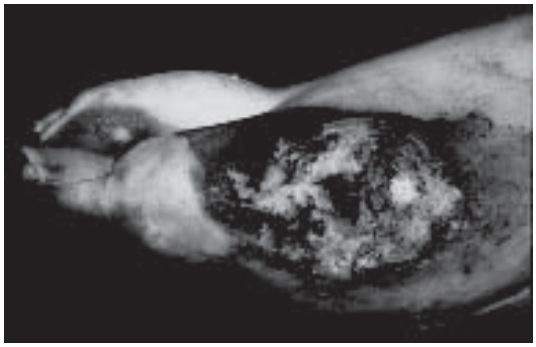


Fig. 10-3. Electrical exit injury.

Electrical Injuries

Electrical injuries result from the conduction of electrical energy through tissue or from heat which is released as the current arcs through the air (Figure 10-2). Current arcs may generate temperatures as high as 3,000°C; as they arc, they ignite clothing, which results in a combination electrical (Figure 10-3) and thermal injury (Figures 10-4 and 10-5).

Injuries caused by low voltage current (< 1,000 V) are occasionally fatal due to immediate ventricular fibrillation. Survivors rarely have significant tissue damage.

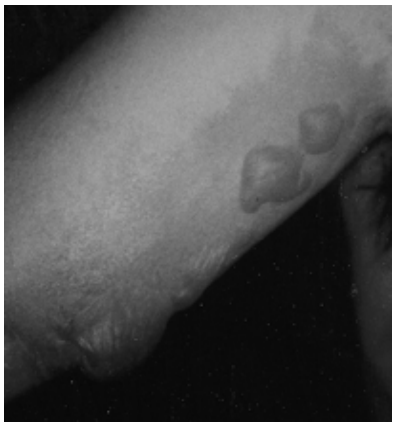


Fig. 10- 4. Superficial partial thickness burn blisters from a thermal burn.

Fig. 10-5. Mixed deep partial and full thickness thermal burn.

High voltage (> 1,000 V) current can damage tissue anywhere along its route. Electrical injuries are heat related. Electrical energy is converted to heat energy as expressed by Joule's law: power or heat equals amperage squared times resistance ($P=I^2 \bullet R$). The higher the voltage and/or the amperage, the greater the amount of heat that will be generated and the more serious will be the problem. Measurement of tissue temperature experimentally reveals that tissue temperature is highest directly underneath and adjacent to the contact site of the entrance and exit wounds. Deep tissue destruction is always greatest in areas of the body with small volume such as the fingers, toes, wrists, or ankles. The farther away the tissue is from the contact point, the less the current density is, and, therefore, the less heat is generated. Various tissues have different resistance to current flow with nerve and blood vessel having low resistance and cartilage and bone having high resistance. Because bone has a high resistance, current tends to flow at its surface and, therefore, temperature is greatest at the periosteum. Thus, muscle damage is often extensive adjacent to the bone, and many times the periosteum and portions of the outer cortex of the bone may not be viable. For these reasons, an electrical injury may not appear severe initially since only the entrance and exit (see Figure 10-3) sites show visible damage, yet the casualty may have severe limb damage that will necessitate limb amputation.[1]

A sensitive indicator of total muscle damage following electrical injuries is the serum creatine kinase (CK). In a recent study, patients with a total CK of under 400 international units (IU) had no significant tissue loss; a few patients with total CK concentration ranging between 400 IU and 2,500 IU had digit amputations or skin grafts. Patients with a total CK greater than 2,500 IU had a high risk of major amputation; and those with a CK total greater than 10,000 IU had an 84% risk of major amputation or permanent neurologic deficit.[2]

FACTORS IN BURN SEVERITY

Age

The severity of burn injury is determined by patient age, total body surface area (TBSA), associated injuries, and to a lesser extent, burn depth and associated illnesses.[3] The very young and the very old do not tolerate illness and trauma, particularly burn trauma, as well as those in the prime of their lives. In the case of burns, this "prime" lies somewhere between 10 and 50 years of age. Persons at the extremes of age generally are more fragile physiologically and tolerate poorly the massive fluid shifts and infectious complications associated with the burn and its treatment. The American Burn Association, in its 1992 Postgraduate Course recognized this effect of aging and recommended that patients with smaller burns, if young or old, be treated in a burn center. During combat, available resources must be expended on those individuals with the greatest chance for survival.

Military burn casualties typically range from 18 to 40 years of age. In contrast, approximately 50% of patients admitted to a civilian regional burn center will be under 18 or over 50 years of age.

Burn Size

Evaluation and treatment of the burn requires an accurate assessment of burn size. The three most commonly used methods of determining burn size are the Rule of the Palm, the Rule of 9s, and the Lund and Browder chart. The Rule of the Palm states that the patient's palm, excluding the fingers and the thumb, is approximately equal to 0.5% of

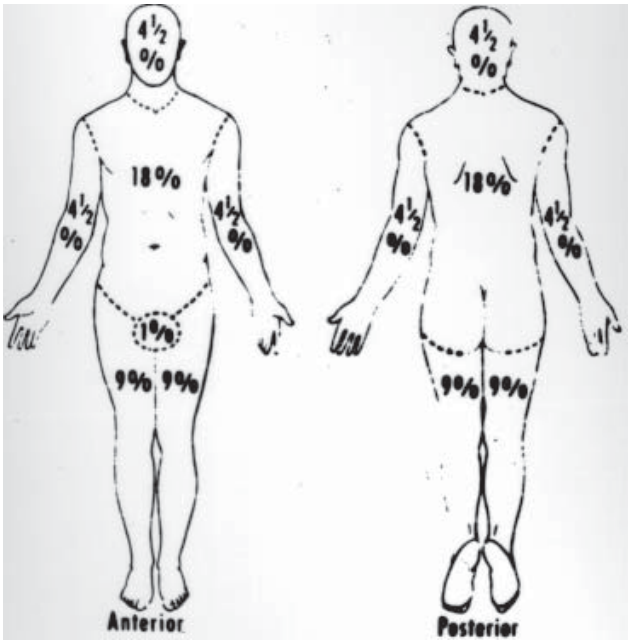
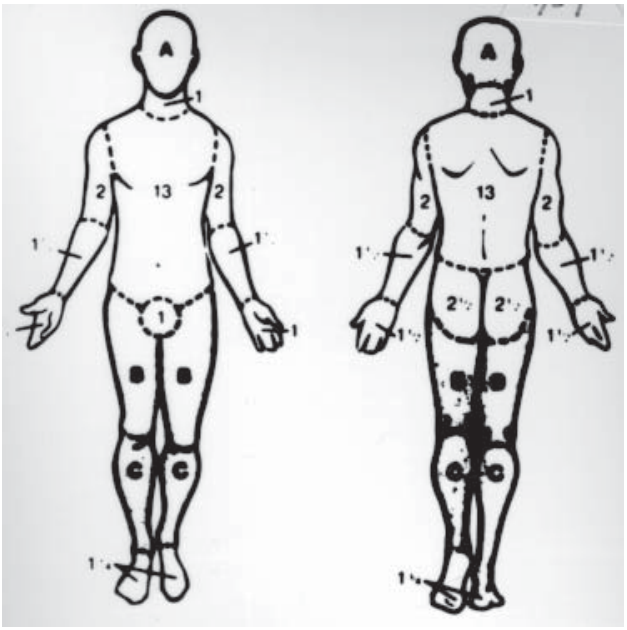


Fig. 10-6. The Rule of 9s. Adapted from Bowen TE, Bellamy RF, eds. *The Emergency War Surgery NATO Handbook*. 2nd rev. Washington, DC: Department of Defense; 1988.



Relative Percentages of Areas Affected by Growth

Age in Years	Half of Head (A)	Half of One Thigh (B)	Half of One Leg (C)
Infant	9 ½	2 ¾	2 ½
1	8 ½	3 ¼	2 ½
5	6 ½	4	2 ¾
10	5 ½	4 ¼	3
15	4 ½	4 ½	3 ¼
Adult	3 ½	4 ¾	3 ½

Fig. 10- 7. The Lund and Browder chart. Adapted from Cioffi WG, Jr, Rue LW III, Buescher TM, Pruitt BA. A brief history and the pathophysiology of burns. In: Bellamy RF, Zajtchuk R, eds. *Conventional Warfare: Ballistic, Blast, and Burn Injuries*. Part 1, Vol 5. In: *Textbook of Military Medicine*. Washington, DC: Office of The Surgeon General, Department of the Army, and Borden Institute; 1991: 341.

the patient's TBSA. The Rule of the Palm may be used as a quick estimate of burn surface area involvement and can be easily applied in the emergency room or field setting for determination of small burns or burns of scattered areas.[4]

The Rule of 9s (Figure 10-6) is a convenient way of estimating adult total body surface area. Developed in the 1940s by Pulaski and Tennison, it is easily remembered because it divides the body surface into areas of 9% or multiples of 9%. The head and neck equal 9%, each arm and hand is 9%; the anterior and posterior trunk are two 9s, or 18% each; each leg is two 9s, or 18%; and the perineum is 1%. The Rule of 9s is easily applied in field situations, but we believe it to be relatively inaccurate.[5]

The Lund and Browder chart (Figure 10-7) was developed nearly 50 years ago and more accurately defines burn size, and is used in most burn centers. This chart assigns a percent of surface area to body segments.[6] It takes into account the disproportionate growth of trunk, head, and lower extremities in children. However, the chart is not always readily available and is too complex to commit to memory.

Burn Depth

Burns historically have been classified into degree categories: first, second, third, and fourth (Figure 10-8). First and second degree burns are partial thickness injuries, whereas third degree burns are full thickness. First degree burns involve only the epidermis, are erythematous or deeply tanned in appearance, and do not blister. Sunburn (Figure 10-9) is a typical first degree burn, heals in 3 to 6 days, and has no long term sequelae.

A second degree burn involves both the epidermis and dermis. A superficial second degree (superficial partial thickness) burn (see Figure 10-4) blisters, is moist and erythematous, and reepithelializes in less than 3 weeks in adults or less than 2 weeks in children. Superficial second degree burns are best treated with daily dressing changes and allowed to heal without surgical intervention. A

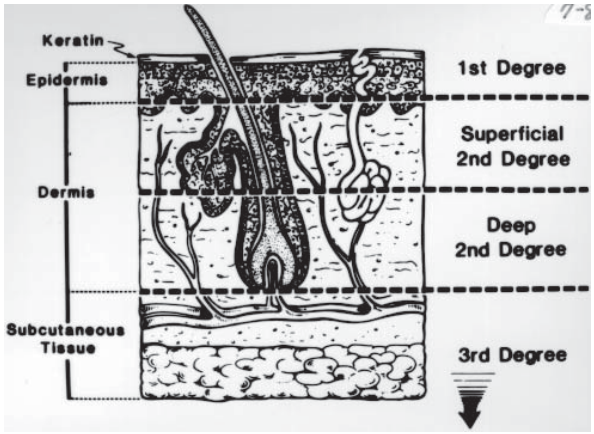


Fig. 10-8. Skin diagram illustrating depth of injury.

superficial second degree burn may heal with minor color and texture changes, but it does not develop hypertrophic scarring.

In contrast, a deep second degree (deep partial thickness) burn (see Figure 10-5) is cream colored or white beneath the blisters, takes longer than 3 weeks to heal in adults (> 2 weeks in children under 10 years of age), and is best treated with early excision and grafting. A spontaneously healed deep second degree burn will have fragile skin and may develop severe scarring.

Fig. 10-9. Sunburn injury.

Fig. 10-10. Burns secondary to explosion and gunshot wound. Note that the explosive device caused fragment wounds and burns. Intraabdominal pathology necessitated splenectomy and repair of gastric lacerations.

A third degree (see Figure 10-5) (full thickness) burn involves the entire depth of the skin, destroys both the epidermis and dermis, and must heal from the margins. A third degree burn larger than 3 cm in diameter is best treated with early excision and grafting.

A fourth degree burn occurs when damage is deep to the skin and involves muscle, bone, and other deeper tissues.

Associated Illnesses and Injuries

Most military casualties occur in healthy adults. If civilians are injured it must be remembered that chronic illnesses such as diabetes, renal failure, and chronic liver disease increase their mortality. A psychiatric illness or chemical dependency will complicate nursing care, interfere with surgical treatment, and impede normal rehabilitation.

Combat burn victims have a high incidence of associated injuries[7] (Figure 10-10). The acute injuries, whether due to penetrating or blunt trauma, are given first priority and will be handled in the field hospital. The patient's burn fluid resuscitation is performed during the treatment of the other injuries. Inhalation injuries complicate about 20% of burn admissions.

TREATMENT OF BURNS

Topical Treatment

Burn wounds are cleansed once or twice daily followed by application of a topical agent. For small wounds (less than 10% TBSA), a soothing ointment such as Bacitracin (Barre-National, Inc.) is a relatively inexpensive topical agent, but does not penetrate well and is ineffective against gram negative bacteria. Superficial wounds may also be treated with synthetic, semisynthetic, or biologic dressings such as Biobrane (Winthrop Consumer Products) or pigskin (Figure 10-11). When these products adhere, they provide a comfortable wound cover that does not separate until the wound has reepithelialized.

For deeper wounds, daily cleansing followed by application of silver sulfadiazine is the most commonly used treatment in the United States. Silver sulfadiazine does not penetrate well but has a good spectrum of coverage. It is easy to apply buttered over the wound or on longitudinal strips of fine mesh gauze and is the least painful agent, but sensitivity and leukopenia are not uncommon. Mafenide acetate (Sulfamyalon [Dow Hickman Pharmaceuticals]), the first wide-spectrum burn cream used, has excellent wound penetration and a broad spectrum of coverage. However, it causes marked pain and has a side effect of causing metabolic acidosis, making it a less popular agent. Most wounds are acutely treated with topical agents and daily dressing changes; wounds that will require longer than 3 weeks to heal are usually excised and grafted beginning 1 to 5 days postburn. Silver sulfadiazine is the most commonly used topical antimicrobial. Furacin (Roberts Pharmaceutical Corp.), 0.5% silver nitrate solution, povidone-iodine, and Bacitracin are also available for topical use.

Fig. 10-11. Superficial burn healing under pigskin. Note the pigskin on posterior thigh.

Complications

Inadequate fluid resuscitation in the presence of circulating nephrotoxins (such as myoglobin) may cause renal failure. Similarly, pulmonary edema associated with excessive fluid administration occurs if the patient is not adequately monitored. Gastrointestinal disorders, including ileus, are avoided by nasogastric tube decompression of the stomach accompanied by enteral feeding through a tube placed beyond the ligament of Treitz. Curling's ulcer with erosion of the stomach and duodenal mucosa has been largely eliminated by the use of histamine-2 blockers, early enteral feeding, and antacids. Sepsis remains a common complication caused by bacterial colonization of the burn wound and the patient's immunosuppressed condition,[7] with the lungs being the most common site of fatal sepsis.[8] These complications must be understood by rehabilitative personnel as the care plan will need to be modified as the complications arise.

Medical Surgical Considerations

When the skin, the largest organ of the body, sustains significant injury, a cascade of metabolic and physiologic consequences occurs that can affect survival adversely. While providing both a fluid barrier and a thermoregulatory mechanism, the primary function of the skin is to maintain homeostasis. Intact, waterproof skin is the first line of defense against the hostile microbial world. The soldier's self-image is dependent on appearance, which has been determined by skin surface. Skin plays a vital part in bodily function. However, its importance is often underestimated, since it readily heals from minor superficial injuries with little pain or inconvenience.

Emergency Burn Care

The initial rescue and treatment of the burn victim, military or civilian, is seldom rendered by a physician but by a bystander, medic, paramedic, or other soldier. This treatment should follow the basics of first aid: (1) stop the burning process, (2) evaluate and secure the airway, and (3) treat other life threatening injuries. Chemical burns should be copiously irrigated with water or saline. If the airway is compromised (see Exhibit 10-1), the ventilation should be maintained by mask and oxygen and intubation if possible. When facial or neck edema is anticipated from fluid administration, intubation is completed prior to transfer to an aid station. The burn wound can be covered with a clean sheet or simple dressing to minimize further contamination and to help conserve body heat. While stopping the burning process, wetting and cooling the burn can rapidly result in hypothermia, a condition to be avoided. The basics of trauma emergency care apply to initial burn treatment as well as to any other injuries.

EXHIBIT 10-1

SIGNS OF AIRWAY AND PULMONARY COMPROMISE

- Facial burns with perinasal, perioricular involvement
- Singed nasal hairs, swollen lips, and tongue
- Carbon particles in mouth and sputum
- Hoarse, raspy voice
- Heavy productive cough with carbonaceous sputum
- Dyspnea, air hunger, or gasping
- Narrowing of airway on lateral cervical radiograph
- Signs of acute pulmonary edema and adult respiratory distress syndrome on chest radiograph
- Information that burn occurred in a closed space

Outpatient Clinic vs Specialized Inpatient Treatment

Recent efforts at health care cost containment have resulted in the treatment of larger uncomplicated burns in the outpatient setting. Although most military burn casualties are managed on an inpatient basis, outpatient care is possible in a garrison setting for certain soldiers with small burns. Exceptions to this trend remain in the extremes of age, an unreliable patient, or lack of family or nursing resources. The success of outpatient treatment involves good wound care by an experienced burn nurse and, later, by the fully instructed patient, family member, or buddy. Most failures of outpatient burn care do not involve wound problems, but rather are related to inadequate pain control and anxiety. Wound elevation, occlusive dressings, and liberal use of appropriate narcotics are the best means of controlling pain. The adequacy of pain control is a decision made by the patient, not the medical personnel.

There are no set criteria to determine which patients can be managed as outpatients because so many factors influence the severity of a burn. A young, otherwise healthy, individual with a 30% partial thickness burn and a good support system could not be treated at the battle front. However, he might do well as a hospital outpatient, whereas patients who are elderly, chronically ill, or alcohol or drug abusers with a 5% TBSA burn may be at risk for dying unless treated in the hospital. Cases of suspected abuse by burning, regardless of age, require admission.

Frequently used guidelines for inpatient burn treatment include:

- Greater than 10% full thickness burn.
- Greater than 20% partial thickness burn.
- Burns involving vital areas, eg, hands, feet, face, or perineum.
- Most infants and elderly—the extremes of age.
- Children with more than a 5% burn who are neglected or abused or lack adequate pain control.
- Inhalation injury.
- Most high voltage electrical injuries.
- Most chemical injuries, with special emphasis on alkali, dichromate, and fluoride burns.

The American Burn Association has identified the following[9] injuries as those requiring a referral to a burn center (Table 10-1). Patients with these burns should be treated in a specialized burn facility after initial assessment and treatment at an emergency department:

TABLE 10-1

ADMISSION CRITERIA

Age (y)	Burn Size (% TBSA)	Admission Yes	Admission No
< 10 or > 50	< 10		x
10–50	< 20		x
< 10 or > 50	> 10	x	
10–50	> 20	x	

Additional Factors Mandating Admission

- Burns of the face, hands, feet, perineum, or genitalia
- Inhalation injury
- Associated major trauma
- Major concurrent medical illness
- Electrical or chemical injury

TBSA: Total body surface area

- Second and third degree burns greater than 10% TBSA in patients under 10 or over 50 years of age.
- Second and third degree burns greater than 20% TBSA in other age groups.
- Second and third degree burns with serious threat of functional or cosmetic impairment that involve face, hands, feet, genitalia, perineum, and major joints.
- Third degree burns greater than 5% TBSA in any age group.
- Electrical burns, including lightning injury (greater magnitude of complications).
- Chemical burns with serious threat of functional or cosmetic impairment.
- Inhalation injury with burn injury.
- Circumferential burns of the extremities and chest.
- Burn injury in patients with *preexisting medical disorders*, which could complicate management, prolong recovery, or affect mortality.
- Hospitals without qualified personnel or equipment for the care of children should transfer burned children to a burn center with these capabilities.
- Any burn patient with *concomitant trauma* (eg, fractures) in which the burn injury poses the greatest risk of morbidity or mortality. However, if the trauma poses the greater immediate risk, the patient may be treated in a trauma center initially until stable, and then transferred to a burn center. Physician judgment will be necessary in such situations, and should be in concert with the regional medical control plan and triage protocols.

Early Life-Support Evaluation and Management

Burns, like any other major trauma, require that attention be directed toward the injury that is most life threatening. The burn injury associated with other major trauma may complicate diagnostic evaluation and significantly impact survival. A thorough, rapid assessment of the casualty helps direct care during the initial critical phase. This would include a history; a physical examination; and visual examination of all areas, undressed; appropriate radiography; and laboratory data.

A burn patient in acute distress on initial presentation is usually experiencing airway compromise, pulmonary insufficiency, or both (see Exhibit 10-1). Injury to the airway and lungs is more the result of inhaled toxic products of combustion rather than heat. However, someone injured in the presence of superheated steam in an enclosed space, such as a boiler room on a ship, may have burns of the airway. Inflammation and edema can rapidly obstruct the upper airway, especially in children. Early intubation may often be the prudent choice of management to avoid traumatic intubation through an edematous airway and associated complications.

Pulmonary edema may be the direct result of inhalation injury, independent of too vigorous a fluid resuscitation course. Inhalation injury can manifest itself early through impaired gas exchange with falling PO_2 and oxygen saturations, followed later by rising PCO_2. These changes can precede changes on chest radiography, sometimes by 12 to 24 hours (Figure 10-12). Inability to adequately exchange gases is an indication for intubation and controlled ventilation. Nasal intubation is generally preferred over tracheostomy for early respiratory distress.

Vascular access can be established peripherally for immediate use or centrally for more long term use. Not without its own risks, central line lumen access can more reliably deliver high volumes of fluid and medications, as well as provide a means of hemodynamic monitoring (central venous pressure) and withdrawing blood. Although an unburned site is preferable, a properly maintained line through burn tissue should still have an acceptably low infection rate. A Swan-Ganz line can provide supplemental data to guide the complicated resuscitation, such as in an elderly individual with coronary artery disease or congestive heart failure. In-

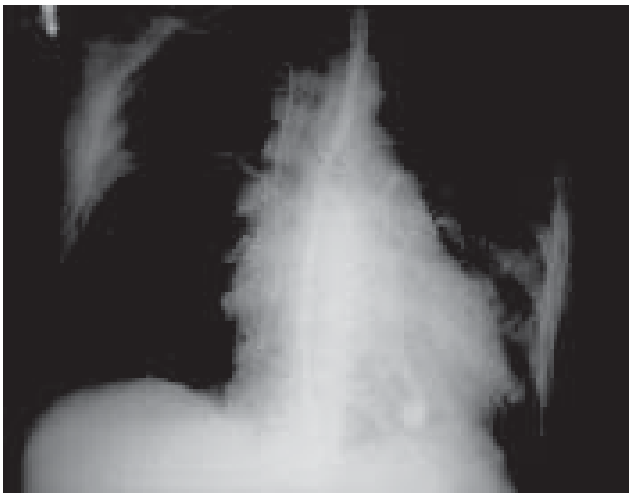


Fig. 10-12. Early chest radiograph showing changes associated with smoke inhalation.

vasive (Swan-Ganz) monitoring may be necessary to optimize resuscitation of the seriously burned patients because there is no correlation between fluid challenges and changes in vital signs and urine output.[10] Invasive monitoring carries an increased risk of sepsis, especially in burn causalities, and therefore, it must be used with caution and for a limited time.[11] The patient with cardiovascular instability or inhalation injury often benefits from an arterial line where the data provided and the blood withdrawing capabilities eliminate repeated arterial punctures.

An indwelling urinary catheter is needed for any major burn resuscitation as urinary output, a good indicator of (renal) tissue perfusion, is generally accepted as a reflection of adequacy of resuscitation. Adequate pediatric urinary output is between 0.5 and 1.0 $cm^3/kg/h$. Adult urinary output should be between 30 and 50 cm^3/h if there is no ongoing hemolysis. If there is hemoglobin and myoglobin in the urine, as indicated by a cherry red to outright black color, urinary output should be pushed to the range of 250 cm^3/h or greater. This is accomplished by using fluids and Mannitol (Astra/Merck Group of Merck & Co., Inc.) as a means of mechanically washing these products from the renal tubules where the sludge tends to accumulate with damaging results. Rapid and adequate resuscitation can minimize or eliminate acute tubular necrosis, which remains associated with virtually 100%[12] mortality in burn patients.

Administration of Mannitol during resuscitation may artificially increase urine output through its diuretic effect, leading to hypovolemia and dehydration. The hematocrit and hemoglobin need to be carefully followed. Mannitol can provide predictable, smooth diuresis, which helps counteract the natural reflex tendency of the kidneys to slow urinary output due to vasoconstriction and the actions of antidiuretic hormone, catecholamines, and aldosterone. Mannitol is also a powerful antioxidant that may have significant benefit in mitigating the effects of free oxygen radical production in the burn wound.

Fluid Resuscitation for Burn Shock

A burn injury sets off a cascade of local events and humoral responses that continue for 48 hours postinjury, resulting in edema formation and fluid losses through the wound. As the burn wound exceeds 15% to 20% TBSA, the fluid losses can exceed the body's compensating mechanisms with circulatory collapse. If distance and time of transport are lengthy, the casualty may suffer burn shock by the time of arrival in the treatment facility. Self-aid or buddy aid will be ineffective. The casualty should receive emergency medical treatment by the trained technician in the evacuation ambulance.

A fluid resuscitation program is designed to overcome the anticipated 24- to 48-hour period of massive fluid shifts, electrolyte derangements, acid base imbalance, edema formation, and fluid and protein losses. More detailed information is found in Exhibit 10-2 and Table 10-2**.** Replenishing the circulatory volume, using any one of the formulas currently in use, is the means to restoring and maintaining organ perfusion and function. The fluid loss that depletes the circulatory volume is the result of increased capillary micropermeability affecting burned and nonburned tissues.[13] Edema fluid forms at the expense of the vascular and extracellular compartments. Electrolyte concentrations can vary con-

EXHIBIT 10-2

AVERAGE FLUID RESUSCITATION REQUIREMENTS (CM^3 CRYSTALLOID/KG/% TBSAB)

Burn	Average adult	2
	Average child	3
Burn and Inhalation Injury	Average adult	4
	Average child	5

TBSAB: total body surface area burned

TABLE 10-2

TYPICAL FLUID RESUSCITATION PROGRAMS

Formula	Fluid Composition	Calculated Volume	0-8 Hours	9-24 Hours	24-48 Hours
Carvajal					
Children	Na 132 mEq/L Cl 109 Lactate 26.1 K 3.8 Glucose 47.5 g/L Albumin 12.5 g/L	5,000 mL/m^2 TBSAB/d^1 + 2,000 mL/m^2 TBSA/d^1 (maintenance fluid)	1/2 vol	1/2 vol	3/4 of day 1 vol
Infants	Na 81 mEq/L Cl 61 HCO_3 20 K 0 Glucose 46.5 g/L Albumin 12.5 g/L		1/2 vol	1/2 vol	
Brooke	Ringers lactate Na 130 Cl 130 Lactate 28 K 4 Ca 3	1.5 mL crystalloid/kg/% TBSAB 0.5 mL colloid/kg/% TBSAB + 2,000 cc D_5W	1/2 vol crystalloid and colloid	1/2 vol	1/2 of day 1 vol
Parkland	Ringers lactate D_5W + 0.5-2 L	4 cc/kg/% TBSAB (to maintain urine output at 50 cc/h) plasma	1/2 vol	1/2 vol	
Hypertonic Saline	Na 200-300 mEq/L Cl -100 mEq/L HCO_3-150 mEq/L	2 cc/kg/% TBSAB (to keep urine output at 30 mL/h [adult] or 1 cc/kg [child])			

Note: For accompanying inhalation injury, add 1-2 cc/kg to resuscitating volume
TBSAB: total body surface area burned
Source: (1) Carvajal HF. Fluid resuscitation of pediatric burn victim: A critical appraisal. *Pediatr Nephrol*. 1994;8:358.

siderably, due in part to large potassium intracellular losses, urinary excretion, and large sodium intracellular and extracellular gains.[14] The currently used burn resuscitation formulas are quite similar in both fluid volume administered and milliequivalent of sodium given when both are calculated at 48 hours postburn.[15] The key component in each formula is the sodium ion; the fluid (free water) is simply the vehicle to deliver the sodium. Depending on the choice of formula, the fluid volumes range from 2 to 5 cm^3/kg/% TBSA. Some formulas use no colloid, others vary in the amount and timing of colloid administration. The role of crystalloid vs colloid resuscitation remains an ongoing debate fueled by ample data and opinion on each side. It is important to note that each formula is merely a guideline for resuscitating the casualty victim. Predictably, the individual response to a prescribed formula may be quite unpredictable and variable, and require corrective adjustment in either direction. None of these formulas reflect evolving trends that add a sophisticated medical resuscitation component to the already existing fluid protocol. The following is a partial listing of components being used or investigated for improved resuscitation, or decreased burn wound edema supplement resuscitation, or decreased burn wound edema and the inflammatory response in the early phase: low molecular weight dextran, fresh frozen plasma, pentastoid, Mannitol, ibuprofen, cimetidine, and vitamins C and E.[15-24]

Contrary to the opinion of some clinicians,[25-29]

excess edema postresuscitation can have severe, long ranging consequences. Organ systems such as brain, lungs, and heart do not function well under the stress of severe edema. Circulation to an edematous extremity can be compromised with possible dire consequences. Early escharotomy is indicated when massive edema is anticipated. Early mobility and rehabilitation may be unsafe, if not nearly impossible, when edema impairs joint motion. Loss of dexterity in edematous hands and digits can further compound the person's feeling of helplessness following injury, leading to a vicious circle of decreased use, joint stiffness, contracture, tendon shortening, and long term disability. Therefore, it is imperative to adequately resuscitate but to do so with minimal edema formation.

The Nonhealing Burn Wound

The surgical goal is to expedite wound closure. Estimation of burn wound depth is an important clinical judgment because it determines proper treatment. Superficial and full thickness char burns can be easily determined. The intermediate or partial thickness burn is difficult to assess. A partial thickness burn wound may vary in depth within a small area, thus, healing may be patchy or delayed. A burn wound failing to heal in 18 to 21 days typically requires skin grafting because the final functional and cosmetic result of a skin graft is superior to the poor quality skin covering of a delayed healing wound. This is especially true in the pediatric age group.

Dressings impregnated with hormones or other factors will soon be available to stimulate improved healing of superficial and intermediate burn wounds. Early excision and grafting of the full thickness wound will remain the standard of burn care in most cases. Although still unproved in controlled studies, early excision is certainly based on sound principles of general surgical wound management and has clinically proven effective[30-35] in diminishing morbidity in the burn casualty.

Burn Wound Excision

The estimated depth of the burn wound often determines the choice of excision technique: tangential, sequential tangential, or fascial excision. Superficial wounds are best excised with sequential passes of the dermatome until viable tissue is exposed. Charring burns deep into subcutaneous fat are excised in segments to the fascia.

Tangential Excision

Dermal burns are debrided with multiple passes of the debridement instrument until viable tissue is reached; this is known as sequential tangential excision. This method of debridement allows maxi-

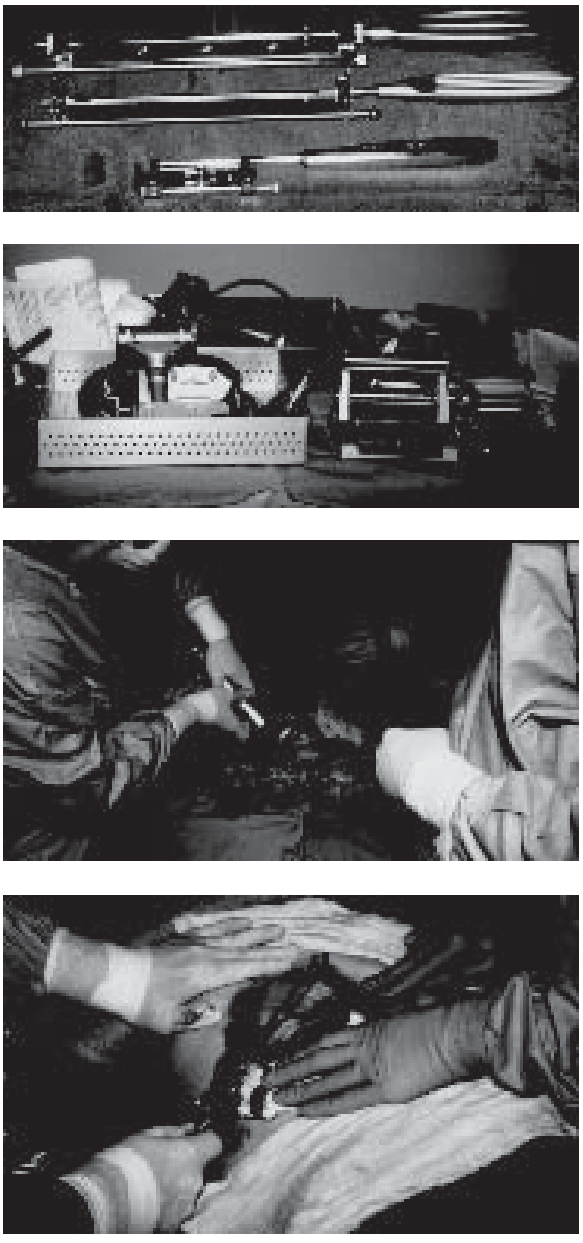


Fig. 10-13. Instruments for graft harvest or debridement. (**a**) Example of manual dermatome for skin debridement or graft harvest. (**b**) Example of power dermatome. (**c**) Skin debridement in progress using power instrument. (**d**) Skin debridement in progress using manual instrument.

Fig. 10-14. Brisk punctate bleeding from viable dermis follows tangential debridement.

mum preservation of viable dermis, which ultimately leads to better long term results in the quality of the healed grafted skin.

There are any number of instruments available for wound debridement, some manual, others electrical or air driven (Figure 10-13). The technique of debridement involves setting the dermatome somewhere in the range of 0.008 to 0.012 in. for excising partial thickness burns or cutting up to 0.030 in. for full thickness burns. Areas requiring intricate or delicate work, such as digit web spaces, are best approached using small instrumentation with shallow settings in multiple passes.

Areas that have been adequately debrided show brisk punctate bleeding in healthy white dermis (Figure 10-14). Poor bleeding in grayish appearing dermis indicates inadequate debridement, which requires repeat passes with the instrument. As debridement progresses deeper into and through the dermis, more fat appears and capillary bleeding gives way to brisker flow from arterioles and veins.

Hemostasis in the debrided wound is obtained using pinpoint electrocautery on larger vessels and dilute epinephrine soaked lap pads on the diffuse capillary bleeding bed. Local pressure and temporary elastic wraps can assist bleeding control. Topical epinephrine solutions in concentrations ranging from 1:10,000 to 1:100,000 can be safely used with few systemic effects in acutely burned patients. Topical thrombin and collagen have also been used for this purpose.

Blood loss from the debrided wound bed can be profuse and can exceed 5% of blood volume per 1% body area debrided. Blood loss of this magnitude requires frequent monitoring of hemoglobin/hematocrit, platelets and coagulation factors, casualty temperature, blood pressure, and urine output. In a well prepared and monitored casualty it is possible for multiple surgical burn teams to rapidly excise and cover a 50% body surface area (BSA) burn in a single 2-hour session. Less experienced teams should limit excisions to under 30% surface area, or 2 hours time.

Excision to Fascia

Deep burns through dermis well into the subcutaneous tissue are best excised with an electrocautery knife to the fascial plane. The excision at this level can proceed rapidly with less blood loss. On extremity burns blood loss can be minimized by the use of tourniquets. When using a tourniquet, the extremity is first exsanguinated (the limb is tightly circumferentially wrapped from distal to proximal to empty the capillary, arterial, and venous circulation) and excision proceeds in a rapid manner along the fascial planes removing all eschar with the underlying subcutaneous tissue. This can lead to major tissue losses, especially in obese casualties with subsequent significant cosmetic defects. To obtain optimal functional and cosmetic results, it is important to obtain nearly complete hemostasis to prevent graft loss.

Graft adherence ("take" or attachment) on fascia is generally better than onto subcutaneous fat. This better graft take, however, comes at a price with inferior cosmetic appearance, increased edema in distal extremities, and, at times, decreased sensation.

Enzymatic Debridement

Enzymatic debridement of the burn wound has multiple advantages, such as more complete and selective debridement of the burn eschar, while at the same time being nontoxic and nontraumatic to normal tissue. Debridement of a deep hand burn is an ideal use of this methodology. There is a risk of promoting sepsis with enzymatic agents, thus their application should be restricted to under 10% of the TBSA. Metal ions such as those found in soaps and antimicrobial agents tend to inactivate enzymes, and therefore, should not be used together.

The enzymatic debridement procedure is as follows.

1. Mechanically debride affected areas of all loose tissue.
2. Wash and rinse area thoroughly.

3. Apply a uniform coating of debridement enzymes such as Accuzyme.
4. Cover area with occlusive dressing. Hands are easily dressed with oversized surgical gloves.
5. Repeat application of enzyme every 4 to 6 hours until punctate bleeding is observed (two or more applications are typical).
6. Do not exceed enzyme application over 10% of TBSA to avoid risk of burn wound sepsis.
7. Chemical escharotomies of circumferentially burned limbs can be performed using strips of the enzyme paste along the length of the burn. If the limb is acutely ischemic, then standard escharotomies should be performed for immediate decompression.

Fig. 10-15. Harvesting a split thickness skin graft using a Paget electric dermatome.

Donor Site Selection

Donor sites are selected on the basis of location, skin thickness, burn size, function, and cosmetics. The face, hands, and feet are rarely used for donor sites, whereas the scalp, thigh, abdomen, and buttocks are frequent choices. If the burn is small, the site selected is usually determined by future cosmetic concerns. The scalp, usually covered by hair, and the buttocks, covered by clothing, are therefore, frequently chosen for donor sites. In the massively burned casualty the scalp is an ideal donor site since it heals rapidly and can be reharvested repeatedly at 7- to 10-day intervals with little risk of alopecia.

The thickness of the skin influences the donor site; for example, the dorsum of the hand may be less than 0.010 in., the back greater than 0.030 in. The back, buttocks, and thighs are often chosen as donor sites because of their thickness and ease of harvesting. Surface contour and subcutaneous adipose deposits can greatly influence the ability to harvest quality grafts and thus have a negative influence on site selection. In body areas such as the ribs or scalp, subcutaneous injection of warm saline improves the contour for skin harvest.

Skin Grafts

Split Thickness Skin Grafts

A split thickness skin graft (STSG) is typically harvested in a range from 0.007 to 0.012 in. using either a manual or powered dermatome. The advantages of using power dermatomes (Figure 10-15) are in the speed, uniformity, and precision of skin harvest. These delicate instruments have a low tolerance of abuse and a high frequency of expensive repair.

Sheet Skin Grafts

Areas of burn graft where an optimal functional or cosmetic result is desirous should be covered with sheet skin grafts. A sheet graft is harvested as noted above and is applied directly to the graft bed without first being meshed as described below. The sheet graft does not have perforations or incisions and is not expanded, thereby reducing scarring. Examples of areas best served by sheet grafting include hands, face, and neck. Availability of adequate donor sites affects how much grafting can be accomplished with sheet grafts.

When blood or serum collect under sheet grafts, the grafts may lift off the bed, resulting in graft loss. Extra time needs to be devoted to obtaining adequate hemostasis, otherwise the grafts slough over fluid collections, which will result in a cosmetic appearance worse than a mesh graft. Any large fluid collection can threaten the entire graft take and needs to be locally drained.

Meshed Skin Grafts

The instrumentation to accurately and reproducibly mesh skin, developed by Dr. Tanner, helped to revolutionize burn care by providing a method of skin coverage for the massively burned casualty. Skin expansion allows for greater graft coverage from limited donor sites. The surgeon has a choice of

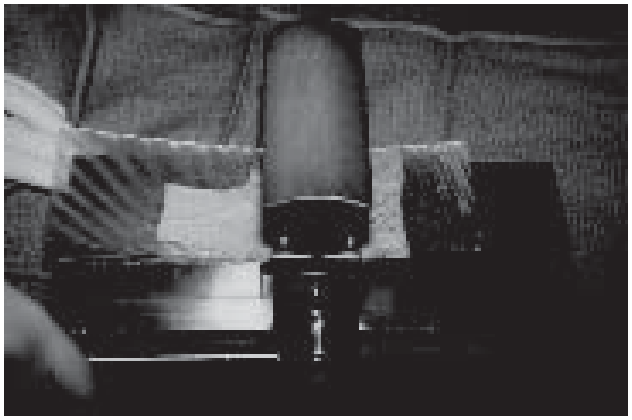


Fig. 10-16. The Zimmer mesher, which uses fixed ratio carriers from 1.5:1 to 9:1.

multiple expansion ratios ranging from 1.5:1 to 9:1. As the expansion ratio increases, the quality and cosmesis of the skin decreases as the healing time for the graft interstices increases. As a general rule, most coverage is accomplished with mesh ratio of 3:1 or less.

There are two basic types of mesh instrumentation. One instrument, the Zimmer mesher (Figure 10-16), uses carriers for the skin that are chosen according to the desired ratio. The other instrument, the Bioplasty mesher, (Figure 10-17) has a preset ratio requiring no skin carriers. Instead, the skin is fed directly into the rollers. The advantage of the Bioplasty mesher is that harvested skin of any shape and length can be fed into it and meshed without seams, which are normally present when carriers are joined to make longer lengths. Fewer seams result in fewer hypertrophic scars, which decreases rehabilitation time. Faster meshing of skin and lower cost make this dermatome more practical to use.

Fig. 10-17. The Bioplasty mesher has a fixed mesh ratio built into the instrument, which cannot be changed. No carriers are required. Bioplasty meshes can be obtained with preset ratios from 1:1 up to 8:1.

Fig. 10-18. Skin grafts are rapidly secured using surgical staples, saving considerable time over the traditional hand sewn method.

Skin graft adherence is a two-part adhesion response beginning with early fibrin bonding when the graft is set on the bed. This is followed by fibrocapillary ingrowth in the ensuing 72 hours. Although tenuous and easily sheared at this time, the viability of a graft is assured by this capillary inosculation. More grafts are lost at this phase through motion and shearing than infection.

Proper management during the immediate postoperative period can significantly affect the final outcome. Graft movement is the first cause of graft failure; infection is the second. Securing the graft to the bed is important because graft motion or shift is the greatest cause of graft failure. Before the advent of staples, all grafts were sewn in place, requiring hundreds of individually placed stitches. Now large grafts can be secured in a fraction of the time with surgical staples (Figure 10-18). In pediatric patients, staple removal is traumatic and it may be wise to secure grafts with absorbable suture or Steri-strips (Johnson & Johnson Medical Inc.). Absorbable staples and fibrin glue show future promise. Splints incorporated into the final dressing help maintain desired position and help prevent graft loss due to motion, especially over joints. Proper splinting techniques are reviewed elsewhere in this text.

To minimize infection, the new graft requires proper wound management. Depending on a par-

Fig. 10-19. A nonadherent dressing may be cut to size to cover a fresh skin graft.

ticular burn center's protocol, skin grafts are treated in an open or closed method. Centers using the closed method apply a nonadherent contact layer to the graft. Tegapore, N-ter-face, and Adaptic (Johnson & Johnson Medical Inc.) are some of the dressings available for this purpose (Figure 10-19). Small burns are dressed with antibiotic soaked gauze, dry gauze, and elastic compression. Small irrigation tubes may be used in the dressing to maintain a moist antimicrobial environment. Either a 2% cerium nitrate solution or an antibiotic solution containing Kanamycin, Bacitracin, and Polymyxin (Burroughs Wellcome Co.) are used. Irrigation is continued until the first dressing change at 3 to 4 days for meshed grafts and 24 hours for sheet grafts. The dressings are kept moist but not wet.

At the first dressing change, the now adherent dressing can be left in place provided there are no signs of suppuration. This layer is easily removed several days later, as the graft interstices fill in, by either soaking the dressing just prior to removal, or applying silver sulfadiazine cream during the previous day's dressing. Grafts showing signs of infection can often be salvaged by removing all dressings, gently irrigating and debriding with once- or twice-a-day dressing changes.

Free Flap

Burns that create large fourth degree wounds (injury to muscle and bone) can be covered by flaps. Traditionally, these have been flaps rotated on a pedicle base into the area of defect. Occasionally

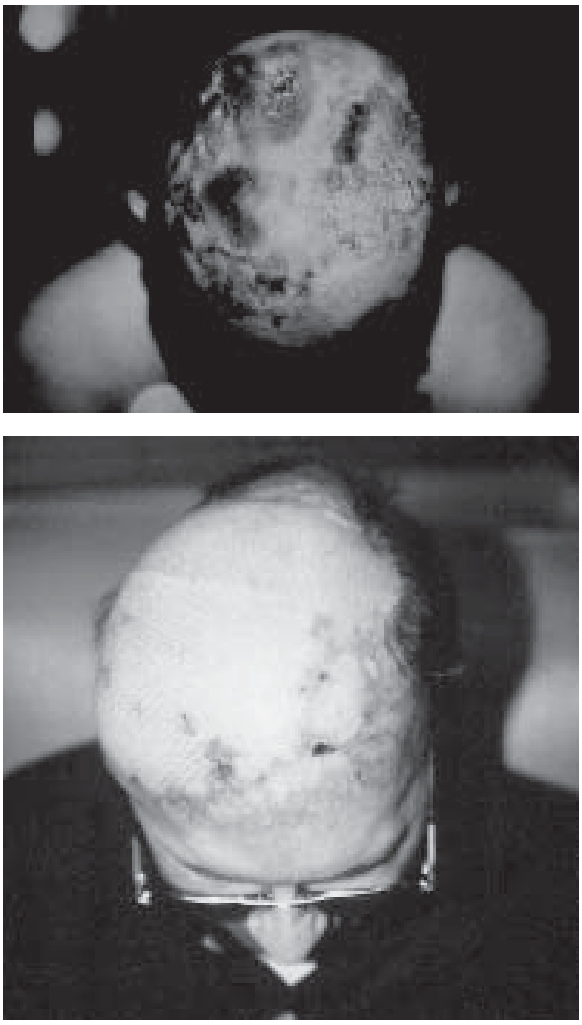


Fig. 10-20. Care of electrical injury. (**a**) Electrical burn of scalp from high voltage contact. Note exposed skull. (**b**) Closure with latissimus dorsi free flap and skin graft six months later.

there is no way to rotate a flap into a wound which is also unsuitable for grafting. The more recently developed method of free flap transfer to a tissue defect has had excellent results. The free flap has greatly facilitated coverage of the difficult "blow out," electrical-type wounds of the scalp, joint spaces, palms of hands, and soles of feet (Figures 10-20 and 10-21).

