Introduction

The purpose of this manual is to provide the Burn Resident and students with information about the care of the burn patients and the organizational structure of the Burnett Burn Center. The contents include information on the admission process, standards of care, daily unit routines, discharge planning and the outpatient burn and wound clinic as well as reference articles. Additional educational resources are available in the burn center work room, through the attending surgeons and nurse educators.

The Burnett Burn Center is an 11 bed inpatient burn center with ICU, telemetry and floor level beds. Care is provided to pediatric and adult patients with thermal (flame, scald, cold etc), inhalation, electrical, chemical, radiation and skin loss injuries. Patients are cared for from the onset of the injury through their hospital discharge, the rehabilitation process and outpatient clinic treatments. Follow-up reconstructive therapy and surgery needs are also addressed. The Burn Center staff also care for trauma patients, surgery patients and patients requiring specialized wound management. Other medical and surgical services also utilize these beds when necessary.

The burn team includes physicians, nurses, nurse practioners, burn technicians, burn (occupational and physical) therapists, neurophychologists, dieticians, pharmacists, case managers and respiratory therapists. Registered Nurses are responsible for 24 hour quality care. The nursing staff participates in daily patient care decision making, multi disciplinary conferences, developing standards of care, and initiating discharge planning. Nursing care includes wound management and debridement, infection control, intensive patient observation and monitoring, patient and family assessments, interventions in skin and mouth care, pulmonary care, positioning, ambulation and splinting and safety management.

Standards of care in the Burn Center are developed using evidence based practices. Performance improvement conferences examine ongoing areas of care with a focus on patient outcomes. Important aspects of care include wound care, with a focus on patient outcomes, nutritional support, infection control, patient education, environment (emergency equipment, other supplies, and physical structure) and risk surveillance.

Admission Criteria

The criteria for admission are listed below these are based on guidelines established by the American Burn Association (ABA).

1. Partial thickness burns greater than 10% total body surface area (TBSA)
2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints
3. Third-degree burns in any age group
4. Electrical burns, including lightning injury
5. Chemical burns
6. Inhalation injury
7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
8. Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient may be initially stabilized in a trauma center before being transferred to a burn unit. Physician judgment will be
necessary in such situations and should be in concert with the regional medical control plan and triage protocols.

9. Burned children in hospitals without qualified personnel or equipment for the care of children
10. Burn injury in patients who will require special social, emotional, or long-term rehabilitative intervention

Excerpted from Guidelines for the operation of Burn Centers (pp 79-86), Resources for optimal Care of the Injured Patient 2006, Committee on trauma American College of surgeons.

**Admission Process**

Patients may be admitted from a referral facility, the emergency department or the Burn and Wound clinic. All outside referral calls are routed through the transfer center (913-588-9999). The transfer Center will collect the patients’ demographic information then notify the attending physician on call. The Burn Center Charge Nurse or Unit Coordinator will be patched into the call and initiate the admission call sheet. The attending physician is responsible for obtaining the initial history and recommending the initial respiratory, fluid and wound management to the referring physician. Any patient with significant concomitant trauma, a high voltage electrical burn or significant chemical burn is to be routed through the emergency department. All other patients may be admitted directly to the Burn Center.

When the Trauma/Critical Care service or Pulmonary Critical service is involved in the care of a burn patient (mandatory with greater than a 20% BSA burn injury, significant inhalation injury/intubated patient, concomitant trauma, a high voltage electrical injury or severe chemical burn or under such other circumstances as is felt to be necessary by the Attending physician) care provided by the Intensivist service shall be considered Concurrent Care. Because of the critical nature of these patients, it may not be feasible for the secondary service to contact the primary service for each and every change in the management plan. The concurrent care service may write orders that do not need to be cosigned prior to being carried out.

Pediatric patients (17 years of age and younger) may be admitted to the Burn Center by the Attending Burn Surgeon. All pediatric patients will be treated under concurrent care guidelines with the Pediatric and/or Pediatric Critical Care service. These patients may be managed in the Pediatric ICU or on the Pediatric floor depending on their level of acuity. Patients < than 4 year old or with a burn > 10% TBSA, any inhalation injury, electrical or chemical injury will be treated by the Pediatric Critical Care Team. The Attending Burn Service will be responsible for all burn and wound related care. Pediatric patients that fall within the following guidelines are to be transferred to a dedicated Pediatric Burn Center (e.g. CMH, Shriner’s in Cincinnati or Galveston) unless cleared for admission and treatment by the Attending Burn Surgeon, the Medical Director of the Burnett Burn Center and the Attending for the Pediatric Intensivist Service: patients < 2 months old with a >5 % TBSA injury, patients 2-12 months with a > 10% TBSA injury, patients 1-3 years old with a > 15% TBSA injury, patients 4-8 years old with a > 25% TBSA injury and patients 9-17 years old with a > 40% TBSA injury.

This is a special circumstance in burn care as a result of the complexity and high acuity levels of the burn patients. For this reason, it is of the utmost importance that the Concurrent Care Service 1) maintain close communication with the primary service and 2) follow the standards of care that are recognized as treatment standards in modern burn care. If questions arise regarding what is best for the burn patient, the Concurrent Care service must contact the Attending Burn Surgeon or his/her designee before proceeding with the treatment plan.

Order sets have been developed for adult burns > 20% or ICU status, adult burns < 20% non ICU status, pediatric burns > 10% or ICU status, pediatric burns < 10% non ICU status and fluid resuscitation. The appropriate order set is to be used for every patient and if you are unsure which order set should be used consult the attending surgeon. Order sets are included with this disc.
Triage

When the maximum census of 11 has been met, the unit coordinator /charge nurse will collaborate with the on-call surgeon and the primary surgeon of the affected patients to determine a triage plan. The decision to triage is based on a consensus determination of patient needs, patient acuity and available resources. Consideration should be given to the individuals’ physical, psychosocial and discharge planning need and the ability to meet these needs on an alternate patient care unit.

All patients admitted to the burn center may stay on the unit for the duration of their inpatient stay. As the patient’s status improves, the need for specialized care may be lessened, yet the continuity of care remains a priority. Patients may be transferred to a alternate site of care if a situation occurs where there is a bed shortage in the Burn Center, or if it is deemed in the best interest if the patient.

Multidisciplinary Team Members

**Nursing**
Responsibilities include medical care and comfort of all patients; they provide for the patient physiological and emotional needs as well as assist in coordinating the overall care of the patient. Provide information to designated family members and/or DPA.

**Nurse Practioner (ARNP)**
The primary goal of the ARNP is to assure continuity of care for patients in the burn center and the burn and wound clinic. Under the supervision by the Medical Director or burn attending, assists in the treatment of surgical and non-surgical wounds as directed by the. The ARNP also acts as a resource in educating residents and student physicians about burn and wound care.