Cultured Autologous Kertinocite (Epidermal) Grafts

Human epithelial cells can now be grown in cultures with techniques developed by Rheinwald and

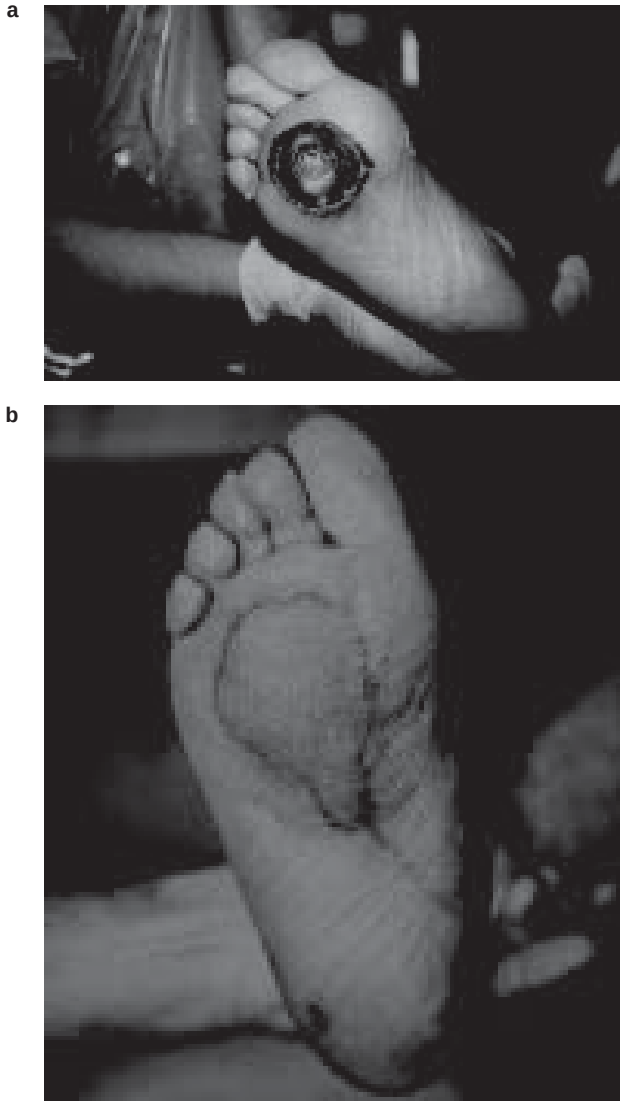


Fig. 10-21. Casualty who sustained an 8,000-V contact burn to the scalp (see Fig. 10-20) with large soft tissue and bone necrosis. (**a**) A deep necrosing wound to the foot with loss of foot tissue and bone. (**b**) Free flap coverage to the sole of the foot provided a substantial graft, which tolerates ambulation and avoided leg amputation.

Green,[37] and modified by Pittelkow and Scott.[38] The technique is a multistep process starting with the harvesting of a small, several-centimeter square piece of thin skin from an unburned site. The epithelial cells are enzymatically cleaved and separated, then placed in a serum-free culture medium where, under ideal conditions, rapid growth is achieved. Keratinocyte sheets, approximately 7 to 10 cell layers thick, are fragile and thin, with the consistency of wet tissue paper.

Careful preparation of the wound bed is of utmost importance prior to grafting with cultured grafts. These grafts will not reliably take on anything but a freshly excised bed. Graft adherence initially is through fibrin adhesion. A backing such as Vaseline gauze, stapled to the wound or meshed cadaver grafts stretched tight over the cultured grafts can be used to assist adherence.

Another approach to providing a better quality skin is the development of an artificial dermis. The product invented by Burke and Yannas is composed of bovine collagen fibers bonded to chondroitin-6-sulfate, a component of shark cartilage.[39] Ideally, thin epidermal grafts heal to this artificial dermis, resulting in a closed wound. A multicenter controlled study of this dermis in general showed favorable results, concluding that the healed artificial dermis covered with thin epidermal graft is essentially equivalent to standard skin grafts but with faster healing donor sites.[39]

Casualties who are grafted with cultured epithelium do not develop hair, sweat or oil glands, or proper sensation. The epidermis permanently remains extremely fragile and requires extraordinary protection from exposure to sun, chemicals, and trauma. Rehabilitation is exceptionally complex. The epithelium tolerates exercise, splinting, and external vascular supports poorly. These casualties may return to have the cultured grafts replaced with autografts as the donor sites become healed enough for reharvesting. The ideal artificial skin replacement has yet to be developed.

Biological Dressings

The surgical goal in burn care is to debride nonviable tissue and provide permanent wound coverage. Biological dressings are designed to function in a similar manner as their more expensive natural counterpart, cadaver skin. There are many biological dressings available, each with its own properties, but none is a true skin replacement. Biological dressings provide temporary coverage and give time for adequate donor sites to become available for repeated graft harvest. This coverage is important in the overall physiological well being of the burn casualty as it provides for better wound and pain management, helps decrease metabolic rate, reduces fluid losses through the wound, and suppresses the growth of granulation tissue.

The ideal biologic dressing would function as natural skin and come prepackaged off the shelf, ready to apply and perform as a complete skin replacement on a permanent basis. Synthetic dressings are laboratory designed to mimic their biologic

counterpart, skin. Since these act as biologic dressings, for the purpose of this discussion, they will be reviewed together with the true biologic dressings. A satisfactory biologic dressing undergoes the same bonding process as skin grafts. Most importantly, when adherence is achieved, the wound gains resistance to infection.

Homograft (also known as Allograft) Skin: Human cadaver skin is commonly used and is the standard against which other biologic and synthetic dressings are measured. Banked frozen human skin is becoming more widely available but is inferior to its fresh counterpart. In the massively burned casualty, no currently available biologic dressing offers the distinct advantages of fresh homograft in providing large burn wound coverage. Improved salvage of these casualties is based on early aggressive burn wound excision and coverage with homograft followed by sequential replacement with autologous skin.

Fresh homograft adherence is similar to autograft take with adherence and capillary ingrowth. A burn casualty with greater than 50% TBSA injury is, to a varying degree, autoimmunosuppressed. This state of immunosuppression can result in slowing of the natural rejection process, especially when the homograft skin is ABO compatible. Aside from providing excised wound coverage, homografts can also be used as onlay grafts to protect thin, widely expanded autografts, or cultured keratinocytes, providing protection to the underlying grafts.

Homograft rejection occurs anywhere from 14 to more than 60 days after the grafting, depending on the casualty's immune status. Replacement homografts tend to reject at a faster rate than original grafts. The rejection process affects the wound bed and may negatively influence further grafting. It is advisable to completely excise the bed prior to grafting.

Availability, cost, and the potential risk of viral transmission are the major drawbacks of fresh homograft. Procurement, preparation, and storage costs are relatively high. In spite of testing, there remains the possibility of viral transmission, including hepatitis, cytomegalovirus, and human immunodeficiency virus (HIV). There is at least one known case of HIV transmission involving autograft from England in 1987.[40,41] Amnion is used for temporary coverage in underdeveloped countries, but not in the United States, and carries the same infectious risks.[42,43]

Because the graft take is expected to be prolonged, the graft area is immobilized postoperatively in a similar method as autografts. Rehabilitation of cadaver grafted limbs can commence in 5 to 7 days.

Heterograft and Synthetic Dressings

Porcine skin heterograft is currently used in this country. It is a nonviable graft with limited usefulness in short term, temporary wound coverage. It has no advantage over homograft and has numerous disadvantages. If used, range-of-motion exercises need not be curtailed.

Numerous synthetic dressings are currently available to the burn clinician, with many more to come in the future (Figure 10-22). Fortunately, there is this large choice of products because there is no one ideal dressing. Also, what works well at a burn center may not work well in a combat zone. Some dressings have been designed for a specific purpose while others are adapted to a wide variety of clinical applications. The choice of a particular dressing is usually based on a mixture of tradition, art, and science.

The synthetic dressings range from the simple transparent polyurethane or polyurethane membranes (Tegaderm, Opsite [Johnson & Johnson]) to a more complicated bilaminate membrane, Biobrane (Winthrop Consumer Products). This dressing is composed of collagen peptides bound to a silicone nylon mesh. To function properly this dressing must be bound to the tissue by ingrowth into the collagen network. Biobrane has been shown to perform effectively on partial thickness burns or excised wound beds.[44] It is contraindicated for use over full thickness burns. Because it binds to the tissues, range-of-motion exercises are temporarily restricted.

Film dressings such as Tegaderm or Opsite work well to relieve pain and protect skin donor sites.

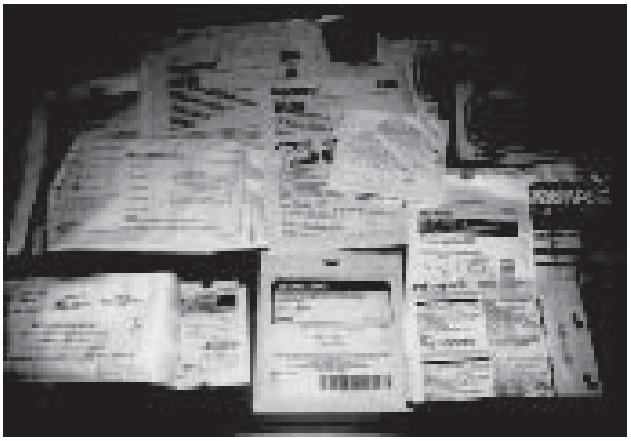


Fig. 10-22. Some of the numerous synthetic dressings available for use in graft and wound care.

These dressings also decrease pain, protect, and decrease fluid loss in small, isolated minor burns treated in the outpatient clinic. There is no restriction in range-of-motion exercises. Partial thickness burns are covered with nonadherent dressings such as Adaptic, Frastec, N-ter-face, or Tegapore (Winthrop Consumer Products), which separate easily, when adherence is not desired. Antimicrobial ointment helps secure the dressing while an absorbent layer of gauze is applied, and can generally be used for small burns.

Various first generation hydrocolloid dressings such as Duoderm (ER Squibb & Sons) are now available and have been used on partial thickness burns and on donor sites. This dressing performs poorly on full thickness burns.[45] Pain under a hydrocolloid dressing is unpredictable. Casualties complain about the drainage as this dressing becomes saturated with exudate from the wound. The calcium alginate dressing Sorbisan (Dow Hickman Pharmaceuticals Inc.) has a similar drawback. Exercise programs continue with these dressings, but for a foot wound, exudate accumulates in the shoe and becomes messy.

Donor Sites

As burn size increases, the donor site takes on added importance. The donor site should be considered the equivalent to a partial thickness burn, which must heal like its burn counterpart. Rapid healing of the donor site is imperative because of the numerous repeat harvestings necessary to close a massive burn. The scalp is probably the ideal donor site since it heals so rapidly and has few associated complications. A scalp donor site covered with a clear polyurethane dressing can be expected to heal in 5 to 7 days for a graft harvested at 0.008 to 0.010 in. (Figure 10-23). As a general rule, the farther the donor site is from the heart, the longer it will take to heal.

Dressing the donor site is done to help in decreasing pain and promoting rapid healing. There is little pain under the clear film dressings (Tegaderm [3M Health Care], Opsite [Johnson & Johnson], Omniderm [Jobst]) when compared to fine mesh gauze, scarlet red, or open treatment. The glue of the clear film dressings does not adhere to the actual donor site, thus a several-centimeter rim of normal skin surrounding the donor site is required for dressing

Fig. 10-23. Use and healing of scalp donor. (**a**) Harvesting scalp in a child at 0.008 inch. (**b**) Covering donor site with polyurethane dressing (Tegaderm). (**c**) Appearance of scalp covered with dressing in early postoperative phase. (**d**) Same scalp donor site approximately one month postharvest showing hair regrowth.

adherence. For donor sites exceeding the size of the largest dressing, multiple dressings can be patched one to another to obtain complete coverage.

The donor site becomes more of a problem as it is harvested adjacent to or between burn areas, a frequent occurrence in the massive burn casualty. If this donor site is covered with a clear film dressing it will rapidly become infected. It is preferable to treat thin donor sites in a more open manner with a nonadherent dressing such as Adaptic (Johnson & Johnson) and a topical antimicrobial similar to the way the adjacent burns are treated.

The clear film dressings are gas and water vapor permeable, but not so to the serum or blood that often collects from the donor site. The pressure of the fluid buildup can disrupt the dressing integrity along the dependent edge with potential for bacterial contamination. Aspiration of fluid and patching of the dressing can minimize this problem.

Donor sites can be a serious problem for children and the elderly. It is difficult to maintain a dressing on children. At these ages the skin is much thinner, and, therefore, the harvested grafts are relatively thicker in terms of amount of dermis removed. The donor site becomes a wound as deep as the original burn and is often very slow to heal. Children are prone to hypertrophy of their donor sites with the end result a cosmetic appearance sometimes worse than the grafted sites.

To avoid problems with the nonhealing donor site in the elderly, the surgeon can harvest extra skin, expand it 3:1, and regraft the donor sites. Excellent results have been obtained using this technique.[46]

Healed donor sites can have problems with blistering, usually self-limited, and pigmentation changes. To minimize splotchy pigmentation, sun exposure should be avoided for a year or more. External vascular support garments should be used on hypertrophic donor sites as well as on healed burn grafts.

Goals of Rehabilitation Management

The optimal rehabilitation goals after a burn injury include: (*a*) healed burn wounds, grafts, and donor areas. (Ideal results include wounds that are durable, soft, supple, flat, properly colored, pain and edema free, and able to tolerate active duty and work.) (*b*) maximal possible status for strength, endurance, AROM, fine motor dexterity and coordination; and (*c*) independent self-care for return to active duty. Optimal recovery is not always possible. In these circumstances the goals are that the casualty is: (*a*) managing epithelial sensory, vascular, and pigment changes through in depth knowledge of protective safety interventions; (*b*) managing edema; (*c*) continuing prolonged stretching of contractures to maintain acceptable motion and appearance; (*d*) continuing aerobic exercise, attempting improved cardiopulmonary status and endurance; (*e*) using appropriate protection from exposure to extremes of heat or cold or trauma; (*f*) learning desensitization and management of itching or hypersensitivity; and (*g*) coping with posttraumatic stress symptoms and permanently changed body appearance.

MANAGEMENT OF BURN CASUALTIES

For purposes of discussion only, burn care can be divided into three phases: (1) acute, (2) immobilization, and (3) wound maturation phases. The acute, pregrafting or early phase of treatment begins when the casualty's burn occurs and is followed by at-the-scene care from the battlefield medic, emergency treatment during transportation to a battalion aid station, evacuation from a mobile army surgical hospital, and finally, hospital admission for wound care followed by reconditioning and rehabilitation for return to duty.[47] In large burns the acute phase consists of the initial 72 hours of resuscitation and shock followed by up to 3 weeks of wound and patient management to achieve primary healing if the wound is superficial. A longer time period is anticipated for grafting when the wound is deeper or greater than 20% TBSA. This phase continues through the healing of partial thickness tissue injury on through debridement or preparation for grafting in full thickness tissue destruction. For chemical injuries, the rehabilitation treatment after the initial flushing is the same as for thermal heat injuries. There are no limits to AROM. Ambulation is encouraged as soon as the casualty is medically stable. Frostbite care, however, in the acute phase is slightly different because the cell is temporarily crystallized and caution is used to prevent any pressure on the damaged tissue until all areas thaw. In addition, frostbite blisters are kept intact, which means active motion must be done very cautiously in bed (Figure 10-24). In the case of an electrical injury, AROM is continued from admission through debridement, even though tendons may be exposed and amputation of a distal extremity is anticipated. Distal function in the electrical injury is often deceptive. The often observed delayed microvascular

Fig. 10-24. Intact frostbite blister that complicates wound management, exercise, and ambulation.

thromboses in the extremity results in gradually increasing demarcation of necrosis. However, distal function is maintained as well as possible until need for amputation has been determined.

The grafting or immobilization phase of treatment begins after the casualty is taken to surgery for grafting and continues until the graft is adherent or has taken and the patient is allowed to be up walking. Care and rehabilitation for all four types of burn injury are similar during immobilization for graft adherence.

The wound maturation phase of treatment begins when the wound is healed and ends when the wounds are mature and prosthetic fitting, if necessary, is completed and when all reconstructive procedures are completed. The wound maturation phase includes the shorter inpatient recovery time, during which open areas become small enough for safe discharge from the hospital and the longer convalescent period, which lasts until all possible rehabilitative and surgical interventions have been performed and all grafts, scars, and donor areas are mature. The long final phase of wound maturation may begin in a rehabilitation center or take place as an outpatient in the home or both.

In actuality, all of these phases of healing overlap because an injury is rarely of a single depth, and varying parts of the body are also at different stages. However, there are general principles of rehabilitation and convalescent care that apply to all phases of healing. These general principles involve exercise, elevated positioning, orthotic management, functional activity, adaptive equipment, and psychosocial adjustment. Therefore, generic comments concerning each of these topics will be discussed initially, with details presented under each phase of wound healing.

Active exercise maintains range-of-motion, maximizes strength, minimizes edema, maintains endurance, and improves circulation, thereby speeding wound healing. Passive motion maintains range-of-motion. Proper and varied positioning decreases edema; minimizes contracture development; and prevents dislocations, neuropathies, decubiti, and complications of bed rest such as pneumonia or phlebitis. Orthoses help decrease edema, eliminate or minimize contractures, immobilize grafts for healing, increase functional use of an extremity, correct a deformity, speed healing, protect healing tissue, and modify scar deposition. Functional activity, with adaptive equipment, if needed, improves range-of-motion, fine motor dexterity, and overall endurance. It increases feelings of self-reliance, improves self-esteem, and hastens discharge from the hospital to a less supervised setting. Psychosocial adjustment includes counseling to reduce the initial shock; fear; anxiety; and symptoms, such as sleep disturbance, disturbing dreams, appetite disturbance, difficulty falling asleep, or frequent awakening during sleep. Later counseling provides interventions for complaints of too much or too little sleep, feelings of estrangement or detachment from others, recurrent intrusive memories of the event, memory impairment, difficulty concentrating, reluctance to accept a changed body image, exaggerated focus on pain or itching, decreased interest in sex, sensitivity to loud noises or other cues related to the accident, as well as irritability and fear of returning to active duty or work. Premorbid drug or alcohol abuse is best managed in an outpatient setting, during the wound maturation phase of care. Depression, anger, grieving, and changed sexual functioning are often other focuses of outpatient counseling.

Acute Phase of Healing

The goals in the acute phase of wound healing are to provide analgesia; assist wound closure; prevent infection; modify edema; maintain and improve joint and skin mobility, and improve strength and endurance; facilitate casualty and family participation in therapeutic procedures; improve self-care; achieve independent self-feeding, personal hygiene, use of phone, and writing; increase sense of security, competence, and self-worth; and provide appropriate outlets for anger.

Wound and Skin Care and Nursing During Acute Phase

The potential for infection related to the loss of skin can be a life threatening event for the burn casualty. Meticulous wound care is crucial. On admis-

Fig. 10-25. Range-of-motion exercises, unimpeded by dressings during wound cleansing.

sion all areas of the body should be exposed and inspected to determine the extent and depth of the burn injury. A complete head-to-toe secondary survey is also made at this time to ensure all associated injuries have been identified and are being managed appropriately. During this process, which involves wound cleansing and dressing procedures, universal blood and body fluid precautions should be used. This includes, but is not restricted to, the use of plastic aprons, gloves, hats, masks, and protective eye wear. The use of plastic aprons prevents contamination of scrubs with body fluids and also prevents cross contamination to other casualties.

The purpose of wound cleansing is fourfold: it (1) provides a total inspection of the burn wound to examine for any signs or symptoms of infection; (2) allows for cleansing and gentle debridement of the burn wound; (3) provides the opportunity for the cleansing of unburned areas and examination of areas for other trauma and skin redness or breakdown[48]; and (4) encourages unimpeded range-of-motion to the affected areas and complete evaluation of the casualty's range of motion (Figure 10-25).

Wound cleansing can be accomplished through a variety of methods, including use of a Hubbard tank or tub that may contain plain tap water or sodium hypochlorite solution with a ratio of 1:200 (1 part hypochlorite to 200 parts water). Casualties may be suspended over a tub and showered, a commercially available shower cart can be used, or a bedside basin can be used (Figure 10-26). Mortality, incidence of positive blood cultures, and length of hospital stay for patients treated with immersion or rinsing has been studied, and no statistically significant differences were found.[49] Time honored submersion in the Hubbard tank can provide reasonably comfortable soaking to remove dressings and a warm, gravity relieved place for exercise.[50] Its disadvantages include wound contamination from contact with intestinal bacteria that multiply in the bath water (avoided by water rinse over a tub or in bed); edema, when a body part is held dependent in the warm water; chilling if total body is exposed exiting the tub; frightening exposure, especially to children; increased itching from edema and drying; and rebound stiffness one hour after the immersion.

Debridement to remove devitalized tissue and foreign bodies is frequently done in the operating room under anesthesia. Épluchage, the removal of devitalized burned tissue by sharp dissection performed serially with premedication for pain,[52] is reserved for very large TBSA burns. Wounds are usually cleansed at least daily. Thorough cleansing can be accomplished by using a soft gauze sponge, and some burn centers may choose to use a mild antibacterial cleansing agent such as chlorhexidine (Hibiclens) (Exidine) or dilute povidone-iodine (Betadine). Care should be taken not to scrub the wound as this can traumatize damaged tissue possibly resulting in conversion to a deeper wound as well as increased pain for the casualty. Intact blisters should be left intact when they provide a physiologic protective layer over the injured part. However, in the case of chemical burns, the blisters should be debrided as they may contain sequestered chemicals. If blister fluid becomes purulent or the blister leaks, then it should be debrided. Any loose skin or eschar should be mechanically debrided to

Fig. 10-26. Shower trolley method of wound cleansing. Note the protective barrier clothing worn by the staff.

prevent a breeding ground for infection. Hair harbors bacteria and should be shaved in the burn wound and clipped or shaved around the burn wound.[52] The eyebrows are an exception and should never be shaved.[54] As hair bearing areas heal, hair follicles may remain sources of infection and shaving is continued until the wound is closed. After this, dry scalp is cleansed daily. Weekly wound cultures should be obtained to determine the microorganisms present. If the wound appearance or type of drainage changes radically, cultures should be obtained more frequently.

Special attention should be given to the perineum. If an indwelling Foley catheter is present, thorough cleansing of the area is important. Catheters should be removed as soon as possible. Thorough cleansing after each stool is important to decrease wound contamination from stool. If diarrhea is problematic, use of a rectal tube may be considered to decrease frequent soiling of the wounds. The balloon on the rectal tube should be deflated every 2 to 4 hours for 10 to 15 minutes to prevent pressure areas.

The nurse or emergency medical technician at the scene interviews the patient before intubation is done to determine allergies or sensitivities; medications being used; any preexisting disease such as hypertension, diabetes, epilepsy, schizophrenia, or cardiac or renal problems; or other situations such as recent fractures, chemotherapy, and alcohol or street drug use, which might complicate immediate care and rehabilitation.

Exposure to fire, smoke, chemicals, and products of combustion resulting in inhalation injuries can further complicate the burn victim's course of therapy. There may or may not be concomitant cutaneous injuries. A complete respiratory assessment should be based on the history of the injury. Respiratory injury should be suspected if the victim was in a closed space. The length of time the victim was exposed to smoke should be noted and also the types of items burning and the condition of the victim at the scene—burns of the face and neck; soot in mouth, throat, or nose; singed eyelashes, eyebrows, or nasal hairs; tachypnea, cough, hoarseness, or stridor. Diagnostic studies, such as arterial blood gases, carbon monoxide levels, and chest radiographs will provide a baseline to gauge future changes. Because of its high sensitivity and specificity, diagnostic bronchoscopy has become the preferred diagnostic study for identifying inhalation injury.[53]

Airway management in the respiratory compromised patient can be achieved by either endotracheal intubation or tracheostomy. The patient should be allowed to talk to family or communicate with the medical staff prior to intubation if the situation is not an emergency. Nasotracheal intubation is the preferred approach as it is a nonoperative procedure, the tube can be easily removed, and it poses less risk of bacterial contamination of the lungs. The use of a high volume-low pressure cuff is advocated with the cuff pressure adjusted to a minimal leak. Minimal leak technique is done to determine the least amount of air needed to seal the cuff on the trachea. This technique will decrease problems of stenosis and vocal cord damage, fistula formation, tracheal dilation, and allow proper

mechanical ventilation. Securing nasotracheal tubes in the patient with facial burns can be achieved by using umbilical tape or twill tape tied securely around the tube, then around the head. As facial edema increases and decreases, adjustments in the ties should be made. Ties should be changed to prevent accumulation of exudate or crusting of the ties.

If orotracheal intubation is used, a bite block should be placed between the teeth to prevent the patient from biting the tube and obstructing it. Advantages and disadvantages are similar to those for nasotracheal intubation plus the disadvantage of decreased ease of providing good oral hygiene in the orotracheal intubated patient.

Tracheostomy may allow for patient comfort and easier oral alimentation. Its disadvantages include increased risk of bacterial contamination of the lungs, trauma to the neck if burns are present, and greater risk of tracheal injury as tracheostomy cuff pressures are higher than endotracheal tubes.[54]

Mechanical ventilation is used in patients not able to maintain adequate spontaneous respirations. There are several respirator modes from which to choose to provide the appropriate therapeutic setting.

Control mode. The patient receives a breath from the ventilator at predetermined rates, whether or not the patient attempts to breathe.

Assist mode (assist/control). The patient receives a ventilator breath whenever an attempt to breathe is made; a minimal rate is provided if no attempt to breathe is made.

Intermittent mandatory ventilation mode. Regular predetermined breaths are delivered and the patient is allowed to breathe at his own tidal volume and, later, between ventilated breaths. This mode is frequently used for weaning.

Positive end-expiratory pressure (PEEP). PEEP improves oxygenation by improving ventilation to poorly or nonventilated lung segments and prevents alveolar collapse.

Continuous positive airway pressure (CPAP). CPAP restores the glottic mechanism of intrapulmonary pressure maintenance, which has been eliminated by intubation.

The use of medications may aid in the management of the ventilated patient. Appropriate analgesics and sedatives will reduce anxiety and allow patient and ventilator to work together. Sometimes the use of muscle relaxants is necessary to assist in this process. In a few cases, paralyzing medications are needed to allow adequate ventilation. Steroid therapy in inhalation injuries remains controversial. Generally, prophylactic antibiotics are not used as this may lead to the development of resistant strains of organisms.

Circumferential thoracic burns may restrict respiratory excursion and escharotomies should be performed to improved respiratory excursion.

Nursing assessments and duties include (*a*) breath sound assessment; (*b*) pulmonary toilet using aseptic suctioning technique; (*c*) notation of color, quality, and quantity of sputum; (*d*) turning patient and positioning; (*e*) postural drainage and chest physiotherapy if tolerated; and (*f*) monitoring for signs of infection and changes in sputum or growth of pathogens, fever, changes in vital signs, or chest pain. They also assist in monitoring arterial blood gas (ABG), chest radiographs, and patient's progress with weaning.

Once the patient is weaned and extubated, aggressive pulmonary hygiene is crucial in maintaining the patient's airway and maintaining pulmonary function within normal limits. Proper care includes frequent deep breathing, coughing, position changes, use of incentive spirometer, or nebulizer treatment, and provision of humidified oxygen. Suctioning may be required if the patient is not able to adequately clear secretions. Continued monitoring of ABGs or oximetry and serial chest radiographs is required.[55]

Constipation is a common side effect of analgesics. The nurse must monitor and treat this problem. Stool softeners, bulking agents, or laxatives should be used. Diarrhea may be a sign of impaction, *Clostridium difficile* infection, high osmolarity or high fat tube feeding, and proper evaluation must precede management decisions.

Weekly photographs starting at admission should be taken to document the course of wound healing. Photographs should include overall body areas as well as close-ups of individual areas and should be taken after cleansing and before dressing applications. Close-up photos with a measuring device next to the small open area or a decubitus are useful.

The nursing staff should closely examine splinted areas during dressing changes to detect pressure areas. Occupational therapists (OTs) and physical therapists (PTs) should periodically see the casualty during dressing changes. During this time, they can monitor range-of-motion without restrictive dressings, view open areas or areas of potential problems, and formulate a plan of action.

Awareness of environmental room temperature is important so the burn casualty undergoing wound cleansing does not become hypothermic or waste calories maintaining body temperature.

Room temperatures in the 80°F range are generally comfortable for the casualty. This temperature can be maintained by thermostat adjustment to increase the individual room temperature or by directing heat energy to the casualty using overhead heat lamps or heat shields.

The nursing staff monitors the casualty's level of pain and anxiety throughout the day as well as before and during painful procedures. Adequate analgesics are administered before and throughout these procedures. Patient controlled analgesia (PCA) is often appropriate when the casualty has an intravenous (IV) infusion in place. Long acting narcotics such as continuous morphine or methadone are given to relieve background pain that is continuous when other painful treatments are not occurring. Other relaxation modalities, such as deep breathing, guided imagery, and listening to music can also be instituted by the nursing staff to provide distraction and emotional support. These relaxation techniques should be introduced to the casualty and practiced by the casualty prior to painful procedures. Some casualties find they can also control their pain by participating in their care, whether it is helping to remove dressings or assisting in gentle wound cleansing. When casualties perceive they have some control over their care and treatment, anxiety, apprehension, and often pain, decrease.[56]

Burn wounds can be treated using an open or closed technique. There are advantages and disadvantages to both techniques. In the open method the topical antibacterial cream is applied directly to the wound and the wound is left open. This method allows for increased visualization of the wound, mobility unencumbered from bandages, requires less initial nursing time, and reduces cost of bandages. Disadvantages to this method may include increased risk to the casualty for hypothermia and trauma to the wound. Nursing staff must frequently reapply the topical cream as it dries out or is wiped off. Also, the sight of the open wound may be difficult for the casualty, family, and visitors.

The closed method utilizes a variety of gauze and or specialty dressings commonly used on burn wounds. This method of dressing usually consists of three layers.

1. Contact layer, such as fine mesh gauze or Adaptic (Johnson & Johnson), that transports secretions from the draining burn or acts as a protective barrier for healing wounds. This layer can be impregnated with the antibacterial cream.
2. An intermediate layer, such as coarse mesh gauze or burn pads, which cushions the wound and absorbs drainage.
3. The outer layer, consisting of Kerlix (Kendall Healthcare Products Co.) or Kling (Johnson & Johnson), which helps keep the other layers in position. It should conform to the body part in such a way as to avoid constriction secondary to edema.[52] Products such as Burn Net (ACME) also aid in keeping dressings in place without using tape. Special attention should be paid to fingers, toes, or areas where burn surfaces are adjacent. These areas should be individually wrapped so burn surfaces do not touch each other. This will help prevent mechanical trauma and minimize wound contractures.[52] Gauze should be wrapped distal to proximal in a gradient manner to allow for better circulatory return.

Nursing protocols should include proper positioning to prevent contractures and reduce edema. Extremities should be elevated above the level of the heart to decrease edema formation, promote venous return, and decrease pain. Frequent checks of circulation and peripheral pulse are important to detect circulatory compromise. Casualties with burns of face, neck, and head should have the head of the bed elevated to assist edema control and respiration. Also, casualties with head and neck burns should not have pillows conducive to flexion of the neck. Pressure on ear burns can be relieved by using plastic protectors, or foam donuts placed under the head instead of pillows. Care with tie tape placement for airways and nasogastric tubes must be taken to decrease the risk of chondritis. If the patient develops sinusitis from nasal airways and nasogastric tubes and these tubes cannot be discontinued, they are either changed to the oral types or a tracheostomy is performed. There is no definite time for a tracheostomy; it is left to the discretion of the surgeon in consultation with the pulmonary team. If the patient is going to require an airway for pulmonary toilet or ventilator use for a prolonged period of time a tracheostomy is preferable. Sometimes a tracheostomy is used to protect new fragile face or neck grafts.

Nurses monitor and apply the orthotics provided by the therapy team to ensure 24-hour compliance with proper alignment without decubiti. It is important for the primary nurse to facilitate open communication with the burn team members in regard to scheduling the casualty's activities to provide

time for medical treatments, occupational and physical therapy, and rest periods. Involving the casualty in the scheduling process frequently reduces casualty stress and promotes acceptance. Posting the casualty's schedule and any special routines regarding splints or exercises will also increase casualty, family, and staff agreement when an OT or PT is not working with the casualty. Optimal outcomes are achieved more readily with team consistency and harmony.

Ambulation or sitting up in a chair the day after injury, if not contraindicated, assists improved respiration; prevents pneumonia and orthostatic hypotension; and also assists the casualty in regaining strength, maintaining mobility, and feeling less passive. Casualties with leg burns should wear single or double elastic wraps when the legs are in a dependent position to increase venous blood return and decrease the pain associated with venous stasis (Figure 10-27). Cotton batting padding strips may also be needed on either side of the tibia to protect thin tissue over this bony prominence in the very old or thin person.

Whenever possible, functional activities around the clock should be encouraged. Not only should the burn team be aware of what the casualty is capable of doing in areas of self-care, but the family should know as well. Frequently, the burn team and family will do activities for the casualty that he is capable of independently performing. The casualty gains self-esteem and self-confidence by being as independent as possible. The family can be directed to participate with the casualty in activities such as applying lotion, organizing get well cards, answering mail, or playing games, rather than promoting casualty dependence by feeding the person.

Casualty and family education is an important factor in understanding and executing the treatment program. The nursing staff must be able to assess the casualty and family's readiness and ability to learn. Apprehension can be decreased and motivation increased with careful explanations and rationale given for all procedures. When the family is included, and has a good understanding of the burn treatment program, they are able to give better support to the casualty. Family members and the pa-

Fig. 10-27. Venous stasis, purple color of dependent tissue and proper elastic wrap support. (**a**) Venous stasis in dependent areas. (**b**) Blisters and vascular insufficiency in legs without venous support. (**c**) Double elastic wraps applied prior to dependent positioning or ambulation.

tient supply important information about the individual's past and present thoughts, feelings, wants, needs, and learning style, which contribute to more effective rehabilitation.

For the burn casualty, adequate nutrition is as vital as any other phase of wound management, for without it, wounds, grafts, and donor sites will not heal and the casualty becomes more susceptible to infection. The nutritional goal in the burn casualty is to achieve a positive or neutral nitrogen balance. Patients with minor burns under 20% TBSA usually can meet their needs with a high calorie, high protein diet and supplemental multivitamins. Casualties with more than 20% TBSA burn may require nutritional support via a feeding tube. Frequently, paralytic ileus is a complication found in the major burn casualty. The ileus generally will resolve in one or two days. With the restoration of bowel sounds, enteral feedings of an appropriate tube feeding supplement can be initiated.[48] These tube feedings can be infused continuously or intermittently by a controlled pump. Depending on the type of tube feeding product used and casualty tolerance, initial administration of hypertonic tube feeding, such as Traumacal (Mead Johnson) should be half strength at an infusion rate of 50 cm^3/h for the first 24 hours, then gradually increasing the rate and then the strength over the next few days. If continuous enteral feedings are used, it is important to check stomach residuals every four hours to ensure the stomach is emptying and prevent aspiration. This can be done by using a piston syringe, aspirating back the stomach contents, recording the amount, and returning the aspirate to the stomach. If the aspirate is greater in mL than 110% of the hourly rate or if the casualty complains of a very full feeling, the tube feeding rate should be decreased or tube feedings held until the residual decreases. Feeding tubes can be held in place by conventional taping methods provided the burn does not involve the face. If facial burns have been sustained, twill tape can be secured around the tube and then tied around the casualty's head (Figure 10-28). The knot should be on the side so the casualty does not lie on it. Also, the ties should be snug but not too tight and should be closely evaluated as edema fluctuates. Twill tape ties should be changed when face care is done.

Daily weights and calorie counts are important in assessing the casualty's nutritional intake and in evaluating progress. As wound size decreases and metabolic demands decrease, the caloric and protein requirements should also be reassessed to avoid overfeeding and excessive weight gain.[48] As the casualty becomes able to tolerate adequate oral nutrition, the enteral feedings are decreased. When nausea or vomiting are problematic, the nurse assesses the cause and, after consultation with the physician, alters the feeding program or administers antiemetics. Casualties with persistent ileus or other complications that would prohibit the use of enteral feedings will require parenteral hyperalimentation and IV fat to meet their nutritional requirements.[48]

Fig. 10-28. Feeding tube secured with twill tape.

Exercise during the acute phase of healing. For the purpose of discussion in this chapter, the types of range-of-motion will be defined as follows:

- Passive range-of-motion (PROM) is movement of the joint through the unrestricted range of motion, which is produced entirely by an external force and there is no voluntary muscle contraction. It is pain free, resistance free and is short of the anatomical end points of the joint or of the limit if a contracture or calcification are present. Movement performed without assistance or resistance on the part of the patient is considered passive exercise.
- Active assistive range-of-motion (AAROM) is movement in which assistance is provided by an outside force. The prime mover muscle for that joint needs assistance to complete the unrestricted motion. AROM with terminal stretch means the patient vigorously moves the joint through available motion, then the therapist gently stretches the joint in its proper plane of motion, toward the extremes of full motion. This is often used for burn patients to elongate contracting connective tissue in the healing wound. During the stretch the reddened,

healed wound blanches and then turns pink again. AROM is movement within the unrestricted range of movement, which is produced by active contraction of the muscles crossing that joint.[57]

- Prolonged stretch is a relatively long term position or equipment controlled stretch, characterized by objective torque application. It is different from all other range-of-motion definitions.
- Low load is applied for a very long, tolerable time relative to the load the joint is able to take. This type of stretch is used overnight or for a prolonged time and therefore must be tolerable for the long term benefit. It is similar to serial casting. Natural healing of burn wounds occurs by contraction, and this shortened connective tissue is particularly responsive to this sustained type of stretch. Low load, prolonged stretch has the additional benefit of gently, slowly overcoming muscular cocontraction by the casualty who is fearful of pain or who is confused and resisting all exercises. Casualties often request desensitization by vibration or massage of adjacent areas to assist them to relax during this type of stretching. Massage directly on the scar is often painful and until the healed scar is durable, may produce painful blisters, so is contraindicated. Distraction of joint surfaces in conjunction with this stretching may decrease pain and muscle spasm and increase the effectiveness of stretching.[57]

A thorough history is needed to determine the type of range-of-motion that will meet the casualty's, physician's, and therapist's mutual goals. Passive stretching is never used in the case of proximal interphalangeal (PIP) joints that have exposed tendon or joint capsule or burned elbows. Active motion decreases the risk of heterotopic ossification at the elbow joint.[58,59] All range-of-motion is contraindicated in cases of torn ligaments, tendons, or muscles; in the region of unhealed fractures; and immediately following surgical procedures to the skin, tendons, or surrounding soft tissue. Soldiers who sustain battlefront burns often sustain accompanying injuries such as penetrating wounds, fractures, or concussions in addition to skin damage.

Muscle soreness can be avoided by light warm up and warm down activities. When severe joint or muscle pain is noted during exercise or when pain lasts more than 24 hours, the therapist should evaluate the cause and change resistance, duration, speed, and frequency of exercise appropriately. When pain persists, consultation with the referring physician is also indicated.[60] Burn casualties seeking pain relief are often seen lying in a flexed, adducted position. This is the position of withdrawal from pain. When contractures develop, they are most commonly noted over flexor surfaces. Contractures in a flexed position are very difficult to alleviate because extensor musculature is usually much weaker than flexor muscles. An extended position is equally comfortable as flexion, once the tissue stretches. Immobility or rest does not relieve pain as well as analgesic medications; in fact, immobility increases pain because initially skin and later joint contractures quickly become resistant to being stretched. Casualties, friends, and relatives often believe the myth that "rest is the best way to heal a burn." However, burned soldiers do not become strong and flexible by passive motion or rest.

Therapists are encouragers. The acutely burned soldier, with the assistance of sufficient analgesics and sedatives, must move gently through full AROM each day to improve peripheral circulation, keep joints nourished, and prevent contractures or decubiti. The therapist is the resource. The casualty is the source of exercise and recovery. Together they collaborate to form the rehabilitation plan most appropriate to this individual injury, with foremost emphasis on active motion.

AROM is the only successful method of keeping healing burned tissue elongated. All areas injured, including the face, neck, bilateral upper extremities, hands, bilateral lower extremities, feet, and trunk require attention. Contractures of the flexor surface such as finger PIP, knee, and elbow flexion are noted most frequently. However, exercise in all planes of motion must take place. The core musculature receives primary consideration in order to stabilize the trunk, neck, and scapula during extremity exercise. It is a challenge to initiate active motion as soon as the casualty is admitted, especially when the injury is greater than 50% TBSA and occurred in combat. However, since passive treatments are ineffective in full recovery, it is important to provide analgesia and sedation levels adequate to enlist the casualty in early exercise such as bed mobility, reasonably comfortable dangling, getting up for bathroom care, sitting in the chair, and ambulation. The tilt table is an excellent preparation for ambulation when the casualty is too weak to ambulate independently (Figure 10-29). Tilt table positioning is begun before grafting is completed. Often the soldier will have many IV lines, a Foley catheter, and

Fig. 10-29. Standing table exercise. Daily living skill practice distracts the casualty during standing.

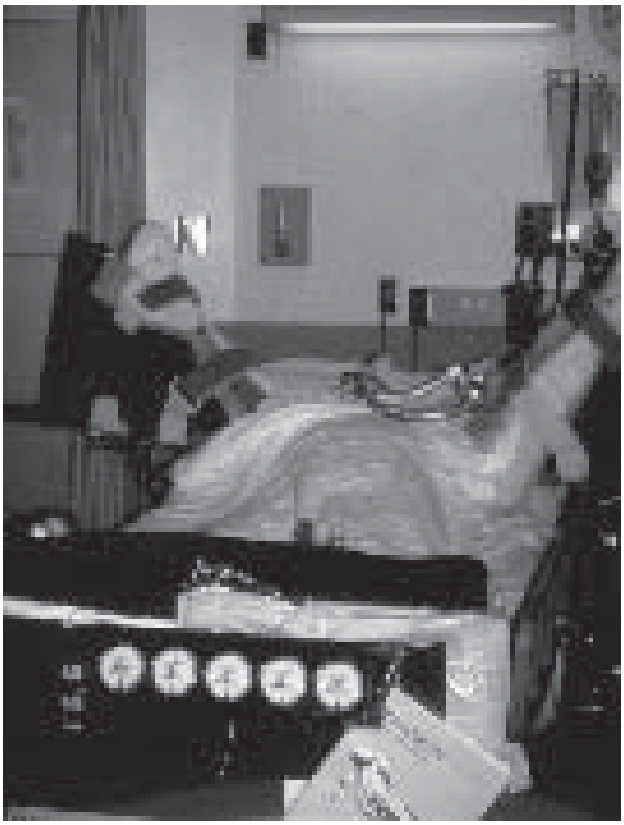


Fig. 10-30. Kinaire bed anticontracture bed positioning, neck extension, shoulders abducted to 90°, arms on wedges, hips and knees straight, and ankles at neutral.

chest and feeding tubes in place when the tilt table exercise is initiated. Tilt table exercise will often be combined with functional activities to help distract the person from wanting to return to bed.

The alert, cooperative casualty must learn to move past the painful range to the extremes of joint motion. Gentle terminal stretching is the least painful method of achieving this mobility. Active assistive exercises with terminal stretching teach the casualty how to move the body part and achieve the extremes of motion which are not used spontaneously during activity (Figure 10-30). Prolonged, vigorous stretch, although sometimes appropriate with a healed, contracted joint, is never appropriate with the early edematous burn. For the receptive casualty, PROM is unnecessary.

Exercise can be done during the bathing procedure and at other times during the day. If the bandages are dry and stuck or the xenograft has dried and is inflexible, pain will inhibit cooperation with full AROM. In this case, exercise during the bathing procedure will benefit the casualty; however, he may be distracted by wound pain, may not be able to do active motion, and pain medications will inhibit his ability to remember the exercises. If there is topical medication under the gauze bandages and they are wrapped in a loose figure-8 method that slides easily, exercise in the bandages is preferred by the casualty. In all cases the therapist and prescribing physician should observe the tissue with bandages removed during the stretching exercises at least twice a week.

Walking is one of the more comfortable early exercises. The use of an overhead walker provides a graded method of elevation and exercise for the upper extremities (Figure 10-31). Additionally, squeezing the overhead bar facilitates a "pumping action," thereby reducing edema in the upper extremities. The overhead bar is large enough to avoid damaging inflamed dorsal finger tendons during exercise. During the early treatment period, ambulation 3 or 4 times a day for 15 minutes, using the overhead walker, will maintain satisfactory shoulder flexion and elbow extension; wrist extension; gross fist of hand; and straight trunk, hip, knee, and ankle flexion and extension. Gentle daily elevated

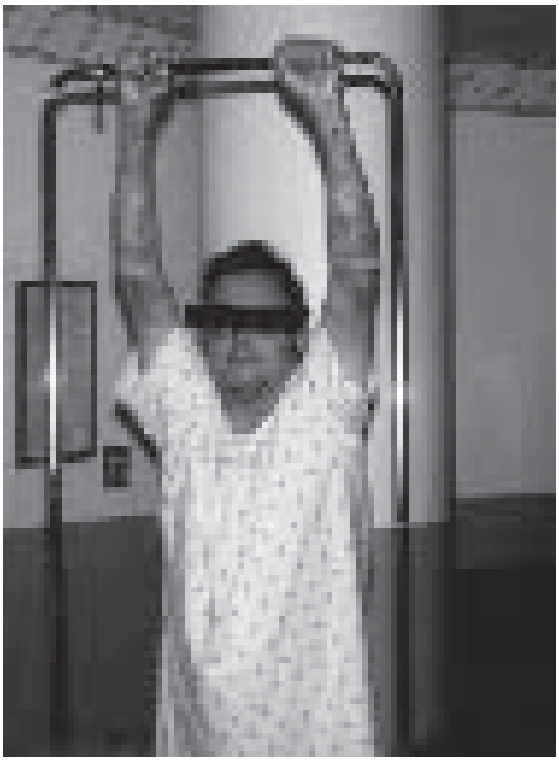


Fig. 10-31. Overhead bar connected to a wheeled walker used for hand exercise, arm positioning, and shoulder flexion.

active exercise not only prevents skin or soft tissue contractures, it also improves circulation and decreases complications such as pneumonia, pulmonary emboli, phlebitis, and venous engorgement. When exercise decreases edema and inflammation, the wound heals more quickly and there is less pain. Physical activity gives a person increased energy, and decreases depression[61] and insomnia, which also speeds healing.

Continuous passive motion (CPM) devices help to modify edema[62] and preserve motion when the joints and soft tissues are not yet stiff. However, casualties who are recovering from larger burns begin to develop stiff joints and contracting soft tissue during the second or third week after injury. Reciprocal pulleys, two-handed calisthenics, slow bicycling, and dowel exercises (Figure 10-32) have been safe methods of providing stretching motion. The casualty controls the speed and duration of the passive stretch. The therapist is the coach. Foam or rubber band grippers are safe early hand exercise devices. Liberal exercise choices and written graded programs assist when a casualty is hostile or obstreperous. It is reassuring to the casualty to be given as much control as possible in exercising, since he does not have control of most other treatment areas.

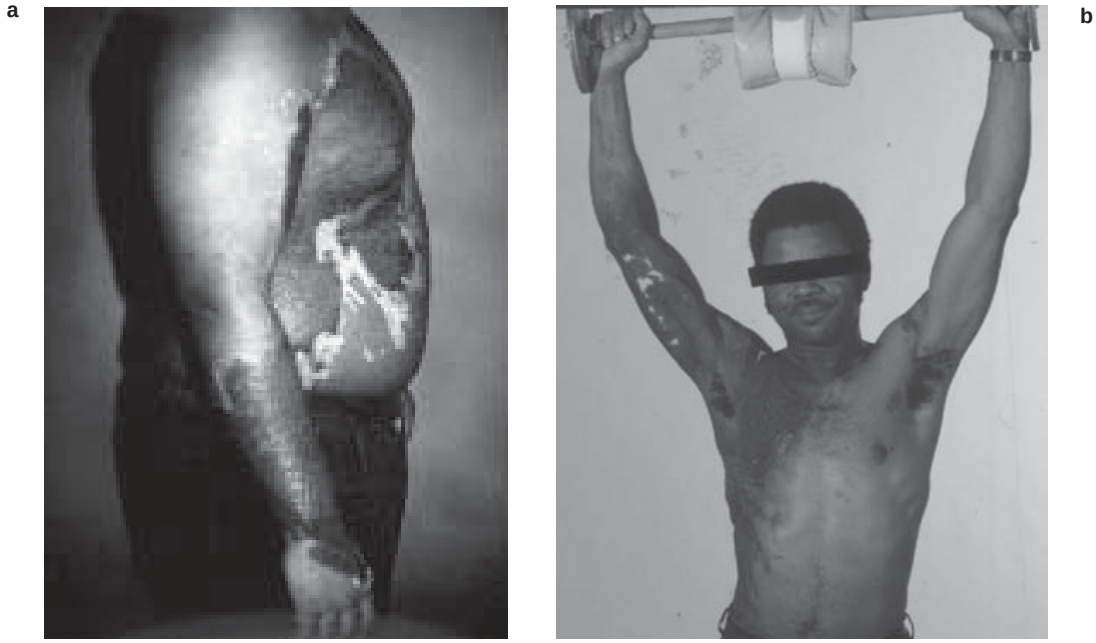


Fig. 10-32. Pigmentation of mature burn wound. (**a**) Hypopigmentation and hyperpigmentation, Caucasian person. (**b**) Hypopigmentation and hyperpigmentation of right arm and chest, African American person. Note the white areas on upper arm represent total permanent loss of pigmentation. Note the patient is using a dowel for overhead exercise.

After several weeks, when the casualty is not maintaining full AROM, it is very helpful to evaluate the range during anesthesia for some other purpose such as skin grafting. If full range-of-motion is present, the casualty should be encouraged to increase the frequency and vigor of independent elevated exercise. When inflammation is present, passive motion must be especially cautious. The therapist moves the joint very slowly and steadily in the proper plane of motion. The joint above and below the one being evaluated are stabilized. Gentle force; slow, steady speed; and correct orientation are the keys to safe range-of-motion. This is particularly true for evaluation when the casualty is anesthetized. The arm is not hyperextended or the shoulder stretched above 120° when the patient is under anesthesia.

The contracted elbow joint or the open PIP joint are never stretched passively, even under anesthesia. It may be possible to allow gravity to stretch the elbow joint into flexion or extension, if "gravity assist" positioning is permitted by the surgeon. In the case of serial or "drop out" casting, an elbow joint may be safely returned to the previous position in the cast if the soft tissue has not contracted more than 1 or 2 hours or the cast has not been off for a prolonged time (Figure 10-33).

Fig. 10-33. Drop-out elbow orthotic.

When the casualty is too ill for active motion, muscle atrophy and joint contractures develop quickly. Inflammation may contribute to heterotopic ossification or fibrosis.[63] Passive motion in the correct planes of motion for each affected joint is indicated except for the elbow joint or open PIP joints. Passive motion helps to prevent contractures, but will not prevent muscle atrophy. When the casualty is confused and combative, passive motion is indicated. However, when the casualty is causing increased inflammation by fighting restraints, positioning appliances, or passive motion, increased heterotopic ossification, wound breakdown and nerve damage are often observed. Team consultation is appropriate to determine safe parameters of increasing analgesia or administration of major or minor tranquilizers.

Electrical neuromuscular. Functional electrical stimulation (FES) has been used in general rehabilitation with the goals of retarding disuse muscle atrophy, reducing contractures due to weak muscles, and increasing venous and lymph flow in the stimulated muscles. It may be technically difficult to perform with burn patients during the acute stage. It does not replace AROM exercise and is not as effective as an active strengthening therapeutic treatment program even when used at a high current intensity. FES may not be comfortable or well tolerated on unhealed burned tissue. Its use in burn casualties may be better reserved for the maturation phase of burn care.

Intermittent compression using elastic wraps can be very effective in edema reduction when coupled with elevated positioning and/or elevated exercise. The elastic wrap needs to be applied uniformly to prevent a tourniquet effect and must have a greater perpendicular pressure distal to proximal. A mechanical device such as a Jobst Intermittent Compression Pump or a Wright Linear Pump (Wright) can be used when the patient is immobilized or resting. These two devices apply pneumatic pressure onto an extremity at selected pressure and time intervals. The pressure and time must be individualized to be within a patient's tolerance, but the pressure and time should be increased for maximum effectiveness. The pressure should not exceed the diastolic blood pressure. A typical Jobst pump starting pressure may be 40 mm Hg with a time interval of 1 minute "on" and 30 seconds "off" with the "on" time increasing to tolerance. The Jobst pump pressure is uniform throughout while the Wright pump delivers a sequential pressure pattern moving from proximal to distal allowing a "pumping" action to the edematous tissue. A typical beginning Wright pump program

would be distal chamber at 45 mm Hg, middle chamber at 25 mm Hg, and proximal chamber at 5 mm Hg pressure; a 2-minute cycle with the distal cell inflated for 90 seconds, distal plus middle cells inflated for 70 seconds, and all three cells inflated for 50 seconds, with a 30 second "rest" or "off" period. These devices should be considered when edema resolution can not be accomplished in another, more conservative fashion. They may not be well tolerated, and increased analgesia will probably be required. The overall treatment time using the pump is increased from 1 hour to overnight as tolerated. The pumps are more commonly used in the maturation phase of healing when the skin can better tolerate their use.

Daily, gently graded activity will diminish loss of strength, while it improves range of motion. This is accomplished by every member of the rehabilitation team actively encouraging the casualty and family to participate in self-care activities and continued exercise, despite the seriousness of the injury. The casualty is motivated by the increased speed of healing caused in part by exercise and activity. Presenting numerous different types of activity helps the casualty choose an activity that is interesting. Nerf games, bicycling, stair climbing, balloon boxing, and calisthenics are good exercises. Crafts, if volunteers or family members join the casualty in these projects, will reinforce activity.

Daily living skills such as independent use of the phone, self-feeding, shaving, brushing teeth, and self-toileting are excellent exercises for the upper extremities. Successful independence is motivating. Unlike repetitive calisthenics, which may be boring, a patient understands the importance of daily living skill practice and is usually motivated by a desire to regain independence. It is helpful for the casualty to keep in mind the goals of regaining maximum independence with the fewest possible scar bands and with the least possible disfigurement while he struggles with self-care or does uncomfortable exercises.

Positioning in the Acute Phase

Proper positioning is the alignment of body parts that is recommended for the burn casualty who is at rest, sitting, lying prone or supine, or standing. During the acute phase, antigravity positioning decreases the potential to develop contractures; assists venous return, which will minimize edema; protects the peripheral nerves from being stretched or further traumatized; assists proper respiratory function; and protects the healing wound. A past medical history of previous arthritis, strokes, brain injury, or residuals from previous trauma may modify the positioning plan. A thorough physical examination and sensory evaluation reveal accompanying injuries that must be considered when developing plans for prolonged positioning. After a burn injury, the inflammatory response initiates a process by which any position maintained for more than 8 hours without active motion causes early contracture formation.

The typical anticontracture bed positioning method would consist of neck extension, shoulders abducted to 90° and forward flexed 15°, elbows lacking 15° of extension and supinated, wrists and hands in functional position, hips extended and abducted 10° without external rotation, knees in extension, and ankles at neutral. There is, however, no single position that totally prevents contractures. (Typical anticontracture positioning—supine, prone, lateral decubitus are shown in Figures 10-30 and 10-34 and are detailed in Table 10-3.)

Fig. 10-34. Regular bed with hyperextension mattress anticontracture positioning, head on foam donut, arms on wedges secured to over-the-bed tables.

TABLE 10-3

TYPICAL ANTICONTRACTURE POSITIONING—SUPINE, PRONE, AND SIDE-LYING

	SUPINE	PRONE	SIDE-LYING
Anterior neck burns	Position in extension or hyperextension. A roll may be placed under the neck. A towel roll under the shoulders or along the spine hyperextends the neck. If contracture develops apply a soft neck collar.	Alternate head to side.	Position the neck in extension.
Shoulder burns	At 90° of abduction and 15° forward flexion (airplane position).	Abducted and externally rotated as possible.	Alternately position shoulder in 90° of flexion, elevate the arm above the level of the heart.
Wrist/Hand	Elevate wrist above elbow and elbow above shoulder. If contractures develop, apply antideformity burn wrist/hand orthoses.	If no orthosis, use glove vascular support for edema control.	If no orthosis, elevate the free wrist/hand.
Hip	Place hips in neutral rotation, 15° abduction, and extension.	Place hips in neutral rotation, 15° abduction, and extension. Avoid frog leg position.	Alternate right and left legs into flexion and extension.
Knee	Position in extension.	Position in extension.	Position the free (top) leg in knee flexion and the other leg in knee extension. Alternate.
Ankle/Foot	Elevate for edema control. Use AFO to control inversion/eversion. Position ankles in 90° of dorsiflexion.	Position ankles in 90° of dorsiflexion.	Position ankles in 90° of dorsiflexion with AFO. Elevate the free leg with a pillow to prevent pressure over the malleolus. If possible, alternate sides frequently.
Anterior elbow burns	Position in 15° flexion. If flexion contracture develops, position in extension using anterior orthosis. Midposition of supination/pronation.	Position elbows in extension when shoulders are not externally rotated.	Position upper arm in extension.

Each burned part of the body must be considered when planning positioning.

1. Ears: Pillows are removed. A foam donut or bandage positioning is used to prevent ear contact with the bed, (see Figure 10-34) pillows or tie tapes (see Figure 10-28). Irritation of ears increases the risk of chondritis. In the Kinaire (Kinetic Concepts) bed, horseshoe cutout pillows protect the ears and allow neck hyperextension simultaneously.

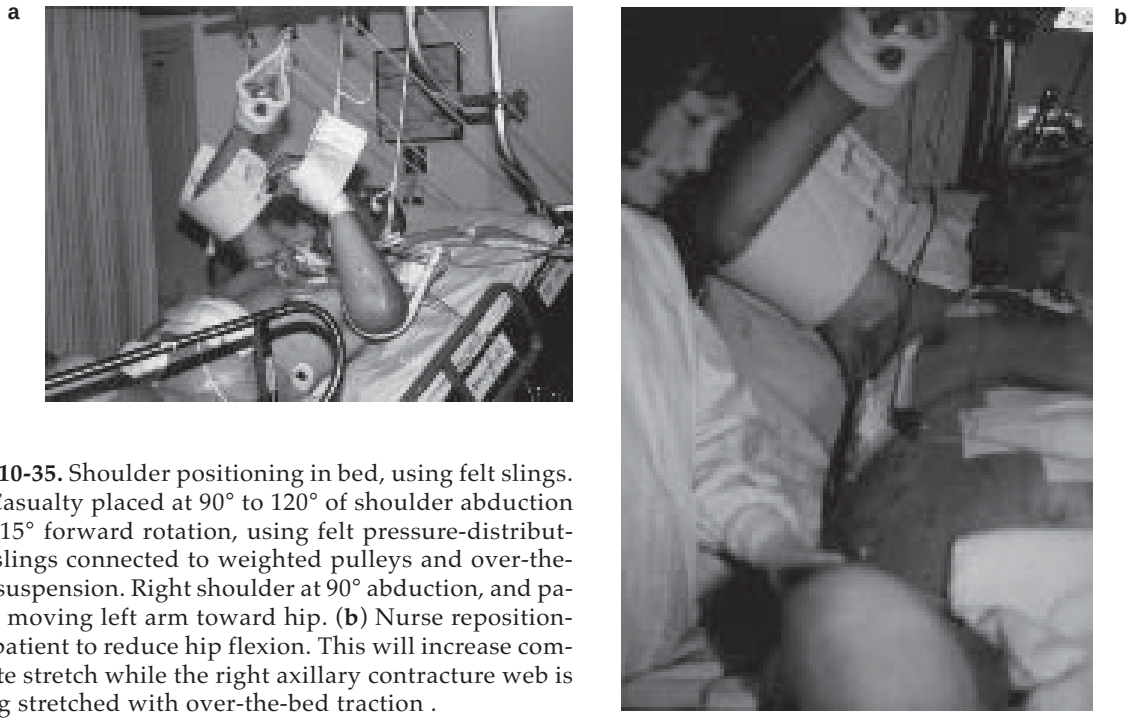


Fig. 10-35. Shoulder positioning in bed, using felt slings. (**a**) Casualty placed at 90° to 120° of shoulder abduction and 15° forward rotation, using felt pressure-distributing slings connected to weighted pulleys and over-the-bed suspension. Right shoulder at 90° abduction, and patient moving left arm toward hip. (**b**) Nurse repositioning patient to reduce hip flexion. This will increase composite stretch while the right axillary contracture web is being stretched with over-the-bed traction .

Fig. 10-36. Skin foam extremity suspension assembly. Note that the left hand is elevated on a wedge and MP flexion is preserved with elastic roll in palm.

2. Nose: A foam face support with a cutout should be used when the person is prone. Wide tie tapes are used to widely distribute pressure under the nose when nasal airways or feeding or gastrostomy tubes are being secured. These tubes may become a source for contamination and sinus infections and therefore should be removed as soon as practical.
3. Mouth: When the person is on a ventilator, the bite block safely positions the jaw and oral opening.
4. Neck:
   - Bed: Neck extension may occur over a crescent cutout in the air flow cushion bed, a foam wedge cutout in the fluidized air flow bed, or a foam elevation wedge or short mattress with a regular bed (see Figures 10-30 and 10-34).
   - Sitting: A pillow behind the scapular area will allow neck extension in a recliner chair.
5. Shoulder:
   - Bed: Slings to a weighted pulley and over-the-bed suspension traction support the shoulder at 90° to 120° of abduction and 15° forward rotation (Figure 10-35). An extremity suspension assembly, foam (Figure 10-36), or stockinet suspension to over-the-bed traction positions the arm

Fig. 10-37. Anticontracture sitting position. Foam wedges are secured to the bedside table.

at 90° forward flexion or a foam arm elevation wedge positions the shoulder in the mid position (see Figure 10-34).
- Sitting: Deltoid aids, foam arm elevation wedges secured to chair armrests or elevating table's position (Figure 10-37) shoulder at 90° and elbow above heart.
- Standing: IV pole or overhead bar connected to a wheeled walker for elevated arm position and shoulder flexion (see Figure 10-31).

6. Elbow: The wedge positions the elbow in supination and lacking 15° of extension to avoid tension on the brachioradialis muscle. It is useful for sitting or supine positions. An IV pole, traction-type bar, or over-the-bed bar is needed for standing.
7. Wrist: The wrist is kept in a neutral position if the hand is strapped into the elevation wedge. If a bandage roll is placed into the palm, the wrist is extended about 15°. In bulky "Robert Jones dressings" for over-the-bed suspension, the wrist is positioned in the mid position. Care must be used to allow Doppler monitoring of peripheral pulses.
8. Hand: When the hand is the only burned area, pillow elevation may be adequate. An arm elevation wedge (see Figures 10-30, 10-34, and 10-37) with an elastic wrap roll can preserve the first web space and decrease edema while protecting the elbow and shoulder (see Figure 10-36). In the acute phase, the fingers should be included in a bulky wrap to prevent impaired distal circulation. If bulky wrapping is not used, the fingers should be wrapped separately to encourage motion (Figure 10-38) and the arm should be elevated.
9. Hip:
   - Bed: The hip is best positioned in full extension with 10° abduction and no external rotation (see Figures 10-30 and 10-34). A trochanter roll may be needed to maintain this position when the patient is supine.
   - Sitting: The hip should be positioned in as much extension as possible if the patient is in a recliner chair, alternating with flexion to 90° unless this is contraindicated because of cellulitis.
   - Standing: The patient should fully extend the hip when walking, and hyperextend the hip with a normal gait pattern.
10. Knee**:**
    - Bed: Knee extension is the position recommended for the majority of time. The "frog leg" position should be avoided to prevent peroneal palsy. When the patient is prone on the air-flow bed, this position is facilitated by tucking the toes between air flow cushions. For short periods of time, the knees may be flexed, as when turning side to side, or just by elevating the foot of the bed.
    - Sitting: The knee should be positioned in full extension, alternating with flexion to

Fig. 10-38. Fingers are wrapped separately in Sof-Kling.

90° unless this is contraindicated because of cellulitis.

11. Feet and ankles:
    - Bed: The Kinaire (Kinetic Concepts) foot cushion is usually adequate unless neurological complications or inadequate analgesia are causing plantar flexion (see Figure 10-30). A cutout in a foam block makes pressure on burned soles of feet more comfortable and can be used for elevation. A foot board can be helpful for ankle positioning when the casualty is supine. Ankle position for prone persons includes placing the foot over the end of the mattress or between foam cushions in Kinaire beds.
    - Sitting: Feet will become edematous if kept dependent for long periods. The ankle can be kept at 90° by the back of a straight chair, if a pillow is placed on the seat to relieve pain and pressure over the calcaneus.
12. Miscellaneous**:** Creative use of slings, sandbags, and sponge positioning devices assist in reducing edema and protecting the healing wound. The ROHO (ROHO, Inc.) bed and wheelchair cushions can also be used creatively for positioning. At times a chair may have the back replaced with a padded dowel to allow air flow to open wounds which are not healing.

Orthosis During the Acute Phase

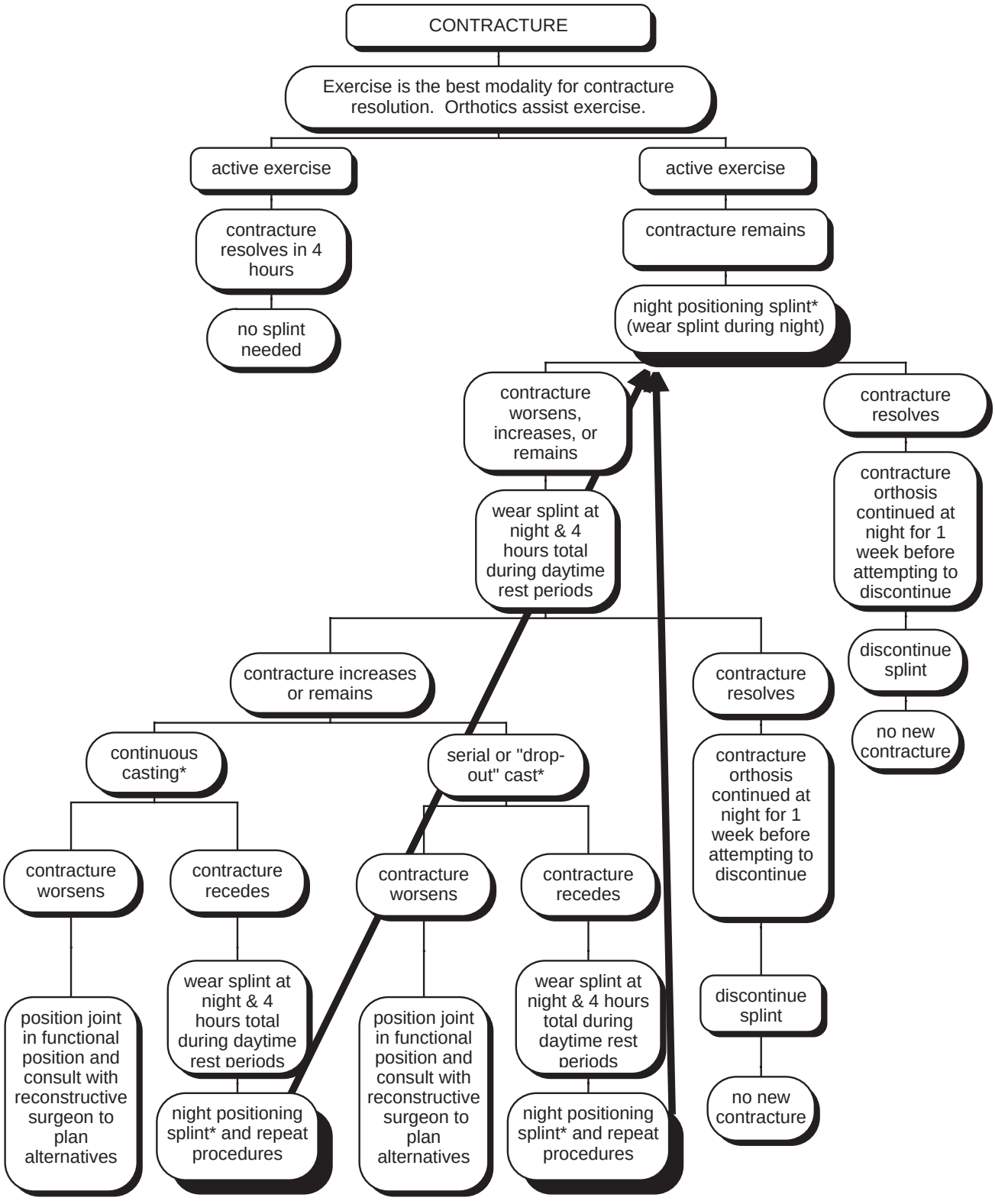
A splint or orthosis is an orthopedic support often used as an adjunct to postburn antigravity positioning. Orthoses are made of low temperature thermoplastic, high temperature plastic, foam, plaster, elastomer or silicone, metal, molded leather, wood, reinforced cloth, and any other material to immobilize a body part or redistribute pressure. An orthosis that has elastic outriggers or attachments to provide stretching or to replace absent function is called a dynamic splint. Static splints are fitted to individual body parts of the burned person who is unconscious or is unable to maintain full AROM by positioning and activity. The purpose of the orthosis in this stage of healing is to immobilize an unstable joint, prevent formation of nonfunctional contractures, keep ligaments in optimal position, protect exposed soft tissue or bone, or assist with antigravity positioning. When antigravity positioning is unsuccessful in managing edema or range of motion, an orthosis is fitted. For the comatose or resistive patient, orthotics may protect the healing wound. Continuous motion splints help reduce edema. However, splints never replace AROM exercises. Resting thermoplastic splints are often custom fitted to the burned person. Sometimes off-the-shelf splints such as LMB (North Coast Medical) foam wire positioning orthoses are prescribed. Whenever possible, active motion replaces orthotics as soon as possible for the optimal outcome.[64]

The indications and contraindications for splinting and casting can be displayed as an algorithm (Figure 10-39).

When evaluating the need for an early hand orthosis, the patient is asked to extend and abduct all fingers and thumb with the wrist in a neutral position. If there is lack of extension of the PIP and distal interphalangeal (DIP) joints (ie, early claw deformity), then a splint may be needed. If this extension lag does not resolve in 4 days, a resting orthosis is definitely needed (Figure 10-40). Often, finger extension troughs or foam extension wraps are used in addition to the resting hand orthosis (Figures 10-41 and 10-42).

The initial burn edema distends the loose, dorsal hand skin, exerting a force on all the joints, which is more exaggerated if the hand is burned. This pulls the metacarpophalangeal (MCP) joints into hyperextension, the thumb into adduction parallel to the second metacarpal, and the inerphalangeal (IP) joints into flexion.[65] The typical resting hand splint is discussed in the next paragraph. When the dorsal hand tendons or joints are exposed, however, the burned fingers are splinted in extension to prevent the central slip of the extensor mechanism from being thinned or stressed. When a rupture of the exposed extensor tendon occurs, the lateral bands of the mechanism slip past the fulcrum of the PIP joint, to become flexors. Over time a boutonniere deformity forms, with the PIP joint in flexion and the DIP joint in hypertension.[66,67] (Figure 10-43) When the extensor mechanism ruptures, the finger PIP joint should be splinted on slack in extension and immobilized until the tendons are granulated, reepithelialized, and stable. This can take up to 6 weeks.[68] After this immobilization, the finger can begin active motion and gradually be stretched into as full flexion as possible. Extension, through the healed scar tissue, may be adequate for most motions.

For a dorsal hand burn a lightweight thermoplastic wrist, hand, finger orthosis (WHFO) is fabricated in the following position[69,70] (see Figure 10-40). Wrist extension of about 20° prevents engorgement in the carpal tunnel area, allows thumb abduction positioning and prevents tenodesis action of MCP hy-



•If open area develops, remodel orthosis to relieve pressure.

Fig. 10-39. Algorithm for use of orthotics or casts.

Fig. 10-40. Wrist, hand, finger orthosis for hand. Note that the arm is elevated on a foam wedge with arm cut-out.

Fig. 10-41. Wrist, hand, and finger orthosis, secured with Kerlix wrap.

Fig. 10-42. Finger wraps. (**a**) Coban wrap. (**b**) Tubiton Oedema sleeves. (**c**) Regular Tubiton size 01. (**d**) Tubiton on finger applicator. (**e**) Finger elastic wrap sleeve. (**f**) Expandover adhesive wrap. (**g**) Lois M. Barber (LMB) Velcro closure. (**h**) Open LMB finger wrap. (**i**) Else roll. (**j**) 2-inch elastic wrap.

Fig. 10-43. Boutonniere deformity.

perextension, which occurs in wrist drop. Metacarpophalangeal joints are flexed to 50° to 65° with the little finger flexed most, ring finger slightly less, progressing toward the index finger to accommodate the ulnar hand mobility. At 90° or 45° MCP flexion, the cam action of the metacarpal head allows shortening of most of the fibers of the collateral ligaments. In flexion, the cam action also limits most abduction or adduction of the fingers at the MCP joint. MCP flexion, once lost, is very difficult to regain due to complex hand anatomy. Therefore, the MCP joints are positioned at about 55° flexion. The PIP and DIP joints are positioned at 0° flexion, which has been described as the "safe" position or the "intrinsic plus" position. The lateral bands of the interosseous muscles and especially lumbrical muscles (sometimes called oblique retinacular or "Landsmere's ligament"), which originate from the lumbrical and finally attach at the middle and terminal phalanx, are on slack with the PIP joints extended. These may shorten and require slow, prolonged stretching to allow flexing the proximal phalanges when the MCPs are extended. The extensor digitorum longus muscle must be relaxed to allow flexion at the PIP and DIP with extension at the MCP joints. The hand bends at the midpalmar crease not at the junction of the finger with the palm. The splint bend should therefore be seen proximal to the palmar crease. If it is impossible to extended the IPs and flex the MCPs on the palmar support of the orthosis, the splint MCPs are flexed too much given the edema and subsequent loss of mobility. The palmar finger support should not be wider than necessary to support the fingers. If it is made too wide, PIP flexion can more readily occur when the orthosis is secured. Sufficient individual finger wraps at the distal phalanx will prevent lateral finger decubiti. Full IP extension is used for the early splint. Full extension puts collateral ligaments at the PIP joint on stretch. When the burn depth damages the dorsal hood mechanism of the finger and reconstruction is not possible, the hand is positioned in a "functional" position. In this case the functional position that is commonly recommended is 25° flexion of DIP joint and 40° flexion at the PIP joint. This allows functional opposition to the lateral finger to the thumb if MCP motion of the fingers and thumb carpometacarpal motions are preserved. Kept in this functional position, either spontaneous joint fusion will occur if the cartilage has been destroyed by the injury or septic joints or else the fingers will contract to this most functional position. Spontaneous fusion with the joint flexed more than 45° results in a painful and nonfunctional finger. If a mallet finger develops, the DIP joint should be positioned in hyperextension and held there until the extension lag resolves or for 6 weeks to restore the extensor integrity.

The thumb web space is best preserved if the thumb is positioned 15° radially. In addition, the thumb MCP and IP are flexed 5° to avoid hyperextension contractures. The thumb is then positioned away from the palm as far as the hand will allow. This is the most optimal position used to prevent burn deformity (Figure 10-44). This positioning is generally used for all burns, whether circumferential, palmar, or dorsal. If the burn is only palmar, a dorsal, "open palm" splint may be used to immobilize finger tips in extension and maintain a neutral wrist position. This splint must be secured with a wrap that supports circulation in a gradient manner from distal to proximal. Wrist straps are never used. However, when healing is causing a contrac-

Fig. 10-44. Classic burn claw deformity.

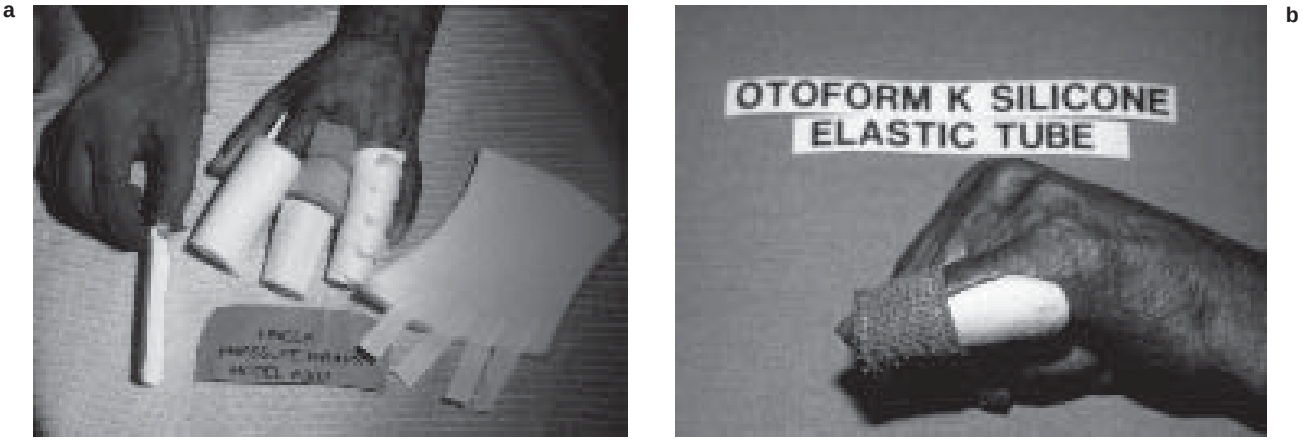


Fig. 10-45. Finger splint secured with external vascular support. (**a**) Finger pressure wraps. Note finger trough being held in patient's right hand. (**b**) Silicone finger trough secured with elastic tube.

ture band in any specific direction, the splint is changed to stretch and put direct total contact pressure on that specific collagen band. Serial casting becomes the static modality of choice.[71-73] Quick, easy off-the-shelf burn splints are advertised commercially but are rarely indicated. These rarely fit. They often block MCP flexion; the thumb web is not adequately radially abducted so the thumb web space is not maintained; the plastic is not adequately rolled away at the wrist, potentially impinging on the excised radial thumb area; and the plastic is often not rolled away from the hypothenar area to allow proper relief.

Early burn splints are secured with a bias gauze wrap such as Kerlix (Kendall Healthcare Products Co.) (see Figure 10-41) wrapped from the most distal end to proximal in a gradient manner. Securing an early burn splint with straps is contraindicated since straps do not allow for changing edema, often compromise circulation, and do not evenly distribute pressure over the edematous extremity. Elastic wraps are rarely used in the early phase to secure an orthosis or to distribute pressure because the fragile epithelium can be damaged by nongradient wrapping. When a casualty says his elastic wrap, an orthosis, or Unna (ER Squibb & Sons) dressing is too tight, or if there is any pain or numbness in the wound or distal anatomy, he must be seen and the device removed, revised if necessary, and replaced. Ignoring a casualty's complaint that leads to a pressure sore or tissue loss of any kind is unacceptable. When redness or sores are observed by the physician, nurse, or patient, the therapist should be notified and a heat gun used to flare out an edge that is rubbing or bubble out an area that is creating too much pressure. Pressure areas can cause nerve damage or convert partial thickness skin injury to full thickness damage. Padding a pressure area only increases the pressure. When adjustments increase comfort, the casualty's concurrence for splint wear increases. Tape is rarely used on splints or to secure them because it becomes sticky when in contact with drainage or topical medications, traps bacteria, may dislodge healing epithelium, and is difficult to clean.

Digits begin to contract as hand wounds are healing. Thermoplastic or silicone troughs may be applied to fingers to decrease edema and straighten the joints (Figure 10-45). These may be worn in conjunction with the resting hand splint. LMB (North Coast Medical) foam finger pressure wraps are another extension alternative. Interdigital web spacers of soft material such as Webril (Kendall Healthcare Products, Inc.) is often begun at this early stage if the webs are healed (Figure 10-46). Frequent splint readjustments are needed in this phase as the edema usually decreases rapidly with proper elevation.

The Iowa City, Buckner Microstomia Prevention Appliance (MPA) can be used to provide prolonged horizontal stretch to the mouth overnight, for several 15-minute periods, or for hourly 5-minute periods during the day (Figure 10-47).

A custom formed foam sandal or the Parkland shoe[74] may also be needed for comfortable early ambulation. If foot drop is noted, an ankle foot orthosis (AFO) is often used as an adjunct to positioning and ambulation to preserve ankle dorsiflexion. The foam off-the-shelf AFO is often adequate for ankle management if the calf is not unusually edematous or large.

Fig. 10-46. Isotoner gloves. Felt interdigital web spacers and individual Tubiton finger sleeves are worn under the Isotoner.

Splint wearing schedules vary depending on the type of splint and the wound condition. An antideformity positioning splint is usually worn 24 hours a day if edema is present, if tendons are exposed, when the casualty is comatose, or is uncooperative with exercise. As wounds heal, splint wear is decreased to nighttime and rest periods so that the casualty may use his extremities during the day.[68] When needed, functional splints are worn during the day to facilitate independent daily living skills. These orthoses are discontinued as quickly as possible to prevent dependence and quickly increase independence. The wearing schedules should be updated daily by the therapists and nursing staff and made available for the patient, family, and physicians. Commercially available and commonly used orthotic materials are found in Table 10-4.

Precautions to observe during orthotic use include monitoring the fit to prevent unnecessary pressure sores or discomfort to the casualty and observing protruding digits for circulation, motion, sensation, and temperature (CMST). If the digits are blue or purple and cold to the touch, or blanch and refill is impaired, the device is too tight and should be removed immediately. An additional precaution is observing the skin for any areas of breakdown caused by pressure from the device or friction from casualty's movement. When the orthosis is first used it should be checked within 2 hours. If the device is not causing any problems, the time can be increased gradually, but at a minimum, the skin needs to be inspected daily. If open areas are observed, a nonadherent contact layer such as Adaptic (Johnson & Johnson) or Xeroform (Chesebrough Ponds, Inc.) is used under the orthosis. Open areas often heal more rapidly under a cast, where the casualty and staff cannot disturb the fragile epithelium. However, ointments under a cast may slow reepithelialization, and, therefore, the use of antimicrobials must be discussed with the physician.

Fig. 10-47. Iowa City Buckner Microstomia Prevention Appliance.

The deleterious effects of prolonged immobilization of the synovial joints demonstrated by numerous orthopedists,[75] was the basis for the development of CPM machines. In 1988, over half the burn therapists participating in the OT/PT special interest group used CPM devices with their burn population[62] (Figure 10-48). There are two basic CPM designs: One is the anatomical design that moves the joint in an arc of motion as similar to actual anatomical movement as is possible with a machine. The other design is free linkage that provides motion to adjacent body parts, such as the forearm, and allows the joint such as the elbow or shoulder to move as it is able.

Anatomical motion is probably more comfortable for the patient. Most of the machines can be set to pause at the end range and resemble slow, prolonged stretch. Machines may be portable, freestanding, or attached to a bed or chair. Those who are most likely to benefit from use of CPM in addition to customary physical and occupational therapy include individuals who have burns involving multiple joints; comatose patients; and patients who refuse active motion because of pain, swelling, or anxiety. There are many brands of CPM machines and one is usually rented from a medical supply provider for use a month at a time.

The hand CPM device is effective in restoring hand range-of-motion when supervised by an experienced therapist. It does not damage skin grafts or newly healed tissue and the pain experienced is

TABLE 10-4

COMMONLY USED ORTHOTIC MATERIALS

Commercial Name	Usage
Polyform	Conforms perfectly to all indentations and projections in "hard to mold" areas such as the thumb. Works best for gravity assisted positions because of its draping ability. Splints must be placed in exactly the same position each application because of comformability. Conformability keeps splint from applying pressure over a scar. Cannot be remodeled.
Ezeform	Does not conform to body parts as exactly as polyform. Drapes well for both gravity and antigravity positions, but is more stretchy. Can be heated and remolded easily. Good for hand or wrist based splints that may require frequent readjustments. Because it is a rigid material, it is stable during a prolonged stretch.
Orthoplast	Best for large splints as it doesn't drape or overstretch. Can be applied to the extremity with an elastic wrap. Good for axillary conformers, ankle foot orthoses, or elbow splints.
Polyflex	Good for circumferential splints such as the elbow hinge splint because it is flexible and has some memory, making it easier to remove from the extremity.
Aquaplast	Good for small finger splints because it is light, durable, and thin.
Fiberglass	Light, strong, good for walking casts or casts which will need strength. Does not conform well to small digits or scars. Makes very little mess, sets up fast, and is durable. Rolls come in various widths so can be used for small and large casts.
Plaster strips or rolls	Drips when mixed with water. Allows more time to mold the cast properly because it sets up slower than fiberglass. Plaster casts are heavy.

Fig. 10-48. Continuous passive motion machine during acute phase. Patient simultaneously using right shoulder, left elbow, and right knee devices.

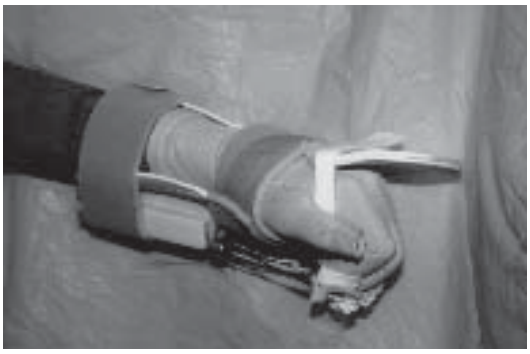


Fig. 10-49. Hand CPM device during acute phase. An Isotoner glove with Velcro strips is used to secure fingers.

the same as that with conventional hand stretching and exercise therapy[76] (Figure 10-49). Present models that include the thumb are difficult to position in a way that the thumb does not rub against the index finger. Finger motion alone is adequate to decrease hand edema. Adaptations can be made to block MCP or PIP motion and some splints can be used over the dorsum of the hand to achieve improved composite MCP and IP flexion.

One model of the shoulder CPM that attaches to the bed and moves the shoulder through 180° of flexion is helpful in preventing axillary scar bands, as well as in nourishing the shoulder joint cartilage. Another model moves the shoulder in a figure-8 pattern when the patient sits in a special chair but does not move the shoulder joint beyond 100° of flexion (see Figure 10-48). Other brands move the wrist up a bar to increase shoulder range and allow ambulation while wearing the device.

The elbow CPM can be set for low load stretching and auto reverse, so there is little risk of trauma. The mobility of elbow flexion and extension (see Figure 10-48) as well as pronation and supination can be addressed. When set for gentle motion, this device should not cause heterotopic ossification.

Knee CPM machines used during rest periods also provide improved motion at the ankle and hip (see Figure 10-48). These CPMs are useful until ambulation is possible, or longer, if joints are resistant to contracture reduction.

Functional Activities and Adaptive Equipment During Rehabilitation

General considerations. Participation in the functional activities of daily living (ADL) (daily living skills) is a very important aspect in the rehabilitation of the burn casualty.[77] Daily living skills include mobility, self-care management of environmental hardware and devices, communication, and home management activities. These major classifications are further defined as follows: (*a*) mobility includes movement in bed, wheelchair mobility and transfers, indoor ambulation with special equipment, outdoor ambulation with special equipment, and management of public or private transportation; (*b*) self-care includes feeding, bathing, toileting, grooming, and dressing activities; (*c*) management of environmental hardware and devices includes the ability to use telephones, doors, faucets, light switches, scissors, keys, windows, and street control signals; (*d*) communication skills include the ability to write; operate a personal computer; read; type; or use the telephone, a tape recorder, or a special communications device; and (*e*) home management activities include marketing; meal planning and preparation; cleaning; laundry; child care; and operating household appliances, such as vacuum cleaners, can openers, ranges, refrigerators, electric mixers, and hand operated utensils.[78]

There are numerous benefits gained from the independent performance of functional tasks and activities. Physical benefits include improving range-of-motion, fine motor dexterity, and overall endurance. The psychologic benefits include feelings of self-reliance, improved self-esteem, and more positive feelings regarding the future. Early involvement of the individual in the planning and implementation of functional activities allows the casualty to more easily resume life roles and decreases posttraumatic disability later. Independent performance of ADL hastens the discharge from the hospital to home or a less supervised setting.

Several factors can influence the overall outcome of a functional activity program. These factors include medical status (percent of TBSA, degree and location of burns); age; degree of cooperation and motivation; premorbid physical, psychological, educational, intellectual, economic, and functional status; and social resources. Additional factors that impact independent living include memory loss from medication, pain or severity of illness, cognitive changes due to anoxia or accompanying head injury, preburn or medication-induced impaired judgment, depression, and pain. Successful programs involve the casualty and family with prioritization, goal setting, and problem solving for accomplishing functional activities.

Functional activity performance can be analyzed in terms of independence, speed of performance, and safety factors when considering how a casualty accomplishes tasks. Independence in daily liv-

ing skills can be achieved in a number of ways. Burned soldiers need to perform daily living skills without adaptive equipment, using repetitions to achieve improved strength and endurance. When adaptive equipment is used in the earliest phase of rehabilitation, it should be discontinued as soon as possible. Recommendations for usage of adaptive equipment, alteration of the task, employment of adaptive techniques, or modification of the environment are provided as appropriate by OTs.

Functional Activities and Adaptive Equipment During the Acute Phase

Precautions to observe during the acute stage include maintenance of good skin integrity; preservation of exposed tendons; prevention of edema in dependent extremities; avoidance of increased shoulder, elbow, and hand contractures from using adapted equipment; and prevention of pain exacerbation.