**Physical Therapist**
A physical therapist is assigned the burn center; consultation is initiated on admission for burn patients. Patients receive a wide range of services including ROM, strengthening programs, assistance with ambulation and discharge planning. The physical therapist evaluates and provides treatments according to the patient’s specific needs

**Occupational Therapist**
The occupational therapist is assigned to the burn center; consultation is initiated on admission. The occupational therapist evaluates and provides treatments according to the patient’s specific needs. These treatments are coordinated with all members of the team to facilitate patient recovery and optimal outcomes. Evaluation consists of motor, sensory, interpersonal, self care, leisure and vocational.

**Dietician**
The dietician is responsible for ongoing review and recommendations for nutritional supplementation

**Social Services/ Case Manager**
A social worker and case manager is assigned to the burn center responsibilities include discharge planning, financial counseling and initiate family care conferences. Social Services assist with suspected child abuse and dependent adult abuse. They facilitate communication between patients, their families and the health care team.

**Clinical Pharmacist**
Reviews medication orders, relates patient labs and makes suggestions for interventions to enhance patient outcome. Provides consultation on request.
Neuropsychology
Available on a consultation basis the neuropsychologist is involved in assessing or treating patients with neuropsychological problems. Circumstances surrounding the recovery course of a burn-injured person necessitates additional guidance and support.

Pastoral care
The chaplain is available 24 hrs a day for patient consultation.

Pain Management
The pain management service is available to assist with issues related to pain control.

Respiratory Therapy
Assist with ventilator management, medications and full range of respiratory therapies.

Palliative Care
Not just for end of life situations. Provide support and communication with the family and coordination of patients advance directives. Mandatory referrals for patients with >60 % TBSA burn injury or > 30% TBSA in patients > 60 yrs of age.

Burn PI Coordinator
Role is to manage the Burn Performance Improvement Program. This includes a system of concurrent data collection, peer review, collaboration/feedback. The PI coordinator is responsible for:
- Identification of those areas where quality or efficiency of care may be improved
- Facilitation of review processes, collection and analysis of data
- Identification of trends and benchmarking opportunities
- Identification of staff education needs and coordinates trauma education and research activities carried out by trauma service.

Decreasing Distractions Quality Initiative

Nurses have to make timely and relevant clinical decisions, yet work within environmental conditions that are conducive to error. A recent study showed that nurses on average were interrupted 3 to 6 times every hour by people, pagers, telephone, etc (Potter et al., 2005). The potential impact of interruptions and distractions includes medical and medication errors, ineffective delivery of care, conflict and stress among health professionals, latent failures, and poor outcomes.

Today’s healthcare environment is characterized by chaotic conditions and an overwhelming sense of change fatigue resulting from the constant barrage of new initiatives being introduced. The challenge is to reduce or eliminate distractions and interruptions that unnecessarily add to the complexity of nursing work and ultimately place patients at greater risk for harm or injury.

Quiet Zones have been created on the Burn Center in order to help decrease interruptions during medication administration times. The established "Quiet Zones" are the front medication room and the area around the accudose in the ICU. Passing medication is a critical process and decreasing distractions during these times are crucial. "Quiet Zone" signs have been posted in these areas.

In addition we are striving to decrease interruptions/distractions during shift change and bedside safety checks.

Everyone involved in our patients care can help decrease distractions in order to make our unit a safer place for all of our patients.
Secretary
- Maintain a quiet environment especially during shift change and medication administration times.
- Present and available to answer all phones / call lights from 0700-0730 & 1900-1930
- No breaks during shift change
- Take a message for RN during report time unless it is an emergency
- Complete chart checks prior to shift change
- Make visitor announcements at all shift changes
- Avoid interruptions/ distractions during shift change, patient safety check / hand off, and medication administration
- Observe Quiet Zones and educate others as necessary

Tech
- Out on the unit by 0710 to collaborate with secretaries to answer call lights and phones.
- Encouraged to stay and help on the unit until all RN bedside reports are finished
- Round, take vital signs and anticipate patients needs prior to shift change
- Utilize tech report sheets to decrease face to face report time.
- Avoid interruptions/ distractions during shift change / patient safety check / hand off, and medication administration
- Observe Quiet Zones and educate others as necessary

RN
- Collaborate with techs to anticipate patient needs by rounding prior to shift change
- Shorten AM/PM group report
- All RN’s are encouraged to stay to help on the unit until all RN’s are finished with bedside reports
- Charge RN/UC ensure that secretaries make visitor shift change announcement
- Charge RN/UC ensure that family/ visitor are following the visiting hours
- Avoid interruptions/ distractions during shift change / patient safety check / hand off, and medication administration
- Observe Quiet Zones and educate others as necessary

MD/NP
- Ensure that charts are available to the RNs for shift change from 0700-0730 and 1900-1930
- Avoid writing orders at shift change unless absolutely necessary
- Avoid interruptions/ distractions during shift change / patient safety check / hand off, and medication administration
- Observe Quiet Zones and educate others as necessary

PT/OT
- Avoid interruptions/ distractions during shift change / patient safety check / hand off, and medication administration
- Observe Quiet Zones and educate others as necessary

Phone Numbers

<table>
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<tr>
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<th>Phone Number</th>
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</thead>
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</tr>
<tr>
<td>Burn ICU</td>
<td>913-588-6546</td>
</tr>
<tr>
<td>Outpatient Burn &amp; Wound Clinic</td>
<td>913-588-5475</td>
</tr>
<tr>
<td>Workroom</td>
<td>913-588-7104</td>
</tr>
</tbody>
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Burn Care Resource Team

Richard Korentager, MD  Medical Director – Plastic Surgeon
Dhaval Bhavsar, MD  Burn Attending – Burn/Wound Plastic Surgeon
Satish Ponnuru, MD  Burn Attending – Burn/Wound Plastic Surgeon
Teresa Buescher, MD  Burn Attending – Burn/Wound Plastic

Michael Moncure, MD  Chief, Trauma Surgeon/Critical Care
Michael Crosser, MD  Pulmonary Critical Care

Maria Pena, RN, MSN  Nurse Manager
Tracy Rogers, RN  Director Trauma/Burn Program Line
Matt Pierce, ARNP  Nurse Practitioner
Kayla Northrop, RN  Unit Educator
Suzanne Mitchell, ARNP  Nurse Practitioner
Sidonie Welsh, RN  Burn PI Coordinator
Maria Weeg, RN  Case Manager
Janelle Epp, OTR  Occupational Therapist
Jessica R  Physical Therapist
Kelle Shubkagel, RD  Dietician