Self-feeding is encouraged despite hand burns. Often, conventional silverware with an elastic roll to enlarge the handle, if needed because dorsal hand tendons are exposed, and an elevated table are adequate to encourage self-feeding (Figure 10-50). Adaptations for self-care are discontinued as soon as possible to avoid dependence and to increase hand and upper extremity range of motion. However, adaptive equipment facilitates self-feeding for the casualty in need of it, such as one who is burned more than 70% or an electrical burn at the acute stage of burn rehabilitation. Adaptive feeding devices include long handled silverware, utensils with built-up handles (Figure 10-51), and a universal cuff for a utensil, or a roto cuff with utensils. Universal cuffs with Velcro or D-ring attachments allow independent application. Expanded universal cuffs can be fabricated for bulky dressings, casts, or splints. For the individual with severe limitations of motion, additional devices such as bent-angled silverware are available to use if wrist radial deviation is permanently limited. Utensils with extensions can replace mobility of the trunk or neck as well as decreased shoulder or elbow flexion. Utensils with a swivel attachment (Figure 10-52) and utensils with horizontal handles replace forearm supination. Vertical handles can be used when the forearm is fixed for midposition. A rocker knife can be used for cutting when a person is permanently unable to use one hand.

Fig. 10-50. Encourage independence in self-feeding without adaptive equipment. Here the casualty is using an elevated table.

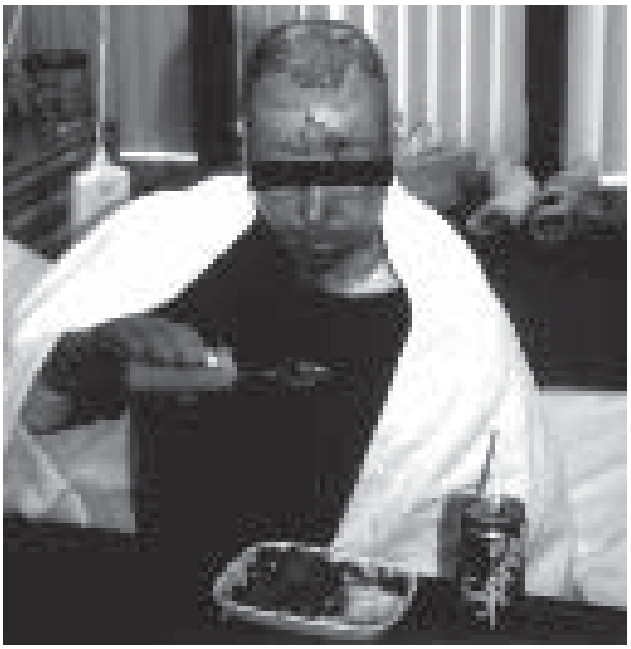


Fig. 10-51. Adaptive feeding utensil: a built up handle. Dycem is used on the table top to create a nonskid surface.

The following are a variety of aids for drinking: a long straw held in place by a straw clip (Figure 10-53), adaptive mugs and glasses, easy grip mugs with protruding handles, glasses with a cutout area by the nose, and bilateral glass holders. Sealed mugs are also helpful when a casualty lacks hand control. If a tremor is present, a weighted mug can be used. In cases when there are inhalation injuries resulting in swallowing difficulties, vacuum flow suction mugs can control the rate at which liquid is released to prevent choking.

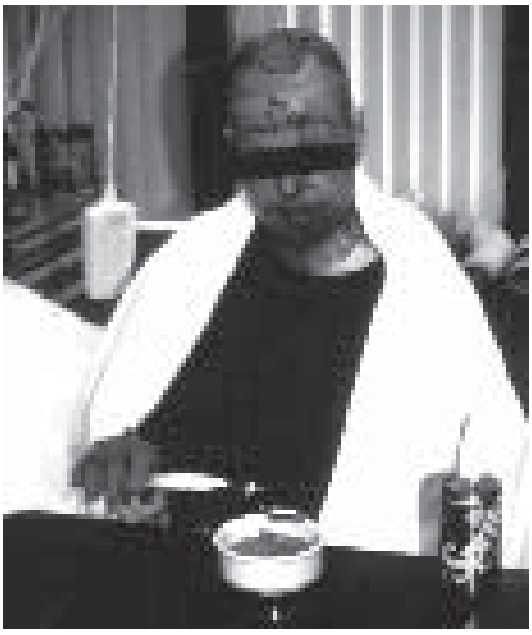


Fig. 10-52. Adaptive feeding utensil: a swivel attachment. This is the same table shown in Fig. 10-51 with a Dycem nonskid surface.

There are several types of adaptive equipment that are used for stabilization when a casualty has the use of only one hand. Dycem (Dycem Inc.) is a nonskid surface that prevents a plate or bowl from slipping when placed on it (see Figures 10-51, 10-52, and 10-53). Scoop dishes or plate guards attached to plates provide stability for utensil usage when only one hand is available for self-feeding.

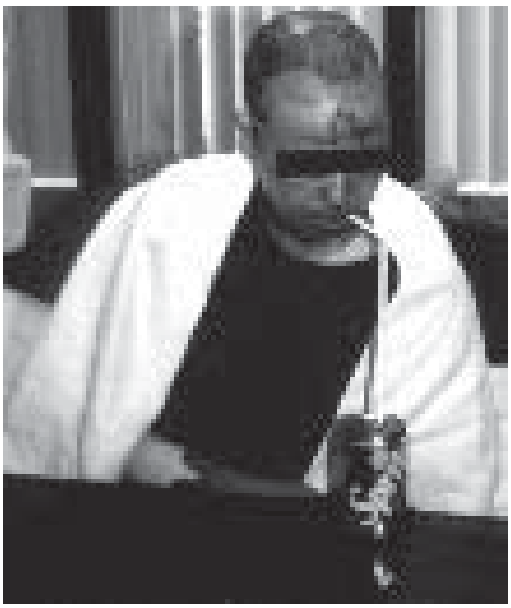


Fig. 10-53. Adaptive drinking utensil: a long straw. Again Dycem is used to create a nonskid surface

Grooming is another self-care activity that can be performed early. Oral care and hair brushing and combing are initiated when bathroom privileges begin. Although rarely needed, a built-up handle or universal cuff can compensate for the decreased ability to grasp the toothbrush. A temporary extended handle can ease teeth brushing while range-of-motion improves. Toothpaste tube squeezers are available if fine motor dexterity is limited. Denture brushes with suction cups are useful when only one hand is functional.

Hair brushes and combs can also be adapted with built-up handles and universal cuffs. Extended handles (straight or bent-angled) are useful when shoulder flexion or shoulder external rotation or both are lacking.

Communication is a functional activity that is very important in all phases of rehabilitation. This is a broad category that includes expression, reading, use of environmental controls, writing, and telephone and typewriter/computer usage. Large button, programmable phones can be adapted to have a speaker, allowing early independent telephone use. Because telephone usage keeps burn casualties in touch with their support systems, adaptations are requested early. A goose neck adjustable phone holder allows a person to speak and hear without holding the telephone. The goose neck holder affords more privacy than the speaker phone. There are special phone holders for weak grasp. A phone flipper is a lever that can be added to the base of the telephone to activate the connection button if a casualty cannot depress the button. This can be operated by hand or by mouthstick. Another type of phone adaptation is a touch-tone phone adapter. This is a device that enlarges regular push buttons. It can be operated by a very light touch.

In the acute phase of rehabilitation, expression assists the casualty to interact with others in the environment and decreases fear and frustration. In severe burn cases, a casualty may be intubated, ventilator dependent, and unable to speak. If there is prolonged exposure to smoke inhalation, vocal cord injuries can result and speech can be unintelligible or contraindicated. Communication boards composed of letters, pictures, body maps, words, or complete sentences can be used to convey thoughts if the casualty can point. There are also sophisticated communication devices such as the Voicaid or Prentke Romich Touch Talker or Light Talker (Prentke Romich Co.) that have voice outputs. These can be operated by touch or by a light-activated

beam. However, casualties are often too ill or medicated to use complicated communication devices.

There are a great number of environmental controls that can be adapted for independent usage. Call lights, bed controls, lights, and other appliances can be operated by environmental control systems. Environmental controls are available in a wide variety of switching systems with specific mounting devices. Examples of switches are the basic plate, light touch plate, air cushion, rocker switch, foot switch, wobble switch, sip and puff control, and the joystick. (The same switch and input device method can also be used to operate a communication device, computer, or electric wheelchair in other phases of rehabilitation.) The switches can be specially ordered from companies such as TASH (Prentke Romich Co.) or can be purchased from Radio Shack.

Reading can be a very important functional exercise when a casualty is confined to the bed (Figure 10-54). There are several types of book and magazine stands available if needed. Bed readers, positioned slightly overhead, are useful when an alert person must stay in supine positioning. A prone person can use a floor stand or music stand with pages stabilized by clothespins. Book stands, height and angle adjustable, clamped to a bedside table or headboard provide optimal positioning. Books or magazines can be placed on a foam wedge. Book stands with automatic page turners or a mouthstick can be used if a casualty is unable to turn pages independently. Prism glasses allow a person to look down at pages to read while the head is positioned forward. In cases of preexisting visual acuity deficits, a variety of magnifiers can be used in addition to large print books.

Fig. 10-54. Reading for recreation and exercise. The casualty is able to read by using a reading stand.

Writing is another important self-care activity that can be performed in early stages of burn rehabilitation. Pen and pencil holders are useful temporary adaptations when a casualty's ability to grasp or pinch is decreased. Built-up foam handles or plastic easy grip adapters facilitate holding the pen. Special splints or adaptive writing utensils can be fabricated out of thermoplastic materials, or commercially available splints can be obtained to customize writing devices. A clipboard can be used to stabilize the paper when the nondominant hand is unable to hold the paper steady for writing. A writing device attached to a mouthstick can be used if both hands are nonfunctional for writing.

Pain Management in Burn Patients

Pain is purely subjective, difficult to define, and often difficult to describe or interpret. It is defined as an unpleasant sensory and emotional response to a stimulus associated with actual or potential tissue damage.[79,80] It is a multifaceted experience extensively influenced by anxiety, depression, and expectation.

Acute pain is a biological symptom of an apparent nociceptive stimulus, such as acute tissue damage or trauma. It lasts as long as the tissue pathology lasts, is generally self-limiting, and as the nociceptive stimulus lessens, the pain decreases. Acute pain means that the patient's pain seems to match in time with what one knows about his injury. A patient with severe burns may have pain that lasts for months, and by examination of the patient's skin there is still evidence of tissue damage. Therefore, he is still having acute pain. The real differentiation between acute and chronic pain is whether the patient's complaints can be matched to the understanding of mechanisms of tissue damage, not the actual duration of the pain.[81] Everyone has experienced a burn from a hot skillet or hot water, so one can only imagine the pain caused by a major burn.[82] Burn pain has been found to correlate with depth of burn and location but not the severity or extent. Also, it is well known that burn pain severity can not be predicted on the basis of age, gender, ethnicity, education, occupation, history of drug or alco-

hol abuse, or psychiatric illness.[83] Nurses have been shown to administer analgesics in less than the maximum allowed dosage and yet complain that the physician is not prescribing adequate analgesia.[83] Nurses have both overestimated and underestimated the patient's pain, and have a tendency to overestimate the degree of pain relief from medications given. Emphasis has been placed on the implementation of systematic procedures to assess pain.[84]

The goal of pain treatment is to try to eliminate pain. However, to abolish pain without producing side effects is difficult if not impossible to accomplish. The successful rehabilitation of a burn casualty depends on active participation of the person in the treatment program. The casualty must be relatively comfortable, that is to say, his pain must be at a tolerable level if the needed active participation is to be achieved. Yet the most intense pain does not relate as much to the burn injury itself as it does to the "trauma" caused by the therapeutic procedures. When patients are at rest, the pain may be relatively mild on the average. In contrast, when the casualty undergoes therapeutic procedures, significantly more pain is experienced and its intensity can reach extremely high levels.[85] Also, the pain experienced does not necessarily lessen over time. Studies have shown no correlation between patients' self-reported burn pain scores and the elapsed time since injury. Although there is an interrelationship between depression, anxiety, and pain, it has been demonstrated[85] that, in burn patients, high levels of anxiety did not necessarily associate with high pain scores during therapeutic procedures.

The pain management should therefore address the background level of pain as well as the breakthrough or procedural pain. The goal should be a tolerable level of discomfort and active participation of the casualty in the rehabilitation program.

In considering the prescription of analgesics, the physician should consider the duration of action, the route of administration, and the dosing schedule. Morphine is the standard drug against which all other analgesics are measured. No other opioid has been shown to be superior to morphine in analgesic effect. All opioids can be administered parenterally, orally, or rectally. Fentanyl ([Fentaugh] Janssen Pharmaceuticals Inc.) can be administered transdermally as a 72-hour skin patch. Parenterally administered opioids have 100% bioavailability, while oral bioavailability varies between 15% to 25% for morphine and 69% for codeine, methadone, and oxycodone. Also, the liver metabolism varies considerably in the burn patient as his acute medical management proceeds. There is correlation between plasma morphine levels and pain relief and there is no known reason to not use opioids in appropriate dosage schedules in burn patients to control pain.[86] The half-life of morphine oral solution was found to be 3 hours, while the half-life of M.S. Contin (Purdue Fredrick Co.) was 14.7 hours. Time to peak levels of morphine sulfate was 30 minutes, and 1.4 hours for M.S. Contin. Therefore, breakthrough or procedural pain may be controlled with rapid release oral morphine, and sustained release morphine is a good choice in the management of the background pain in burn patients on an 8- to 12-hour dosage schedule.[86] When pain control during the acute phase is inadequate, the experience is unnecessarily traumatic, with psychological and physical difficulties later. Even after the pain is eventually controlled, the patient has been conditioned to diminish effort and movement and, therefore, exercise and repetitive movement crucial to maximum function is not achieved.[87]

Anxiolytic therapy, in addition to analgesics, may well help the burn casualty attain a satisfactory comfort level. Benzodiazepines are the drug of choice for this management. The aim of sedation is to reduce restlessness, anxiety, and fear. The use of benzodiazepines in conjunction with morphine is more effective in controlling pain and anxiety then using one agent alone. Versed ([Midazolzam] Roche Laboratories) has a rapid onset of anxiolysis and amnesia and is gaining popularity for acute burn procedures. In the elderly it should be used cautiously. Cardiovascular monitoring is suggested initially since it can cause cardiac arrhythmias (and respiratory arrest). Intranasal administration is possible because of its neutral pH and absorption across the nasal mucosa.

Inhalation analgesics have been shown to be very effective and safe in a large series of more than 800 patients during more than 1,400 treatments with less than 5% side effects in the patients and no long term side effects to patients or staff.[88] During the acute phase, if the patient is on a respirator, depression of the respiratory center is less of a concern and more analgesia can be given at times to allow tolerable levels of discomfort during rehabilitative therapeutics.

Hypnosis with burn cases has been reported as effective in some patients with reports dating to 1965.[89] The studies are difficult to control since other treatments such as analgesics are used simultaneously; however, most report hypnosis as a useful adjunctive treatment. The contraindications to hypnosis are (*a*) if the patient is not interested in it, and (*b*) if the patient has a large secondary gain compo-

nent to pain.[89] The person administering the hypnosis must know the patient's allergy history to avoid stimulating allergic reactions during suggestion. Relaxation techniques and self-imagery are at times very helpful as an adjunct to rehabilitation procedures and are recommended since adverse side effects are almost nonexistent. Group and individual psychotherapy is also effective in reducing pain behavior in some patients. Individual psychotherapy is needed more commonly in patients with previous maladaptive behavior.[82]

Use of transcutaneous electric nerve stimulation (TENS) has been attempted in burn patients. There is at least one controlled study[90] of conventional TENS being as effective as morphine in the acute stage of burn care during Travase debridement. In general, the burn injury and the pain would need to be quite localized for this treatment to be effective and, therefore, it is used only occasionally. There is one report[91] of effective use of TENS as auricular acupuncture to reduce pain in burn patients with less than 35% TBSA burn. Since the side effect of TENS is limited primarily to skin rash, this treatment modality should be further investigated and utilized when the conditions so indicate.

Psychosocial Aspects of Burns During the Acute Phase

Intervention to diminish maladaptive emotional reactions of burn casualties is an important aspect of burn treatment. Adjustment to the burn injury is influenced by the severity of the burn, location of the burn, age, sex, preinjury psychosocial stability, educational status, hospital and outpatient treatment environment, and by community and family support systems.[92] The burn casualty's ability to cope with the stresses of his situation are influenced by his past experiences and by the awareness, understanding, anticipation, and response of the team managing his care.

Burns sustained during a combat situation are usually accompanied by the psychological effects of battle stress. Multiple other physical agent wounds may be experienced at the same time. The depth of the wound as well as the location will determine whether the casualty will return to duty or be evacuated. A nonbattle burn injury may be the result of accidents secondary to battle stress conditions that reduce performance, making the soldier vulnerable to injury.[93] Sleep loss is one of the most significant contributing factors to nonbattle injury. When under stress, the soldier's mental abilities are affected, including alertness, attention to details, perception, reasoning and comprehension, memory, motor responses, communication, self-control, and interpersonal relations. Soldiers with minor burn injuries, especially if separated from their units and treated in the rear, have psychological reactions that retard their recovery unless they are also treated with the same intervention provided for a battle stress casualty.[94] Shock, numbness, and detachment are commonly noted at the time of injury, which protects the person while he collects emotional resources to cope with the injury.

The principles of battle fatigue prevention are taught to prepare soldiers who will face the stress of battle and, if burned, the additional stress of injury. The routine training of soldiers in stress control principles, including rapid relaxation techniques, is valuable in the event of a burn injury. Coping with the stress of battle involves balancing internal reactions to meet and overcome external stressors. When the external stressors of sustained battlefield conditions cannot be removed, the soldier must learn to use stress reducing strategies to cope. These techniques are taught by leaders and practiced with the use of the buddy system to reinforce learning. In the event of injury, the soldier's mind-set for recovery may be positively affected by what leaders and buddies say and do.[95]

The mental health section at the unit level can provide support that focuses on mild and moderate battle fatigue and burns such that the soldier can return to duty. For the minor burn injury of less than 1% TBSA, in which return to duty will occur as soon as the wound heals, the soldier needs to be treated using the principles of proximity, immediacy, and expectancy. Keeping the soldier as close to the action as possible reinforces his identity as a soldier, rather than a casualty. The farther away the soldier is from his primary group, the more difficult it is to have him return to normal duty. Immediacy is important in helping the soldier to cope with the situation as early as possible and to identify battle fatigue symptoms as they appear. Expectancy means to expect the soldier to return to normal duty where his comrades need him. Treatment using the principle of expectancy is appropriate not only for the soldier returning to duty within a short recuperation time, but also for the soldier who will require extensive burn rehabilitation.

For the soldier with severe enough burns to be evacuated, early psychological intervention and support is a key factor in obtaining motivation and cooperation with treatment. The burn casualty will be separated from his unit and does not have ready access to family or friends for psychological support. An important role of the treatment team at all

echelons includes providing emotional support and reassurance to reduce the anxiety and fear experienced by the soldier. The evacuation team provides ongoing orientation information, including calling the soldier by name. Part of the chaplain's mission is to provide comfort, assurance, and encouragement to the soldier. The provision of positive affirmations and encouragement even during initial delirium reinforces his internal will to live.[96] The speed of physical recovery may be affected by the early emotional adjustment to an acute burn.[97] This adjustment is facilitated by keeping the soldier informed about what is happening to him. Providing preparatory information prior to intervention procedures and encouraging the use of simple relaxation techniques during treatments contribute to emotional well-being and ability to tolerate pain during this acute stage. It is important to repeat instructions, provide frequent orientation, and if possible, allow verbalization of fears.

The immediate reaction of a massive burn casualty includes psychological shock. This reaction usually lasts a short time and may involve disorientation delirium, emotional instability and lability, and sleeping problems with nightmares of being burned.[92] Fear and anxiety also accompany the initial part of the acute phase of burn recovery. The soldier should be allowed to express his fears regarding death. These fears should be met with a reality oriented response regarding his chance of survival.[98] Behavioral manifestations, such as increased startle response, difficulty in concentrating or following instructions, withdrawal, resistance to treatment, overt hostility, or other inappropriate behavior, are often noted immediately after the burn.[99] The burned soldier may or may not realistically perceive a major threat to his survival. Information regarding the seriousness of the burn is given, if possible, before pain medications cloud awareness.

Treatment team members need to obtain information regarding the soldier's background, interests, personality, and family and unit relationships. This information is useful in developing a plan to deal with the immediate psychological responses as well as approaches that will be most effective in helping him cope with a prolonged, rigorous recovery. The early inclusion of the family in the rehabilitation process is very important to the adjustment of the soldier and family. The Red Cross may be helpful in relaying information between the soldier and his family while they are separated as well as assisting the family in securing quarters near the medical treatment facility that the soldier returns to for treatment. Intact and supportive families have been influential in successful long-term psychosocial adjustment of survivors of severe burn injury.[100] Family members may be interviewed by the social worker, nurse specialist, psychologist, psychiatrist, or chaplain to get an accurate history of the casualty's preburn personality, coping styles, and reactions. This will add to the information from the soldier to facilitate development of strategies in managing the rehabilitative care of the casualty.

It is important to involve the family in a support group and provide educational classes to inform them about burn injuries and treatment. Through interactions in the group, family members have the opportunity to learn from one another and support each other. Family members are often responsible for immediate communication with girlfriends, boyfriends, and community groups or churches. Family and friends at home can provide significant support and focus toward the future by letter writing and maintaining positive contacts with the burned soldier.

Following the resolution of the initial shock of the burn incident, the casualty becomes more aware of the impact of his burn. Orientation improves and survival anxiety diminishes. Thoughts are more focused on concerns about oneself, including the effects of changed appearance and altered function or life-style. The soldier's preburn physical, emotional, intellectual, social, and spiritual nature provide his initial coping skills. Additional skills are usually needed. Psychologists, social workers, or chaplains help the casualty to focus on regaining as much control as possible and in redefining the meaning of the accident, desensitization from the reminders of the injury, dealing with stress in a positive way,[101] and in gradually accepting loss and trauma as a matter-of-fact part of the past. "Getting their feelings out" is discouraged[102] to preserve fragile but useful coping mechanisms, including denial.[103] Adequate pain control, correction of sleep disturbances, decreasing the fear of long-term consequences, and cooperation with the burn team become crucial for optimal outcome.[92] Numerous interventions are appropriate and may include (*a*) providing as much physical comfort for the casualty as possible; (*b*) providing ongoing orientation information including calling the soldier by name; (*c*) mentioning the date and time of day; (*d*) providing explanations about the procedures that are being used, even if the casualty is comatose; (*e*) providing relaxation training after orientation is established; (*f*) providing routine for bathing time, exercise, and meal times to decrease unexpected proce-

dures; (*g*) encouraging family involvement as soon as possible; and (*h*) emphasizing individual control over as many situations as possible.

Losses and changes related to the burn injury affect each soldier differently. Growth, finding new strengths and coping mechanisms, recovery from grief, and developing renewed goals or emotional growth occur sometime after the soldier realizes the impact and disruption he will probably experience from the injury.

When the soldier determines that there is potential for survival, his focus may turn to the perceived pain and its alleviation. This focus frequently results in increased reports of pain as well as requests for analgesia. When adequate pain control is not provided, the casualty begins to believe that pain will be associated with each treatment and may result in poor compliance with treatments. The anticipation of pain may be complicated by having painful procedures done at different times, thus increasing the anxiety level. Adequate medication dosage for pain, anxiety, and sleep is increased because of the hypermetabolic state of the casualty. When IV lines are in place, adequate PCA to allow activity during the day, interspersed with comfortable rest periods, improves cooperation with antigravity positioning and elevated exercise that ultimately also result in diminished pain. Relaxation training, counseling, and behavioral management are effective nonpharmacological ways to deal with pain. However, they never replace analgesic, hypnotic, or tranquilizing medications. The goals of pain management are to maximize comfort, minimize disruptive behavior, and increase cooperation and productivity.[92] When complaints of dysesthesias and pain are misinterpreted by the staff as manipulative behavior at about the same time pain medications are being tapered, cooperation with therapeutic modalities is undermined. Short continuance of narcotics combined with desensitization techniques will undoubtedly reduce the problem. Most neuropathies resolve slowly. However, in addition to being taught desensitization and compensation techniques, the patient will appreciate assistance with reintegration of sensory information. Benson's relaxation[104] (Exhibit 10-3), practiced daily, will help the person tune out sensations he would not have been aware of before the accident. For some casualties, dysesthesias from the healed tissue become a central, compelling part of their awareness. Individual counseling as well as reassurance by the physician and therapist help the soldier accept the return of sensation as a positive sign, even if it is temporarily distorted and therefore painful. Patients slowly come to realize that the skin emergency has passed and by using vision as well as tactile sensation from the burned and unburned parts, the sensory information will be more quickly reintegrated.

As orientation improves, additional behavioral methods of relaxation may by implemented. These include Benson's relaxation response, autogenic training, biofeedback, imagery, and distraction. Other behavioral interventions include deep breathing exercises, which may alter sensation in a negative way, especially if the casualty hyperventilates when attempting deep breathing; and progressive muscle relaxation (although this is painful if the overlying skin is burned and therefore can cause pain instead of relaxation). Soldiers are taught rapid relaxation techniques as a part of their training for management of stress in army operations. A combination of what the soldier is familiar with and these nonpharmacologic techniques assist the individual to be in greater control of his situation.

Immobilization Phase of Wound Care

The goals in the immobilization phase of wound healing include continuing analgesia; permanent wound closure with graft adherence; modifying edema; preventing complications; maintaining joint and skin mobility as possible; educating the casualty and family to the expected results and appearance of early skin grafts; behavioral interventions to assist prolonged bedrest and to redefine skin graft operations as positive, rather than negative, in the course of wound healing; and counseling to assist the soldier to focus on the positive final outcome, rather than on loss of independence, pain, or inactivity.

Wound and Skin Care and Nursing During the Immobilization Phase

The immobilization phase of healing after grafting can be a trying time for casualty, family, and staff alike. Casualties may see it as a setback if they are unable to exercise areas they had diligently been exercising. Thorough explanations to casualty and family about grafting and the period of immobilization will help to prepare them emotionally for the postoperative period. Postoperative positioning and splinting should be discussed with the physician, therapist, and nursing staff preoperatively. Whenever possible during preoperative teaching, the nurse should assist the casualty into the position that will be assumed postoperatively. This will

EXHIBIT 10-3

OUTPATIENT HOME CARE PROGRAM: THE RELAXATION RESPONSE

1. Sit quietly in a comfortable position. Choose a place where you will not be disturbed.
2. Practicing is best done sitting on a comfortable chair with the feet flat on the floor, the hands on the legs, and the head unsupported.
3. Close your eyes.
4. Breathe through your nose. As you breathe out, say the word, "one," silently to yourself. Breathe easily and naturally.
5. Continue for approximately twenty minutes. You may open your eyes to check the time, but do not use an alarm. When you finish, sit quietly for several minutes, at first with your eyes closed and later with your eyes opened. Do not stand up for a few minutes.
6. Do not worry about whether you are successful in achieving a deep level of relaxation. Maintain a passive attitude and permit relaxation to occur at its own pace. Distracting thoughts are normal. When these thoughts occur, return to repeating "one".
7. Some patients report that it is difficult to judge for themselves whether this technique is working. Often, after a week of consistent practice, they report feeling more alert and either losing their discomfort or becoming less aware of discomfort.
8. Patients also report that if they practice this procedure within two hours after a meal, the relaxation does not seem as satisfactory. Deep relaxation can often occur best just after awakening when the body is well rested and before any food is eaten. You may be familiar with increased dreaming when you have eaten a large meal just before going to sleep. That is one example of increased activity of the mind in response to digestion.
9. Also, this procedure may interfere with your sleep if done within 3-4 hours of bedtime.

Modeled on the work of H. Benson, MD, Thorndike Memorial Laboratory, Harvard University.

assist in solving discomfort issues in advance. Preoperatively, a low air loss bed or air fluidized bed should be considered, not only for comfort reasons, but also for pressure reduction on healed, unhealed, old or new graft sites, and donor sites.

Postoperatively, the nursing staff must know exactly what operative procedure was performed to maximize positioning and to avoid any potential complications. The activity level must be known and also what nonsurgical sites can continue to be exercised. Continuous elevation and checking CMST of grafted extremities is performed at least every 2 hours to prevent complications, which may include increased edema; poor circulation; or pressure caused by dressings, splints, or casts that may be too tight.

Appropriate analgesia and sedation should be administered to keep the casualty comfortable yet not oversedated during the immobilization phase. Other techniques such as relaxation, imagery, or music that the casualty found helpful in the past should again be used. Casualties may require more emotional support during this phase; the nurse can provide this support by effective listening, giving reassurance, explaining all procedures that are done, providing pain relief, and enlisting the assistance of the unit chaplain or psychologist.

Meticulous wound care in nonsurgical areas needs to be performed at least daily. Observation of the surgical areas for signs of increased bleeding, infection, or because of complaints of pain from splints or dressings should continue throughout the period of immobilization.

The first postgraft dressing change, at the direction of the physician, occurs between 1 and 5 days postoperatively. This dressing change can be done at the bedside or at the hydrotherapy area. Thorough soaking of the gauze outer dressings with water or saline will facilitate their removal without disruption of the underlying grafts and any overlay dressings that may be used to secure and protect grafts. Graft disruption is less if the dressing is

bent back 180° as it is pulled away from the wound, rather than lifting it at 90°. Daily dressing changes of the graft sites are usually resumed after this time (Figure 10-55). If the contact layer is adherent over the graft, application of a fine mesh gauze impregnated with an antibiotic ointment for 1 hour prior to removal will decrease sticking and bleeding with removal. This layer is not removed until the interstices are closed, unless infection is noted under it. Evaluation to determine time for resumption of exercises is completed. Safe exercise depends on graft take, durability, and location. When it has been determined that the casualty can resume range-of-motion exercises, daily living skills should also gradually be resumed. Activity levels should be increased daily. The casualty should assist in goal setting and scheduling of activities with the assistance of the primary nurse.

Exercise During the Immobilization Phase of Wound Healing

Many contractures originate during the postgraft period when any joint underlying a skin graft must be immobilized for optimal autograft adherence. It is impossible to maintain ideal positioning at all joints. For the severely burned casualty, 3 to 7 days of immobility during skin graft vascularization severely limits active motion. When a severe inflammatory process surrounding a joint is noted preoperatively, the results of immobilization can be disastrous. However, with early grafting procedures, early resumption of supervised gentle-active motion, and carefully designed immobilizing orthoses, satisfactory outcomes can be anticipated. While the casualty waits for skin grafts to adhere, the therapist recommends an exercise program to prevent phlebitis, pneumonia, and contractures during the bedrest period. Exercise is excluded from any joints underlying the graft and one joint proximal and one joint distal to the graft. Quadriceps isometric exercise and ankle pumps are easy to teach the casualty whose leg is not grafted. However, casualties often need cueing to initiate exercise and to avoid moving grafted areas. When only the upper extremity, head, or neck is grafted and can be safely immobilized, the casualty may be up in a chair and ambulate (Figure 10-56).

It may be possible to provide positioning for the anesthetized casualty who is undergoing grafting,

Fig. 10-55. Wound cleansing and assessment postgrafting.

Fig. 10-56. The patient is ambulating on the first postoperative day with immobilization of upper extremity graft.

which will allow the contracted areas of skin and scar to elongate because of the plastic property of connective tissue. Excessive stretching or forcefulness can result in bleeding, swelling, and increased tenderness, so great care must be used. To stretch an ankle, for instance, it may be acceptable to place the casualty's foot on a foam block, with the hip and knee bent, and allow the heel cord to elongate slowly as the casualty lies relaxed in the supine position. The "creeping" elongation of tissue in this way results in change that may be maintained by active exercise when the casualty is awake; the slow elongation will be painless because of the anesthesia for grafting.

Therapists must adhere to the medical center's policies and procedures governing who may attend casualties in the operating room; there must be documentation of each person who enters the operating room and techniques followed during surgical procedures. The therapist who wishes to evaluate range-of-motion or provide this type of stretching when the casualty is under anesthesia must first discuss this with the surgeon. Then a protocol should be written covering the roles and responsibilities of the therapist. The operating room nurses and the person administering anesthesia will appreciate being consulted prior to the therapist participating in casualty care in the operating room.

Safety factors are stressed for everyone involved in surgical procedures. The anesthetized casualty is unable to produce a normal response to painful or injurious stimuli. Therefore, proper positioning and padding are important to avoid pressure points, stretching of nerves, or interfering with circulation to an extremity. Whenever the casualty's position is changed, it must be done slowly and gently to allow circulation to readjust. The casualty has a diminished ability to compensate for physiologic changes caused by motion or stress. The anesthetic agents are depressants and predispose the casualty to respiratory complications. The casualty's chest must be free for adequate respiratory excursion at all times and pressure must never be exerted on the chest while the therapist is holding an arm or hand. The tidal volume is decreased as much as one third when a casualty lies horizontally so constriction of the neck must also be avoided. The casualty benefits from unhindered diaphragmatic movement and a patent airway. The anesthesiologist guards the head and supports it during movement. Arms must never be hyperextended, and shoulders may not be moved above 90° to 100° of flexion or abduction.

The therapist checks with the anesthesiologist and the circulating nurse before examining range-of-motion. Motion must be checked quickly if the area is being prepared for grafting or as a donor. The therapist may "scrub in" if this has been arranged in advance. IV lines, monitoring electrodes and connectors, airway connections, and electrical equipment are always preserved. Range-of-motion evaluation cannot cause inaccessibility of the operative site. Sterile technique is not broken or the sterile field contaminated. Avoid occlusion or pressure on peripheral blood vessels, and ensure that restraining straps, if removed, are properly replaced. Bony prominences should be protected from constant pressure against hard surfaces, and prolonged compression to or stretching of peripheral nerves should be avoided. The extremities must be well supported whenever the therapist is not working with them. If injuries occur from malpositioning during anesthesia, the brachial plexus and ulnar, radial, and peroneal nerves are most frequently injured. Finally, strain on the casualty's muscles can result in needless postoperative discomfort from lack of protective muscle tone during anesthesia.

Positioning During the Immobilization Phase

The casualty must continue antigravity positioning and prevent disruption of the new graft. The team consults with the surgeon to determine positioning well before the scheduled grafting procedure. Clinitron (Hill-Rom) or Kinaire (Kinetic Concepts) beds distribute pressure; however, they promote protraction of the shoulders and thoracic kyphosis with a subsequent reduction in vital capacity. When postoperative use of the air cushion bed is recommended, high air flow cushions are placed under donor areas to facilitate drying, and low flow cushions are placed under the grafted area to prevent desiccation. The bed cushions must be changed before the person is placed in the bed postoperatively. All positioning should be tried for a night by the casualty, to solve any discomfort or daily living skill problems such as urinal use. The graft and one joint proximal and distal are immobilized. All of the positioning devices available during the early phase may be adapted for this phase. Wedge pillows or over-the-bed suspension with slings are useful for upper extremities. Deltoid aids and elevating tables also assist in alternating positions during this time. Properly positioning the body part so that the new graft is at optimal length will minimize contractures. The casualty is kept on bedrest unless immobility of the graft can be maintained

Fig. 10-57. Axillary thermoplastic orthosis applied in operating room. (**a**) Molding splint into correct position at the axilla. (**b**)Total contact thermoplastic orthosis setting up over a new graft.

while sitting in a chair or walking for short distances during bathroom trips. The body part grafted is elevated to prevent edema. If the posterior side of the body or head is grafted, the casualty is positioned prone or on an air-fluidized bed or air-flow cushion bed. In these cases, the graft must be protected with a plastic barrier, if needed, because thin dressings do not prevent graft desiccation from high air flow.

Orthosis During the Immobilization Phase

Widely varying materials and protocols have been suggested for postoperative skin graft dressings and orthoses. All have the common purposes of immobilizing and protecting the grafted area, preventing edema, and speeding wound healing. Thermoplastic splints applied in the operating room conform precisely to the graft and immobilize the extremity. (Figure 10-57) Additional considerations for orthoses are convenience, comfort, and cost.

In centers using the exposure method of graft healing, elevation, support, and protection of the grafted areas are accomplished using pillows, slings, metal and net "hammock" positioning, open thermoplastic orthoses, or skeletal traction. Safely securing a thermoplastic orthosis without impairing circulation is difficult when the burn is circumferential and extends beyond the borders of the graft. Restless casualties dislodge postoperative orthoses. If the orthosis rests on the graft it will inhibit tissue survival.

When the healed wound is expected to be especially fragile, as it is after cultured epithelial or artificial skin grafts, overhead suspension of the body part is indicated. The proper use of skeletal immobilization prevents nerve damage and joint or soft tissue strain.[105] Precautions to be addressed include use of proper counterbalance weight for each individual limb, thorough investigation of the casualty's complaints, frequent observation of the entire rope and pulley system to avoid weights resting on the floor or bed parts, lubrication of pulleys with silicone spray before attaching traction, and shielding of the weights to keep them from being bumped by passing visitors, children, and equipment.

After tangential excision using a tourniquet, a bulky pressure wrap is often used to prevent bleeding and protect the grafts. In this case, the whole extremity is wrapped in cotton batting and elastic bandages and suspended from overhead traction for 24 hours. After 24 hours, the bandaged extremity is elevated on an arm wedge or the foot of the bed is elevated.

To make a bulky wrap, a single layer of nonadherent dressing is used in contact with the graft. An example of this use is in a hand burn. A contact layer such as Biobrane (Winthrop Consumer Products) is stapled in place over the grafts. Wet fine mesh gauze is wrapped around the contact layer. An adequate number of completely opened gauze 4 x 4 in. sponges are placed into the palm, between the interdigital webs and into the thumb web space.

A Kerlix (Kendall Healthcare Products Co.) roll is placed into the palm to increase the thumb web space. Fluffed gauze pieces are placed over the dorsum of the hand and thumb with a snug Kling (Johnson & Johnson) wrap. The entire wrap is covered with cotton batting and secured with a gradient elastic bandage wrap. Gradient means progressively decreasing the pressure from distal to proximal. The purpose of gradient pressure is to improve venous and lymphatic return, to support arterial supply, but not enhance it, and to assist in hemostasis after wound excision. The entire bulky dressing can be reinforced with a dorsal or a palmar plaster or plastic orthosis, or both. The plaster should not contact the skin. A single layer of Webril (Kendall Healthcare Products Co.) interface is needed to ease plaster removal. The orthosis can be secured with an elastic wrap or Kerlix (Kendall Healthcare Products Co.) wrap.

When thermoplastic immobilizing orthoses are used, they may be fitted over a single layer of nonadherent gauze, over a bulky wrap, over a stent dressing, or over a wet fine-mesh gauze dressing. Postoperative skin grafting orthoses may be fabricated preoperatively, intraoperatively, or postoperatively. Orthotics applied in the operating room fit well initially since they are molded to the final dressings after grafting. The area immobilized includes the grafted area and the immediate joints proximal and distal to it. Any plastic orthosis can be cut open so drainage can escape. Very wet dressings if not changed frequently, can cause maceration and superficial infection.

When the anesthetized casualty is fitted with an orthosis, it is important for the body parts to be aligned in an anatomically correct position. Casualties adjust easily to wearing an immobilizing orthosis when adequate pain medication is administered postoperatively. Later, when pain medications are being decreased, the orthosis often feels comfortable, which increases wearer acceptance.

Areas That May Require Immobilization Orthosis

Face and neck. Halo skeletal traction is sometimes used. Thermoplastic halo immobilizing devices are difficult to fabricate and allow some movement, but are sometimes used. The halo with a thermoplastic jacket with a very high trim line, which extends onto the neck, totally immobilizes the neck.

Shoulder. Skeletal traction or foam wedge pillows optimally immobilize and position the shoulder.

Fig. 10-58. Airplane splint.

These methods are most commonly used to manage axillary immobilization. Rarely, when total contact or 3-point airplane splints (see Figures 10-56 and 10-58) are fitted postoperatively, they position the shoulder in up to 120° of abduction and 10° to 15° of shoulder flexion to prevent a neuropathy.[67] If needed, a separate orthosis supports the elbow in slight flexion and the wrist in slight extension. A total contact airplane splint, formed over the under surface of the abducted arm, keeps the graft from shrinking and distributes the pressure over a grafted area (see Figure 10-57) more accurately than the 3-point airplane splint. Prosthetic elastomer inserts may be molded to the axillary area before the splint is fabricated to increase the conformability of the splint to the axilla. The 3-point airplane splint does not immobilize as well and allows problematic webbing (shrinking of the anterior and posterior axillary fold skin limiting shoulder movement) between the chest wall and the arm[65] (see Figure 10-58).

Elbow. A volar extension splint or posterior flexion splint may be made to keep an elbow graft in place.

Hand. When a pressure wrap is not used for postoperative hemostasis, a WHFO (see Figure 10-40)

is fabricated to keep the IPs extended, the MCPs flexed at 65°, the wrist extended to 20°, and the thumb abducted. It is important to include the palmar arch contour in the orthosis since the arch is necessary for opposition.

Hip-knee-foot. The hip, knee, and foot positions can be immobilized with a commercially available foam AFO with a derotation outrigger. A bulky pressure wrap with cotton batting, followed by gradient pressure elastic wrap is used, and the leg is positioned with the knee above the heart and the foot above the knee for control of postoperative bleeding. An OCL plaster support for 90° ankle may be fitted. When only the ankle needs postoperative positioning a posterior thermoplastic or plaster ankle-foot-orthosis may be used.

Functional Activities and Adaptive Equipment Use During Immobilization Phase

In the immobilization phase it is important to avoid trauma or shearing the skin surface during ADL. Performance of functional activities such as feeding (Figure 10-59), grooming, and communication are appropriate as long as the graft is immobilized. Adaptive equipment is continued as needed. Applying lotion to healed or unburned areas increases sensory input and decreases hallucinations from sensory deprivation. Additional functional activities that can be performed in the immobilization phase are sedentary recreational activities such as viewing television or the VCR. It can also be therapeutic to watch educational videos regarding burn treatments. In addition, the casualty can participate in activities with others, such as board games, cards, or crafts if the graft is protected.

Fig. 10-59. Feeding during the immobilization phase.

Psychosocial Adjustment During the Immobilization Phase

The immobilization phase following skin grafting may be very difficult. Preparation for grafting includes briefing the casualty and family about the procedures and time frames of the immobilization. An informed soldier will experience less unfocused apprehension concerning the operation. Increased acceptance of the procedures is observed when both the family and soldier understand the need for grafting and the alternatives for achieving wound healing. The surgeon and rehabilitation team reassure the soldier by helping him redefine the grafting operation in a positive light, rather than as a setback, and allay fears related to loss of control during anesthesia.

The casualty is not able to exercise the grafted area or perform as many activities due to potential skin shearing from movement. The resultant lack of movement and sensory deprivation create the potential for confusion and hallucinations. The potential for confusion or hallucinations is reduced by staff or family providing appropriate sensory stimulation, especially if the casualty is sensory-deprived on a Rotobed or a Clinitron bed.[70] The use of tactile input through rubbing lotion on closed areas will provide itch control as well as a sense of reassurance through therapeutic touch. Auditory and visual input may be emphasized through the use of television, radio, music, and frequent family and staff interaction.

Explanations of procedures before they are performed provide reassurance. Adequate analgesia and sedation as well as the use of familiar relaxation exercises help to provide a level of comfort that is tolerable during this phase. Avoiding repeated, unexpected, painful, and frightening treatments reduces the potential for developing posttraumatic stress disorder (PTSD). The staff should provide patient choices as much as possible. The soldier should be invited to participate in procedures such as staple removal, wound cleansing, and antigravity positioning, thus reinforcing the casualty's control and responsibility in the healing process.

Wound Maturation Phase of Healing

The goals during the wound maturation phase of healing are to:

- assist in nonnarcotic analgesia;
- maintain wound closure;
- prevent infection;
- control edema;

- regain joint and skin mobility;
- regain strength and endurance;
- facilitate casualty and family participation in resumption of family roles;
- assist learning self-care;
- fit total-contact, stretching orthoses to minimize hypertrophic scar formation;
- learn compensation techniques for exposure to friction, trauma, ultraviolet light, chemical irritants, extremes of weather or temperature;
- develop awareness of sensory changes;
- fit prostheses;
- develop a profile for active-duty training, return to part-time modified duty, or to full-time active duty; and
- continue counseling to deal with life and psychological stresses regarding permanently changed appearance, altered ability levels, and difficulties with posttraumatic stress symptoms.

Casualties with large, deep burns may not become independent without being transferred to a rehabilitation center. For transfer, the casualty should be medically stable and able to tolerate and benefit from a minimum of 3 hours a day of therapy. Appropriate general goals for the burned soldier treated at a rehabilitation center include the following. The patient will:

- be able to direct skin and wound cares, need minimal assistance with bath, and be improving in self-care and independent donning of external vascular supports;
- recover preburn AROM and be able to demonstrate prolonged stretching to decrease joint and skin contractures;
- recover preburn strength as compared with normal for his age group;
- develop endurance to tolerate 2 hours of work equivalent activity and 10 hours of activities, including homemaking or home chores;
- recover coordination sufficient for work and to accomplish daily living skills with minimal adaptive equipment at preburn speed;
- control limb edema using external vascular supports 23 hours a day and elevated positioning;
- demonstrate independent donning of orthoses to modify burn scars, wear devices the prescribed number of hours, and explain the purpose of these devices;
- learn and use protective interventions for sensory, vascular, and pigment changes;
- have healed burn wounds, grafts, and donor areas and will demonstrate care of blisters;
- demonstrate successful use of interventions to control itching;
- participate in appropriate, coordinated discharge planning;
- participate in family education;
- explore vocational issues with a vocational rehabilitation counselor;
- explore and participate in recreational activities, leisure planning, and social and community reintegration while wearing external vascular supports and splints;
- demonstrate consistent independence in self-care and homemaking; and
- be learning to cope constructively with posttraumatic stress symptoms, changed body appearance, and adjustment to disability.