Internet Resources:
www.ameriburn.org
www.burnsurgery.org
www.pheonixsociety.org

Burn Service Rotation

Resident/Student Educational Objectives

- Learn assessment and classification of burn wounds, including estimation of burn size and depth and reduction of related morbidity and mortality
- Gain an appreciation of stress response to acute burn injury, including hemodynamic, metabolic, nutritional and immunologic sequelae.
- Learn initial management of the acute burn patients, including fluid resuscitation, nutritional support, wound care and ventilatory management.
- Learn wound management of burn patients including and understanding of wound healing, wound sepsis, topical antimicrobial agents, biological dressings, skin substitutes and skin grafts.
- Develop fundamental surgical skills in treatment of burn patients, including wound debridement, wound dressing and splinting, skin grafting and scar contracture release.
- Gain an appreciation for burn rehabilitation, including physical/occupational therapy, psychological support and reconstructive needs.
- Improve communication and leadership skills through interactions and coordinated discussions with patients and their families, attending physicians, medical personnel, medical students and fellow residents.
- Learn Principals of management of special problems; including inhalation injuries, chemical burns, electrical injuries and toxic epidermal necrolysis.
- Opportunities exist for additional nonburn/wound operative experience and can be coordinated through the attending surgeons but burn/wound procedures must always take priority.
Clinical research opportunities are available and all residents and students are encouraged to become involved. Students are required to present a 10 min presentation during the last week of their rotation during burn rounds on a topic of their choice relating to burn, wound or critical care management of patients.

**Resident Responsibilities**

- Admit new patients to the burn center, assess and document initial assessment, complete burn diagram, obtain history and physical and complete admission orders utilizing the pre-printed orders.
- Take primary responsibility in coordinating all efforts toward daily patient care of all acute inpatients in cooperation with nurse practitioners.
- Coordinate morning rounds and afternoon sign out rounds with the attending, NP, medical students and Unit Coordinator Nurse.
- Assist in the evaluation and treatment of outpatients.
- Participate in all operative cases of burn patients, including major excisions and grafting and post burn reconstruction cases. You are expected to make all preparations for surgical cases, including scheduling, obtaining informed consent and appropriate perioperative planning. The resident is expected to call surgery scheduling 8-2829 and send a completed surgery scheduling form to (fax 8-2430)
- Keep the attending physicians aware of any significant changes in the patient conditions and discuss proposed changes in treatment prior to initiation, when appropriate.
- Assist in the education of the assigned medical students

**Call Schedule and Vacation**

You are to be available according to the published call schedule for assistance with new admissions, emergency referrals and acute patient transport. In general, you will be off call on the evenings and days that are being covered by the Nurse Practitioner and on Sundays. If you are approaching 80 hours in a given week inform the Medical Director so that an appropriate adjustment can be made to your schedule.

Inform the Medical Director of scheduled vacation times as soon as possible.

**Documentation**

In the burn center, the medical records department has prepared a through manual with rules and regulations to help you keep the records correctly. It is primarily the responsibility of the residents to maintain complete and accurate medical records. This should include a thorough history and physical including burn diagram, detailed operative dictation and notes, legible medical orders and daily progress noted. The green burn registry sheet should be kept up to date and is found in the front of each chart. All documentation should be completed immediately following the event.

The rule is simple: If you don’t write it down, you didn’t do it. A corollary should be if an order is written a progress note should document why. This helps those who follow you and helps maintain continuity of care. Medical notes are not just for now, but also to lend information years from now. Document! Document!

**Admission-History and Physical**

Obtain a thorough general medical history and physical assessment. Patient evaluation should include an AMPLE history:
- Allergies
- Medications
Pre-existing diseases—medical and surgical

Last meal

Events of the injury— including time, location and concomitant injuries.

A history of loss of consciousness should be sought. When where and how did the accident occur? With children, stories that are inconsistent with the injury are suspicious for child abuse and what is the situation at home? What time did the burn occur? What was the initial treatment, including any narcotics or sedation administered and resuscitation prior to transfer to the burn center? What is the immunization status, especially tetanus?

Burn Diagram

The diagram must be completed at the time of admission and on PBD # 2 and # 4. The diagram is to be done while viewing the patient in the tank room or at the bedside with all dressing off and blue denotes partial thickness injury and red denotes full thickness injury.

Admission Orders

Utilize the pre-printed admission order sheet and fluid resuscitation sheets. Order sets are available for adult burn > 20% and < 20% and pediatric burn > 10% and < 10%. There are a wide range of useful order sets in the formulary section of the KUMed hospital links (insulin orders, sedation, alcohol withdrawl etc) and should be used if applicable.

Orders

Orders are only ‘orders’ once they are written and signed off. Nurses do not take verbal orders and telephone orders are taken only for urgent or emergent situations. Hospital policy is no verbal orders if the physician is on site. Students cannot write orders in the medical chart. All orders should be written legibly in black ink, dated, timed and signed. Listen on rounds for faculty directions and follow-up to ensure optimal patient care. Explanations for changes in the treatment plan should be clearly outlined in the progress notes.

Progress note

Progress notes are written daily on all inpatients. Notes should include the date, the time, post burn day number, vital statistics, examination findings (including wounds), pertinent tests and laboratory data, clinical assessment, antibiotics and the number of days it has been prescribe, infectious organism identified, number of days individual vascular lines have been in place, number of days with foley, number of days with ETT and plan. Data should support the impression and plan. If the case was seen or discussed with an attending, that should be documented.

Pre-operative Notes

Pre-operative notes should be completed the day before each surgery, reflecting the planned procedure, predicted blood loss (0.5cc/ cm2 to be excised, take into account use of tourniquet, injection of tumescent solutions) and allograft skin needs. Review of appropriate labs, wound cultures and appropriate antibiotic coverage should also be ascertained. Documentation that informed consent has been obtained from the patient and/or their legal representative should also be contained in these notes.

Operative Notes

Since many of our patients return to the operating room multiple times, accurate descriptions should include: donor sites, area and depth of excision (tangential vs. facial), areas autografted, size of meshing, coverage with homograft or other dressings, levels of amputation, untoward events in surgery and estimated blood loss.
Estimation of blood loss usually equals blood replacement if post-operative hemoglobin is acceptable. The Immediate Post Op burn form should be completed any special instructions must be written on the standardized burn wound order form.

End of Service /Discharge Notes

Upon completion of your tour of duty here in the burn center you are expected to complete an off-service note on all inpatients to facilitate continuity of care with the incoming resident. This should include a summary of the patient’s stay, including current issues and treatments. The dictated discharge summary should include history, exam, labs, hospital course and disposition, including diet, activity and medications.

Out patient Clinic Notes

Notes should be dated and briefly describe the patient including name, MR number, birth date, date of burn, size of burn, last operation, last visit to the clinic and previous identified problems. The note should than detail current status, examination, impression and an acute care or rehabilitation plan. If the patient is a Worker’s Compensation injury, make note of work status. Planned follow-up visit is recorded. Any procedures done in the clinic should also be dictated as an operative note.

Conferences

Attend all required surgical house staff conferences including:
Burn Multidisciplinary Rounds- Wednesday 1400 in burn center conference room.
Burn Performance Improvement Meetings- 3rd Wednesday of each month at 0700 in Lied Auditorium.

Taking Referrals

The Burnett Burn Center is a tertiary burn care center and large portions of our patients are transferred from other medical centers throughout the region. Patient’s can only be accepted after your attending speaks to the referring physicians as a “physician to physician” referral and this is to be done through the transfer center.

Acute Burn Management

INTRODUCTION

Although burn injuries are frequent in our society, many surgeons feel uncomfortable in managing patients with major thermal trauma. Every year, 1.2 million Americans sustain a burn injury requiring medical attention. About 50,000 of these need hospitalization. Up to 10,000 people die every year from burns and burn-related injuries or infections. Only motor vehicle accidents cause more accidental deaths than burns. Mortalities are highest among the very young and very old. Two-thirds of all burn accidents occur at home and most commonly involve young adult males and children. Young adults are most commonly burned by flammable liquids, while toddlers are most often scalded by hot liquids while in the kitchen. 16% of burns in children are due to child abuse. Structural fires result in about 5% of burn-related admissions, but account for 45% of associated deaths. Inhalation injury has the biggest impact on both early and late mortality.

Advances in trauma and burn management over the past 3 decades have resulted in improved survival and reduced morbidity from major burns. 25 years ago, the mortality rate of a 50% body surface area (BSA) burn in a young adult was about 50% despite treatment. Today, over 50% of these patients are surviving. Improved results are due to advancements in resuscitation, surgical techniques, infection control and nutritional/metabolic support. In the last year for which complete data is available (1998) 1/3 of the deaths were due to invasive fungal infection, 1/3 from anoxic brain injury and 1/3 from pulmonary failure.
DEFINITIONS

The skin is the largest organ of the body, comprising 15% of body weight and covering approximately 1.7 m² in the average adult. The function of the skin is complex: it warms, it senses, and it protects. Of its 2 layers, only the epidermis is capable of true regeneration. When the skin is seriously damaged, this external barrier is violated and the internal milieu is exposed and altered.

Burn Injury

A burn injury implies damage or destruction of skin and/or its contents by thermal (hot or cold), chemical, electrical or radiation energies or combinations thereof. Thermal injuries are by far the most common and frequently present with concomitant inhalation injuries.

A thermal injury involves the heating of tissues above the critical level at which damage occurs via protein denaturation. Tissue injury is a function of the heat content of the burning agent, length of exposure and thermal conductivity of the involved tissue. The hydrophilic human skin possesses a high specific heat and a low thermal conductivity. Therefore, skin becomes overheated quite slowly, but also cools slowly. As a result, thermal damage continues after the burning agent is extinguished or removed.

The Burn Syndrome

Following a major burn injury (>20% in adults and >10% in children but these are only estimates) a myriad of physiologic changes occur that together comprise the clinical scenario of the burn patient.

These derangements include:
1. Fluid and Electrolyte Imbalance - The burn wound becomes rapidly edematous due to microvascular changes induced by direct thermal injury and by release of chemical mediators of inflammation. This results in systemic intravascular losses of water, sodium, albumin and red blood cells. Unless intravascular volume is rapidly restored, shock develops.
2. Metabolic Disturbances- This is evidenced by an increased resting oxygen consumption (hypermetabolism), an excessive nitrogen loss (catabolism), and a pronounced weight loss (malnutrition).
3. Bacterial Contamination of Tissues- The damaged integument creates a vast area for surface infection and invasion of microorganisms. Burned patients with a major thermal injury are unable to mount an adequate immunologic defense, increasing the risks for septic shock.
4. Complications from Vital Organs-All major organ systems are affected by the burn injury. Renal insufficiency can result from hypoperfusion or from nephron obstruction with myoglobin and hemoglobin. Pulmonary dysfunction may be caused from initial respiratory tract damage of from progressive respiratory insufficiency due to pulmonary edema, adult respiratory distress syndrome or bronchopneumonia. Gastrointestinal complications include paralytic ileus and gastrointestinal ulcerations. Small bowel ischemia and stasis promote bacterial translocation as a mechanism for endogenous infection. Multi-system organ failure is a common final pathway leading to late burn mortality.

EMERGENCY TREATMENT

Initial Burn Management
Treatment of the burn injury begins at the scene of the accident. The first priority is to stop the burning. The patient must be separated from the burning source. For thermal burns, immediate application of cold compresses can reduce the amount of damaged tissue. This application must be guarded in large burns and in children, as prolonged cooling can precipitate a dangerous hypothermia. For electrical burns, the offending source should be removed from the victim with a nonconductive object made of wood or rubber. In chemical injuries, the agent should be diluted with copious irrigation, not immersion. A person with burning clothing should stop, drop, and roll.

As with other forms of trauma, initial establishment of an adequate airway is vital. Endotracheal intubation is not an essential part of management of all inhalation injuries, but may be prudent prior to patient transport or referral as airway edema will gradually increase over the first 18-24 hours post-injury. If the patient displays evidence of airway edema and impending obstruction with hoarseness, wheezing, or stridor, then intubate the patient. In all fire victims, administer 100% oxygen by mask or tube to reduce the likelihood of problems from pulmonary dysfunction or carbon monoxide poisoning. If present, control external hemorrhage and stabilize fractures from concomitant trauma. Burn wounds should be covered by a clean, dry sheet.

Although, a 20-40% injury can initially appear fairly benign, burn shock can develop rapidly if fluid resuscitation is delayed. Burns of less than 15% BSA in the conscious and cooperative patient can often be resuscitated orally. The patient with more than 15% BSA burn on cursory assessment requires IV access. Cut downs or central lines initially is less desirable. Begin infusion of Ringer's lactate solution of about 500 ml/hr in adults, 200-250 ml/m² BSA/hr in children along with their maintenance requirements for children < 2 years old in the form of D5/1/2 NS, until more accurate assessments of burn size and fluid requirements can be made. An indwelling Foley catheter should be placed to monitor urinary output. A nasogastric tube is inserted for gastric decompression.

Patient evaluation should include an AMPLE history: allergies, medications, pre-existing diseases, last meal, and events of the injury; including time, location and insults. A history of loss of consciousness should be sought. In adults and adolescents, burn injuries are frequently associated with alcohol or drug use, smoking, or psychiatric problems. A complete physical exam should include a careful neurological exam, as evidence of cerebral anoxic injury can be subtle. As in all trauma patients, occult injuries must be ruled out. Patients with facial burns should have their corneas examined with fluorescein staining. Routine admission labs should include CBC, serum electrolytes, glucose, BUN, creatinine, albumin, and calcium. Pulmonary assessment should include arterial blood gases, chest x-ray, and arterial carboxyhemoglobin. Despite a toxic level of a carbon monoxide (i.e. greater than 15%), pO2 and saturation values may be normal. An EKG is especially important in patients > 40 years of age or in case of electrical injuries.