Wound and Skin Care and Nursing During the Wound Maturation Phase

During the maturation phase of healing the epithelium in the healing partial thickness burns is very fragile, and if not protected, is prone to shearing, pressure, and subsequent breakdown. It is not uncommon to have small blisters form during this time because the epidermal layer is not firmly attached to the underlying dermis for several months.[56] All areas should be gently cleansed and rinsed well with water. Infection is no longer a consideration, and therefore, antibiotic ointments are discontinued. Blistered areas should have light, nonadherent dressings applied for protection. The intact blister should not be opened or debrided. If the blister is large and spreads when the external vascular support wrap is applied, the blister should be drained and the wound protected with the dry skin. If the dry skin peels away, the open area is treated with Unna ([ConvaTec] ER Squibb & Sons) dressing, Merthiolate ([thimerosol] Eli Lilly & Co.) to dry the area, or other topical medication if infected. Assessment is made for applying external vascular support to protect the skin and decrease edema. Use of external vascular support garments is begun when open areas are dry, will not adhere to the garment, or tear with garment removal. Careful inspection of the casualty's skin should be ongoing for any condition changes resulting from increased activity, exercise, and the skin's response to treatment procedures. Figure-8 elastic wrapping should be applied to the lower extremities prior to dependent positioning or ambulation.[106] Standing

in the shower with legs dependent is permitted only after all open areas are closed on the lower extremities, and purple color of dependent wounds is decreasing.

After a burn injury the number of sebaceous and apocrine glands are decreased, therefore, the healed skin may appear dry and flaky. The casualty may be very distressed by pruritus. Vigorous rubbing or scratching results in newly opened areas. Moisturizing lotions should be applied to all healed areas after bathing and routinely as needed. The lotion should not be perfumed, have an alcohol base, or be so viscous that it causes blisters during application. Adequate dosages of long-acting oral antipruritic medications should be used[107] in conjunction with lotion to modify the itch. Fingernails should be kept trimmed, smooth, and clean to prevent excoriation of fragile skin. Desensitization exercises and vibrator use (Figure 10-60) may be helpful to reduce itching. As sweat glands, sebaceous glands, and hair follicles return, the casualty may notice a condition similar to acne caused by plugging of pores. A grit soap and cleansing sponge such as Buf-N-Puff (3M Healthcare) may soften the tough outer layer of keratin and allow pores to function normally. When apocrine function returns, it is not uncommon to have excessive sebum production and perspiration. The casualty then benefits from a more drying, alcohol based lotion. If sunscreen protection lotions are being used, it is important to prescribe the appropriate type of sunscreen according to the natural condition of the skin. The avoidance of sun exposure for about 1 year is the best method of preventing permanent hyperpigmentation (see Figure 10-32).

Fig. 10-60. The casualty is desensitizing the scar area using a vibrator.

During this maturation phase the burn casualty must come to terms with being a survivor and prepare to leave the safe environment of the burn unit and reenter society. This reentry may be done in steps: an excursion outside the burn unit, a day pass with family or friends, passes to restaurants, or trips home. These outings will help the soldier to adjust to stares and rude comments. It can also help problem solve for the discharge date as to what adaptive equipment will be needed at home. At this stage, these casualties can benefit from talking to other burn survivors, a psychologist, psychiatrist, or social worker, and from viewing videotapes about other burn survivors and their families to learn how they coped and what their questions and concerns were. Along with physical and emotional recovery, ongoing social support is a necessity for the burn survivor to be a "survivor" and not just another "victim." Nurses provide psychological support and encouragement to the burn casualty as he prepares to leave acute care and return to society. At this time nurses also recommend referral to appropriate services such as alcohol and drug treatment facilities or chronic pain programs. Studies[108] have confirmed that burn victims who are likely to abuse drugs or alcohol or both did so before the accident. Outpatient treatment in these situations may be indicated.

Although no direct central nervous system damage occurs from a burn, most burn survivors notice changed reflexes and changes in their perception of tactile and visual information. Proprioception is often diminished. The itching, tenderness, and skin pain subside gradually. Before the soldier returns to coordinated independent activities that could be dangerous, such as getting into and out of the bathtub alone, driving, using power tools, climbing ladders, or cooking, he should practice these activities with supervision. Medications that cause drowsiness should be discontinued prior to the operation of power equipment or motor vehicles.

A desensitization program will allow the soldier to control the level, frequency, duration, and pressure of differing external stimuli applied to a healed wound. As the casualty's tolerance increases, his ability to withstand unexpected stimuli improves.

Sensations such as pain and itching from the healed wound decrease very slowly. Sensations from the healed wound become closer to the preinjury feeling more rapidly when a desensitization program including massage, vibration, and exposure to varying textures and temperatures is practiced regularly (see Figure 10-60).

Massage desensitizes the skin and assists venous return. It is manipulation performed with the hands to produce effects on the neuromuscular and circulatory systems. The direction of the massage should be with the venous and lymphatic circulation. The purpose of massage is to relax as well as to improve circulation from the limb. Using too much pressure causes pain or blisters. The massage should be a slow repetitive motion, moving distal to proximal. The limb should be elevated above the heart during massage.

Another method of desensitization involves using wooden dowels, wrapped in various pieces of cloth, to produce repeated stimuli over the affected area, which increases tolerance. Desensitization can be performed by graded contact with particles that produce different sensations. The hand or foot may be immersed in a basin that contains various objects such as cotton, popcorn, plastic insulation pieces, rice, plastic squares, or beans.

Vibration is a controlled method of stimulation of nerve endings that may lessen pain, response, or irritation. An electric or battery operated vibrator is used to massage around the areas surrounding a burn. As tolerance increases the vibrator can be placed directly over the healed wound, first with a stocking covering the skin and then directly against the healed skin.

Another desensitization method is controlled exposure to warm and cool water. The extremity is maintained at heart level, and water is allowed to run over the healed wound: begin by running the cool water over the wound for 20 seconds, followed by warm water for 5 seconds, and repeat this procedure for up to 10 minutes. Contrast baths of warm, followed by cool water may be substituted by dipping hands slowly into the contrasting water.

Burn recovery, return to active duty, and return to a normal home life usually include resuming sexual relations.[109] Former burn patients report that regaining their sexual identity is their most important goal for recovery. They have been suddenly and traumatically shocked into realizing their vulnerability. They want to deepen and strengthen relationships with a domestic partner and are afraid of rejection. They may seek satisfying, relaxing intimacy even if that was not important to them before the accident. They find it reassuring when their doctor initiates a matter-of-fact discussion of sex and birth control in the same way he discusses other medical aspects of their care.

The soldier's partner needs to be included in discussions about changes that take place during recovery and the expected final outcome. The casualty must take responsibility to initiate communication with his partner, and must understand that human sexuality is communicated to the partner through behavior, appearance, and personal hygiene, which reflect the soldier's self-image. Most companions appreciate an open discussion prior to resuming sexual activity.

The casualty often worries about rejection. Counseling to encourage trusting, honest communication can become the basis of a loving, caring, exciting relationship. Understanding, communication, imagination, and experimentation can expand opportunities for a good relationship.[110] Potential problems related to sexual activity as well as birth control should be addressed by the physician before the soldier is discharged. Friction or trauma to healed burns during sexual activity can cause blisters. These blisters may heal slowly. They are normal and decrease as skin toughens and matures. A lubricant decreases friction. The areas least burned are helpful in sexual activity. A commonly used means of sexual expression is the mouth. The casualty may receive more pleasure from this option, because the lips and tongue are rarely severely burned and are more sensitive to touch and temperature than other body parts. Any part of the body can be made clean enough for oral contact.

Pregnancy may cause hypertrophy of burn scars and should be avoided until the scars are mature. Burns of the female genitalia are very rare because these structures are unusually well protected. However, contractures with shortening of the skin around the inner thighs and lower abdomen can be a problem. Burns of the male genitalia often need urologic consultation to achieve optimal outcome. Stretching the tissue away from the direction of contracture and frequent erections assist wound maturity. Vigorous exercise and stretching of these areas as healing progresses will result in the best outcome. Contracture releases are possible.

Talking together, kissing, and caressing each other in a tender, sensuous way assists arousal, which is commonly more difficult after the burn injury. It is common for the casualty to be anxious. A major part of sexuality depends on the way an individual chooses to use the body, attitudes about a variety of sexual behaviors, and informed choices

made based on internal feelings of competence, effectiveness, and self-satisfaction. Recovering sexuality and intimacy after a burn injury is a dynamic process that can sometimes be facilitated by a counselor or trusted confidant.

Erickson's[111] sexual counseling approach was to avoid pointing out or interpreting patient's fears. He did not emphasize insight. His approach was based on action to bring about change and he emphasized the positive. His focus was on expanding the person's world, not educating him about his inadequacies. When working with couples, Erickson often relabeled what they were doing in a positive way. He attempted to gain a small response and build on that. In this way, positive forces were freed to allow the couple's further development. Couples who had worked out an amiable way of living together before a stressful event, such as a burn, with positive support and commitment to each other, resolved sexual difficulties. One of Erickson's basic premises was that the art of marriage included achieving independence while simultaneously remaining emotionally involved with one's relatives. This type of adjustment is crucial for the burned individual, whose full recovery is dependent on his ability to capitalize on family resources.[111]

Exercise During the Wound Maturation Phase

Full AROM returns most quickly when inflammation is minimal, when grafts are on dermal remnants, and when the casualty continues hourly, elevated, active motion during waking hours. The burn casualty needs to exercise for strengthening (AROM against gravity will increase strength when less than antigravity strength is present), for improving speed and accuracy of movements, for flexibility, and to improve skill in activities. With prompting, the casualty who has had adequate analgesia during the first two phases will put out maximum effort to move through the extremes of motion. This will prevent joint motion from becoming painful, nourish joint cartilage, and elongate surrounding soft tissue. Exercise continues to speed healing by improving circulation and by decreasing edema and the inflammatory response to burn injury. At this phase of recovery, the casualty should exercise wearing external vascular supports. It may be necessary to remove the support garment for 10-minute periods for composite stretching, but the support must be donned immediately after the exercise. The garment can only be removed at the distal limb. If the garment must be off an elbow, the whole sleeve must be off, or an elbow zipper can be opened for prolonged flexion and supination but it must be closed after exercise. A glove must not be removed without also removing the sleeve, which presents complications if the sleeve is attached to a vest.

Former patients report that to be effective, exercise periods require mental concentration as well as vigorous physical investment. The casualty should eliminate distractions such as visitors during this important time and concentrate on restoring greater function with each exercise. A clock that announces time intervals, such as ringing every 15 minutes, assists the soldier to remember to stretch eyelids or other important contractures throughout the day without the verbal cues that may come to seem like nagging from a therapist.

Manual resistive exercises, progressive resistive exercises, use of Cybex (Cybex Co.), BTE (Baltimore Therapeutic Equipment), rowing machines, stair climbers, bicycle riding, and other therapy modalities should be done daily to improve strength and endurance (see Figures 10-32 and 10-61). It is generally considered that high repetition, low resistance exercise increases endurance, while lower repetition, high resistance exercise increases strength. However, strength can be increased with low

Fig. 10-61. The stationary bicycle provides strengthening, active range-of-motion, and endurance exercise.

weights as long as fatigue occurs during exercise. Walking continues to be a favorite aerobic exercise. Furthermore, walking restores good posture, ie, body straight, chest up, chin in, shoulders back and down, and hips tucked in. When ambulation is done out of doors, it provides distraction from pain with focus on the surrounding scenery.

During this phase of wound maturation, prolonged stretching is almost always recommended for decreasing joint contractures. Elbows remain susceptible to heterotopic ossification when they are stretched too vigorously. However, gentle, graded prolonged stretch, preferably active, will assist the collagen to realign in a longer, less tightly convoluted, mat-like configuration. Contractures at this point are usually so severe that they will not resolve without prolonged stretch in addition to the strengthening exercises. Adequate time for prolonged stretch and composite motions must be reserved by the therapist because the patient will almost always need coaching and hands on supervision for this part of rehabilitation. The other modalities can often be incorporated into written, home programs and sometimes can accompany prolonged stretch. Stretch can be combined with work-equivalent activity. Sometimes an activity such as having the casualty copy an enticing advertisement with one hand, while the therapist stretches the other hand, helps the soldier to relax and benefit more from the stretch.

Varying the exercise program makes it more enjoyable. Individual sports such as biking, jogging, and tennis are wonderful beginning exercise. Graded to increase as endurance increases, these sports return control to the soldier. Caring for pets is excellent exercise and increases variety and pleasure. If the animal lives in a barn, open areas of the casualty should be healed or well covered to avoid infection. Exercising by doing activities that were routine and important to the soldier before the injury rewards performance (Figures 10-62 and 10-63). When the person is discharged from the hospital, doing the motions of active duty, a job, homemaking or similar activity strengthens muscles. This focuses attention on habitual activities and toward the outcome or product of work. Success is motivating even when it takes longer to do a task after burn recovery than it took before the injury.

Outpatient treatments have the additional benefit of establishing a pattern of leaving the protective home environment every day. Objectively documented improvement is encouraging. Attending a health club increases social contacts and may improve self-esteem as strength and endurance increase. Swimming is an exercise recommended by former burn patients. Swimming in chlorine water is irritating to newly healed skin and external vascular support garments. Therefore, after swimming, the chlorine is washed off; lotion is applied; and clean, dry, support garments are donned. During swimming, the benefits of exercise combined with joint protection and skin moisturization outweigh the nuisances of showering, extra laundry, and lotion application.

Fig. 10-62. The casualty is repairing a small engine as part of overall rehabilitation.

It must be remembered that when exercising out of doors, the patient's healed burned skin or donor areas should be protected from sunlight until all the red color has faded. Damaged, thinned skin will turn very dark brown with even brief sun exposure. Healed skin will tolerate graded sun exposure 3 to 18 months following injury. However, exposure to sun must be gradual and a commercially available waterproof sunscreen with a sun protection factor rating of 15 or more should be applied to all burned areas when exposed to the sun. A wide brimmed hat can protect the ears and nose during exercise in the sun. Sunburn through exposed custom fitted elastic external vascular support garments is common.

If the soldier's skin does not sweat, he should avoid prolonged exposure to temperatures above

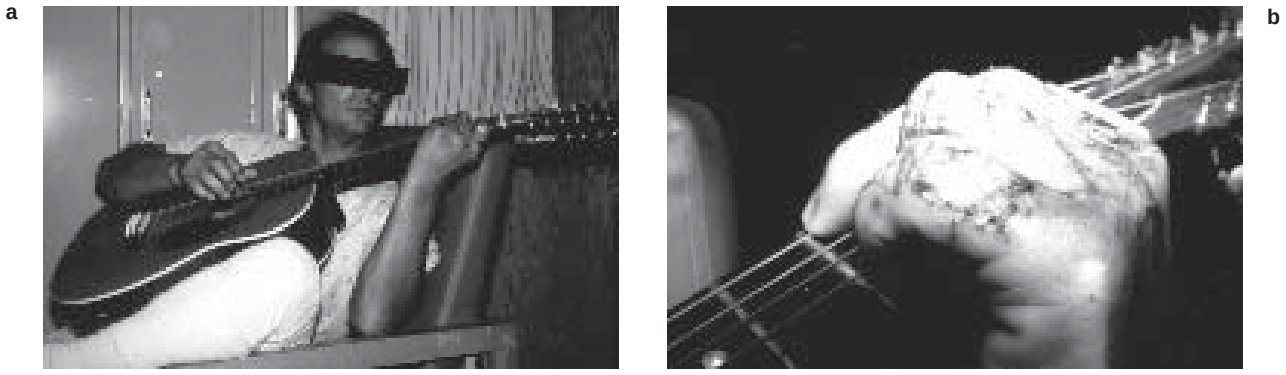


Fig. 10-63. Resumption of recreational activity after skin grafts provides exercise during an activity that was routine and important before the injury. (**a**) Recreational outlet provides therapeutic activity. (**b**) Close-up of grafted fingers exercised into flexion to play the guitar. Skin durability gradually increases during practice.

85°F. A fan or air conditioner may be needed in the summer to aid the body in cooling by evaporation. Hyperthermia during exercise is possible. The casualty must remove garments and orthosis and must shower and cool down after vigorous exercise, then reapply scar management devices. The opposite of hyperthermia and sunburn, frostbite injuries are a risk when the soldier is exercising out of doors and the temperature drops below 32°F. Casualties who have sustained frostbite in the past are at greater risk for frostbite. Warmer clothing, avoiding constricting bands around the extremities, and wearing several layers of clothing during exercise, reduces risks of frostbite.

Casualties often view hospital discharge as a welcome termination of burn care, exercise, and pain. Often casualties eagerly anticipate what they believe is a well-deserved rest. The recalcitrant person who endures exercise and scar control devices at the hospital may abandon custom-made elastic stockings, traction or total contact splints and activity once he feels safe at home. It is the casualty's dream that home will magically bring back the previous physical and emotional status. However, it quickly becomes obvious that achieving adequate epithelial healing for safe home care is only the beginning of rehabilitation and return to active duty.[112] Work hardening programs are appropriate for severely burned casualties (see Figure 10-62). They have the advantage of providing supervised heavy work, with consultants for psychologic assistance to adjusting to changes and dealing with slow return of endurance and ability. In addition, they make needed adaptations for exercise and work apparent. Work hardening also reinforces protective measures for friction, trauma, chemical irritants, and extremes of weather or temperature.

The best outcomes result when the casualty, therapist, and physician formulate an appropriate active duty limitation outline with each clinic visit. Returning part time, in whatever limited way is necessary, to as many active duty tasks as possible is also excellent exercise. Jobs done by habit eliminate the need for the soldier to constantly think about the discomfort of exercising.

Positioning in the Wound Maturation Phase

The goals and techniques for positioning during the wound maturation phase of healing are very similar to the acute phase already discussed (see Figures 10-30 and 10-34). Initially, dependent positioning of the extremities will be painful, which will remind the soldier to elevate hands or feet. Later, as the soldier must take responsibility for varying his own position and using antigravity edema management techniques, a kitchen timer ringing every hour is a nonthreatening reminder.

Water beds are contraindicated initially for sleeping due to the rounding of the neck and shoulders and difficulty getting out of bed. In addition, if kept warm, they increase perspiring and itching. Antideformity and antigravity positioning is continued for at least 4 to 6 months postdischarge from the hospital.

Orthosis in the Wound Maturation Phase

Especially during the first 4 to 6 months after the wound is closed, the use of orthotics does not replace exercise. Orthotics (in addition to the functions discussed in the previous sections) stretch contractures, substitute for lost function, and minimize scars.[66] Individualized, custom-made orthot-

ics enhance positioning, allow reasonably painless maintenance of exercise gains, block undesirable motion, and encourage active motion away from a contracture. Custom made orthotics assist in minimizing hypertrophic scars by flattening the hypertrophic tissue against the underlying body structures. Serial drop-out casts, used for progressive scar elongation, have the additional advantage of softening the scar, preventing orthotic slippage, and eliminating patient removal.

Head and neck. During the maturation phase, the preservation of facial contours, while applying pressure to reduce hypertrophic scarring is an ongoing challenge. The position of teeth and the facial contours are developed from the counter pressures of the tongue against the teeth and the active motion and tension of the external facial musculature. The presence of a contracting scar or the use of an orthosis will alter the balance of these mechanics. A dental consultation is therefore recommended every 4 months for a patient needing external vascular supports for management of facial scars. A transparent facial orthosis or neck orthosis, described later, provides optimal management for face scars or oral contractures. The MPA can continue to be used for oral contractures (see Figure 10-47). The Macfarlane microstomia correction device (Figure 10-64) maintains horizontal oral aperture gains.[113] The Macfarlane device has the additional benefits of preventing tooth migration when it is worn daily and fitting well with a clear orthosis because the portion at the corner of the mouth has no flange. The Macfarlane appliance also spreads the lips over the teeth, so it is easier to blanch the tissue. Unless the dentist determines that the lower teeth are in a solid arch shape, patients who need pressure for scar modification over the lower lip and chin also need a retainer fitted for the lower teeth to prevent lower tooth migration from this imbalance of pressure.

Fig. 10-64. Macfarlane microstomia correction device (shown here) can easily be used with clear facial orthosis.

Fig. 10-65. A casualty shown with simultaneously worn chin-neck and axillary-elbow-hand appliances.

The neck responds well to clear cervical collars, but foam or thermoplastic devices also manage scars and prepare the epithelium for more accurate total contact supports. Tubular ring collars can toughen neck tissue and if applied over a smooth contact layer such as Xeroform (Chesebrough Ponds, Inc.), assist in neck scar maturation. Often the chin, neck, elbow, and shoulder need splints at the same time. Making sure they fit together and are comfortable helps the soldier use them regularly (Figure 10-65).

Shoulder. Shoulders may require prolonged attention during the maturation phase. Positioning orthoses, figure-8 straps, deltoid aids, and CPM devices have their place in the treatment of difficult cases. Positioning orthoses, such as the open axillary abduction splint (often called an airplane splint), are seldom left in place for prolonged periods but must be used in conjunction with active exercise. However, total contact axillary orthoses are worn for prolonged times and provide continuous pressure and stretching to hypertrophic webbing bands of the anterior and posterior axillae. When there is early hypertrophic scarring along the anterior and posterior axillary folds and the skin is healed and durable, a commercially available figure-8 clavicle strap may be applied (Figure 10-66). If the tissue breaks down, the strap must be dis-

Fig. 10-66. Figure-8 clavicle strap.

Fig. 10-68. Deltoid aid used as positioning dynamic orthosis.

continued (Figure 10-67). The strap may be worn at night when motion does not cause blistering or irritation if wearing is tolerated and the scar heals. Deltoid aids are utilized to help position for prolonged stretching of contracture bands when the soldier relaxes, and yet allow active motion as well as permit the person to participate in some ADLs (Figure 10-68). CPM devices are helpful to move the shoulder continuously and provide stretching at the ends of motion.

Elbow. The elbow contracture responds best to a the serially revised or "drop out" orthotic (see Figure 10-33). For serial casting or splinting, the device is usually changed every 2 to 3 days to accommodate a resolving contracture.[68] Bivalved casts are difficult to put on, but if the casualty is independent in using them, a prolonged stretch can be achieved when the casualty is not exercising or involved in functional activities. Circumferential bivalved arm casts are applied to achieve independent composite stretching exercises of the shoulder, elbow, and wrist. An elastic wrap can secure these for night wear (Figure 10-69). Elbow CPMs are also helpful.

Hand. The purpose of hand orthoses in this phase is to reduce or prevent deformities or replace lost function. Deformities such as boutonniere (see Figure 10-43) and swan neck are tendon injuries, which need a combined approach by the reconstructive surgeon and the therapists. However, traditional orthotic management (such as three-point flexion or extension splints, extension troughs, and LMB

Fig. 10-67. Irritated area resulting in temporary discontinuance of garment. Open area along left axillary contracture, stretching during exercise. Patient discontinued figure-8 clavicle strap during exercise, but wears it at night without increased irritation.

Fig. 10-69. Circumferential bivalved casts assist shoulder abduction with composite chest, and bilateral shoulder and elbow stretching. In this simulation, the patient is simultaneously doing neck extension and mouth stretch.

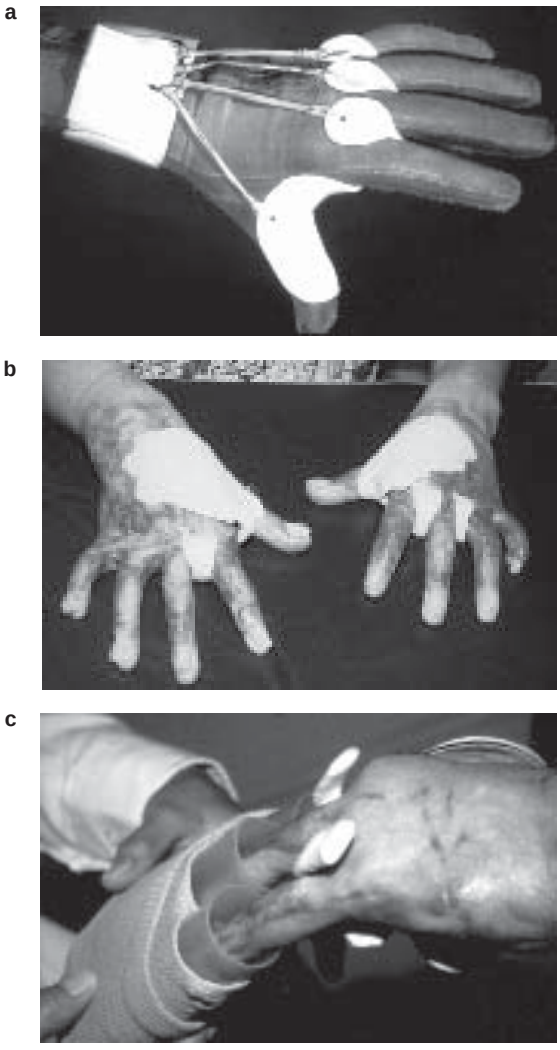


Fig. 10-70. Management of interdigital contractures. (**a**) Thermoplastic interdigital thumb and finger web spacers attached to Velcro wrist band. Wrist band must not restrict venous return. (**b**) Silicone interdigital thumb and finger web spacers prior to glove being applied. (**c**) Felt interdigital web spacers. Note that external vascular support glove is being applied with the aid of tubes.

[North Coast Medical] flexion or extension springs or joint jacks) is used in maturing burns as the healed epithelium becomes tough enough to tolerate these splints. Conforming total contact thermoplastic or silicone orthotics are used in the hand to apply pressure to contracture bands. The interdigital web space and thumb web contractures are especially responsive to silicone inserts (see Figures 10-46 and 10-70). Concave areas of the hand, such as in the palm, are also improved with silicone inserts, especially when the soldier is not using the hands (Figures 10-71 and 10-72). Total contact pressure on the scar tissue softens and elongates this plastic tissue better than three-point splints. Foam sandwich splints may be used to achieve wrist and digit extension and abduction.[114] This orthosis would be secured with an elastic wrap at this state of tissue durability. Air splint devices also reduce edema and stretch the hand or foot.

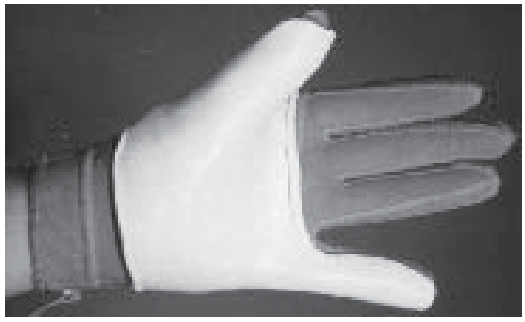


Fig. 10-71. Total contact thermoplastic palm orthosis.

Dynamic splints are not well tolerated by individuals because of discomfort associated with unrelieved, constant stretch (Figure 10-73). Serially revised or drop out orthotics provide slow, intermittent stretching and, therefore, are better tolerated. Serial orthotics may be used for any individual hand joint or for a composite stretch (Figure 10-74). Hand CPMs are also useful for prolonged stretch at the limits of range-of-motion (Figure 10-75).

Orthotics are also fabricated to replace lost function secondary to peripheral nerve injury. Examples are the thumb positioning post used in a median nerve injury or a dynamic extension orthosis for radial nerve injury. When digits have been amputated, temporary prehension posts aid in grasp and pinch (Figure 10-76).

Fig. 10-72. Night interdigital web orthoses. Note elastomer thumb saddle and separate Otoform K finger spacers.

Fig. 10-73. Dynamic elastic thermoplastic extension orthosis for treatment of fifth finger flexion contracture.

Fig. 10-74. Plaster drop-out hand orthosis.

Knee. A posterior serially revised or drop out orthosis is used at night to stretch resistant flexion contractures of the popliteal space. An orthopedic knee immobilizer orthosis may also be utilized in less severe cases.

Foot. During the maturation phase, foot scars can be very uncomfortable. For people who spend much time standing or walking, a custom shoe and total contact insert may increase comfort by redistribution of pressure. Cutouts such as donuts are never appropriate since they cause edema formation into

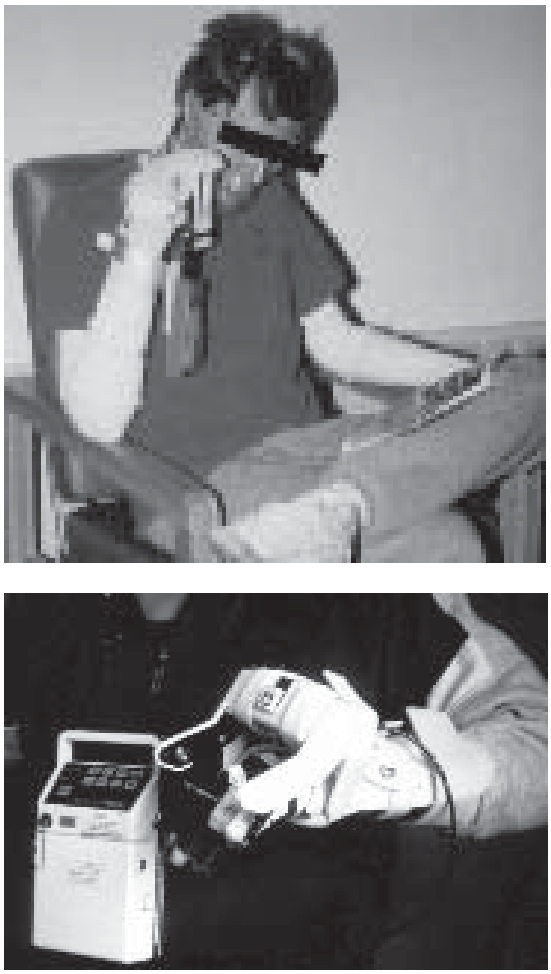


Fig. 10-75. Continuous passive motion machines (CPMs) for the hand. (**a**) Toronto II hand CPM worn as outpatient. Note clear facial orthosis. (**b**) Sutter hand CPM.

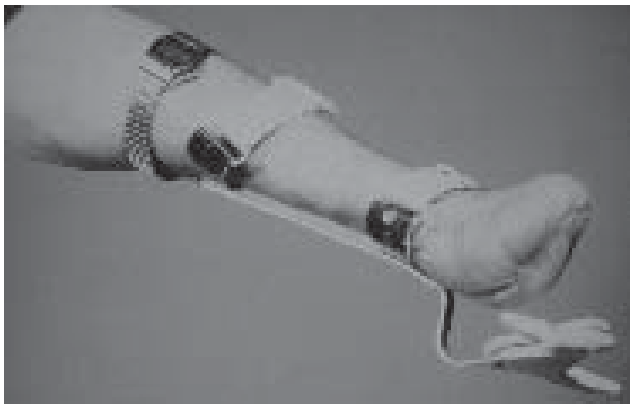


Fig. 10-76. Temporary palmar prehension orthosis.

Fig. 10-77. Cloth shoe with custom-fitted total-contact sole insert, with metatarsal bar, and silicone insert over dorsum of toes.

Fig. 10-78. Management of foot scars and contractures. (**a**) Felt interdigital web spacers. (**b**) Elastomer silicone insert below medial malleolus applied under external vascular support stocking.

Fig. 10-79. Hypertrophic scar appearance. (**a**) Graft and adjacent partial thickness wound healing. (**b**) Donor area healing.

the relieved area, ultimately increasing scar formation. If forefoot, toe flexion, or extension contractures develop, shoe inserts that apply pressure onto the hypertrophic scar band and stretch the contracture may be required (Figure 10-77). For severe toe extension contractures with hammer toe deformities, a nighttime dynamic toe flexion orthosis will be necessary. A shoe with metatarsal bar, toe insert, and steel shank is another alternative. When toe syndactyl is noted, interdigital web spacers are useful. Elastomer silicone inserts are used to add pressure over hypertrophic scars (Figure 10-78). If a foot drop is present, an AFO may be needed.

Contracture and Hypertrophic Scar Management

The complex pathophysiology of hypertrophic scar formation is not yet fully understood. Unopposed natural wound healing occurs by the processes of contraction in a centripetal fashion and epithelial migration from wound margins and retained epithelial elements at the base of sweat glands or hair follicles.[69] In addition, because wounds into the reticular dermis level are allowed to heal longer than 3 weeks, unnecessarily hard, thick red scars are formed[115] (see Figures 10-67, 10-79, and 10-80).

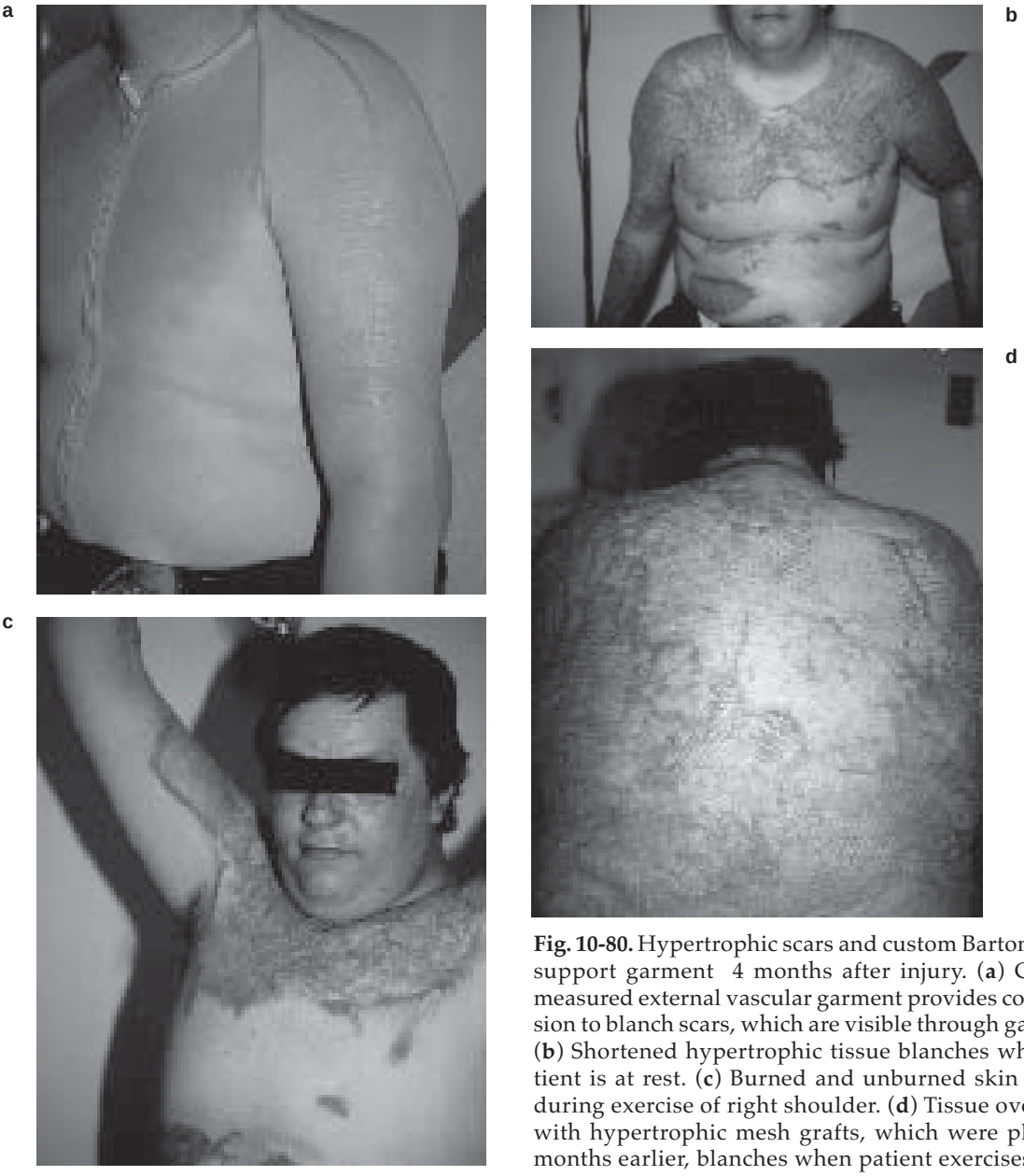


Fig. 10-80. Hypertrophic scars and custom Barton Carey support garment 4 months after injury. (**a**) Custom measured external vascular garment provides compression to blanch scars, which are visible through garment. (**b**) Shortened hypertrophic tissue blanches when patient is at rest. (**c**) Burned and unburned skin blanch during exercise of right shoulder. (**d**) Tissue over back with hypertrophic mesh grafts, which were placed 4 months earlier, blanches when patient exercises.

Fig. 10-81. Mature sheet graft over fingers; mesh graft over dorsal hand; and mature, healed, nongrafted forearm.

The duration of the scar process differs depending on the depth of wound and coverage. Full thickness skin graft recipient areas tend to scar less than thin partial thickness grafts. However, full thickness donor areas must be either split thickness skin grafted or primarily closed by undermining the surrounding tissue. The linear scars on tension are likely to become hypertrophic, particularly if they cross perpendicular to the lines of relaxed skin tension. The linear scars may also spread and become unsightly. Skin grafts over granulation tissue or infected granulation tissue scar worse than grafts to wounds excised in 3 days. Meshed grafts leave a permanent pattern of epithelial decussations and interstices. The larger the mesh, the larger the permanent criss-cross pattern. In contrast, a sheet graft, with no hematomas or seromas to disrupt adherence, often appears smooth in 1 or 2 months (Figure 10-81). Donor areas into the reticular dermis are more likely to scar than superficial donors (see Figure 10-79).

During hypertrophic scar formation, there is an increase in collagen and myofibroblast production, a proliferation of new capillaries, with capillary endothelial budding forming a rich vascular network. Fibroblasts appear in the interstitial spaces in greater quantities than normal. These fibroblasts begin to synthesize collagen and produce myofibroblasts that exhibit contracting characteristics similar to a smooth muscle cell. With delayed epithelization, collagen in the connective tissue is produced at 4- to 5-fold the normal rate. The new collagen is profusely vascular, immature, and lacks organization because the interstitial matrices are not correctly regulating its production. The adhesiveness of collagen fibers and bundles, more densely packed and lacking spatial orientation, are associated with a delay in epithelization. Serum protein in the blood inhibits collagenase resulting in a decreased collagen lysis.[116]

The scar tissue begins dynamic remodeling as soon as the inflammatory phase of wound healing is completed. However, the scars are rarely observed with the naked eye until 3 to 6 weeks after the wound is closed. They are noted as hypervascular, dark red, indurated, almost cartilaginous, hard, excessively strong, itching, tender, raised areas at the site of an injury. They may be noted at donor sites if these are taken into the dermis or if the healing donor becomes infected. The myofibroblasts remain active, dynamically remodeling for more than a year. Keloid is often used to designate a larger, thicker scar that grows beyond the limits of the original injured area. The time of scar onset, duration, and regression vary. However, the scar is usually noticed in the first months after healing is complete. If epithelization requires more than 2 to 3 weeks, the scar usually raises above the level of the surrounding tissue. By the third to sixth week, the scar becomes hard, at which time the soldier and physician usually are interested in beginning treatment. The hypertrophic scars spontaneously regress, partially, 1 to 3 years after healing. This regression is age dependent.[117]

The maximum height of scar elevation is usually seen at 3 to 9 months following healing, after which regression begins. Scars will not regress fully if the tissue contours have been altered during the inflammatory phase of healing, when the myofibroblasts were forcefully contracting. Total contact external vascular support by an elastic garment, cast, or plastic orthosis over the healing area reduces circulation, prevents edema, and thereby, interrupts scar buildup.

Factors that influence increased formation of hypertrophic scars include:

- the presence of infection or necrotic material in the wound or both,
- inflammatory response,
- foreign bodies imbedded in the tissue,
- suture materials that act as foreign bodies,
- crushing or irritating the wound during surgical procedures or wound debridement, and
- topical antibiotics that increase the vascularity of the wound.

Another factor that increases hypertrophic scar formation is tension on the healing wound. Tension might result from tight grafts, contractures, mature shortened scar cords in a constantly stressed area such as the anticubital fossa, burns that cross lines

of relaxed skin tension, the normal skin elasticity of teenagers, and collagen overgrowth during prolonged debridement and healing. Other influences are a familial predilection or the racial predilection of more darkly pigmented races to form overly protective scars. Because the newly formed cells are especially susceptible, the growth hormones of pregnancy, puberty, and childhood increase the duration and intensity of dynamic scar build-up.[118]

Hypertrophic scars can be decreased by meticulous, gentle wound care; early, thorough wound excision by an experienced surgeon; and avoiding removal of adherent epidermal cells during dressing changes. Discontinuing topical antimicrobials that are fibroblastogenic as soon as practical, maintaining adequate nitrogen balance and zinc and vitamin levels, and avoiding wound infections also positively influence scar formation.

Effective scar management includes external vascular support, which is begun as soon as wound healing is adequate so the support does not adhere to the injured tissues[119-123] (Figure 10-82, Vascular support for (*a*) superficial burn, (*b*) superficial partial thickness burn, (*c*) split thickness donor, (*d*) deep partial thickness burn, (*e*) full thickness burn, and (*f*) full thickness donor). Unless worn only for protection, the external vascular support appliance must apply continuous pressure in a gradient manner. The pressure must be adequate to decrease capillary circulation and must be continued until the scar matures. Pressure adequate to decrease edema and compress scar tissue cannot be applied to the middle of an extremity without impairing lymphatic return. Therefore, the principle of gradient pressure, the most support at the distal limb and the least at the proximal limb, is important. The hand or foot must always be supported in some manner. During the day for instance, a laced shoe can support scar tissue and provide a satisfactory outcome. A clean shoe must then be worn at night or the vascular support fitted over the foot. Although scar tissue usually looks shiny and is lighter in color than surrounding tissue, the optimal final healed wound should appear flat, soft, mobile, durable, supple, of proper color, and have minimal thinning and wrinkling.

The healed wound, donor, and grafted areas are evaluated for application of external vascular support when open areas are smaller than 3 cm^2 on the trunk or leg and 1 cm^2 on the face or hand, and when the tissue is durable enough to tolerate the shear of garment application. A thin, moist contact layer prevents the external vascular support appliance from sticking to the epithelium at the wound edge. The elastic wraps or garment should be soaked off during bathing to prevent denuding skin. When coarse mesh gauze wrap, such as Kerlix (Kendall Healthcare Products Co.), or fine mesh gauze, such as Unna, are used as a contact layer, a nylon stocking may be used to allow donning the support without rolling the bandages. The nylon stocking is left in place under the external vascular support wrap or garment. As the wound matures, the individual stops using the contact layer, gauze, or nylon stocking and applies the support directly to the healed skin.

The most distal part of the extremity, that is the hand or foot, must be properly managed first. Even if the upper arm is developing thick, rope-like scars, the hand must tolerate support before the arm is included, and the elbow must be supported without causing damage before the upper arm is supported. When it takes several weeks to achieve tolerance of support garments for the hand or foot, the more proximal scar tissue will still respond to support and become softer and lighter in color when the full limb garment is begun.

The most universally used early external vascular support is the elastic bandage wrap, applied in a gradient figure-8 manner, from toe to groin. Since early excision and grafting has become the rule, external vascular support has rarely been provided in the acute phase of healing for the head, neck, upper extremities, and trunks. Once wound closure is complete, a wide variety of commercially available off-the-shelf support designs are available (Figure 10-83). Many patients tolerate the cotton and rubber prefabricated garments well, the scars recede and no other support is needed.[124] In addition, fabric with varying elasticity characteristics is available from most custom measured garment manufacturers, and custom fitted orthoses of multiple types are also available for external vascular support and scar compression.

Contracture and Scar Management

Head and neck. Facial skin is loosely connected to underlying structures. If this connective tissue is allowed to contract around the face or neck, permanent, grotesque distortion of the nose, eyelids, mouth, ears, and neck may result. When the wound extends into the reticular dermis and heals spontaneously, an unnecessarily bulky, hard, red scar will almost certainly occur. Similar distortion during healing is noted when the wound is on the loose anterior or lateral neck (Figure 10-84). The beneficial use of external vascular support equal to capil-

a **b**

Fig. 10-82. Vascular support after burn injury. (**a**) Shallow, superficial burn and (**b**) Superficial partial thickness burn.

c

Fig. 10-82 continued. Vascular support after burn injury. (**c**) Split thickness donor.

d **e**

Fig. 10-82 continued. Vascular support after burn injury. (**d**) Deep partial-thickness burn, and (**e**) Full-thickness burn.

f

Fig. 10-83. Prefabricated external vascular support garments, Isotoner gloves, Tubigrip long sleeve shirt and long leg pants.

Fig. 10-82 continued. Vascular support after burn injury. (**f**) Full-thickness donor site.

Fig. 10-84. Contractures of the neck.

lary pressure, which compresses and supports the healing burn wound, is widely utilized for the face and neck.

A variety of appliances are available to manage face and neck scars. An accurately fitting, total contact, transparent facial orthosis worn 20 hours a day during the maturation phase of wound healing is one method to prevent distortion of facial contours. A less expensive, less therapist-intensive, but less than optimal, method of modifying the scar tissue is a custom measured elastic hood that secures a custom made silicone facial insert. However, used alone, an off-the-shelf hood or chin strap or even a custom measured elastic hood are ineffective because the elastic garment cannot conform to hypertrophic scars in concave areas. Scars in concave areas, such as under the mandible, need an insert for compression (Figure 10-85). Off-the-shelf hoods can be modified to decrease perspiration by replacing the crown of the hood with X-cross elastic straps. Patients wearing external vascular supports or orthoses for the face and neck must be closely observed for complications such as sleep apnea,[125] changed bone growth,[126] and posterior migration of the teeth. Patients who have severe breathing problems may need observation for sleep apnea and oxygen saturation monitoring overnight to determine optimal safe night positioning. Sleep apnea monitors used at home are very disruptive to the family and, therefore, hiring a night attendant to check breathing at short intervals of time is more appropriate.