All extremities should be examined for pulses, especially with circumferential burns. Evaluation of pulses can be assisted by use of a Doppler ultrasound. If pulses are absent, and fluid resuscitation is adequate, the involved limb should undergo urgent escharotomy for release of the constrictive, unyielding eschar. In severe chest burns, escharotomy may also be indicated to relieve chest wall restriction and improve ventilation. Escharotomies are generally performed at the bedside under sterile conditions with IV sedation and local anesthesia using electrocautery. Incisions are completed through the eschar until viable tissue is encountered, extending the full length of the eschar onto normal tissue to assure adequate release. Limbs should be elevated above heart level and pulses should be monitored.

Occasionally, escharotomy alone will fail to relieve intra-compartmental pressures, and a formal fasciotomy under general anesthesia is indicated. Distal numbness and tingling are the earliest signs of ischemia, and loss of pulses is a late finding. This is seen most commonly in high voltage electrical injuries. Intra-compartmental pressures can be measured with a wick catheter or inserting a spinal needle connected to a pressure catheter, such as for an arterial line, into all compartments of the affected extremity. Compartment pressures of >20 cmH2O are significantly elevated and require immediate attention. Keep in mind that as a patient is resuscitated, new swelling and reperfusion injury can cause delayed onset of compartment syndromes. This highlights the need for continued vigilance.

All patients with significant burns should receive 0.5 ml of tetanus toxoid. If prior immunization is absent or unclear, or their last booster was more than 10 years ago, 250 units of tetanus immunoglobulin is also given.
The Administration of Burn Assessment

When cardiopulmonary assessment is complete and resuscitation underway, a more careful evaluation of the burn wounds is performed. If the patient is adequately hydrated, appropriate doses of sedatives and narcotics may be safely administered. Excessive narcotic doses in light of inadequate resuscitation, however, can precipitate burn shock. The wounds are gently cleaned and loose skin and blisters debrided. Blister fluid contains high levels of inflammatory mediators which increase burn wound ischemia. The blister fluid is also a rich media for subsequent bacterial growth. Deep blisters on the palms and soles are generally aspirated instead of debrided to improve patient comfort. After burn wound assessment is complete, the wounds are covered with a topical antimicrobial agent or a biologic dressing, and an appropriate burn dressing applied. Outer elastic compressive dressings (e.g. Ace wraps) are applied carefully, and all involved extremities are elevated.

An estimation of burn size and depth assists in determinations of severity, prognosis and disposition of the patient. Burn size directs the efforts of fluid resuscitation, nutritional support and surgical interventions. Estimation of burn depth is a clinical judgment based on experience.

<table>
<thead>
<tr>
<th>DEGREE</th>
<th>DEPTH</th>
<th>HISTORY</th>
<th>ETIOLOGY</th>
<th>SENSATION</th>
<th>APPEARANCE</th>
<th>HEALING</th>
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<tbody>
<tr>
<td>1st degree</td>
<td>superficial</td>
<td>momentary exposure</td>
<td>sunburn</td>
<td>sharp, uniform pain</td>
<td>blanches red, pink, edematous, soft, flaking, peeling</td>
<td>+ 7 days</td>
</tr>
<tr>
<td>2nd degree</td>
<td>partial thickness</td>
<td>exposure of limited duration to lower temperature (40-55°C)</td>
<td>scalds, flash burn without contact, weak chemical</td>
<td>dull or hyperactive pain, sensitive to air/temp changes</td>
<td>mottled red, blanches red/pink, BLISTERS, edema, serous exudate, moist</td>
<td>14-21 days</td>
</tr>
<tr>
<td>3rd degree</td>
<td>full thickness</td>
<td>long duration of exposure to high temperature</td>
<td>immersion, flame, electrical, chemical</td>
<td>painless to touch and pinprick, may hurt at deep pressure</td>
<td>no blanching, pale white, tan charred, hard, dry, leathery, hair absent</td>
<td>granulates, requires grafting</td>
</tr>
<tr>
<td>4th degree</td>
<td>underlying structures</td>
<td>prolonged duration of exposure to extreme heat</td>
<td>electrical, flame, chemical</td>
<td>usually painless</td>
<td>charred, ‘skeletonized’</td>
<td>amputation fasciectomy</td>
</tr>
</tbody>
</table>

Attempts at estimation of burn depth with ultrasound, temperature mapping and vital stains such as fluorescein have not proven clinically useful. 1st degree burns are superficial and involve just the epidermis. Typified by a sunburn, 1st degree burns are inconsequential in subsequent burn management. Partial-thickness injuries are 2nd degree burns that involve variable amounts of dermis. The hallmark of a partial-thickness burn is a weeping, blistering, painful wound that will potentially heal within 2 to 6 weeks. 3rd degree burns are full-thickness injuries, which require skin replacement following loss of the devitalized dermis (eschar). Classically, full-thickness burns are identified as dry or leathery wounds that are initially insensate to light touch or pinprick. However, 3rd degree burns can still hurt. In infants, 3rd degree burns may also appear cherry red. Determinations of burn depth can be somewhat misleading initially, as the tissue destruction is progressive over the first 48 hours. Burn size is based on the percentage of 2nd and 3rd degree burns as compared to total body surface area.

Burn injuries are quantifiable, and pathophysiologic derangement is related to the size of the injury. The surface area of a patient's palm is approximately 1% of their total body surface area and provides a quick estimate of burn size in smaller injuries. Typically, burn size estimations are derived from the "Rule of
Nines”. The body’s surface is divided into areas of roughly 9% each, which includes the head and neck, the chest, the abdomen, the upper back, the lower back and buttocks, each thigh, each lower leg, and each upper extremity. Although useful in adults, the "Rule of Nines" overestimates burn size in children. The head and neck account for a larger proportion of the total body surface area (BSA) in children, more than 21% BSA in toddlers and babies. For greatest accuracy and reproducibility, burn size should be determined by plotting the burn wound on Lund and Browder burn diagrams.

A major burn injury is defined as greater than 25% BSA involvement (15% in children), or more than 10% BSA full-thickness involvement. Major burns require aggressive resuscitation, hospitalization, and appropriate burn care. Additional criteria for major burns include: deep burns of the hands, feet, eyes, ears, face, or perineum; inhalation injuries; and electrical burns. Moderate thermal burns of 15-25% BSA, or 3-10% BSA full-thickness, often require hospitalization for optimal patient care. Other criteria for admission include concomitant trauma, significant pre-existing disease, and suspicion of child abuse. Minor burns can generally be treated as outpatients.