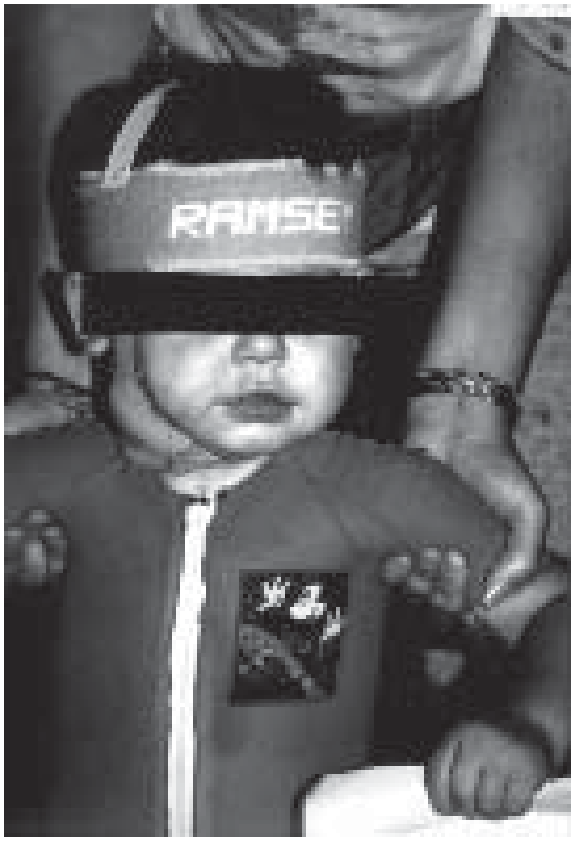


Fig. 10-85. Hood with pocket used to secure compression insert.

Fig. 10-86. Clear facial orthosis. Xeroform gauze is used on the chin.

A properly fitting clear plastic facial orthosis will compress the tissue against the underlying skeletal surface to preserve natural contours. The person wears a thin disposable contact layer such as Xeroform (Chesebrough Ponds, Inc.) over infected facial hair follicles (Figure 10-86). This is changed whenever the mask is removed. If heat rash develops, a thin paper towel sheet may be used and discarded each time the mask is removed. The person must learn to speak slowly and enunciate clearly to be understood while wearing the orthosis. The orthosis is removed for chewing and for oral stretching exercise.

A properly fitting neck orthosis is more difficult to achieve because there are no bony landmarks on the anterior neck, the larynx must move during

Burn Rehabilitation Outpatient Home Care Program

THE TRANSPARENT FACE MASK HOME INSTRUCTIONS

Transparent day orthosis

Transparent night orthosis

Night orthosis is worn with mouth stretching orthosis, nose cones, and eye humidity domes, as needed for scars.

PURPOSE The splint maintains normal face contours, decreases pain and itching, prevents contractures, minimizes scars and moisturizes tissue.

WEAR Continuously, except to bathe, eat and exercise. (20 hrs/day)
NEVER LEAVE MASK OFF LONGER THAN ONE HOUR!!!!!!

APPLY ___ Directly to skin. (Kerlix patch if needed)
___ Over or ___ under elastic elastic hood.

SPLINT CARE Splint is plastic. Wipe with soapy cloth and cool water.
Rinse well.
Dry thoroughly before re-applying.
Clean splint hourly, decreasing to daily.

SKIN CARE Observe face for swelling or poor circulation. Observe skin under splint for reddened areas and call therapist if rash or breakdown is observed.
Do exercises thoroughly before applying splint to prevent rubbing.
Wipe splint and skin dry as needed. Re-apply splint quickly.
Normal skin will gradually decrease perspiring. Burned skin will not sweat.
Do not perforate splint in any red areas!!
Wear gauze or towel to keep skin dry, if needed.

ALWAYS BRING ALL SPLINTS AND MOUTH INSERTS TO CLINIC!

Problems with open areas or infections must be referred to the doctor, clinic, and therapist.

If patient will be in sunlight, wear sunscreen under splint when removing splint for exercise.

Have teeth checked by a dentist or orthodontist prior to beginning to wear this splint. Dentist or orthodontist should check for tooth alignment, decay, and hygiene at least every 3 to 4 months and up until 6 months after wearing the orthosis.

SPLINTS ARE FLAMMABLE. DO NOT EXPOSE TO SOLVENTS, OPEN FLAME OR CIGARETTES.

Fig. 10-87. Burn rehabilitation outpatient home care program. Reprinted with permission of Regions Hospital (formerly, St. Paul-Ramsey Medical Center), 640 Jackson Street, St. Paul, MN 55101-2595.

speech or swallowing, and the sternocleidomastoid muscles change as they contract and relax for neck movement. However, with practice, a neck orthosis may be fitted that reduces edema and supports the tissue between the sternal notch and the chin at the maximum possible length. Neck hyperextension alone will not prevent neck contractures. Because the shortest distance between two points is a straight line, the neck skin migrates anteriorly and forms a neck contracture with bands around the neck. The night neck splint incorporates some hyperextension. The head is in the neutral position for the day neck orthosis so the person can read and walk safely without having to bend forward caus-

ing strain at the hips or back. The day position resembles "hanging" from a rope under the chin.

Written wearing instructions are given to each wearer (Figure 10-87). Some individuals ask for wallet identification cards indicating the facial orthosis is a medical necessity. If questioned by authorities, this card can identify a resource to call for verification that the person needs the splint.

Although orthotic use is very helpful to achieve an optimal outcome for the maturing face or neck burn, the orthotic device alone will not create a mobile, supple scar. Wearing an orthotic device that causes decubiti increases the inflammatory process and worsens final outcome. The wearing of an orthosis never replaces AROM to improve the quality and length of the healing epithelium and underlying connective tissue. Wearing a facial orthosis can exacerbate oral contractures. Syringe cases assist the patient to stretch the horizontal oral opening to the same distance every day (Figure 10-88). Proper use of nongreasy sun screen and the use of adequate medication to decrease pruritus assists the individual to avoid damaging newly healed tissue. Exercise (see Figures 10-69, 10-88, and 10-89) reduces facial and neck edema, meticulous hygiene decreases the inflammatory process, and gentle massage prevents selective tethering of the skin to the underlying wound or muscle. When the skin is tethered, it wrinkles and makes the mature scar obvious to an observer.

Fig. 10-88. Mouth stretch using syringe cases.

After the tissue becomes light in color and the scar is mature, the orthotic support is discontinued. Because the capillaries have not developed normal tone, there is an initial hyperemic response. The likelihood of scar build up after the face or neck orthosis is discontinued can be decreased by initially having worn a properly fitting orthotic device, having had frequent revisions made as the wound changed, and having continued use of the orthosis until the scar was mature, and then by continuing frequent follow up visits to review wound changes.

Fitting a casualty with a transparent total contact orthosis is a four-step process. The first step is taking a negative impression of the face or neck. The whole process of taking this impression requires approximately 15 to 30 minutes for an experienced therapist or orthotist. Scalp hair is contained in a surgical cap and this is taped in place. Hairy surfaces such as eyebrows are coated with petrolatum to facilitate moulage removal. Alginate dental impression material, prepared in cool water, is spatulated in a flexible bowl until the mixture is bubble free. It is poured over the face, leaving an oral or nasal airway. Some centers use Duplicast[127] instead of alginate for the contact layer of the moulage. In this case, the skin must be well lubricated to allow removal of the moulage. A gauze strip may be imbedded as the alginate or elastomer sets, before the entire moulage is reinforced with four layers of fast setting plaster bandage strips. The reinforced moulage sets in two minutes, the soldier sits forward, inhales, and gently puffs air into the closed moulage to break the vacuum. With a gentle tug on the adjacent skin, the moulage falls away from the face. Care must be used to return the back of the model to its original dimensions, or the positive plaster cast will be wide at the back of the jaw and ears, causing unnecessary carving for proper fit of the mask. Some centers use silicone elastomer to take facial impressions. It is important to practice with the catalyst and elastomer to assure the material has completely set-up. Removal of liquid elastomer is complicated, can destroy fragile skin, and is painful.

The neck moulage is taken by massaging plaster strips around the scarred areas of the neck, leaving a back opening for removing the plaster from the neck. The neck and any hairy areas to be included

DO EXERCISES AT LEAST FOUR TIMES EACH DAY

(1) Remove splint. (2) Exercise. (3) Wash skin and splint. Dry well. (4) Reapply splint after exercise. (5) Do not leave splint off longer than 10 minutes. (6) Repeat exercises for both sides of face. (7) Hold each stretch at least for 2 minutes. (8) When skin will tolerate more stretch, increase case size.

To keep facial tissue loose and mobile, *slowly stretch* the cheek by placing a syringe case between the teeth and into the pouch of one cheek. The corner of the lips on the opposite side of the mouth is also stretched.	Stretch both corners of the lips backward. Pull them into a large "EEE" by placing the syringe case between the teeth and pulling backward at the corners of the mouth. This is the second exercise to do with the cone-shaped stretching device or syringe case.	The third exercise stretches the corner of the mouth. Slide the cone between the cheek and the teeth. This stretches one side of the lips and cheek pouch. Hold the stretch on each side for a count of 60.	The fourth stretch uses two cones, one in each side of the mouth. Slide one syringe case between teeth and corner of lips on the most difficult side. Then slide the second device in, crossing the syringe cases at first. Both corners of the lips and both cheek pouches stretch. Hold for a count of 100 or longer.
			

Fig 10-89. Face exercise program for home care of burn rehabilitation outpatient.

are well lubricated with petrolatum, or an equivalent, to facilitate removal of the negative mold without removing hair. Two or three layers of plaster strips are placed in progressive layers from the lower lip and ear area to 1 in. below the sternal notch. The first strip is massaged into place around the ears and chin, then the second is attached, and then the third is placed over the lower neck and clavicle area and folded into a "V" shape to conform to the anterior neck. This negative mold is removed and used the same way as the alginate and plaster facial mold.

The second step in fitting a casualty with the proper orthosis is forming a positive plaster cast of the casualty's face or neck. The positive plaster cast takes approximately 20 minutes to finish, depending on the setting time of the plaster. The following materials are needed:

- 12-minute impression plaster,
- plaster spatula,
- mixing whisk,
- Flexible, 4-in. angled reinforcement bar or bolt,
- petroleum jelly,
- a plaster stand,
- a clay modeling tool or tiny spoon,
- file,
- sandpaper,
- fiberglass sanding strips,

- cloth strips; and
- a vise.

Openings for the nose or mouth are closed with Jeltrate (LD Caulk Division) and supported with plaster strips. The bowl shape is formed with plaster strips over a paper towel to close the top and the bottom of the form. Bubble-free impression plaster is mixed in equal parts of water to plaster and is poured immediately onto the lubricated negative impression. This positive cast must be made immediately because alginate shrinks rapidly once mixed with water and exposed to air. When the anterior or deep portion of the mold has firmly set, the rest is filled with plaster and an angled bar or bolt is incorporated into this part. The mold sets in 20 minutes, whereupon the bar is clamped in a vise and the alginate and plaster are gently separated. Special care is needed to remove the alginate over the nose area because the poorly reinforced protruding nose breaks off easily. A paper clip can be dropped into the plaster to reinforce the nose, but this may complicate carving later. The neck is prepared in the same manner, except the plaster is more likely to adhere to the positive cast without the alginate interface, and additional care must be used during separation.

The bar or bolt is firmly clamped in a vise and the surface of the plaster model is painstakingly smoothed with a modeling tool, a small spoon, and Durite cloth. The hypertrophic scar details are marked with marking pen and smoothed off in the plaster mold so that the plastic mask will provide adequate total contact pressure to the maturing face or neck wound. Finally, the mold may be buffed with a cloth strip to provide a polished surface over which the plastic mask will be shaped. This total process takes about 30 minutes.

The third step in fitting the orthosis is fabricating the transparent plastic orthosis over the finished plaster cast. This may be done with a vacuum former or by hand, gently pressing the plastic over the plaster. This process takes 15 minutes, more or less, depending on the therapist's past experience. When tools fail or if the plastic bubbles, completion time is extended. Materials needed include:

- a 25.40 x 30.48 cm sheet of copolyester,
- a sheet of clear plastic,
- a toaster oven (204°C/400°F dry heat),
- a heat gun with spot-heater attachment,
- metal files,
- 3-0 steel wool,
- utility knife,
- felt cutters,
- scissors,
- Dremel motor tool with cutting blades and sanding drums,
- a round punch or drill press,
- four elastic Orthobands,
- four rivets,
- hammer,
- anvil,
- vise, and
- two pairs of double gloves.

The sheet of copolyester is heated in an (204°C/400°F) oven for 1 to 5 minutes and gently draped over the mold while two people carefully depress the plastic into the contours. This must be done quickly since the plastic cools in less than 1minute. Orthotics laboratories do this with a vacuum former. The excess plastic material is then removed and openings are cut for the eyes, nose, and mouth. The straps are attached in an "X" pattern from the temple to behind the opposite ear with the top of the "X" anterior to the crown of the head. This total process can take from 30 minutes to 3 hours.

The fourth, and by far the most difficult step in this fitting process, is revising the mask to be certain of accurate total contact pressure on the healing tissue. This is time consuming. It may take several hours. Sometimes the center of the face is all that can be fitted in one visit. Revisions of small areas must be done at each visit. Some less active scar areas can wait until later visits. As more dense scars soften and thin, these areas are revised for improved pressure.

Once the orthosis is strapped in place, the evaluation for revisions and fit begins. Areas of the hypertrophic scar are observed through the plastic. If they do not blanch, the areas are marked, transferred to the plaster model, and the plaster is carved down to develop gently rolling final contours. The plastic orthosis is changed until all scar tissue is flattened against the underlying bony contour. Scarred areas that need additional pressure can be revised by cutting away the plaster and spot heating the plastic with a heat gun. The transparency of the plastic mask permits continuous assessment and precise remolding. If the scars are very irregular and thick, the plaster positive must be gradually shaved off so the plastic mask will provide constant, total contact pressure. Excessive pressure applied before the scar has begun to soften can cause ischemic necrosis of the tissue. Too much undistributed pressure in the areas overlying the gums can irritate

gum tissue. The pressure should be applied in a way to "capture" the scar and distribute pressure evenly over the total scar, not just in the center of the scar. The plastic will tolerate at least four to six reheatings for revisions before it bubbles or becomes too brittle or too flexible to apply adequate pressure. Initially, the revisions for total face contact are done weekly; as the scar tissue matures, longer intervals are possible. A new plaster mold is needed only if head growth takes place or the plaster positive has been carved beyond repair.

The mask must be worn at least 20 hours a day to attain the desired result. A plastic orthosis that does not conform to the contours of the underlying skeletal structure is not likely to control the hypertrophic scar activity even if it is worn 20 hours a day. Although patients sometimes leave the orthotic appliance in a drawer and expect scar relief by wizardry, wearing the splint for a year or more is the only successful way to modify the scar.

If possible, when the entire face is scarred, it is preferable to control the forehead scars with a wide elastic head band; and the nose, cheeks, and chin with the transparent facial orthosis. This technique permits more freedom for motion of the jaw and facial muscles and less shearing force on the healed skin when the patient talks.

The casualty may require an orthodontic retainer to prevent posterior displacement of the teeth. If microstomia is a problem, the patient must also wear a mouth-stretching device. At least 4 half-hour exercise periods must be set apart each day for the patient for exercise. The mask must also be removed for 3 half-hour meals daily and for a 30-minute shower. Patients are encouraged to exercise and eat in 3 one-hour periods at the usual times, and to bathe and exercise before bedtime. The mask is never off for more than 1 hour at a time. Patients, family, and nurses need a written wearing schedule and instruction card (see Figure 10-87).

A special orthosis may be fitted to keep the nares patent. Custom fitted inserts may be made of soft silicone or hard acrylic. A separate nose orthosis may be fitted under the clear facial orthosis to maintain patent nostril openings.

If the ear meatus is scarring closed, it can be maintained with a silicone elastomer insert or a hard plastic or acrylic insert. An "Oyster shell"[128] orthoses can be fitted to preserve the upright pinna of the ear and to reduce hypertrophic scars over the outer ear. These are very complex and difficult orthotics to fit and wear.

There are several prosthetic companies that fit prosthetic noses and ears as well as other parts. The Life-Like Laboratory, 2718 Hollandale Lane, Suite. 400, in Dallas, Texas 75234, will provide these by mail order if an accurate model of the patient's head, color photographs, and a prescription is supplied.

Hypertrophic Scar, Edema, and Contracture Management of the Thorax and Limbs

As soon as the wound or donor tissue have no open areas larger than 3 cm^2, external vascular support management of edema and scar compression is initiated (see Figure 10-83). Although early continuous vascular support for hypertrophic scar treatment is well accepted, debate continues regarding the optimal pressure for these supports.[129] The majority of literature indicates that 25 mm Hg is necessary for scar treatment in order to exceed the level of capillary pressure.[130] The lowest was reported at 4 mm Hg to 5 mm Hg. Some clinicians stress that correct measuring of pressure in mm Hg against varying density of bone, muscle, and fat and differing body surface contours is impossible. Pressure measurement is probably not as important as having a fit that controls the scars and does not cause decubiti or nerve damage. It is suggested that children need less than 10 mm Hg to 20 mm Hg. A patient should be given the least pressure in the support that will decrease edema and modify the scar. Friction and shearing, especially at the elbows, axillae, and knees causes increased fibrotic reaction; chronic open areas develop and final wound resolution is slowed. Adequate support is postulated to enhance progressive devascularization of hypertrophic scar tissue and to speed wound maturity.[118-120]

The initial purpose of the external vascular support is to protect fragile, newly healed skin from blistering; improve venous and lymphatic return; decrease extremity pain; decrease itching; prevent sunburn or frostbite; moisturize epithelium; modify overly bulky, thick, hard, scars; and elongate maturing contracture bands. Complete baseline descriptions of the healed wound, any open areas, and areas of early scar symptoms or contractures are documented. Patients usually have signed a release for photographs, which become a part of the medical record. These photographs are taken at regular intervals to reveal scar changes. The least abrasive external vascular support is initiated to increase the durability of the epithelium. Gradually, tighter supports are introduced until maximum scar control is achieved without circulatory or nervous system complications.

External vascular support is initiated in the posthealing phase when staples are out, grafts are stable, and most open areas are dry. Gradient elastic wrapping progressively decreases the rate of applied pressure from the bandage and is changed according to a variable magnitude.[131] Elastic bandaging that is the tightest at the distal end and loosest at the proximal end of the limb simulates the pressure of water against a limb when vertical in a swimming pool, which pressure will improve venous and lymphatic return. This kind of bandaging can prevent hemorrhage of granulation tissue or hematomas under recently adherent STSG, and it will relieve blistering on dependent limbs (see Figure 10-27).

Generally, burned legs have been supported with figure-8 elastic bandage wraps from the acute injury through discharge from the hospital to facilitate ambulation, prevent pain, and lower extremity edema or hemorrhage.[106] These elastic wraps are applied while the soldier is recumbent, to avoid edema and poor venous return when standing. In cases of severe edema or poor quality elastic bandages, double bandages are used. Studies have shown early ambulation on the third to sixth day after grafting is safe, using an Unna support, which is a fine mesh, nonbias gauze medicated gelocast dressing impregnated with zinc oxide[132,133] (Figure 10-90). Wrapped in a spiral or figure-8 pattern around a lower extremity graft, a nearly healed burn or a donor area with small open areas, the Unna ([ConvaTec] ER Squibb & Sons) dressing will dry the wound, accelerate healing, and provide durable support and protection. An Unna dressing can be worn for 3 to 7 days in between changes. When fingers or hands are edematous and draining, they may respond to early edema management with Unna dressings along with elevation and exercise. When present, open tendons should be protected from the drying of an Unna dressing by a contact layer of Duoderm ([ConvaTec] ER Squibb & Sons) or other moisturizing dressing and the dressing must be changed daily. When the extremity is healed, it is usually durable enough for tubular external vascular support to begin on a foot and leg or Isotoner gloves on a hand. The prefabricated garments are made of a variety of materials from unidirectional, stretchable, rubber, elasticized cotton, to elasticized nylon, nylon/spandex, spandex, and rayon.[122]

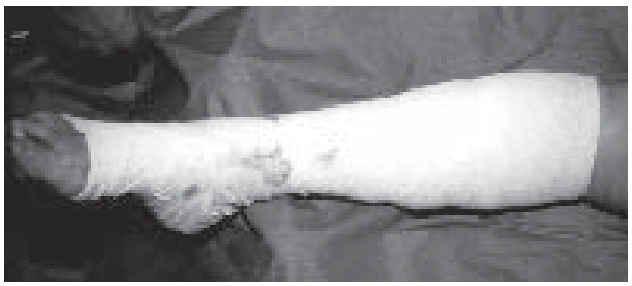


Fig. 10-90. The lower extremity, wrapped in a Unna dressing, is ready for the elastic wrap.

The casualty is given written directions for care of the wound and the external vascular supports (Exhibit 10-4). Elastic bandages are hand washed, rinsed well, and hung or laid over a net to dry. Some supports can be machine washed and dried. Others are hand washed in a mild soap (such as shampoo but not detergent), rinsed thoroughly, and air dried. The second support is worn while the first one is being cleaned. It is helpful to date or number the supports to keep track of their age.

Skin covered with support garments may develop offensive odors. Daily bathing, washing open areas and body wrinkles thoroughly, drying skin meticulously, and applying a lotion every day improves wound hygiene. Lotion should be rubbed in well prior to donning the support garment. Heavy petrolatum or oil-based lotions should be avoided because they liquefy natural sebum and it is then washed away. Wearing deodorant is appropriate if it does not cause contact dermatitis. If blisters form or open areas increase in size, discontinue the support garment, resume elastic wrapping of the extremity and explore the causes of blistering. If excoriation is from scratching, increase or change the antihistamine medications. Continue ambulation and exercise. If movement is causing open areas, exercise may be done in bed in an elevated position before the elastic wraps are applied until tissue becomes more durable. Drain the blister from the edge if the area is spreading from the pressure of elastic wrap. Drained seromas or hematomas need a pressure dressing to prevent them from reforming. Apply a small dressing over the blister, under the garment. It may be necessary to remove elastic wraps when the casualty is lying down to help open areas heal. Once they heal, resume 23-hour-a-day use of the external vascular support garment. It is normal for casualties to develop blisters for several months because absent dermis does not regenerate and fragile skin very slowly develops rete pegs, which increase durability. Attempt to continue the garments as tolerated. The garments are applied directly to the skin as soon as it becomes durable enough to tolerate them. Very fragile skin may be painted with Merthiolate or tincture of ben-

EXHIBIT 10-4

OUTPATIENT HOME CARE PROGRAM: TUBIGRIP EXTERNAL VASCULAR SUPPORTS

PURPOSE:	Compression sleeves, stockings, and garments support newly formed blood vessels; prevent swelling; decrease itching; decrease the thickness of scars; help scars elongate; help moisturize skin; and protect fragile, newly healed skin from blistering. Tubigrip is a rubber and cotton material that comes in either presized tubular rolls, premade garments, or shaped support bandages.
WEAR:	Continuously, all the time except during a bath or when applying lotion. Never leave off more than one hour.
APPLY:	____ Directly to skin ____ Over Kerlix wrap ____ Over nylon stocking interface ____ Over/under custom measured elastic garment. ____ Small amount of _____ to open area, gauze patch, then nylon and then "tubi"
WASHING:	Wash tubis daily, by hand, in warm water and mild cleanser such as shampoo. RINSE WELL. Air dry or use dryer on air fluff. Rubber deteriorates when exposed to oils or extremes of heat.
SKIN CARE:	Keep skin very clean and dry and moisturize with lotion every day. If blisters form or open areas increase in size, discontinue using the Tubigrip™ cylinder. Resume elastic wrapping of your extremity until checked by your doctor.
PRECAUTIONS:	Shearing of the fragile skin as the Tubigrip™ is donned should be avoided. A coffee can may be helpful to stretch the tubi as it is donned. Do not wear the tubi if it is causing sores. Padding usually makes the tubi tighter, so check with the therapist before adding padding. If scars are getting thick and hard, check with therapist or doctor. Elastic wrap over the tubi until you are seen in clinic. Tubigrip cylinders must often be worn in double layers to adequately compress the tissue. If your extremity is swelling, report it to your doctor at your clinic appointment.

If you need more Tubigrip, inform the clinic nurse. Be sure the therapist has checked the fit before you order more Tubigrip, especially if your scars are hard and dark red. Be sure you get the correct size. The tubular rolls are available in sizes A through G and J through L, the Tubigrip garments come in sizes 1 through 5. Shaped support bandages come in 6 sizes.

Make a list and pick up enough supplies to last until your next clinic visit. If you are having problems with supplies ask your Qualified Rehabilitation Counselor, your Medical Assistance Financial Worker or the Burn Clinic Social Worker for assistance.

For problems with scars, contact _____.

For problems with blisters or infections, discontinue using Tubigrip, elevate extremity, and contact your doctor.

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zoin to dry and toughen the area.

The supports are removed while bathing and occasionally during a rigorous exercise program. If they are left off for more than 1 hour, the area should be rewrapped with an elastic bandage. The most distal part of the limb must always be supported, so a glove, for example, cannot be removed for exercise or to view the wound unless the sleeve and axillary supports are also removed. Support for the thigh is initially accompanied by support toe to groin. When using Biker's compression shorts (Figure 10-91) for thigh donors or grafts, it is necessary to observe the ankles for edema because this support may have a tourniquet effect on the distal limb.

The external vascular support garments are usually worn for 12 to 24 months with an average time of 18 months. If the scar process worsens, inserts or overlays are added. Eventually all scars begin to

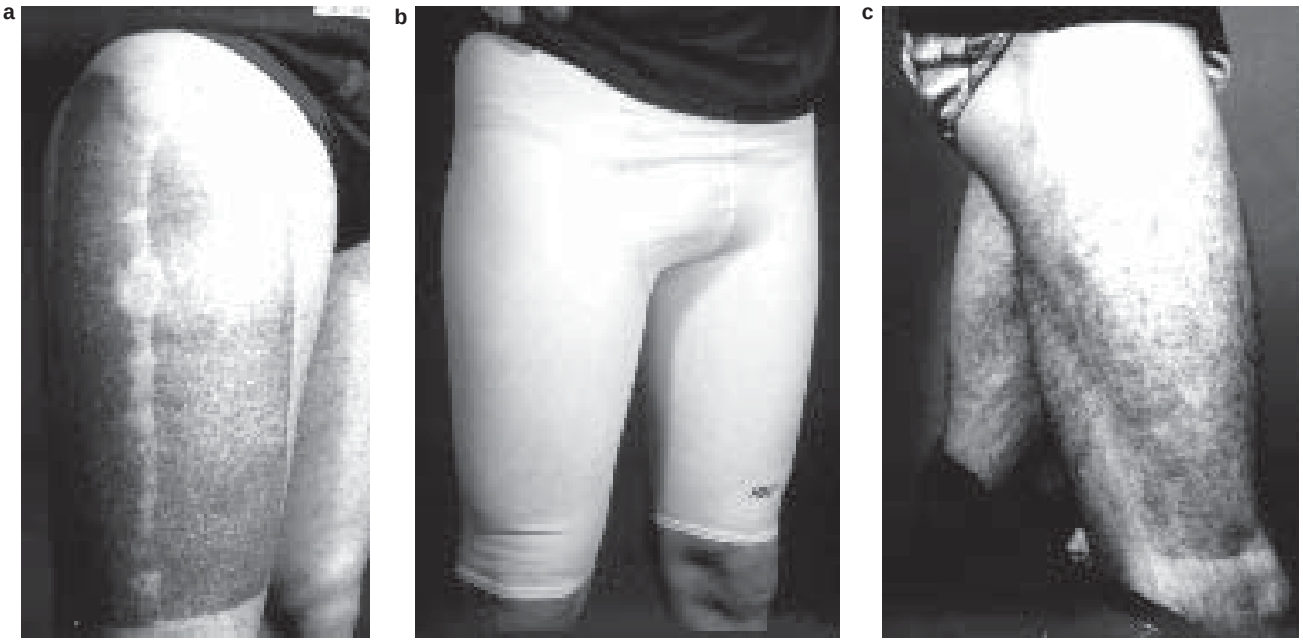


Fig. 10-91. Good donor outcome with biker's compression shorts. (**a**) Immature donor. (**b**) Biker's pants. (**c**) Mature donor.

regress (see Figure 10-82). When the healing wound becomes soft, of proper color, and flexible, the garments are discontinued for 3 to 7 days. If no changes in scars are noted, the wound is mature and the external vascular supports are discontinued. There is a hyperemic rebound response during the first 7 to 21 days after the support is discontinued. Initially it may be necessary for the soldier to wear the garments when ambulating and discontinue them when in bed. When stinging and itching are noted during ambulation or standing, the support stockings are continued at those times. If edema and the scar process re-forms, the supports are resumed for another 3-month period.

For external vascular support of the hand (see Figure 10-46), Isotoner gloves are an economical off-the-shelf type of support glove which is manufactured in three sizes for hands that are not extraordinarily large or small. Elset (Seton/Tubiton House) is a lighter type of low tension elastic bandage that allows freer finger movement. It can be wrapped in the figure-8 "boxer" wrap when the soldier has adequate strength to make a fist against the elastic wrap tension.[134] The fingers can be individually wrapped in a variety of 1 in. spiral wraps such as Sof-Kling (Johnson & Johnson) or Unna. Coban (3M Healthcare) is a light crepe self-adherent elastic wrap that supports fingers well but can become too tight (Figure 10-92). It also has a light adhesive that sticks to whatever it comes in contact with. Several compression companies provide elastic digi-sleeves, also called edema-sleeves. A thicker protective foam called LMB (North Coast Medical) finger pressure wraps can be applied with Velcro. A slip-on sleeve can be made by sewing a small section of Ace, cotton elastic, or spandex fabric. Tubiton is a finger stockinet that can be doubled over the finger to take up the shear when applying a glove (see Figure 10-42). If the hand itself is not ready for a prefabricated glove, it can be wrapped with Unna, PEG self-adhesive bandage, Coban or other elastic wrap. The fingers of the glove can be cut off, and it may be used as a gauntlet. The glove can be modified by splitting the dorsal aspect or side and sewing in Velcro for ease of application. Several companies provide prefabricated, variable-sized gloves, sleeves, vests, and pants. The amount of tension can be easily altered with a serger sewing machine.

Prefabricated garments, such as the Tubigrip (Tubiton House) line, provide external vascular support to the trunk and limbs (see Figure 10-83).[124] Measurements for a prefabricated tubular compression garment for an extremity or the trunk are taken from the widest circumference of the body part, and the appropriate width tube is selected.[135] Tubigrip provides wide tape measures that give you a choice of low, medium, and high tension selections. Experience indicates low tension improves durability of fragile epithelium, and high tension is appropriate after distal extremities are tolerating high tension

Fig. 10-92. Hand external vascular supports: (**a**) blue soft fabric custom measured Barton Carey glove; (**b**) spiral Unna finger and hand wrap; (**c**) Jobst Interim glove; (**d**) Coban spiral finger wrap with dorsum of hand included; (**e**) Elset "Boxer" wrap over dorsum of hand; (**f**) Tubiton Oedema sleeves on black Isotoner glove; (**g**) Gray Isotonor driving glove; (**h**) Palm of leather work glove; (**i**) Barton Carey custom glove with soft fabric over MCP; (**j**) Insert stabilizer glove with seamless thumb design.

support. Straight tubes are often doubled over with the shorter layer being next to the skin and a slightly longer layer on the top to avoid a tourniquet effect when they both end at the same place. If the extremity is a variable circumference, as in a heavy person or with someone with well defined musculature, a tapered or shaped support bandage can be used. The regular tube can also be put on in a single layer in the area of wider girth and doubled over in the thinner area. The tubes come in rolls and are cut to the desired length. A lightweight cardboard strip inserted into a wide fold at the proximal end of a Tubigrip tube decreases the risk of proximal rolling, which may cause blisters or the tourniquet effect. When the patient has large open areas and the dressings fall off the trunk or legs, a nylon stocking can hold the dressing in place for donning the lightweight tubular bandage. Tubular garments can be placed on a metal applicator or coffee can (Figure 10-93). The can is brought over the extremity. At the proximal end, the elastic tubular support is gently taken off the applicator as the applicator is moved distally, leaving the elastic support on the extremity. The garment can be doubled back up the arm proximally if additional pressure is needed. If the skin is durable and able to tolerate the shearing of applying the garment without an applicator, the garment can be applied like regular clothing. An alternate method is to leave the distal portion of the garment like normal and turn the rest of it inside out. Then pull the garment up an inch at a time, pinching the sides and bringing it right side out as it is applied proximally. A vest would be put on as a jacket.

Weight gain and loss should be stabilized before measuring for custom garments. This may take as long as 6 to 8 weeks. Custom garments are usually measured circumferentially every 1 to 1½ in. for the extremities (Figure 10-94) and at the waist, hips and chest for the trunk; the measurements are noted on the company's ordering form. Joints are marked on the circumferences record and measured on the pictorial form. Usually, hands and feet are drawn. Each company has its own forms, tapes, and style of measuring. Tape measure designs include longitudinal paper tape with many cross-sections taped on the extremity or a light adhesive measuring device placed

Fig. 10-93. Donning prefabricated Tubigrip sleeve using an applicator.

directly on the body. Some tapes are circular and others may be weighted. Measurement information can be quickly and accurately communicated by facsimile transmission. If a photocopy copy of the hand is used, it is sent by ground mail and facsimile, because on the original copy of the hand, what you see is exactly what the hand measures; facsimile copies distort this sizing slightly.

Accurate measurements are taken by an OT or PT, a seamstress, or a company representative. In-depth knowledge of the patient's injury and course of recovery helps plan the proper design and individual options.[136] Climate, employment conditions, physical limitations, and psychological status also influence the garment type.

Patients should be measured as early in the morning as possible when extremities are the least edematous. Measurements are taken in direct contact with the patient's skin, not over clothing or dressings. The tape measure should be placed firmly but not tightly. When there are two adjacent garments, that is, a glove and an arm sleeve, overlap measurements so the garments themselves overlap and do not gap or pinch. When doing a tracing, one should use a thin marking pen. For some digit amputations that are hard to measure, a negative impression can be taken, and a positive plaster model can be made and sent off to the company with the other measurements. In these models, a paper clip or other stabilizing piece of wire should be included in the fingers to improve durability if plaster, not dental stone is used for the model. Most companies employ a bioengineer to calculate the correct formula to apply accurate compression. The garments are then produced and mailed back. The soldier tries the garment on at the therapy department (Figure 10-95).

Fig. 10-94. A casualty is being measured for a garment using the Jobst custom stocking measurement system.

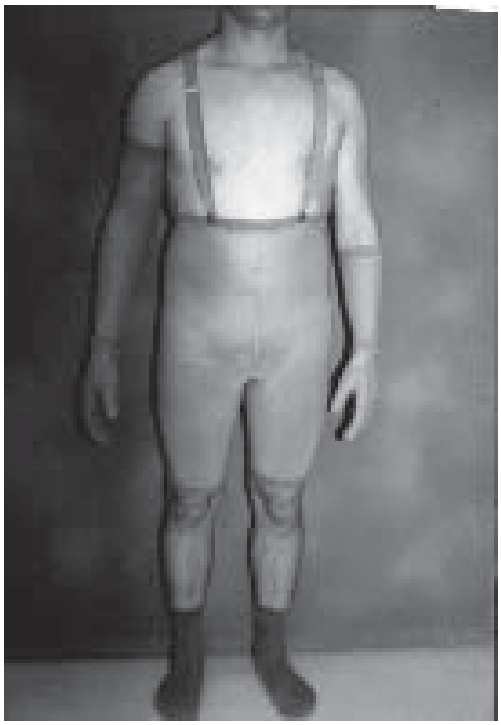


Fig. 10-95. Custom measured external vascular support garments (gloves, sleeves, and brief with suspenders).

Variables that influence garment design are the burn site, the age of the patient, the burn depth, the presence of STSGs, and the length of time to wound healing. Multiple garment designs are offered by manufacturers. Of primary importance is predicting whether a wound will scar and the location and size of the scar area. The garment should completely cover the potential scar area with a 2- to 3-in. overlap at either end so that when the patient moves, the garment will still be in contact with the area being treated. Edema and deep vein thrombosis are always a concern, therefore, the garment design must include tissue distal to the burn. Fingertips and feet can be either open or closed, depending on the patient's needs. The toe covering can be of extra soft material, enclosed as a unit or separated individually. Netting can be used to surround unburned areas for ventilation. Liners can be placed around joints with bony prominences.

The garments need firm attachment points so they do not roll, slide down, or ride up. The points could be at the waist, forearm, shoulders, or hips. Ending the garment on the muscle belly should be avoided as the edge may constrict when the muscle is flexed. Ending the garment directly on a joint can decrease circulation as well.

For the hand, the initial custom measured full glove with closed or open finger tips, slant interdigital seams, and a thumb design that allows radial and palmar abduction without losing fit over the dorsum of the hand is appropriate. Often the initial glove is made of soft fabric; the density of the fabric is increased to heavy duty when the skin can tolerate this. A leather palm work glove is also available from custom glove providers. Later, a gauntlet or mitten style design may be used if fingers are not involved. A variety of interdigital and thumb web space adaptations are available from custom garment companies. Soft fabric may be used around especially fragile areas such as the middle MCP joint (see Figure 10-92).

For the thorax and limbs, a few basic designs can be varied in myriad ways. The thorax garment can be a basic sleeveless vest; or a full suit with long arms and thighs with a crotch that is opened, closed, or has a Velcro, zipper, or snap flap. If the vest rides up, not covering the lower trunk and a body brief is not desired, the vest itself can be made several inches longer or a heavy duty snap or Velcro closing crotch strap can be added. Vests can have anterior or posterior closures of Velcro or a zipper. Velcro allows for some adjustment in the tightness. In a female, breast cups are measured and a front closure is used. A bra can sometimes be sewn into the garment instead of the compression fabric. Soft tank-top type fabric may be comfortable for unburned breasts. An unburned arm can have a short sleeve. Sleeveless vests tend to have little pressure on the chest or upper back secondary to the open arm holes. A vest with only one arm will pull the neck opening away from the open side, take away the chest and back pressure, and exaggerate poor posture. This is contraindicated. Various lengths of arm sleeves are feasible. However, if the shoulder requires compression, a vest style is more effective; and attachments keeping the waist from riding up to release pressure over the top of the shoulder is important. If the axilla is irritated from a vest that rides up, a body brief or a body suit is recommended to prevent this pinching. The axillary area may also be made larger if no compression is needed there. Pants can be waist high but if the pants fall down several options are available. Clip-on wide suspenders can be used, or a wide elastic band may keep the waist from rolling down. If a vest is also required, overlapping Velcro tabs or heavy duty snaps can be used. For bilateral thigh-high stockings, a garter belt can be used. A garter belt will not work on a unilateral thigh-high stocking. If the skin is durable enough, some skin adhesive or foam tape can be used. Knee-length stockings and anklets usually stay up well, especially if the skin is well moisturized before donning the stocking. Zippers can be placed in any of the extremities to assist initial donning and doffing when the skin is still fragile. Zippers decrease the uniform compression of the garment and at times need to be padded; it is best to avoid them if possible. Other options to add to compression garments are inserts, gussets, pads, and darts.

The initial fitting of a garment should always be done in the clinic rather than mailing the garment to the patient. This assures an accurate measurement and fit. To be therapeutic, the correct level of compression should slightly blanch the hypertrophic scar areas. There should not be any restrictions in motion, compromise of circulation, or skin integrity. Color, motion, and sensation should be checked before the patient leaves the clinic. The fingers and toes should be observed for swelling, coolness, and duskiness, and the patient should be asked about numbness or tingling. The patient should be instructed to discontinue the garment, reapply elastic wraps, and call the therapist if problems occur at home.

Applying the new garment for the first time is challenging. It should fit tightly like a wet suit, and it should take several minutes to don it. A child may

require a back closure to keep the garment on. Children will naturally require assistance for donning and fastening the closures. If the garment is a trunk tube it can be stepped into, pulled up to the axillae, and sleeves pulled up or shoulder straps fastened. This avoids irritating the ears. If the ears are not injured, trunk tubes may also be donned like a tee shirt (ie, pulled over the head).

The fit can be checked by how the garment feels to the casualty and how the scars feel to the experienced therapist, through the garment. The garment should be tight enough that it is not possible to grab hold of it easily and pull it away from the skin. Shoulders, elbows, and knees should have adequate relief for full AROM without causing open areas. Listen closely to any complaints from the casualty and evaluate them accurately. The garment should not have wrinkles in it. Many times the first garment does not fit correctly. If the garment fits well, an additional set is provided. If it is not a good fit alterations can be made or new measurements taken. Most commercial companies will replace a problematic garment within the first 7 days.

The garment is worn 23 hours a day throughout the duration of the skin maturation process. The garment must be removed for bathing, and occasionally it is necessary to remove it during vigorous exercise sessions when it is causing blisters. It should be washed daily to remove perspiration, body oils, and dirt. Meticulous hygiene is essential for the skin, as well. The garments should be cared for as the manufacturer recommends. Some are hand washable and air dried; others are machine washable.

Some helpful tips may make a difference. A very light cornstarch or powder dusting may help with garment application. Remind the casualty to wash the powder away each day to avoid a plugged pore condition. Wearing nylon under the garment can decrease the shear on skin and increase the ease of application. Foam pads at the joint creases of the knee and ankle can prevent the garment from cutting into the underlying skin. A Duoderm protective patch on the olecranon, the antecubital area, or both, can prevent scrapes in these vulnerable spots. Plastic food wrap over lotion on dry, scaly areas can keep moisture in and protect the garment. In the summer, when the skin is prone to heat rash, the garment can be worn damp to keep the person cool. Some laborers carry a cooler of ice frozen in a sprinkle bottle to cool themselves at work. Old garments are used for swimming.

Reassessment is best done weekly initially, to assure wearing tolerance and to watch for any complications and changes in weight or muscle mass. If an aggressive therapy program is not required, the scars are becoming soft and light in color, and the patient is doing well, visits can be decreased to biweekly, monthly, and bimonthly through the maturation process. Generally, prefabricated garments last only 1 to 2 months, depending on the patient's activity level. A new garment should be issued at each clinic visit until the patient has five garments that fit well. Custom garments generally last 2 to 3 months. Some patients may require more than 2 sets, secondary to their work or leisure situation. It may be necessary to set aside one set of garments for dress and use the stained ones for daily activities. On return to the clinic setting, the state of the skin (contractures or hypertrophic scar tissue) is compared with the previous visit. Narrative or photographic comparison should be made. An objective score can be obtained through measurements based on the assessment form de veloped by Vancouver General Hospital[137] (Figure 10-96).

If there are bothersome open areas, they should be checked for infection. If they interfere with motion or cause excessive pain the garment can be removed for exercise. It may be necessary to wear Ace bandages for a few days before reapplying the garments. Hands and feet should be checked for a narrowing of the transverse arch. The burn team must remain alert for delayed growth in children who are wearing elastic pressure garments for a long period of time.[126] Parents are also taught to check for regression of skeletal growth. The garment is modified in response to any complications, and reordered when it is fitting well, but the elastic is worn out. Remeasuring is necessary if there has been a significant weight change or growth, as in the case of a child.

The wound is mature when the skin texture is soft and scars appear of proper color and are flat and thin. The skin will be more flexible with some extensibility. There may be some loose, excess skin folds appearing to be wrinkled. Erythema will have faded or lightened from a purple color to red, to pink, to dark brown or white. In people of color, the skin will return closer to its normal pigmentation. Most of the time the pattern of a mesh graft can be seen. Even with optimal results, there is usually some change in color tone. The external vascular supports decrease the amount of hyperpigmen-

GUIDELINES FOR USING THE VGH BURN SCAR ASSESSMENT

This document is intended to clarify procedures for selection of a scar and to offer guidelines for using the VGH Burn Scar Assessment Form. The form is composed of 3 sections: body diagram, rating scales, data record

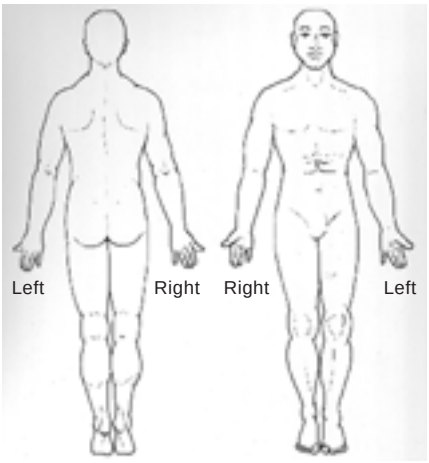
1. SELECTION OF SCAR

Prior to using the VGH assessment, pressure garments should be removed for a minimum of 5 minutes and the area should be in a non-dependent position.

One or more scars are selected at the rater's discretion. As a guide, it is recommended that selection be based on the scars' potential to limit joint range, to become excessively hypertrophic or to require specific therapeutic intervention. If possible, choose the perimeter of the scar to permit greater accuracy for comparison with the normal skin. The area of any scar being rated should not exceed 25 mm x 25 mm (l " x l "). It is recommended that one form per scar is used to allow easy monitoring of scar maturation.

2. BODY DIAGRAM

Once selected, the location of the scar is circled on the schematic body diagram and a number is written adjacent to it. As an adjunct, Polaroid photos may be used, encircled and numbered in a similar manner.



3. RATING SCALES

In the analysis of each scar, 4 components are assessed: pigmentation, vascularity, pliability and height. Each component has a separate scale with zero as the normal reference point.