<table>
<thead>
<tr>
<th>Classification of Burn Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major Burns</strong></td>
</tr>
<tr>
<td>Burn surface involvement of 25% body surface area.</td>
</tr>
<tr>
<td>Full-thickness burns 10% body surface area.</td>
</tr>
<tr>
<td>Deep burns of the head, hands, feet, and perineum.</td>
</tr>
<tr>
<td>Inhalation injury.</td>
</tr>
<tr>
<td>Chemical or high-voltage electrical burn.</td>
</tr>
<tr>
<td><strong>Moderate Burns</strong></td>
</tr>
<tr>
<td>Burn area of 15-25% body surface area.</td>
</tr>
<tr>
<td>Superficial partial-thickness burns of the head, hands, feet or perineum.</td>
</tr>
<tr>
<td>Suspected child abuse.</td>
</tr>
<tr>
<td>Concomitant trauma.</td>
</tr>
<tr>
<td>Significant pre-existing disease.</td>
</tr>
<tr>
<td><strong>Minor Burns</strong></td>
</tr>
<tr>
<td>15% body surface area.</td>
</tr>
<tr>
<td>Nothing involving the head, feet hands or perineum.</td>
</tr>
</tbody>
</table>

**BURN SHOCK**

The burn wound is a 3-dimensional mass of damaged tissue. At its margin is the zone of hyperemia and at its center is the zone of coagulation. Surrounding the coagulation region is the zone of stasis, so named because it starts with a circulation, which becomes static. Due to direct thermal effects, the microvasculatures in this region dilate and its endothelial lining 'leaks' plasma and intravascular proteins. Within minutes to hours, the circulation in this region ceases as the capillaries become packed with red blood cells and microthrombi, aggravating the inflammatory response. Although the cellular damage in this region is potentially reversible, injury to the microcirculation is progressive over 48 hours. Extent of the zone of stasis is minimized by adequate resuscitation. The inflammatory response in the zone of stasis is responsible for burn edema and shock.

Regional edema occurs in the burned tissue due to increased microvascular permeability, vasodilation, increased extravascular osmotic activity in damaged tissue, and infiltration of tissues by leukocytes with release of vasoactive substances. Endogenous inflammatory mediators implicated in the pathogenesis of burn shock include interleukins, histamine, serotonin, kinins, oxygen free radicals, lipid peroxides and products of the eicosanoid acid cascade. This last group includes products of cyclooxygenase, such as thromboxane, prostacyclin, and prostaglandins E and F2; and products of lipoxygenase, the leukotrienes B4, C4, D4 and E4. Thromboxane, through its effects on vasoconstriction and platelet aggregation, may markedly increase dermal ischemia, augmenting tissue destruction of the thermal injury.

In burns greater than 30% BSA, a more generalized capillary permeability occurs due to systemic hypoproteinemia and inflammatory mediators, resulting in edema formation in non-burned tissues as well. Excessive leakage of plasma, especially in the first eight hours post-burn, causes hypovolemia, hypoproteinemia, hemoconcentration, electrolyte imbalances and acid base disturbances. Plasma volume is reduced by as much as 23-27%, with a reduction in cardiac output and an increase in peripheral vascular resistance. In the absence of prompt fluid replacement, burn shock is imminent.
Fluid Resuscitation

The most crucial aspect of early care of the burn patient is prompt initiation of volume replacement of large quantities of salt-containing fluids sufficient to maintain adequate perfusion of vital organs. Many formulas for burn resuscitation have proven clinically efficacious, and each differs in volume, sodium, and colloid content. Currently, the most widely used Adult formulas are the Parkland (Baxter) formula and the modified Brooke formula, which deliver Ringer's lactate solution (LR) at 4 ml/kg/%burn and 2 ml/kg/%burn respectively, during the first 24 hours post-burn.

### Fluid Resuscitation

<table>
<thead>
<tr>
<th>Initial 24 hours:</th>
<th>Initial 24 hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>Children</td>
</tr>
<tr>
<td>Lactated ringer's 2-4 ml/kg/%burn/24 hours - given in the first 8 hours post-injury.</td>
<td>LR at 5000 ml/m² body surface area burn/24 hrs plus 2000 ml/m² body surface area burn/24 hrs given in the first 8 hours post-injury.</td>
</tr>
<tr>
<td>Additional fluid required for inhalation injury.</td>
<td>Urine output of 1 ml/kg/hr.</td>
</tr>
<tr>
<td>Urine output of 30 ml/hr.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subsequent 24 hours:</th>
<th>Subsequent 24 hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ml/kg/% body surface area burn/day</td>
<td>3750 ml/m² body surface area burn/day plus 1500 ml/m² total body surface area/day</td>
</tr>
</tbody>
</table>

In each case, half of this volume is administered in the first eight hours post-burn. The rate is adjusted hourly to assure a urinary output of 30 ml/hr in adults and 1 ml/kg/hr in children. Serum albumin is replaced to keep levels >2.5 gm/dl. We calculated appropriate replacement boluses at 6.25 gm for patients < 20 kg, 12.5 gm for patients between 20 and 40 kg, and 25 gm for patients over 40 kg.

Resuscitation of burned children differs in 2 aspects. First, the standard Parkland formula commonly underestimates fluid requirements in a burned child and may not provide even usual daily maintenance requirements. There is great variability between body surface area and weight in a growing child. More accurate estimation of resuscitation requirements in burned children can be based on body surface area, determined from nomograms of height and weight. For children, we recommend initial resuscitation with 5000 ml/m² BSA burned/day plus 2000 ml/m² BSA total/day lactated ringer's, one half over the first 8 hours. Second, infants require glucose due to small glycogen stores and are prone to hypoglycemia in the initial resuscitation period. Serum and urine glucose levels are monitored and replaced as indicated. Over-aggressive dextrose infusion can produce an osmotic diuresis, paradoxically increasing burn shock.

In the subsequent 24 hours, transcutaneous evaporative losses from burn wounds are replaced at 1 ml/kg/% burn daily. In burned children, fluid requirements are 3750 ml/m²BSA burned/day plus 1500 ml/m²BSA total/day. The sodium content of the replacement solution is altered as needed to maintain a normal range serum sodium level, e.g. D51/2 NS solution + 10-20 mEq/l of potassium phosphate. Hypophosphatemia is common following burn injury. Generally, enteral feedings are begun within 6 hours, often immediately following burn injury and gradually increased. Intravenous fluids are diminished as enteral intake increases. By 48 hours, most of the fluid replacement can be provided enteraly. Care should be taken to avoid rapid shifts in serum sodium concentration which may cause cerebral edema and neuroconvulsive activity.

All resuscitation formulas are meant to serve as guides only. The response to fluid administration and physiologic tolerance of the patient is most important. Additional fluids are commonly needed in inhalation injuries, electrical burns, associated trauma and delayed-resuscitation patients. The appropriate resuscitation regimen administers the minimal amount of fluid necessary for maintenance of vital organ perfusion measured as adequate urine output. Inadequate resuscitation can cause further insult to pulmonary, renal and mesenteric vascular beds. Fluid overload can produce pulmonary or cerebral edema. Over-resuscitation will also increase wound edema and thereby, dermal ischemia, producing increased depth and extent of cutaneous damage.

The appropriate use of colloid solutions for acute burn resuscitation remains debated. Development of hypoproteinemia in the early resuscitation period increases edema in non-burned tissues. Interestingly, in the absence of inhalation injury, lung water content does not increase. Early infusion of colloid solutions may decrease overall fluid requirements in the initial resuscitation period and reduce non-burn edema. However,
injudicious use of colloid infusion may cause iatrogenic pulmonary edema, increasing pulmonary complications and mortality. We recommend an albumin beginning 8 hours after the burn injury if it is to be used.

Monitoring

The acute resuscitation period following burn injury generally lasts 24 to 72 hours. Fluid shifts are rapid. Serial determinations of hematocrit, serum electrolytes, osmolality, calcium, glucose and albumin can help direct appropriate fluid replacement. Persistent metabolic acidosis on arterial blood gases may be indicative of ongoing hypoperfusion from hypovolemia.

The single best monitor of fluid replacement is urine output. Acceptable hydration is indicated by a urine output of more than 30 ml/hr is an adult (0.5 ml/kg/hr) and at least 1 ml/kg/hr in a child. Diuretics are generally not indicated during the acute resuscitation period. Patients with high voltage electrical burns and crush injuries have an increased risk of renal tubule obstruction from myoglobinuria and hemoglobinuria. Urine output should be maintained at 1-2 ml/kg/hr, if pigment can be seen in the urine and the urine alkalinized with IV sodium bicarbonate or acetazolamide with IV mannitol to aid in diuresis and to act as a free radical scavenger. Pulse rate and pulse pressure are more sensitive indicators of hemodynamic status than blood pressure. Hypotension is a late finding in burn shock. Normal sensorium and adequate peripheral capillary refill are additional clinical indicators of adequate organ perfusion. Invasive hemodynamic monitoring with central venous catheters, arterial lines, and Swan Ganz catheters is usually not needed in the absence of a severe inhalation injury, and discretion is advised. Pulmonary artery lines especially carry an inordinate risk of sepsis, thrombophlebitis and endocarditis in thermal injury patients.

POST-BURN HYPERMETABOLIC RESPONSE

The hypermetabolic response to burns is the greatest of any other trauma or infection. A major burn injury provokes a complex disruption of hormonal homeostasis that induces an increased resting metabolic rate and oxygen consumption, increased nitrogen loss, increased lipolysis, increased glucose flow and loss of body mass. Normal metabolic rates of 35-40 kcal/mBSA/hr are increased by 50% in a 25% BSA burn and doubled in burns greater than 40% BSA. The normal central core temperature is elevated by 1-2 °C due to a reset of the thermostatic control center in the hypothalamus. This post-burn stress response is associated with severe fat and muscle wasting, growth delays in children, immunologic compromise, cardiomegaly, hepatic lipodystrophy, poor wound healing and prolonged recovery times.

To meet post-burn energy demands, all main metabolic pathways are utilized. Most of the caloric deficit is met by oxidation of fat deposits, which comprise about 24% of body weight. Typically, post-burn respiratory quotients are 0.70-0.76. However, fats can only be burned in the fire of carbohydrates. Carbohydrates stores are small, less than 1% of body weight. The main supply of carbohydrate intermediates is from catabolism of proteins, providing alanine and glutamine. Hepatic gluconeogenesis and ureagenesis are elevated. Urinary nitrogen losses are 25-30 gm/m²BSA daily. Increased breakdown of skeletal and visceral proteins gradually exhausts protein stores and severe peripheral wasting ensues. Increases in hepatic lipid metabolites lead to fatty infiltration of the liver.

Primary mediators of the post-burn hypermetabolic stress response include catecholamines, glucagon, and corticosteroids. The 14 interleukins, tumor necrosis factor, prostaglandins, and leukotrienes have also been implicated. Post-burn insulin deficiency and increased insulin resistance result in diabetic-like glucose tolerance curves. Serum levels of growth hormone and IGF-1 (insulin-like growth factor) are markedly reduced in patients with major burns.

The post-burn hypermetabolic response can be further exaggerated by prolonged wound inflammation, pain or anxiety, environmental cooling, and sepsis. Unbalanced hormonal levels will not return to normal until the burn wound is closed. Perception of pain or suffering will dramatically increase levels of catecholamines and metabolic rate. Evaporation is a cooling process and reduces heat by 0.576 kcal/ml. In a burn patient with evaporative fluid losses of 350 ml/hr, evaporative heat losses are 3000-3500 kcal/day. If this heat energy is not provided by the environment, it must be supplied by the internal combustion of the patient.

The main principles for successful management of the post-burn hypermetabolic response are:

1) Providing adequate nutritional support
2) Controlling the external environment by warming
Nutritional Support

Burn size is proportional to increases in oxygen consumption, urine nitrogen loss, lipolysis, and weight loss. In patients with greater than 40% BSA burned, lean body weight loss will be reduced by 25% over the first 3 weeks in the absence of adequate nutritional support. Malnutrition is a premorbid condition in this setting. Wound healing, immunocompetence, and cellular membrane active transport functions are profoundly diminished.

Caloric requirements in burn patients have been calculated based on linear regression analysis of intake versus weight loss. The Curreri formula, which is the most popular estimation method, calculates caloric requirements of 25 kcal/kg/day plus 40 kcal/%BSA burned/day in a burned adult. For children, formulas based on body surface area rather than weight may be more appropriate. Our recommendation for caloric replacement in burned children is 1500 kcal/mBSA(total)/day for maintenance plus 1500 kcal/mBSA.

The composition of the nutritional supplement is also important. Caloric replacement should be based on non-protein calories only. Approximately 50% of the calories should be supplied as carbohydrates, 20% are protein, and approximately 30% of the calories should be supplied as fat. In adults, protein requirements are 100-150 gm/day, or about 1-2 gm/kg/day. In general, protein should be provided to achieve a calorie to nitrogen ratio of 100:1, which results in better immune function and survival in experimental and clinical burn trials than a ratio of 150:1. For a balanced daily diet, administration of vitamins C, A and E, zinc, iron, folate, and trace minerals are essential.

In burn patients, caloric support is best provided with enteral feedings. We recommend beginning nasogastric or nasoduodenal tube feedings within 6 hours following burn injury. Despite post-burn gastric hypomotility, post-burn intestinal ileus rarely occurs. Early enteral feeding sustains intestinal mucosa, maintains caloric support in the resuscitation period, and may reduce the degree of the hypermetabolic stress response. Gastric residual volumes are checked hourly then returned. Rates of enteral infusion are gradually increased as tolerated, and intravenous infusion reduced to keep total fluid intake rate constant. By 48 hours, on-going fluid requirements are delivered enterally. Many commercial feeding solutions are available, but hypertonic solutions commonly caused diarrhea. For children 1 year and older, we prefer 3/4 strength Vivonex TEN (total enteral nutrition) providing 0.75 Kcal/ml. It is carbohydrate-based and raises endogenous insulin levels, which is postulated to increase endogenous insulin with the beneficial side-effect of reducing donor site healing time.