PIGMENTATION

This is assessed by applying pressure with a piece of clear plastic (for example, 'UVEX') to blanch the scar. This eliminates the influence of vascularity, so that a more accurate assessment of pigmentation can be made. The blanched scar is compared to a nearby blanched area of the person's unburned skin. A variation from the normal skin colour indicates a pigment change. Scale ratings are as follows:

0 - normal (minimal variation from the normal skin pigmentation)
1 - hypopigmentation
2 - mixed pigmentation
3 - hyperpigmentation

VASCULARITY

This is assessed by observing the colour of the scar at rest. In addition, the scar is blanched with the clear plastic and the rate and amount of blood return are observed The more intense the colour return, the higher the rating. Scars which are congested and refill slowly or cannot be completely blanched are grouped in the purple category.

0 - normal (colour and rate of its return, closely resembles that of normal skin)
1 - pink
2 - red
3 - purple

PLIABILITY

This is assessed in the following manner. The scar is positioned to minimize its tension, after which it is manually palpated between thumb and index finger to assess how easily it distorts under this pressure.

0 - normal (resembles pliability of normal skin)
1 - supple (flexible with minimal resistance)
2 - yielding (can be distorted under pressure without moving as a single unit, but offers moderate resistance)
3 - firm (inflexible; scar moves as single unit)
4 - banding (rope-like tissue that blanches with extension of the scar; full range of movement)
5 - contracture (permanent shortening of scar producing limited range of movement)

FIGURE 10-96, Guidelines for Scar Assessment, *continues*

HEIGHT

The height of the scar is visually estimated to be the maximum vertical elevation of the scar above the normal skin. A millimetre scale is included on the form to facilitate this assessment.

0 - normal - flat, flush with normal skin.
1 - > 0 to 1 mm (more than one quarter of the area being rated is raised more than 0, but less than 1 mm)
2 - > 1 to 2 mm (more than one quarter of the area being rated is raised more than 1 mm, but less than 2 mm)
3 - > 2 to 4 mm (more than one quarter of the area being rated is raised more than 2 mm, but less than 4 mm)
4 - > 4 mm (more than one quarter of the area being rated is raised >4 mm)

VANCOUVER GENERAL HOSPITAL
OCCUPATIONAL THERAPY DEPARTMENT

PATIENT NAME:

PIGMENTATION (M)

0 normal - colour that closely resembles the colour over the BURN SCAR ASSESSMENT rest of one's body.
1 hypopigmentation
2 mixed pigmentation
3 hyperpigmentation

VASCULARITY (V)

0 normal - colour that closely resembles the colour over the rest of one's body.
1 pink
2 red
3 purple

PLIABILITY (P)

0 normal supple - flexible with minimal resistance
2 yielding - giving way to pressure
3 firm - inflexible, not easily moved, resistant to manual pressure
4 banding - rope-like tissue that blanches with extension of scar
5 contracture - permanent shortening of scar producing deformity or distortion

HEIGHT (H)

0 normal - flat
1 > 0 to 1 mm
2 > 1 to 2 mm
3 > 2 to 4 mm
4 > 4 mm

Scale in mm

Fig 10-96. Vancouver General Hospital Burn Scar Assessment. Based on the assessment form developed by Vancouver General Hospital, 855 West 12th Avenue, Vancouver, BC, Canada V5Z 1M9

tation deposited in the wounds of people of color (Figure 10-97).

When a scar appears to be mature, a trial period without external vascular support is initiated for at least 1 to 3 days but not longer than 1 to 2 weeks. If the symptoms or signs of active scar formation do not recur, the ultimate outcome has been achieved. In evaluating the scar maturity, some professionals consider the scar inactive when less than 10% of the wound remains immature or hyperemic. However, the small hypertrophic area often is more bothersome to the casualty than the large one when it becomes painful, pruritic, and fragile. Continuing use of vascular support garments can prevent this complication.

For a list of prefabricated and custom garment companies,[120] see Exhibit 10-5.

An insert is used to accelerate the hypertrophic scar maturation process.[65] It fills in concave areas that a custom measured garment cannot reach. It is usually placed between the skin and the compression garment over a thick hypertrophic scar, tight

EXHIBIT 10-5

COMPANY PRODUCT AND SERVICES AVAILABLE

This list of products and services is provided here for information only. The mention of these products and services here is not to be construed as an endorsement by the U.S. Department of the Defense, the U.S. Department of the Army, or the US Government.

Prefabricated Garments: Acme United Corp. (800)-243-9852 Note: Tubigrip products were formerly handled by Sepro in the USA and Seton in England. Cloth and paper measuring tapes, measuring guidelines and garment charts provided. Regional representatives supply in-house teaching with a network of local suppliers. Phone discussions are welcomed.

Caromed Int'l., Inc. (800)-833-2237 Polli surgical garments use regular measuring tapes if i.e., circumferential measurements are needed (i.e., a waist size), but some garments vary with Velcro. Sizes by s-m-l. Standard size vests 36", 42" and bra cup size. Order from two national distributors. Phone discussions are welcomed.

Aris Isotoner, Inc. (800)-223-2218 Isotoner gloves are one size fits all. There are some variations in s-m-l corresponding with standard glove sizes 6 to 8 ½. They are variable lengths. Order forms are available. They are also found in some medical catalogues or local stores. Phone calls are welcomed.

Elastic Sport Garments: Bike compression support performance shorts, (92.5% polyester/3.5% Lycra-Spandex), s-m-l-xl, price $15 each, 2801 Redog Drive, Knoxville, TN 37914, phone 1-800-272-6060. This fabric gives protection, and is supportive. Patients often wear the shorts reverse side out to avoid wound abrasion from the seams. Wilson Compression Shorts, 4-way stretch sports girdle, (75% Nylon/25% Lycra-Spandex), s-m-l-xl, price $14.99 each, Martin Manufacturing Co., Inc., 5200 Highway 153, Piedmont, South Carolina 29673, phone 1-800-237-9356. This fabric gives protection, but is not ideal for support. Patients like the "slippery" feel of the fabric, worn reverse side out, which prevents blisters from the seams. Brawn Weightlifter Short (20% Spandex/80% Nylon with full 100% nylon liner), s-m-l-xl, price $24 each, through International Male Magazine, 7412 "F" Street, San Diego, CA 92112-9027. This fabric gives protection, and if the fit is snug, support. Patients say these shorts are preferable because of the soft liner. Stromgren Supports knee length, 25% Lycra/75% Nylon, price $12 each. This fabric is too thin to give support or protection. It is hot. The legs of the shorts are too short to cover donor areas. Beware of discount prices. Measured in standard sizes at your local biking, aerobics or sporting stores.

Custom Garments: Barton-Carey Medical Products (800)-421-0444 A measuring device, "locator" tapes to use with the measuring device, measurement forms, and order forms are provided at no charge; a measuring instruction booklet can be obtained from the company. On request, Barton-Carey sends qualified personnel to train staff members in any hospital in the United States or Canada; for any hospital preferring not to do the measuring, the company will provide that facility with an outside source to do the measuring. Telephone conversations about measurement problems are invited.

Bio-Concepts, Inc. (800)-421-5647 Measurement tapes, a measurement kit (containing a tape "gun," a transparent flexible ruler and other measuring and marking devices, measurement forms, and order forms) are obtainable at no charge. Periodic training seminars for select qualified personnel are held. Bio-Concepts invites participants to this expense-paid seminar; there were 44 seminars with 261 participants as of 1990. A free videotape for patient education is available. Problem solving is encouraged and can be done by telephone. Prefabricated garments are available.

Gottfried Medical, Inc. (800)-537-1968 Paper measurement tapes and measuring forms that use a cloth measuring tape are supplied at no cost. A 20-minute instructional video on measuring and fitting techniques can be provided. The company furnishes support to facilities that request measuring services through an extensive dealer network. Telephone dialogue regarding any questions or difficulties about specific measurements of a pressure support is encouraged.

Jobst Institute, Inc. (800)-537-1063 Paper measuring tapes, measuring forms, and order forms are available at no cost. Training opportunities include a measuring and fitting manual, a measuring and fitting video. 32 service centers in the United States and Canada with staff trained to measure and fit as well as to teach the techniques, five regional service managers available for in-house teaching of the procedures, and a network of dealers throughout the United States and Canada who can serve patients living great distances from the burn center. Phone discussions about orders are welcomed. Prefabricated and interim garments are available.

Wright Linear Pump, Inc. (800)-631-9535; Sticky back measuring tape, measuring forms and Rx forms (800)-922-4226. Forms are available at no charge in a measuring kit. The measuring forms are self-explanatory. There are consultants that use this product in hospitals and training centers across the country. Telephone discussions are welcomed. Note: This is for extremities ONLY that are edematous and used in conjunction with the pump.

Fig. 10-97. Outcome of deep thermal injury. (**a**) Impaired venous return, dependent immature graft and donor. (**b**) Mature graft and donor; note the permanent cosmetic changes secondary to excision of fascia.

skin, contracture, or a concavity where a bridging area has begun. Some inserts have been used successfully alone, for small areas, without compression. Overlays are placed over the custom measured garment with an elastic wrap or another garment to press the garment into concavities in between bony prominences or anatomical structures that compression garments "tent" over. The overlay or insert fills in the negative spaces for a smooth total contact compression from the external vascular support garment. Inserts also are used to help flatten and soften taut, rope-like contractures. These are often noted over joints. Eventually the tissues become longer, so that blanching is decreased when the skin is put on a stretch, and contractures decrease. Inserts add extra pressure over thick nodular hyperemic scars. When used in this manner, tapering the edges of the inserts will assure total contact by preventing tenting from the elevated ridges. Inserts can be used as padding for protection over bony prominences, under zippers, and at the inner angle of flexor creases, such as the ankles or elbows, to prevent the garments from cutting into the skin. Inserts and overlays help elongate, flatten, and soften scar tissue. Closed cell inserts may need to be worn with an open cell, fabric or disposable gauze, or paper liner to absorb perspiration. A pocket can be sewn into the compression garment to hold inserts (see Figure 10-85). They can also be held in place by applying Velcro to the insert and the garment or running a Velcro strap through the insert itself (Figure 10-98).

Wounds must be healed prior to the use of inserts. Inserts can be fabricated prophylactically for areas of anatomical vulnerability, such as the thumb web space, or concave areas, such as between the breasts (Exhibit 10-6). At the onset of the skin shrinking before contracture can form, a properly placed insert prevents more difficult problems later. As the dynamic scars change, inserts can be serially made for increasingly larger anatomical spaces as the skin stretches. As the scar flattens, impressions can be filled in until the insert is flush with the surface and the scar impression is no longer seen in the insert. Eventually, during the course of maturation, inserts can be made completely flat, using a rolling pin. Larger inserts can be made flat on old x-ray films. Reevaluation and modifications are made at regular outpatient visits.

Fig. 10-98. Examples of materials for inserts, overlays, and accompanying support gloves: (**a**) Rolyan Silicone Elastomer; (**b**) Isotoner glove and silastic elastomer "brass knuckles"; (**c**) Smith and Nephew Prosthetic foam material; (**d**) Otoform K material and Otoform K "brass knuckles"; (**e**) prosthetic foam palmar insert; (**f**) prefabricated Jobst glove with Otoform K web spacers; (**g**) Jobst interim glove with stockinet overlay (note applicator distal to fourth finger); (**h**) prefabricated Tubigrip glove with Velfoam "brass knuckles"; (**i**) Isotoner glove with finger inserts (left to right—orthopedic felt, lamb's wool, Betapile, at wrist: small orthopedic felt split into layers); (**j**) Elastogel cast and splint pad; (**k**) Bioconcepts prefabricated glove with Otoform K separated interdigital web inserts; (**l**) Spenco skin care pad; (**m**) prosthetic foam palmar insert, prosthetic foam palmar insert; (**n**) Jobst interim pediatric gauntlet; (**o**) orthopedic felt layers.

There is a wide variety of materials to use for inserts or overlays to increase pressure over a hard scar. The creativity of both therapists and casualties has been the source of many successful scar modifiers. Fabric, open or closed cell foam, rubber or plastic pieces, and silicones are all appropriate inserts or overlays (Figure 10-99). Inserts can be ready made and cut to the individual's needs, or they can be custom formed to the body's contours. These inserts can be secured in external vascular support garments by pockets (Figure 10-100). Fabric envelopes, Webril (Kendall Healthcare Products Co.), or other disposable wrap may be used to protect the skin from direct contact with the oily silicone. Often the silicone can be placed between two Isotoner gloves or between two Tubigrip stockings, which increases the pressure on the scar and prolongs the life of the insert. When contact dermatitis is caused by the insert (Figure 10-101), that insert must be discontinued and after the area is healed a different insert material tried.

The insert and support must be applied in a way to maintain gradient pressure. They cannot be applied like a tourniquet in the middle of an extremity. This will impair venous return and cause edema in the distal hand or foot. Even if edema is not severe enough to be seen with the naked eye, the distal circulation will change. Therefore, the insert must be placed under or over a support that is donned from the hand or foot to the shoulder, knee, or hip. The following prefabricated commercially available fabrics and foams are listed in order of

EXHIBIT 10-6

INDICATIONS, CONTRAINDICATIONS, AND PRECAUTIONS FOR USE OF INSERTS WITH EXTERNAL VASCULAR SUPPORTS

Indications
- Area of concavity (ie, chest sternum, palmar arch)
- Particularly active hypertrophic scar
- Contracture bands
- Use in both old and new scars
- Problematic body areas vulnerable to contracture (ie, finger webs, popliteal, and antecubital fossae)
- Bony prominences vulnerable to breakdown

Contraindications
- Sensitive skin or prior dermatologic condition such as prolonged use of steroid creams
- Prior skin diseases (ie, eczema)
- Impaired cognition
- Open wounds
- Allergies

Precautions
- Maceration secondary to moisture build-up
- Friction blisters
- Decubiti
- Contact dermatitis
- Heat rash
- Allergic reactions

increasing abrasiveness. Lamb's wool in coil form is a very soft natural fiber. It absorbs moisture in interdigital web spaces and protects fragile areas. It is useful with people fearful of replacing their present dressings with another texture. Fibers will adhere and incorporate into open wounds and therefore wool should be covered if applied where open areas or drainage is present.

Orthopedic felt is a white polyester fabric padding ⅛, ¼, or ½ in. thick that can be cut into various sizes and shapes. It can be separated into layers to vary the thickness. The inner surface is softer. It thins out with repetitive use and must be replaced often.

Sheepskin is a thick, fluffy synthetic material that looks like real sheepskin with a firm fabric backing. It is good for protection of the bony prominences or for increasing compression.

Moleskin is a very thin soft padding fabric with self-adhesive backing. It can be placed against garments or splints for protection and to even out two surfaces.

Hypafix is a contact medium in the form of a soft adhesive gauze. It can be left in place for several days and creates tension on anatomical depressions. Success has been reported using this in place of compression garments over small areas.[138]

Velfoam and Betapile are cushioned strapping materials that work well as finger inserts. They are loose fabric compatible with hook Velcro.

Hollister Odor Absorbent dressing is a thin, absorbent, open cell, charcoal black foam encapsulated by a soft white mesh material. It is machine washable and dryable. It works very well as a liner to absorb perspiration or prevent maceration under elastomer inserts.

Reston foam is a white, open cell foam. It compresses with pressure. The adhesive adheres to wood or plastic securely and cannot be removed easily. The foam also absorbs odor and can be unpleasant in the presence of drainage.

Polycushion is a beige, closed cell foam with an adhesive back. It can be placed on splints or gar-

Fig. 10-99. Overlays and inserts for hypertrophic scars. (**a**) Dow Corning silicone sheet; note that tape adhesive may irritate surrounding healed tissues. (**b**) Spenco skin care pad protecting flexion crease. (**c**) Elastogel on open area.

Fig. 10-100. Custom measured Barton Carey garments. The garment is turned inside out to show the pockets that secure the silicone inserts.

Fig. 10-101. Contact dermatitis caused by the Otoform K thumb insert.

ments. The two adhesive sides can be folded together to make a nonadhesive insert.

Kushion flex is a white, very firm, closed cell padding with adhesive backing. It may be beneficial in an area where durability is required such as a shoe insert.

Plastazote is a flesh colored, closed cell foam that can be formed on the skin after it is heated to a low temperature. It is also good for shoe inserts. It comes in either adhesive or nonadhesive forms.

Neoprene is a blue-black, closed cell rubbery material. It is spongy with elastic memory and is available in variable thicknesses.

Contour form is a blue colored, open cell, slow recovery padding. Body heat helps to mold the foam. It is available in different thicknesses.

Microfoam tape is a soft tape similar to Reston but of closed cell foam. The two adhesive sides may be placed together to form an insert or zipper pad.

The following silicones and elastomers are also listed according to increasing abrasiveness:

Skin care pad (formerly known as Dermapad) comes in 4 x 4 in. by ⅛ or ½ in. sizes. It is a cream colored protective pad with a solid gelatinous consistency described as artificial fat. It is lightly adherent and cuts into any shape. It provides cooling comfort. Thicker pads eliminate friction and absorb pressure. Thinner, flexible pads are excellent for use on mobile joints such as the elbow. Both sizes are excellent to increase compression. The pad's surface is very oily, and the scar must be protected or observed for maceration. Using these pads for 8- to 12-hour periods, and leaving them off for 12 to 16 hours may relieve skin over-moisturization.

Dow Corning silicone gel sheeting (see Figure 10-99) is a clear, soft, slightly adherent, semiocclusive, flexible insert made from medical-grade silicone polymers without fillers.[139,140] One version is very tacky, stays in place well, but crumbles fairly easily. Another type has a netting back woven through. It is unique in that it is advertised to modify a scar with or without pressure. When it is effective, it is worn a minimum of 12 hours per day rather than the usual 23 hours per day.[141,142] If both compression and the silicone gel sheeting are worn, they should only be worn together 12 hours a day. For the other 11 hours, one or the other can be worn separately. Otherwise, skin irritation may develop and the gel sheet will have too much wear, disintegrating it.

Otoform K ([Dimethylpolysiloxane] Dreve Co.) is a white silicone elastomer with a putty base. It is mixed with a red tube catalyst resulting in a firm, pink, rubbery, closed cell insert. It does not run, sets in five minutes, is odor free and semirigid but flexible. It positions, yet allows some motion. It is easy to work with in small to medium quantities. It works well for interdigital web spacers of the hand, thumb, and feet, and as a shock absorber, decreasing contractures and filling in concavities (see Figure 10-72).

Silastic (Dow Corning) elastomer is a closed cell, gray-liquid-based, taffy-like elastomer mixed with a clear catalyst out of an eye dropper. It cures to a rubbery texture. The setting rate depends on the amount of catalyst used. It is a little more challenging to handle, requiring a tongue depressor. It sticks to hair, so a protective layer on the skin of lotion or plastic wrap is helpful. It does stain before the catalyst is added. It requires refrigeration or storage and has a 1-year shelf life. It picks up very fine detail. It is fairly rigid and works well on large areas. Serial inserts can be made by filling in the impression of the scar as it improves with silastic medical adhesive. Repetitive fabrications can be made on a revised scar until it is flush. On large body areas a pattern can be made and the insert fabricated on old radiographic material. It works well on flatter surfaces with less mobility such as the trunk, lateral ankle, or palmar arch. It can be mixed with prosthetic foam.

Dow Corning prosthetic foam is an open cell, tan colored, liquid-based, silicone elastomer mixed with a clear bottle of catalyst. When the catalyst is added, it will increase in volume and have an exothermic reaction. It can be contained by forming it inside of transparent plastic wrap against the body. It sticks to hair. It is soft and spongy. It can be used in conjunction with the hard, low temperature splinting material outer shell. It works well as a total contact padding on delicate or fragile areas. It is sometimes placed on a fresh graft with a moist sterile dressing underneath it.

Elastogel (South West Tech, Inc.) cast and splint pads can be used as an insert under a compression garment (see Figure 10-99c). It has a nice feature of a cloth covering on the back, protecting the garment from its oils. It is also an occlusive dressing that can be used on open wounds. The insert can be cut to size, but should extend 1 to 2 in. beyond the wound or be 25% larger than the wound. It can be worn over topical medication; it can be made waterproof by covering it with a film dressing such as Tegaderm (3M Health Care); and can be secured with tape, gauze, or elastic compression.

Spenco (Spenco Medical Corp.) second skin is a clear, breathable-type, hydrogel gel. It is 96% water and 4% polyethylene oxide with a feel and consistency similar to human skin. It removes the fric-

EXHIBIT 10-7

PRIORITIZED OPTIONS FOR SCAR COMPRESSION—UPPER EXTREMITY

Fingers-External vascular support must be satisfactory at the most distal part (fingers or hand) to prevent a tourniquet effect if any support is planned for the wrist, forearm, elbow or upper arm.

I. Compression Garments
  A. Finger wraps
    1. Sof-Kling, one inch rolls, used in spiral wrap
    2. Unna bandage, split, folded and wrapped in a spiral, distal to proximal
  B. External vascular support, Tubiton finger oedema sleeve, digisleeve
  C. Isotoner glove
    1. Elastic spiral wraps (Elset, Coban, PEG self-adhesive bandage, regular elastic bandages, 1- or 2-inch size)
    2. Elastic, old fashioned "boxer" type, finger and hand figure-8 wraps (Must have adequate strength to overcome dorsal pull of wrap, or wrap must be applied in reverse "boxer" style.)
  D. Silastic mitt or foam "sandwich" secured and supported with elastic wraps

II. Inserts
  A. Finger Webs
    1. Web spaces
      a. When fragile:
        (1) Lamb's wool strips
        (2) Webril strips in rolls
        (3) Orthopedic felt strips
        (4) Hypafix strips
        (5) Velfoam or Betapile strips, formed in "brass knuckles" pattern
        (6) Various foams
      b. When durable:
        (1) Otoform K "saddle" pattern with Webril wrap to prevent contact dermatitis
        (2) Silastic elastomer "brass knuckle" cut-out pattern
        (3) Skin care pad or Elastogel strips
        (4) Plastazote strips
        (5) Neoprene strips or cutout in "brass knuckle" pattern
        (6) Various foams strips
        (7) Thermoplastic inserts
  B. Fingers
    1. Volar surface
      a. When skin begins to contract:
        (1) Otoform K "gutter" secured with one inch Sof-Kling or Coban or equivalent
        (2) Silastic elastomer thin strip under glove
        (3) Skin care pad strip
        (4) Elastogel strip
        (5) Thermoplastic "gutter" splint from the tip of finger to the "V" of the digit or palmar base

Thumb

I. Compression Garments
  A. Sof-Kling, one inch rolls, used in figure-8 wrap thumb to wrist, to abduct thumb
  B. Unna bandage, split, folded, and wrapped in a spiral, distal to proximal
  C. Elastic wrap including the thumb, hand, and fingers
  D. Prefabricated or custom gauntlet including thumb hand and base of index finger
  E. Prefabricated or custom glove

II. Inserts
  A. Thumb Web
    1. Orthopedic felt "saddle" shaped pad
    2. Webril "saddle" pad
    3. Velfoam or Betapile "saddle" pad
    4. Skin care pad
    5. Elastogel

EXHIBIT 10-7 *continues*

EXHIBIT 10-7 *(continued)*

PRIORITIZED OPTIONS FOR SCAR COMPRESSION—UPPER EXTREMITY

6. Otoform K saddle to thumb IP and index MCP
7. Sheepskin
8. Various fabric liners

B. Radial Border
1. Otoform K strip
2. Skin care pad
3. Elastogel

Hand

I. Compression Garments
A. Isotoner glove
B. Sof-Kling one inch rolls
C. Elastic wraps (Elset, Coban, PEG self-adhesive bandage, regular elastic bandages, 1- or 2-inch size)
D. Unna bandage
E. Prefabricated or custom gauntlets
F. Prefabricated or custom gloves
G. Silastic elastomer or foam mitt

II. Inserts
A. Palm
1. Otoform K
2. Silastic elastomer, sculpted
3. Skin care pad
4. Elastogel
5. Various fabrics as liners, secondary to perspiration

B. Dorsum
1. Skin care pad
2. Elastogel
3. Second skin
4. Duoderm
5. Silicone gel sheet with or without compression

Wrist

I. Compression Garments
A. Prefabricated or custom long gloves, long sleeves, both overlapping or separate wrist band

II. Inserts—same as elbow

Elbow

I. Compression Garments
A. Prefabricated, shaped support bandage or tube; prefabricated single arm, custom sewed shaped support bandage with larger elbow insert, prefabricated or custom measured long sleeve vest
B. Custom measured arm sleeve
C. Antecubital or circumferential liner (Note liner fabric is tighter than the elastic garment and may cause irritation if not relieved. Shearling inserts may be used for extremely fragile areas.)

II. Inserts
A. Anterior
1. Skin care pad
2. Elastogel
3. Spenco second skin
4. Duoderm
5. Moleskin
6. Hypafix
7. Hollister odor absorbing dressing
8. Various fabrics
9. Various foams

EXHXIBIT 10-7 *continues*

EXHIBIT 10-7 *(continued)*

PRIORITIZED OPTIONS FOR SCAR COMPRESSION—UPPER EXTREMITY

B. Posterior
1. Duoderm
2. Foam sponge
3. Various pads

Upper Arm and Forearm

I. Compression Garments—Same as elbow
II. Inserts
A. Dow Corning silicone gel sheeting with or without compression
B. Silastic elastomer
C. Otoform K
D. Adhesive backed foams
E. Skin care pads
F. Elastogel
G. Neoprene

Shoulders

I. Compression Garments
A. Prefabricated, interim or customized vest with long sleeves
B. Vest with short sleeves
C. Axilla can have netting if it is unburned. Axilla may be left open if durable and nonburned
D. Figure-8 Ace wrap with foam inserts
E. Clavicle straps
II. Inserts
A. Axilla
1. Skin care pad
2. Elastogel
3. Prosthetic foam/elastomer mix
4. Various thick foam paddings
B. Superior Shoulder
1. Skin care pad
2. Elastogel
3. Various thin adhesive-backed back foam padding
4. Spenco second skin
5. Otoform K
6. Duoderm, if friction is a problem
7. Silicone gel sheet, if shoulder motion does not displace it

tion between two moving surfaces and will not stick to wounds or dressings. It keeps tendons hydrated and cushions blisters, protecting and preventing them. It helps ease burn pain and itching; it is placed directly against the skin and it is held in place with a bandage or tape. The outer plastic film can be left in place to prevent drying or removed to allow air passage; uncovered, it will dehydrate after 24 hours, but placing it in water will return it to its original position.

Duoderm is a thin, caramel colored, hydroactive, cell-adherent occlusive dressing. It works well on bony prominences for protection and can be used over mobile joints such as the posterior elbow by cutting darts into it and holding it in place during flexion, melding it into position. It works well on hands and allows a tight compression glove to be applied over it.

There are many different ways to provide effective compression to body parts that have scars for various other types of problems. Exhibits 10-7, 10-8, and 10-9 provide lists of prioritized options for specific situations in regard to scar compression using external vascular support garments and compression inserts or overlays.

In cases where grafts are onto fascia or a face develops poor cosmetic outcome, camouflage makeup is indicated. Additionally, accessories can

EXHIBIT 10-8

PRIORITIZED OPTIONS FOR SCAR COMPRESSION—TRUNK

Anterior Flank and Intrascapular Area

I. Compression Garments
   A. Prefabricated tube
   B. Prefabricated or custom vest with or without sleeves
   C. Female vest with breast cups
   D. Inserts

II. Flank and Intrascapular
   A. Silicone gel sheeting with or without compression
   B. Silastic elastomer
   C. Otoform K
   D. Prosthetic foam
   E. Skin care pad
   F. Elastogel
   G. Spenco II skin
   H. Various adhesive backed foam

III. Between Breast Cleavage
   A. Otoform K
   B. Prosthetic foam
   C. Thick sculptured foam
   D. Silastic elastomer
   E. Plastazote
   F. Skin care pad
   G. Elastogel
   H. Spenco II Skin

IV. Buttock/Groin Compression
   A. Body suit
   B. Vest with Velcro crotch
   C. Pants or shorts
   D. Scrotum may require support cup

Inserts

I. Buttock Crease
   A. Otoform K
   B. Prosthetic foam
   C. Thick sculptured foam
   D. Plastazote
   E. Skin care pad
   F. Elastogel

II. Genitalia
   A. Males may require a foam roll to stretch the penis over if there is constriction during erection
   B. Males may require a catheter or penile implant for the above or if the urethra is restricted producing difficulty with ejaculation and/or urination
   C. Female genitalia is usually well protected secondary to anatomical makeup

be used to camouflage, such as wigs, scarves, fashion gloves, adaptive clothing, and prosthetic foam covers, may be needed. If a multidisciplinary approach is used with the soldier as the active principal team member, the outcome can be cosmetically and functionally acceptable. Protection from sunburn is an additional benefit from camouflage make-up applied over the face, ears, nose, and neck.

Functional Activities and Adaptive Equipment During the Wound Maturation Phase

In the wound maturation rehabilitation phase, a casualty continues active participation in functional activities that are consistent with life roles and return to active duty (see Figures 10-62 and 10-102). As an individual becomes medically stable and epi-

EXHIBIT 10-9

PRIORITIZED OPTIONS FOR SCAR COMPRESSION—LOWER EXTREMITY

Thigh and Lower Leg

Same as in the Upper Extremity, upper arm and forearm (Exhibit 10-7)

Hip

I. Compression Garments
   A. Biker pants or shorts
   B. Prefabricated or custom pants or shorts
   C. Custom measured and fitted body suit with thighs incorporated

II. Inserts
   A. Skin care pad
   B. Elastogel
   C. Various thin adhesive backed foams

Knee

I. Compression Garments
   A. Prefabricated tubes are shaped support bandage or pants
   B. Custom thigh highs or pants
   C. Biker pants or long shorts

II. Inserts
   A. Anterior knee not usually necessary
   B. Posterior knee
      1. Skin care pad
      2. Elastogel
      3. Thin fabric liners may be necessary secondary to maturation

Ankle

I. Compression Garments
   A. Prefabricated tubes
   B. Prefabricated or custom knee highs or higher garments
   C. High anklets
   D. Boots with elastomer or prosthetic foam circumferential lining

II. Inserts
   A. Anterior
      1. Foam pad
      2. Otoform K
      3. Orthopedic felt
      4. Skin care pad
      5. Elastogel
   B. Lateral
      1. Silastic elastomer
      2. Otoform K
      3. Foam pad
      4. Duoderm
      5. Spenco II to skin
      6. Skin care pad
      7. Elastogel
   C. Posterior
      1. Duoderm
      2. Foam pad
      3. Silastic elastomer
      4. Otoform K
      5. Skin care pad
      6. Elastogel

EXHIBIT 10-9 *continues*

EXHIBIT 10-9 *continued*

PRIORITIZED OPTIONS FOR SCAR COMPRESSION—LOWER EXTREMITY

Foot

I. External vascular support
   A. Prefabricated tube
   B. Prefabricated anklet or stocking
   C. Custom measured anklet or stocking
   D. High top tennis shoe
   E. Boots with silastic or prosthetic foam circumferential support

II. Inserts
   A. Dorsum
      1. Otoform K
      2. Silastic elastomer
      3. Various thin adhesive back foams
      4. Skin care pad
      5. Elastogel
      6. Silicone gel sheet with compression
   B. Sole
      1. Thick foam secured over elastic wrap for comfort
   C. Ankles and High Top Shoes
      1. Sheepskin to protect bony prominences
   D. Toes that are hyperextended
      1. Plantar lift from the heel to the metatarsal head
         a. Kushion flex
         b. Polycushion
         c. Plastazote
         d. Neoprene
         e. Silastic elastomer
         f. Otoform K
      2. Plantar negative space for toes to flex into.
         a. Lamb's wool
         b. Sheepskin
         c. Orthopedic felt
         d. Reston foam
         e. Contour foam
         f. Other compressive open cell foams
      3. Dorsal insert to flex toes
         a. Otoform K
         b. Silastic elastomer with moleskin or odor absorbent liner
         c. Sheepskin
         d. Thick closed cell foam

thelium becomes more durable, it is vital to pursue a variety of activities, but, in this phase, it is still important to be cautious with fragile skin. Casualties must learn proper interventions to compensate for sensory, pigmentation, and circulatory changes while performing daily living skills. In this phase of rehabilitation the casualty is weaned off adaptive equipment used in the initial phases of healing. However, electrical injuries, amputees, or casualties whose burns are greater than 70% TBSA may continue to use the equipment if residual deficits exist. In the severely impaired person, sophisticated orthosis and adaptive equipment will need to be pursued to reduce disability.

Feeding. In the wound maturation phase adaptive silverware, drinking aids, and stabilization devices are rarely used. If decreased shoulder AROM with proximal weakness is permanent, suspension slings or mobile arm supports (ball bearing feeders) can be used when a casualty is in a seated position. These devices support the entire arm, use mechanical devices to assist shoulder flexion, and allow the elbow to move in a gravity eliminated plane. The mobile arm support is available

PATIENT'S DAILY SKILLS CHECK LIST

By discharge, all burn patients will have learned to do the following tasks independently:

	YES	NO	Needs more practice	PHN or other relative
I Hygiene/grooming:				
Wound Care:				
Wash wound				
Apply medication				
Tub bath				
Shower				
Appropriately wash				
healed and unburned skin				
Lotion and massage				
self appropriately				
Care of overgrafted tissue				
& sweat & oil gland regrowth				
Buff-n-Puff				
Grit Soap				
Shampoo:				
Wash				
Rinse and dry hair				
Trim around open areas				
Comb and brush				
Shave:				
Remove ingrown hairs				
Toileting:				
Approach and sit on stool				
Raise and lower clothing				
Wipe self				
Clean hands				
Oral Hygiene:				
Brush teeth				
Stretch mouth				
Lotion lips				
II. Dressing:				
Independent applying aces				
Independent in bra,				
Independent donning custom (top)				
elastic garment (bottom)				
Independent				
dressing lower body				
including tying shoes				
III. Eating:				
Feed self				
Cut meat, open milk carton,				
sugar pkg., butter, bread				
IV. Homemaking:				
I. Meal Preparation:				
Safe with cold meal				
(milk, sandwich, apple)				
Safe with hot liquids				
(coffee, soup, etc.)				
Safe with stove top and oven				
2. Kitchen Care:				
Wash dishes				
Put away dishes				
Empty dishwasher				

FIGURE 10-102 *continues*

in standard, elevating, and table mounted models. In cases of severe burns resulting in upper extremity amputations, there are battery powered or electric feeding machines that are operated by microswitch control. The switches can be operated by the chin or another body part that can more predictably and consistently control a machine.

Grooming. In the wound maturation phase the casualty can participate in additional grooming tasks, and can perform shaving activities with spe-

FIGURE 10-102 *continued*

	YES	NO	Needs more Practice	PHN or other relative
Sweep floor				
Clean counters				
Clean stove and oven				
Defrost refrigerator				
3. Other:				
Make bed				
Change bed linen				
Vacuum				
Dust				
Wash windows				
Change light bulbs				
Carry and put away groceries				
Do laundry				
Mop floors				
4. Misc.:				
Set and wind clock, watch				
Put coins in machines				
Handle wallet				
Sign name				
Write letter				
5. Clean bathroom				
Change toilet paper roll				
V. Mobility:				
Walk for 10 minutes				
Run				
Stair climbing				
Ride bike				
Safe motor vehicle operation				
Safe riding bus and public transportation				
VI. Recreational Activities:				
1. Knows precautions regarding:				
A. Fragile healed skin				
B. Sensory changes				
C. Pigmentation changes				
D. Circulatory changes				
E. Exposure to irritants, eg. petroleum products, concentrated animal waste				
2. Initiates old or new social contacts				
3. Initiates stress reducing physical recreation 3 times a week or more				
4. Initiates discussion of desires in social interaction				
5. Initiates doing things for others in family or social contacts				
VII. Work Activities:				
Return to old job (usually in 6-12 months)				
Find a new job				
Work with Vocational and Rehabilitation Counselor				
VIII. Return to school:				
Able to concentrate on learning				
Takes part in non-contact sports				
IX. Sexuality:				
Resolving changed body image				
Initiates discussion of desires				

Burn patients who have had grafts to all extremities and the head will routinely be offered intensive therapy in a Rehabilitation Unit and public health nurse assistance to achieve independence at home. The parents or caretakers of all children under 5 years of age will be offered public health nurse assistance. Contact your social worker for help if you are interested in these services.

Fig. 10-102. Clinical history sheet. Reprinted with permission of Regions Hospital (formerly, St. Paul-Ramsey Medical Center), 640 Jackson Street, St. Paul, Minnesota 55101-2595.

cial holders for electric or regular razors if unable to hold a razor in the conventional manner. The casualty should perform nail care to prevent excoriation of skin during scratching. Mounted nail clippers or files are available if needed.

At this stage, the casualty can begin to assume responsibility for the condition of the skin, inspecting it regularly for detection of breakdown areas. Flexible skin-inspection mirrors assist with this. The casualty can also begin to be responsible for independent wound care and management and should demonstrate the ability to safely wash the wounds and to apply medication and gauze dressings. As the skin heals, the casualty should perform scar massage as indicated and apply moisturizer.

In the wound maturation phase a casualty will want to be able to perform toileting tasks independently. There are a variety of types of adaptive equipment to ensure safety and independence with the task. Toilet safety rails can be mounted on either side of the toilet to increase stability with transfers. Use of a raised toilet seat is discouraged, but is useful when an individual permanently lacks strength or control in the lower extremities and cannot perform transfers with a standard seat. A bedside commode is necessary in the hospital or at home only when ambulation to the bathroom will not be possible. Toilet aids are helpful if an individual is lacking the necessary upper extremity range of motion for hygiene.

There are a number of adaptive safety aids to allow independent bathing. Often it is safer for the casualty to bathe in a seated position if endurance is low. Edema is minimized by keeping burned legs elevated until the bathing is finished and external vascular supports are replaced. Shower seats, with or without backs, are useful to provide stability in walk-in showers. Extended tub benches allow a casualty to bathe independently on a seat if he is unable to step over the tub safely. Grab bars can be mounted on the tub or wall to further increase stability with transfers. A flexible shower hose permits a person to bathe independently in a seated position if he is unable to stand for a long period of time. Long handled sponges compensate for decreased trunk or upper extremity range of motion and allow casualties to wash the feet and back independently. A bath mitt stabilizes a bar of soap if the grasp is weak. Nonskid surfaces or bath mats applied to the bottom of the tub are safety features used to avoid slippage.

Dressing. Assuming total responsibility for donning external vascular support garments, orthoses, and clothing is achieved during the wound maturation phase. The casualty must be cautioned against pulling too rigorously on garments while donning them, which could injure fragile skin. A nylon stocking contact layer over gauze dressings secures them and facilitates donning external vascular supports. The casualty demonstrates donning face masks, microstomia splints, hand splints, and lower extremity braces independently in front of a mirror to ensure proper fit.

There are a number of adaptive aids that assist with donning the pressure garments and regular clothing. In prioritizing practice time, often it is more cost effective to practice donning items without adaptations when in 3 or 4 days the trunk and upper and lower extremity contractures will stretch to allow independence without adaptations. Long handled aids are helpful in cases where there is decreased trunk, hip, and knee flexion, and hip external rotation. Many brands of "reachers" can be used to don pants (Figure 10-103). They are available in a standard size, extended length, and a self-closing model for decreased hand grasp. There are long handled shoe horns (Figure 10-104) and stocking aids (Figure 10-105) that are useful in donning shoes and socks. A dressing stick can be used for donning pants or for donning shirts if upper extremity range of motion is limited.

Other adaptive aids are useful if finger dexterity is limited or if a person has use of only one hand. Elastic shoe laces and button and zipper aids are available in standard and easy-grasp varieties.

Fig. 10-103. A "reacher" aid for donning pressure garments and regular clothing. The casualty wears Isotoner glove external vascular support when hands will be dependent.

Fig. 10-104. The casualty is using a long-handled shoe horn to facilitate donning shoes.

Velcro closures can replace buttons or zippers, and large loops can be sewn onto pants. In general, some types of clothing are relatively easy to don such as large shirts, gym pants (Figure 10-106), and Velcro closure tennis shoes. There are catalogues for special-order, easy-to-don clothing.

Home Management

As a casualty becomes more independent in the hospital setting, it is important to identify home management responsibilities for eventual discharge. This can involve a variety of tasks including general maneuvering, operating home appliances, cooking, cleaning, and several other activities. It is important for the casualty and family to identify the tasks that the individual wants or needs to perform. Ideally, a survey of home needs can be accomplished with the casualty, family, and a staff

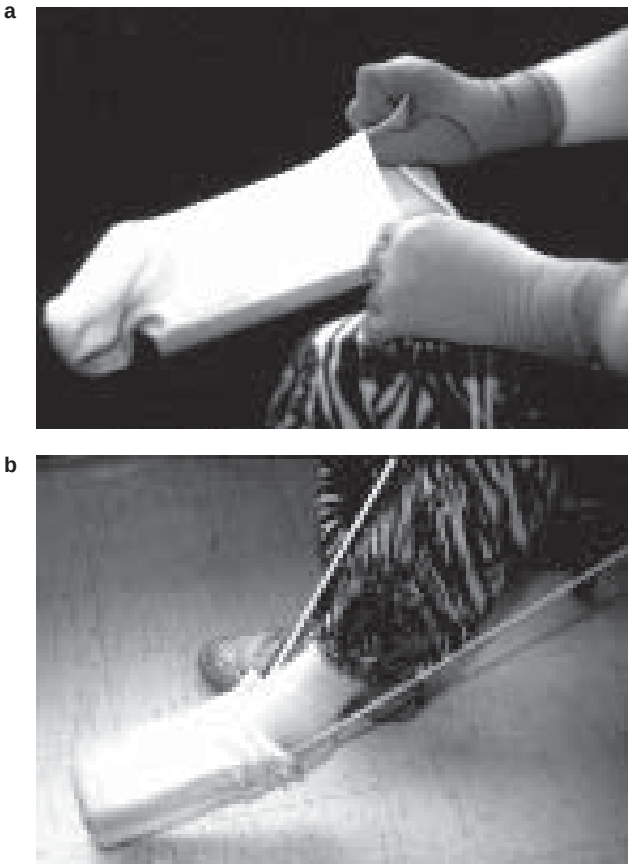


Fig. 10-105. The casualty donning stockings. (**a**) The casualty is placing the stocking over the sock aid and (**b**) is using a sock aid to place the stocking on his foot.

Fig. 10-106. The casualty is independently donning gym pants without adaptations. He is using Tubigrip external vascular supports.

member. It can also be performed by the casualty and family alone. A home evaluation, with an emphasis on independence and safety, can identify any functional or environmental limitations. The casualty has the opportunity to use actual mobility aids and adaptive equipment in his own home to determine the level of assistance required postdischarge.

There are a number of home accessibility aids to facilitate independence. A ramp to enter the house is very important if a casualty is wheelchair bound. Stair glides are often used within a house to allow movement from one floor to another. Various types of high rise furniture leg extenders (for chairs and couches) increase the ease of transferring independently. There are lamp and light switch extensions that are helpful if a casualty has decreased finger dexterity or is functioning from a wheelchair. Also, a variety of turning adaptations exist for the operation of faucets, stoves, and radiators when a weak grasp is present.

As the burn casualty continues in the rehabilitation process, he will generally resume kitchen activities (Figure 10-107). There are special devices that can be used for safety when operating the oven. There is a push/pull device that is used to manipulate hot oven racks when there is limited finger usage or sensory deficits. Long oven mitts made out of flame retardant fabric offer protection for sensitive skin. Kitchen roll carts are effective in moving hot or heavy pans and dishes. If the cart is sturdy it can be used like a wheeled walker for stability. If an individual is cooking from a wheelchair, a positioning mirror over the stove allows him to see the burner to cook safely.

There are a variety of devices for use in the kitchen if the casualty has only one functional hand. There are pan and bowl holders that provide stability to compensate for the inability to hold with a nondominant hand. Dycem, the nonskid surface, provides stability under plates and bowls. The adaptive cutting board has a nail to stabilize items for cutting and a built-up corner to hold bread while buttering. A rocker knife, with a sharp, rounded blade, is useful with the use of one hand. There are many types of special openers for jars, cans, or bottles that can be used when a casualty has only one functional hand or decreased hand strength or control.

As with many of the other functional activities, there are adaptive housekeeping aids that compensate for decreased ability to reach or grasp. Extended dustpans with brushes, long reach sponge mops, and extended dusters are available for independent housekeeping. There is also a housekeeping cuff with Velcro attachments that permit an individual with a weak grasp to hold a broom or mop handle.

Fig. 10-107. The casualty is doing kitchen activities from his wheelchair. Note the use of a lapboard.

Communication

In the wound maturation phase of healing some of the earlier communication devices will not be necessary while others will continue to be required. At this stage, when the casualty is able to be out of bed in a seated position, typing and computer activities can be explored. These prevocational activities can be very important aspects of the rehabilitation process.

There are several adaptive aids that are useful with keyboard usage. Typing aids that fit over the hand and depress the keys are commercially available or can be custom made. They are useful when fine motor dexterity is lacking and the casualty is unable to access the keyboard in a traditional way.

Keyboards can be mounted on special devices if an individual has limited range of motion in the shoulders or elbows for accessing the keyboard. There are also detachable keyboards for when a person is unable to access the keys in the usual location. Key guards are special devices that are useful with individuals who have impaired coordination. The keyboard separates the keys and allows depression of the correct keys. A keylock is a device for one-handed users to simultaneously depress multiple keys. There are a variety of special switches to operate the environmental controls or activate the computer if an individual cannot directly operate the keyboard.

Functional Mobility

During the wound maturation phase of rehabilitation the casualty becomes more mobile as part of the exercise program. A transfer or gait belt is generally used around the individual's waist for stability during early phases of ambulation. Sometimes assistive devices for ambulation are used at this stage. For example, straight or quad canes or regular, tall, platform, or wheeled walkers. Frequently, these devices are discontinued as the casualty progresses to independent ambulation.

A casualty who is severely burned or has lower extremity amputations may use a wheelchair. Wheelchairs are available in a variety of models including standard, reclining, narrow, lightweight, and amputee models. In severe cases, electric wheelchairs can be used. For each type of wheelchair there are numerous options regarding additional supports, special seating systems, and accessories. Wheelchair supports can be designed specifically for an individual: headrests, lateral supports, adjustable height feet rests, and wheelchair safety straps. The correct seating system is extremely important for the burn casualty to protect the fragile skin and prevent decubiti. There are special cushions that can be placed over solid seats and back inserts. Cushions composed of gel, foam, or neoprene are helpful in maintaining skin integrity. There are several cushion manufacturers including JAY (Jay Medical), and ROHO (Roho Inc.). Wheelchair accessories include lapboards, arm troughs, sliding boards, and special gloves. Lapboards, which are available in many styles, including stand, clear, hinged, and swingaway, provide a desk top area for feeding or writing. Arm troughs, available in regular, foam elevating, and rotating models, are beneficial in maintaining appropriate upper extremity position and controlling edema.

Driving is a functional activity that should be performed cautiously. A physician's recommendation is made after psychoactive drugs, including analgesics, are discontinued. A driver's evaluation is beneficial in cases of severe burns to further determine the safety of the individual and the need for any adaptive equipment. An evaluation provided at an accredited facility can provide information regarding reaction time; the need for modifications in neck, face, and upper extremity orthoses; and resources and training with special equipment.

There are many types of adaptive equipment for driving. Hand controls for the accelerator and brake are used when a casualty has limited or no lower extremity function. Nonskid material can be placed on the wheel for a better gripping surface. Steering wheels with special rings and knobs, hooks or lever extensions for brakes, turn signals, gear selectors, and large side mirrors are available.

If a casualty is in a wheelchair, there are vans that can be driven independently with special controls. Portable ramps facilitate independence with getting in and out of the van. If fine motor dexterity is lacking, there are special car door openers and key turns that can be used to facilitate manipulation of these items.

Recreation

Recreation is an important functional activity. The benefits, in addition to decreased pain during exercise, include an appropriate physical or emotional outlet for anger, the enhancement of self-esteem, and increased feelings of accomplishment (see Figure 10-63). Card holders and card shufflers are available if someone has decreased grasp or one-handed usage.

In the wound maturation phase of healing, a burn casualty can begin to participate in organized games and sports or health clubs. This participation should be incorporated into a graded exercise program. The games and sports can have many physical goals such as increasing AROM, strength, coordination, sitting or standing tolerance, and endurance. Sports provide opportunities to improve attention, concentration, and problem solving abilities, as well as an opportunity for social interaction between casualties, families, other casualties, and friends.

Intermittent compression using elastic wraps or mechanical devices such as a Jobst Intermittent Compression Pump or a Wright Linear Pump (Wright Co.) can be used in the maturation phase as described in the acute phase. The mechanical devices should be considered when edema persists

and simple compression and elevation does lead to resolution. These devices have been used successfully to attain skin closure of chronic ulcers secondary to chronic edema caused by lymphatic and venous insufficiency. In this phase, inflammation is probably less of a factor than in the acute phases. The underlying problem may well be more secondary to reduced lymphatic or venous flow secondary to thermal damage of underlying subcutaneous tissues or excision to fascia. Therefore, these pumps may be needed on a lifelong basis. If this is the case the casualty will need specific instruction in home use prior to discharge.

Functional electrical stimulation (FES) has been used in rehabilitation with the goals of retarding disuse muscle atrophy, reducing contractures due to weak muscles, and increasing venous and lymph flow in the stimulated muscles. In the burn casualty the goals would be similar. The skin must be healed enough to tolerate the electrodes and conductive gel or tape needed to hold the electrodes in place as well as to tolerate the current necessary for stimulation. Use of FES has been sporadic in rehabilitation in general as well as in burn rehabilitation. However, late improvement in objectively measured hand function was reported in one pilot study using FES in burn survivors with severe hand injuries.[143] This technique should be considered in this phase of burn care when the more common therapeutic exercise modalities are not providing the desired outcome.

Psychosocial Adjustment During the Wound Maturation Phase

Psychosocial issues continue throughout the wound maturation phase of healing. The soldier at home or in the rehabilitation center learns how to return safely to duty and routine life despite his injury. Physical changes are often bothersome, and physical fitness is now a prolonged, daily struggle; reconditioning may take place at a much slower pace than before the burn.[144]

Normal responses to a major burn injury often include crying, degrees of fear, depression,[87] grief, loss of hope, and other reactions unfamiliar to the soldier. Discharged patients report it takes about 6 to 7 months of being at home before they can cope, as they did before the injury, with emotions and activities that require concentration. Distractibility gradually subsides. Impatience, irritability, and frustration are common. The casualty can learn to accept gradually improving function instead of perfection in activities. Family members often can help sort out the realistic reactions from overreactions.

Psychological adjustment for returning to work in an area where the injury occurred must be considered. Few people will return easily to the injury site. Referral to a psychologist is appropriate. Return to duty at the earliest possible time maximizes the benefits of buddy support, as well as routine and work. Strength and coordination improve much sooner from work than from therapy. Ego strength and social interaction are also improved with return to duty. Feelings of anger, fear, loneliness, or helplessness bring pain acutely to the patient's awareness.[145] The soldier benefits from sharing personal experiences of pain relief. Former burned patients report helpful assistance from participating in a trauma survivors group. With leadership from social workers and psychologists or both, the group is able to deal positively with symptoms such as disturbing dreams, appetite disturbance, difficulty with sleep, feelings of estrangement or detachment, recurrent intrusive memories of the event, memory impairment, difficulty concentrating, reluctance to accept a changed body image, decreased interest in sex, sensitivity to loud noises or other cues related to the accident, irritability, and fear of returning to field duty or other work. Patients are often referred for group participation when these symptoms are noted by the casualty, family members, or involved staff members.

A minor burn affecting an exposed area of the body such as the face or neck may be more psychologically devastating than a severe burn that can be covered with clothing. In the event of disfigurement or loss of a body part, the casualty normally grieves these losses. Extensive burns produce one of the most devastating and dehumanizing injuries.[146] In addition, premorbid psychiatric disorders, alcoholism, or chemical abuse are observed more often in burned patients than in other populations.[147] Preburn psychiatric morbidity is associated with poor postburn psychosocial adjustment.[148] Burn severity does not usefully predict psychosocial outcome.[148]

A high incidence of PTSD among recently burned patients has been noted.[148] This syndrome is defined in the DSM III[149] with specific criteria. The burn patient responds to a recognizable stressor that evokes the distress symptoms. In addition, he often experiences vivid, intrusive dreams or recollections of the incident. Other frequently noted characteristics are an exaggerated startle response, impaired memory, concentration problems, avoidance of cues of the accident, and withdrawal from normal social interaction, chores at home, tasks at work,

or participation in active duty. Treatment is aimed at giving the soldier as many choices as are reasonably possible during recovery, thereby relieving a sense of helplessness. Stress reduction strategies and goal directed individual counseling are also beneficial. Short term pharmacological intervention may also be appropriate. It is helpful for the soldier returning to active duty to know that exacerbation of PTSD may occur following such events as the dedication of the Vietnam War Memorial.[150] Reading about a similar burn injury may also revive PTSD symptoms.

Return to active duty improves the casualty's self-concept. The burn physician must consider the duty tasks and the progress of the wound when recommending return to active duty (Figure 10-108). Food handlers must remain off-duty until open areas are closed and wound cultures reveal no pathogens. Heavy laborers may need job modifications when they first return to duty. Often a transition period of half-day work progressing slowly to full-time work is needed. Rehabilitation counselors, nurses, or OTs can assist with changes in the work setting when these are needed. The adaptations are often inexpensive: for example, placing a foot stool near a bench or counter, on which the soldier places his alternate foot for half-hour periods; or arranging items within the reach of the soldier so he will not have to reach beyond his center of balance when he first returns to duty.

Appraising the extent of the burn injury and objectively estimating residuals that affect performance are most accurate when based on objective criteria[151] and experienced prediction. Rating permanent impairment is a physician's function. Disability or handicap is related to performance loss, preinjury age, education, economic and social situations, sex, and the burned person's attitude toward recovery. The physician has the final responsibility in determining when it is medically safe for the soldier to return to active duty.

Nutritional Care of Burn Patients

The burn injury results in major changes in metabolism that are believed to be largely hormone mediated due to increased catecholamines, glucocorticoids, and glucagon-to-insulin ratios. The metabolic alterations include increased gluconeogenesis, proteolysis, ureagenesis, and decreased lipolysis and ketone utilization. In addition, destruction of the skin barrier results in physiologic losses of heat, water, and water soluble nutrients. These changes result in increased energy expenditure, increased nitrogen losses, and changes in nutrient metabolism.

The hypermetabolic-catabolic response becomes evident within 2 to 3 days of the burn injury, reaches a peak between 4 and 20 days, and then gradually decreases with wound closure and healing. The magnitude and duration of the response can be decreased, though not totally ameliorated, by placing the patient in a warm environment, providing adequate pain relief, completing early wound closure, applying occlusive wound dressings, and preventing sepsis. Thus, nutritional support should be initiated early, meet estimated needs, and be monitored closely to promote healing.

Nutritional support for the burned patient may include any combination of diet, oral supplements, and tube or parenteral feeding, or both. Nutritional care includes early assessment of nutritional requirements, development of an appropriate nutritional care plan, and close monitoring of the adequacy of nutritional intake.[152]

Nutritional Assessment

Traditional indexes of nutritional status such as anthropometric measurements, weight, plasma proteins, and immunocompetence are of limited value when assessing burned patients since they are altered by the injury itself. Thus, nutritional assessment should be aimed at estimating current nutritional requirements.

Energy. Energy needs can be estimated using equations based on body size, age, and activity level or percentage of burn, or both; it can also be measured using indirect calorimetry. For children, energy needs for growth should be included in total energy estimates. Preburn weight should be used whenever possible because postburn weights are affected by edema and bulky dressings. Exhibit 10-10 summarizes the most commonly used equations for estimating energy requirements in adult and pediatric patients that were identified in a recent survey of US burn centers.[153-163]

A criticism of these equations is that they frequently overestimate energy needs, particularly for patients with greater than 50% TBSA. Studies[164,165] using indirect calorimetry to measure energy expenditure indicate that there appears to be an upper limit of energy expenditure at approximately twice basal energy estimates.

Serial measurements of resting energy expenditure by indirect calorimetry are increasingly being viewed as the best method to determine the energy requirements of a burn patient. Indirect calorimetry

PATIENT QUESTIONNAIRE

PHYSICAL ISSUES TO BE ADDRESSED BEFORE RETURN TO WORK OR ACTIVE DUTY

Yes	No	
		Epithelial system
____	____	1. Is the skin intact?
____	____	2. Are pathogens absent from the open areas (if the skin has open areas)? Which pathogens are present?
____	____	3. Is the skin moist, supple and resistant to low humidity?
____	____	4. Is the partial thickness healed skin durable enough for the person's occupation?
____	____	5. Are the sheet and meshed grafts durable?
____	____	6. To what extent can the employee's skin tolerate exposure to extremes of heat?
____	____	7. To what extent can the employee's skin tolerate exposure to extremes of cold?
____	____	8. Does the healed skin tolerate unfiltered ultraviolet light?
____	____	Has protective re-pigmentation developed?
____	____	9. What is the tolerance to contact with chemicals or petroleum products?
____	____	10. What is the skin's tolerance to exposure to vapors such as ammonia in cleaning solvents or animal urine
____	____	11. Is the healed skin resistant to dust?
____	____	12. Are scar control garments still needed? Do these interfere with work?
____	____	13. Is the skin cosmesis altered?
____	____	Has redness faded?
____	____	Are hypo- or hyperpigmentation permanent?
____	____	In what areas?
____	____	Is the skin thinned, wrinkled?
____	____	Is the mesh graft pattern faded?
____	____	Has the healed donor changed color?
____	____	14. Is unsightly disfigurement present, especially in the facial and hand areas? Can it be camouflaged?
____	____	Does it interfere with job performance?
		Cardiovascular/respiratory system
____	____	15. Is chronic edema a problem in dependent tissues? Are external vascular supports needed?
____	____	Do they interfere with job performance?
____	____	16. Is there loss of respiratory capacity?
____	____	17. Has normal endurance returned?
____	____	Does tiredness interfere with job performance? How many hours of work can the employee tolerate?
		Musculoskeletal system
____	____	18. Are joint contractures present? Do these interfere with job performance?
____	____	19. Does the employee exhibit decreased eye-hand coordination and impaired dexterity?
____	____	20. Has the patient achieved maximum benefits from therapy?
____	____	Is strength normal for age group? Does weakness interfere with job performance?
____	____	21. Have accompanying bone fractures, osteomyelitis or septic joints healed?
____	____	22. Are amputations present? Has the prosthesis been fitted? Is the patient using it in a coordinated, useful
____	____	way?
		Nervous system
____	____	23. Does the employee have residual pain? Does it interfere with job performance? Prolonged activity?
____	____	What pain medications is the patient taking?
____	____	24. Is the employee's sensation changed?
____	____	Has he learned to compensate for this?
____	____	25. Is brain function changed?
____	____	Is the patient depressed?
____	____	What psychotropic medications is the patient taking?
____	____	26. Is there fear of returning to work or places where similar cues as the place of injury are encountered?
____	____	27. Is chronic itching resolved?
____	____	What itch medications is the patient taking?
____	____	28. Is sexual dysfunction and changed body image being resolved?
		Eye, ear, nose, and throat systems
____	____	29. Are there any changes in hearing? Do they interfere with job performance?
____	____	30. Does the patient hear "buzzing," ringing or other sounds? Does it interfere with job performance?
____	____	31. Is visual impairment present? Does it interfere with job performance?
____	____	32. Does the patient have "dry" eyes? Does this interfere with vision or cause pain?
____	____	33. Does the patient have frequent nose bleeds?
____	____	34. Does the patient have a dry nose?
____	____	35. Does the patient have hoarseness?
____	____	Adequate vocal volume?
____	____	Proper enunciation to be understood?

Fig 10-108. The patient questionaire used when the burn physician is evaluating the casualty for readiness to return to duty.

EXHIBIT 10-10

FORMULAS FOR ESTIMATING ENERGY REQUIREMENTS

ADULTS
- Modified Harris-Benedict Equations (BEE)*
  - Long: BEE x activity factor x injury factor[1]
    - Activity factor = 1.2 in bed; 1.3 out of bed
    - Injury factor = 2.1 severe injury (> 45% TBSA)
  - Wilmore: BEE x Injury factor for 20% to 45% TBSA = 1.6 to 2.0[2]
  - Bell: BEE x 2[3]
- Curreri Formulas
  - Ages 16 - 59 years: 25 kcal/kg + (40 x % TBSA)[4]
  - > 60 years: 20 kcal/kg + (65 kcal/kg x % TBSA)[5]

CHILDREN
- Curreri Junior Formulas[6]
  - 0 to 1 year = Basal Calories + 15 kcal x % TBSA
  - 1 to 3 years = Basal Calories + 25 kcal x % TBSA
  - 3 to 15 years = Basal Calories + 40 kcal x % TBSA
- Galveston Formulas (Hildreth)
  - Infants < 1 year: 2,100 kcal/m^2 + 1,000 kcal/m^2 burn[7]
  - 2 to 12 years: 1,800 kcal/m^2 + 1,300 kcal/m^2 burn[8]
  - Teens: 1,500 kcal/m^2 + 1,500 kcal/m^2 burn[9]
- Wolfe Formula[10]
  - BEE x 1.55 to 2

*Harris-Benedict Equation (Basal Energy Expenditure, BEE)
Male: 66.47 + [13.75 x (Wt in kg)] + [5.00 x (Ht in cm)] – [6.76 x (Age in years)]
Female: 655.10 + [9.56 x (Wt in kg)] + [1.85 x (Ht in cm)] – [4.68 x (Age in years)

Sources: (1) Long CL, Schaffel BS, Geiger JW, Schiller WR, Blakemore WS. Metabolic response to injury and illness: estimation of energy and protein needs from indirect calorimetry and nitrogen balance. *J Parenteral Enteral Nutrition*. 1979;3:452-456. (2) Wilmore DW. *The Metabolic Management of the Critically Ill*. New York: Plenum Medical Book Co; 1977. (3) Bell SJ, Wyatt J. Nutritional guidelines for burned patients. *J Am Dietetic Assoc*. 1986;86:647-653. (4) Curreri FW, Richmond D, Marvin J, Baxter CR. Dietary requirements of patients with major burns. *J Am Dietetic Assoc*. 1974;65:415-417. (5) Adams MR, Kelley CH, Luterman A, Curreri PW. Nutritional requirements of the burned senior citizen: The Curreri senior formula. *Proc Am Burn Assoc.* 1987;19:83. (6) Day T, Dean P, Adams MC, Luterman A, Ramenofsky ML, Curreri PW. Nutritional requirements of the burned child: The Curreri junior formula. *Proc Am Burn Assoc*. 1986;18:86. (7) Hildreth MA, Herndon DN, Desai MH, Broemeling LD. Caloric requirements of burn patients under one year of age. *Proc Am Burn Assoc*. 1992;24:153. (8) Hildreth MA, Herndon DN, Desai MH, Broemeling LD. Current treatment reduces calories required to maintain weight in pediatric patients with burns. *J Burn Care Rehabil*. 1990;11:405-409. (9) Hildreth MA, Desai MH, Herndon DN, Duke MA. Caloric needs of adolescent patients with burns. *J Burn Care Rehabil.* 1989;100:523-526. (10) Gorman M, Broemeling L, Herndon DN, Peters EJ, Wolfe RR. Estimating energy requirements in burned children: A new approach derived from measurements of resting energy expenditure. *Am J Clin Nutrition.* 1991;54:35-40.

involves the use of a portable metabolic cart that measures respiratory gas exchange from which resting energy expenditure is calculated. This measured energy expenditure includes the increased needs due to the injury but not the energy needed for activity because it is performed when the patient is at rest. Additions of 10% to 30% for activity are recommended to estimate total calorie needs. A respiratory quotient (RQ) also can be derived that allows estimation of overfeeding (RQ > 1.0) or underfeeding (RQ ~ 0.7). Indirect calorimetry is, however, relatively expensive, time consuming, and requires an experienced technician to obtain reproducible results.

Whatever method for estimating energy need is used, it should be reevaluated at least weekly during the early recovery stages. Overfeeding can result in increased respiratory requirements and carbon dioxide production, hyperglycemia, osmotic diarrhea, and fatty liver. Underfeeding can affect wound healing and immunocompetence. Several studies have measured energy needs over time following the burn.[165]

Protein. The burn injury results in profound changes in protein metabolism with an increase in liver synthesis of acute phase proteins. Energy needs are met by muscle proteolysis, which results in muscle wasting. In addition, significant amounts of protein are lost through the open wound. Although optimal protein requirements are unknown, current protein recommendations for adults and children are 20% to 25% of total calories or a calorie to nitrogen ratio of 100:1 to 150:1.[166-168] This is approximately 80% to 100% above maintenance needs. However, it remains unclear if increasing protein intake results in increased anabolism.[169] Protein intake should be adjusted serially, based on nitrogen balance, whenever possible.

Recent studies have focused on the need for and role of specific amino acids in nutritional support of the burn patient. Arginine supplementation has been shown to improve cell mediated immunity and wound healing and decrease morbidity and mortality in several studies.[170-172] Arginine at 2% of calories is recommended by those researchers.[172,173] Glutamine supplementation is advocated by others because of its role in preserving gut integrity, and decreasing translocation and wound infections.[174] Some researchers advocate 0 to 40 g per day.[175] Use of high branched-chain amino acid formulas have not been found to be beneficial to burn patients.[176]

Carbohydrate and fat. Alterations in carbohydrate metabolism during the acute postburn phase include increased glucose production from gluconeogenesis. Carbohydrate is the primary energy substrate but should be limited to approximately 5 to 7 mg/kg/min, the maximum oxidation rate in adults.[177] At higher rates, hyperglycemia and osmotic diuresis can occur, and the carbohydrate is converted to fat and the sequelae associated with overfeeding.

The optimal amount and type of lipid to use in nutritional support of the burn patient is controversial and currently the subject of extensive research. During the acute postburn phase, there is a decrease in lipolysis since protein is the preferred fuel source, and an increase in serum free fatty acids and triglycerides. Lipids are a concentrated source of calories for the burn patient, but high levels of lipid intake, especially long chain polyunsaturated fats, may impair immune function. Modification of lipid intake with omega-3 fatty acids have been shown to improve immune competence and tube feeding tolerance.[178] Medium chain triglycerides may be helpful in decreasing omega-6 fatty acid intake, yet provide an easily absorbable source of fat calories. Many enteral formulas contain medium chain triglycerides as part of their fat content. Current recommendations are to limit lipids to about 15% to 20% of total nonprotein calories.[166,178,179]

Vitamin and mineral requirements. Specific requirements for vitamin and minerals have not been established although it is thought there are increased needs for at least those nutrients involved in wound healing and tissue synthesis (vitamins C and A, and zinc). Provision of a vitamin-mineral supplement equal to the recommended dietary allowances (RDA) is commonly recommended. Additional daily supplements of one gram of ascorbic acid, 10,000 IU of vitamin A, and 250 mg of zinc sulfate are used at many burn centers for adults.[153,180,181] Recommendations for pediatric patients include a daily multivitamin equal to the RDA for age, vitamin C at 5- to 10-fold the RDA, and 2-fold the RDA for zinc.[182]

Nutrition Care Planning

Development of a nutritional care plan involves selection of the appropriate route of nutritional support and selection of the specific formula, diet, or supplement to be used. Early enteral support within the first 24 hours is the preferred method of nutrition support as it may attenuate the hypermetabolic response.[183]

Oral high calorie and high protein. Patients with small percentage burns of 1% to 20% TBSA have modest increases in calorie and protein needs that can usually be met by diet alone or with the addition of between-meal supplements. The care plan should include individualization of meal plans and meal times to facilitate maximum intake because routine burn cares and rehabilitation frequently interfere with scheduled hospital meals. Calorie counts and documentation of supplements actually consumed are important for monitoring the adequacy of intake.

Enteral nutrition support. Adult patients who have burns greater than 20% to 30% TBSA, will usually require nutritional support in addition to diet. Pediatric patients with burns greater than about 10% TBSA will also likely need nutritional support. Children, especially young children, with burns of an even relatively small percentage TBSA may refuse to eat and thus require tube feeding. The enteral route is preferred for reasons of safety, better utilization of nutrients, preservation of gut integrity, and lower cost. Recent studies[183,184] of initiation of feeding within 6 to 12 hours of injury indicate the desirability and safety of early enteral

feeding. Feeding protocols that outline formula selection, initial goals, and initiation rates are helpful in starting enteral nutrition support early.

Selection of the appropriate route of enteral nutrition (nasoenteric, nasogastric, gastrostomy, or jejunostomy) depends on the aspiration risk, patient's condition, and the expected duration of enteral support. Nasoenteric feedings are preferred by many centers since they afford decreased risk of aspiration and can be continued during times of gastric ileus and surgical procedures. Small bore feeding tubes should be placed under fluoroscopy past the ligament of Treitz. Tubes made of erythrothane or polyurethene are suitable for long term use since they remain soft and pliable. Gastrostomy and jejunostomy routes are not used frequently in the acute phase because of the increased risk of wound infections in burn patients.

A moderately low fat, high protein formula is recommended. Elemental or hydrolyzed protein formulas are usually not necessary because digestion and absorption are usually normal in burn patients. Isotonic formulas can be initiated full strength at low rates (25 to 50 cm^3/h) and advanced to the goal over 24 to 48 hours. Complications include aspiration, diarrhea, metabolic abnormalities, and mechanical problems. Usually these can be treated or reduced without discontinuing the tube feeding.

Parenteral nutrition support. Parenteral nutrition support should be reserved for patients who have a nonfunctioning gastrointestinal tract or as a supplement to enteral nutrition when requirements cannot be achieved enterally. Close attention to line care is essential since the burn patient has a high risk of developing infection and sepsis.

Nutritional Monitoring

Monitoring the adequacy of nutritional intake is an essential component of the nutritional care of the burn patient regardless of the route of support. Because no single parameter accurately indicates nutritional status and most parameters are altered by the burn injury, several indexes should be selected for monitoring. These parameters are followed serially for trends rather than using their absolute values. Weight, nitrogen balance, calorie counts, and visceral protein status are useful when evaluated globally, along with consideration of the patient's clinical situation. Weight changes should be evaluated in relation to preburn weight and as a trend. Nitrogen balance requires an accurate 24-hour urine collection and a record of the patient's protein intake. Nitrogen excretion should be modified to include open wound losses. Two formulas proposed by Bell and Waxman are shown in Exhibit 10-11.[185,186]

Calorie counts are particularly important when a patient is being transitioned from parenteral or enteral support to oral diet or when diet is providing all of the nutritional support for the patient with significant surface areas burns.

EXHIBIT 10-11

NITROGEN BALANCE EQUATIONS

Nitrogen balance = Nitrogen intake - (total urinary Nitrogen [TUN] + fecal nitrogen loss + wound nitrogen loss)
(If TUN is not available, use urinary urea nitrogen [UUN] plus 1 to 2 g for nonurea nitrogen)

Equations to estimate wound nitrogen Loss:

Bell[1]:
- < 10% burn = 0.02 gm nitrogen/kg/day
- 11% to 30% burn = 0.05 gm nitrogen/kg/day
- > 31% burn = 0.12 gm nitrogen/kg/day

Waxman[2]:
- Postburn days 1 to 3 = 0.3 x BSA x % burn
- Postburn days 4 to 16 = 0.1 x BSA x % burn

BSA: body surface area in m^2

Sources: (1) Bell SJ, Molnar JA, Krasker WS, Burke JF. Prediction of total urinary nitrogen from urea nitrogen for burned patients. *J Am Dietetic Assoc.* 1985;85:1100-1104. (2) Waxman K, Rebello R, Pinderski L, et al. Protein loss across burn wounds. *J Trauma.* 1987;27:136-139.

Visceral protein status is difficult to evaluate because all of the indexes (albumin, transferrin, prealbumin, and retinol binding protein) are abnormally low in patients with major burns. Albumin is the poorest indicator due to its long half-life (21 d) and susceptibility to fluid shifts. Transferrin (half-life ~ 8 days) or prealbumin (half-life ~ 2 days) are better indicators of the patient's response to nutritional intake. Trends should be evaluated along with other parameters. Nutritional support requires the cooperation and support of the entire burn team to plan, provide, and monitor adequate nutritional intake.

Neurologic Problems in Burn Patients

Neurologic problems, many of which are preventable in burn patients, are the result of many etiologies. It is important to understand the etiologies of these deficits so precautions can be taken for prevention. Early recognition and treatment may help to prevent permanent deformity. Peripheral neuropathies are frequent and, yet, the diagnosis is often missed and the clinical weakness or atrophy noted is attributed to disuse weakness as a result of prolonged hospitalization with periods of forced immobility. The incidence of peripheral neuropathy has been reported at almost 30%. The most frequently diagnosed neuromuscular abnormality is generalized peripheral neuropathy, which commonly presents as distal weakness in the upper and lower extremities. The patient's complaint, however, is usually lack of endurance and easy fatigability, not weakness. When weakness is noted, it occurs in the burned as well as unburned extremity. Clinically detected sensory deficits are uncommon. However, with electrodiagnostic testing, slowing of sensory nerve conduction velocities is detected. There is a greater incidence of peripheral neuropathies as the burn size increases above 20% TBSA in adults and 30% TBSA in children. Electrical burn patients develop neuropathies with smaller burns. The cause of generalized neuropathies is not entirely understood but is probably multifactorial, related to toxic, nutritional, and metabolic factors. Additional research is needed to discover preventive interventions for the generalized neuropathies. Localized neuropathies are of great concern because they are probably related to preventable causes such as compression or stretch injuries of a peripheral nerve or damage from intramuscular injections.[187]

Predisposing factors make some patients more susceptible to neuropathies: the aged are more prone to develop compression neuropathies because their peripheral nerves do not tolerate pressure well, and older patients are less mobile. Alcoholics and diabetics are also prone to neuropathies because of already diseased nerves.[188]

The most commonly affected peripheral nerves are the peroneal, ulnar, and brachial plexus. The peroneal nerve is prone to both pressure and stretch injury. It courses around the fibular head and is covered only by skin and superficial fascia. Prolonged sidelying in bed creates excess pressure along the course of the nerve. Additionally, this nerve can be compressed by orthoses or elastic compression applied too tightly over the fibular head. Bulky wraps used for immobilization postgrafting must be applied so as to limit compression and actually provide pressure relief to this area. Stretch neuropathies occur by improper positioning with the hips flexed, abducted, externally rotated with knee flexion, plantar flexion, and inversion of the foot. This "frogleg" positioning is assumed by the patient because it is the position of comfort for the burn casualty. Therefore, preventive measures include low air loss beds, rotating the sidelying bed position, and positioning the knees in extension and the feet in dorsiflexion when the casualty is supine. Hip trochanter rolls are used to position the leg, rather than knee rolls.

Ulnar neuropathies occur in a similar manner. The ulnar nerve is at risk of compression as it passes through the cubital tunnel at the elbow. When the elbow is pronated, the tunnel is narrowed. The burn victim commonly lies with the elbow elevated on pillows or arm troughs flexed at approximately 90° and pronated. The ulnar nerve thereby receives both external and internal compression. The subsequent damage to the ulnar nerve results in weakness of the ulnar intrinsic muscle of the hand, which causes a claw hand deformity with loss of sensation to the ulnar side of the hand. Prevention with proper positioning would include limiting the external pressure applied over the cubital tunnel as well as avoidance of the static pronated position.

Brachial plexus neuropathies are sometimes blamed on the use of strenuous stretching techniques. However, the problem is more likely caused by improper positioning. When the arm is flexed to 90° and externally rotated, the clavicle comes into close proximity to the first rib and can impinge on the plexus. This impingement can be prevented, however, by horizontally adducting (forward flexion) the arm to 30°. The staff should monitor a casualty carefully when this position is necessary for a prolonged period postgrafting. The arm may be safely positioned in abduction of up to 120° as long as sufficient horizontal adduction is allowed. The

plexus is prone to injury in the operating room especially if the patient is supine and the arm is allowed to be abducted and not elevated above the level of the operating table. Also, if an axillary contracture is released, great care must be taken not to overstretch the also contracted neurovascular bundle.

Tourniquet injuries are seldom seen with the advent of pneumatic tourniquets in the operating room. However, these tourniquets, which are so important in providing a bloodless field necessary for tangential incision and grafting, must be used with care so as not to cause either direct pressure damage to underlying structures or cause ischemic injuries to distal tissues.

Bone and joint changes are common complications following thermal and electrical injuries.[189] Commonly noted changes include internal changes in bone, such as osteoporosis; bone necrosis; bone growth disorders in children; and periosteal bone formation. Early mobilization and weight bearing is thought to diminish the risk and severity of osteoporosis. Periarticular changes include heterotopic ossification and calcific tendonitis. Heterotopic ossification has been reported with an incidence between 13% and 23%. No definite etiology is known, although superimposed trauma or repeated minor trauma with local hemorrhage have been considered. Aggressive stretching with local trauma has also been implicated. Generally, periarticular ossification is noted in the area of deep burn, although it has been noted in areas distant from the burn; the elbow is the most common site, although the shoulder and hip are also common sites. It should be considered if there is a sudden onset of joint pain; swelling or redness may not be easily detected in the burn patient. When this diagnosis is made by plain radiograph or bone scan, the rehabilitation therapy consists of AROM exercises without stretching and orthotic positioning in the position of maximal function.

Joint changes such as septic arthritis and ankylosis occur when the injury occurs deep into the joint or when bacteremia seeds the joint. When a joint is thought to be infected, it should be positioned and rested using a static orthotic device in a functional position. If ankylosis occurs secondary to the septic process, the joint will then be at a maximal position of function. Dislocation occurs from improper positioning of a injured joint or, more commonly, by skin contracture. If a joint is subluxed by a skin contracture, orthotic management should be instituted immediately. If the orthosis cannot adequately control the deformity, internal fixation or release of the contracture or both should be strongly considered.

Plastic Surgery Strategies and Rehabilitative Considerations

Timing of reconstructive surgery and subsequent rehabilitation team efforts are a significant consideration during the rehabilitative phase of burn recovery. Correctly timed, the patient improves functionally, cosmetically, and psychologically. Incorrectly timed, the patient loses function, wastes valuable donor areas, and receives no benefit from the procedure.

Plastic surgeons avoid the words cosmetic and cosmesis, which continually emerge in the discussion of burn injuries. These descriptive words have connotations in American language that result in misinterpretation of the procedures being considered. Once a surgical procedure is termed "cosmetic," it carries a tainted, frivolous identity. Almost no procedure for reconstructing the burn patient fits this category. Plastic surgeons fully understand the medical necessity of functional reconstructive surgery, which is vital for patients, to enable them to perform skillful work, recreation, and family life with self-confidence. This reconstruction for function should not be confused with "cosmetic" interventions.

In addition to reconstructive surgery, plastic surgeons recommend camouflage make-up. Cosmetic products that are used to enhance appearance and self-confidence for both male and female patients should not be considered unnecessary or frivolous.

The phases of recovery addressed by the plastic surgeon include the acute phase, during which the wounds are closing, and the wound maturation phase, during which the scars are maturing. The ideal time to undertake reconstructive surgery is after the scars have become mature. However, there are a few specific situations in which reconstruction must begin earlier. In many cases the patient wants reconstruction at an early date, and one must give a thorough explanation of the disadvantages of increased inflammatory scar deposition during the early scar maturation phase. As time progresses and the scars mature, the patient often becomes more satisfied with the appearance of the scars.[190] In addition, as the person becomes involved in former activities, he is less interested in prolonged interruptions for operations or in-hospital care.

The reconstructive surgeon and the patient select the most troubling functional deficits or disfiguring scars or both and discuss the possible correc-

tion. The patient takes an active part in the planning process. Surgical teams frequently perform multiple operations under the same anesthetic so that the time is used efficiently and recovery time is minimal. For instance, a 5th finger flexion contracture is released at the same time as a web space contracture is corrected with a Z-plasty on the same hand. Only one hand is operated on at a single sitting and early motion cases are not mixed with procedures that require immobilization. In most cases, external vascular support garments are not worn and compression is usually not helpful after the reconstructive operations. If difficulty with hypertrophic scarring develops after reconstruction, the team then starts using pressure, gel sheets, or intralesional steroids. It is important in discussing the rehabilitation of burn patients to understand the choices available for reconstruction. Generally the reconstructive surgeon determines the problem to correct, and then considers multiple ways of performing the corrections. The surgeon then chooses the optimal method for a particular patient as well as a backup procedure in case of complications or tissue loss postoperatively.

Skin Graft

Skin grafts for reconstruction are the most common source of covering tissue. For the best outcome, new donor sites should be available in unscarred areas, and these areas must be acceptable to the patient because of the resulting donor site scars. Thicker skin grafts are used for reconstruction than those in the initial skin grafts. The thin grafts contract far more than the thicker grafts but take with greater certainty. Any skin graft done when the scar tissue is active contracts severely, limiting the possibilities available to the plastic surgeon. The contraction in immature scars is related to the presence of the myofibroblast in the healing scar in contrast to the mature scar. In some areas of the body, contraction of the graft provides a poor functional outcome so that full thickness grafts are desirable. Such areas are the lower eyelids, dorsum of the fingers, nasal tip, ala, and upper lip. Reconstruction of the ala will require using composite grafts that include skin, fat, and cartilage.

Flaps

Skin flaps are frequently used in burn reconstruction when vital structures need coverage. These may be used in any phase of the reconstruction, and various flaps are used for different purposes. Musculocutaneous flaps or muscle flaps are often used acutely to cover bone, vascular grafts, or vital organs exposed by the burn itself. Musculocutaneous flaps are also used during the reconstructive procedures. Muscle provides excellent blood supply, new lymphatics, and thick composite coverage. In some cases the initial reconstructions are bulky and do not shrink adequately, so that the volume must be reduced at a later procedure.

Free flaps are used to provide blood supply to large avascular areas such as the scalp following electrical injury. These flaps require a microvascular anastomosis and a very specialized and individualized donor site. For example, a free flap of omentum has been used to cover a complete scalp defect. An overlying skin graft is then required (see Figure 10-20). Abdominal burns or gastrointestinal pathology may make this choice unwise; if so, a latissimus dorsi flap may be selected.[191,192] A thin, free flap including skin, such as a dorsalis pedis flap, may be better than a muscle flap reconstruction, which would require an additional overlying skin graft. Free flaps are useful in all phases of burn healing and allow for a great deal of creativity and flexibility for the plastic surgeon.

Axial flaps are long, cutaneous flaps that have an anatomically recognized artery and vein within the flap itself. The flap is either turned, rotated, or moved into position. Axial flaps are usually used for hand procedures such as a pollicization or island pedicle finger pulp reconstruction.

Random or local flaps were the earliest flaps used, do not have a recognized artery, and are used almost anywhere on the body surface. The skin flap survives on the subdermal plexus of vessels. These flaps may undergo a delay procedure to enlarge the flap. Tissue expansion may be utilized to expand the size of tissue available.

The Z-plasty is a procedure using multiple small flaps to lengthen a contracture. Z-plasties may have multiple flaps set around a specific joint or have multiple flaps set along a contraction line. Occasionally, these flaps are mixed with small skin grafts.

Timing of reconstructions may depend on the type of burn wounds. Chemical and thermal burns may need no reconstruction at all as they slowly improve. Radiation burns, in contrast, tend to be chronic and gradually worsen. These injuries require late debridement and flap coverage years after the initial trauma. Skin grafts in these cases are ineffective; musculocutaneous flap coverage to provide a new blood supply is ideal.

Electrical burns often require reconstruction during the acute phase of burn injury. These burns ex-

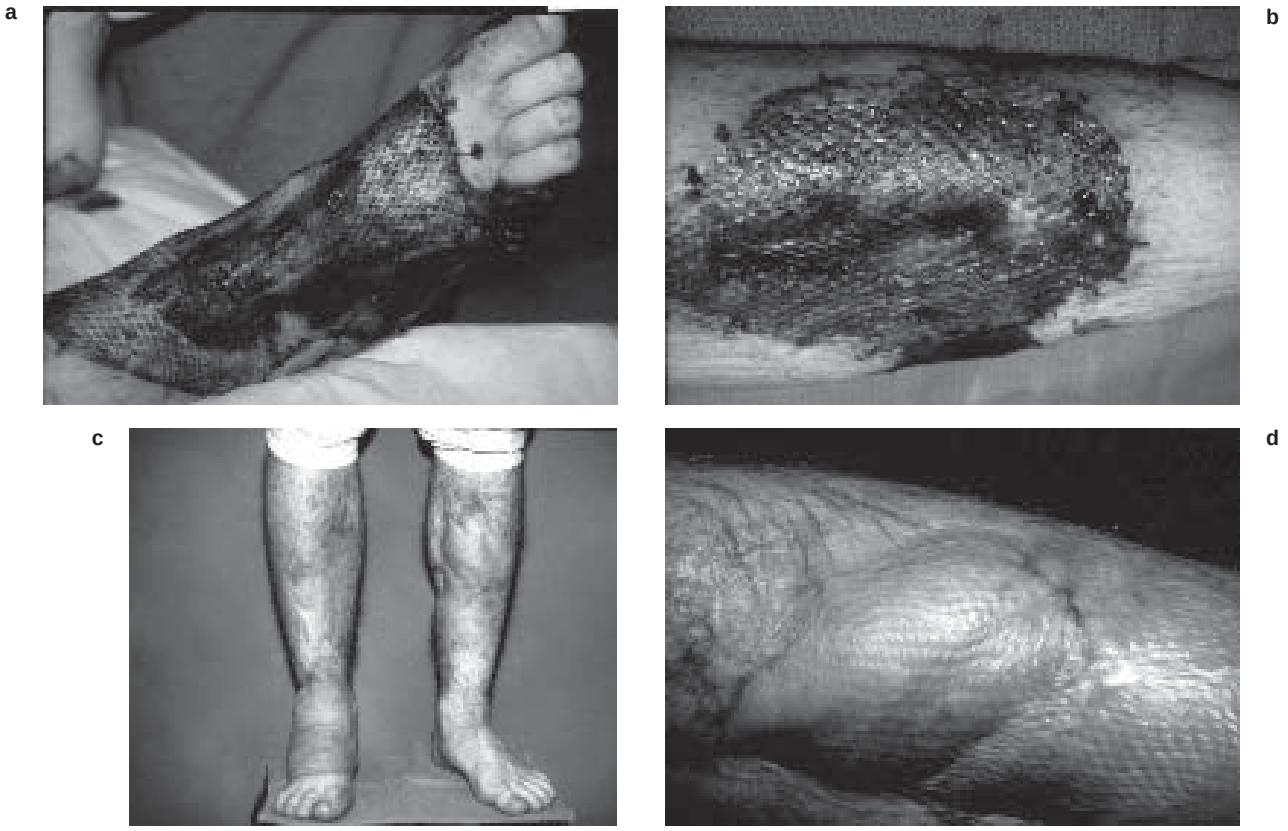


Fig. 10-109. Care of deep thermal burn of the leg. (**a**) Deep thermal burn of right foot dorsum with tendon involvement. (**b**) Exposed tibia on the same patient's opposite extremity. (**c**) Closure of both wounds 10 months later with free flap to foot. (**d**) Closure of open tibia with gastrocnemius muscle flap.

pose vital structures such as tendons, bones, or viscera, which must be covered. Rarely will split thickness skin grafts provide the quality of coverage needed, and flaps are vital to introduce new blood supply during the first few weeks. Musculocutaneous flaps and free flaps are the most adaptable methods for coverage of electrical wounds (Figure 10-109).

Release of an axillary contracture is related to function of the shoulder. Resurfacing of the forehead is related to the patient's appearance. In the face, reconstruction and function begin to merge. The function of the facial skin is to identify the individual, transmit emotion in communication, protect corneas, and form the mouth and nose. Eyelids, vital to the protection of the eye, may require reconstruction at a very early stage in the acute phase of burn recovery. To correct eyelid eversion or contraction, full thickness donor skin must be obtained in sufficient quantity to replace the eyelid skin. If hair-bearing skin or scarred skin is used, the results may give an unacceptable appearance and rapid reoccurrence of ectropion. Reconstruction of aesthetic units of the face during the acute phase gives an optimal appearance that may not be matched by any other procedure again until the patient has completed the maturation phase of burn wound healing. In the interim, facial orthoses, for example, transparent face masks, are the primary option for improving the appearance.[193]

Timing of functional hand burn surgery is fairly independent of reconstructional considerations for appearance. In society, hands are necessary for their function and not for their appearance in most situations. After initial closure of the wound, motion of fingers is vital, and surgery assumes a secondary role until the wound has become mature. Once the skin begins to feel supple, reconstruction can be undertaken. Skin grafts to the hand need immobilization for 10 to 14 days, followed by aggressive remobilization utilizing prolonged stretch and AAROM, AROM, and CPM equipment as necessary.

Extensor tenolysis is undertaken only when skin coverage is good. The patient must start range-of-motion exercises within 24 to 48 hours of extensor tenolysis surgery. Web space reconstruction using Z-plasties is managed like skin grafts with 10 to 14 days of immobilization and 6 to 8 weeks of spacers at night. It is not unusual to need an unexpected skin graft during a web space release because, as the scars are incised and defects are opened, the need for additional skin coverage becomes obvious. The patient's needs influence the timing of reconstruction, and all problems cannot be addressed at one sitting. Functional problems with hands, eyelids, mouth, axillae, elbows, and neck are the most important to the well being of the patient. Muscles, tendons, and nerves shorten when the skin over a joint is contracted. In these cases, reconstruction takes a precedence even if the maturation phase has not been completed.

Facial features themselves are not reconstructed until the scar tissue has become inactive, supple, and mature. An example would be an electrical burn involving the commissura of the mouth, such as that which occurs from a toddler biting into an electrical cord or sucking on an outlet. These injuries result in quite extensive tissue destruction. Only after these open wounds are allowed to heal are any reconstructions undertaken. In many cases the spontaneous healing, with the use of a microstomia appliance, produces such an excellent result that no further reconstruction is necessary.

The rehabilitation personnel need to understand the objectives and timing of plastic surgical interventions in the burn casualty. They need to consult with the plastic surgeon and provide objective measures of function. Outcomes are improved when there is appropriate timing of the needed procedure. Proper postoperative rehabilitation care is best directed by the plastic surgeon who knows the surgical intervention and proper timing to resume therapy, splinting if needed, and independent activity by the patient.

CONCLUSION

This chapter was written to summarize the critical elements of burn rehabilitation of the injured soldier, and discuss and illustrate proper rehabilitation of the burned individual. It was written by a team of specialists including physicians, nurses, dieticians, physical therapists, occupational therapists, and psychologists. This gives it both a comprehensive approach as well as a flavor of team work which is needed for the successful rehabilitation in a complex patient.

It provides medical knowledge at the level of all team members so as to provide an overview for all caregivers.

It is hoped that it will provide an excellent field guide to all military personnel as well as a more comprehensive guide for personnel located in a designated burn treatment area. More information can be found by utilizing the references provided.

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