A good alternative where commercial feeds are not available is milk (0.66 Kcal/ml). Milk is nutritionally balanced, inexpensive, easily available, and well tolerated. The electrolyte composition of milk is such that potassium requirements are easily supplied, however the amount of sodium in milk (25 mEq/L) is insufficient to meet demands. Frequently during diuresis, sodium losses exceed intake and hyponatremia occurs. Sodium supplementation can be administered via milk in amounts of as much as 50 mEq/L. Such supplementation is usually necessary as long as milk is the only enteral foodstuff. With the introduction of a regular diet, sodium supplementation can usually be discontinued.

Infants under one year are normally fed an infant formula. Infant formula has even lower sodium and potassium than milk:
- Enfamil = 9.96 mEq/L Na 17 mEq/L K+
- Prosobee = 12.5 mEq/L 21 mEq/L

Enteral supplements that may be taken orally are as follows:
Lactose-Free Products
Sustacal (vanilla, chocolate, strawberry)
.1 Kcal/cc + .06 gm protein/cc
Ensure (vanilla, chocolate, strawberry)
.106 Kcal/cc + .04 gm protein/cc
Resource Fruit (orange, peach, wild berry)
.76 Kcal/cc + .037 gm protein/cc
Resource Just for Kids (JFK) (strawberry cream, french vanilla, swiss chocolate)
1 Kcal/cc + .03 gm protein/cc
Pediasure - general purpose liquid food for children 1 to 10 years of age
1.0 Kcal/cc + .03 gm protein/cc

Lactose-Containing Products
Fortified milkshake (vanilla, chocolate, strawberry)
1.3 Kcal/cc + .052 gm protein/cc

Patients should be ordered a regular diet as soon as it is tolerated. Patients do not receive any fluid other than milk (i.e. juice, cola, water) without a physician's order.
When the patient's wounds are virtually covered, the diet should transition from one in which the majority of the nutrition is supplied via tube feedings to a totally oral diet. The transition should be slow and may take several days. The following steps should be followed:

a. Reduce tube feedings to a rate that, with the p.o. intake, equals 100% of goal.
b. As p.o. intake increases, provide only nocturnal tube feedings to equal 100% of goal.
c. When p.o. intake is at least 50% of goal, begin 3-day trial of p.o. diet with tube feedings held.
d. If goal is not being met at the end of the trial, re-evaluate feeding methods and, if necessary, resume tube feedings.
e. During all of the above steps, specific fluid orders with guidelines as to amounts and contents should be written. (The guidelines for juices and sodas should be followed)

| RECOMMENDATIONS FOR JUICE/SODA INTAKE IN PEDIATRIC ACUTE BURNS |
|---------------------|---------------------|---------------------|
| AGE                  | JUICE               | SODA               | TIME PERIOD |
| 0 - 1 yr.           | 0                   | 0                   | Shift      |
|                     | 0                   | 0                   | 24 hours   |
| 1 - 4 yrs.          | 60 cc/8 hrs.        | 0                   | Shift      |
|                     | 180 cc              | 0                   | 24 hours   |
| 5 - 10 yrs.         | 100 cc/8 hrs.       | 60 cc/8 hrs.       | Shift      |
|                     | 300 cc              | 180 cc             | 24 hours   |

**Patient Support**

Hypoproteinemia due to malnutrition and ongoing serum protein losses in burn exudate will persist until wound closure is achieved, especially with massive burns, burn sepsis, and post-burn hepatic dysfunction. Hypoproteinemia can have an adverse effect on intestinal absorption. Intravascular proteins can be replaced by albumin or by fresh frozen plasma if a significant coagulopathy is also present. In light of serotransmitted viral diseases (e.g. AIDS), processed albumin is generally preferred. Anemia is commonly seen 2 to 5 days post-burn due to thermal destruction of about 10% of the red cell mass. It can be corrected with incremental transfusions of 10-15 ml blood/kg. The use of 'split' units in small children who would not use the majority of a unit of blood will minimize the risk of transmission of blood-borne diseases.

Environmental control is a well-recognized part of appropriate burn care. Burn patients lose some of their thermo-regulatory abilities and are prone to hypothermia. An ambient room temperature of 28-33°C keeps the patient more comfortable and reduces the patient's heat loss from evaporation. The hypermetabolism is slightly diminished but not corrected to normal. Internally, the patient's body will still strive to maintain a temperature of 38-39°C. In order to accommodate this, we maintain patient care areas and operating rooms at elevated temperatures to minimize the amount of futile cycling required by the patient to generate the heat to achieve these elevated temperatures.
The value of appropriate pain management in acute burn management should not be underestimated. Pain is the most immediate concern of the burn patients. Suffering, a combination of physical discomfort and mental torment, increases the post-burn hypermetabolic stress response. The key to pain management is closure of the burn wound. In the interim, reduction in pain and suffering by sedatives, narcotics, and psychological support improves comfort and quality of life. It also reduces the hypermetabolic response. Treatment for a patient's suffering involves more than control of pain. Emotional support is essential. Uninterrupted sleep is very beneficial. Over-zealous use of narcotics alone provides a poor substitute, reduces GI mortality, and interferes with enteral nutritional support.

Hormonal manipulation of the post-burn hypermetabolic response may reduce morbidity from burn injuries. Continuous intravenous infusion of insulin and glucose reduces nitrogen and fat losses and maintains body weight, but is difficult to manage. Post-burn hypermetabolism is also reduced by anabolic steroids and adrenergic blockade. Propranolol reduces the hyperdynamic post-burn response and improves cardiac function, possibly protecting against post-burn cardiomyopathy. Recombinant human growth hormone reduces protein catabolism in the post-burn patient and increases the role of wound healing in donor sites. Oral oxandrolone is converted to testosterone upon metabolism by the liver.

POST-BURN INFECTION & SEPSIS

Before embarking on the antimicrobial therapeutic approach in the treatment of burn wound sepsis, it is important to establish certain consistencies in terminology.

- **Bacteremia:** The transient presence of bacteria or other microorganisms in the blood. (e.g. bacteria in the blood after brushing one's teeth)
- **Septicemia:** The invasion of the blood stream by pathologic microbes from a focus of infection or a locus minoris resistentiae and an active proliferation of these microbes accompanied by hyperthermia, hypothermia and/or prostration. Frequently, it is diagnosed clinically by the presence of any 3 of the cardinal signs: obtundation, hyperventilation, ileus, thrombocytopenia, hyperglycemia, leucocytosis or leukopenia.
- **Colonization:** The mere presence of bacteria, establishment of a colony; bacterial counts of 105 bacteria/gm of tissue with no evidence of invasion into viable tissue.

Infection is the most common and most serious complication of a major burn injury related to burn size. Sepsis accounts for 50-60% of deaths in burn patients today despite improvements in antimicrobial therapies. Sepsis in burns is commonly due to bronchopneumonia, pyelonephritis, thrombophlebitis, or invasive wound infection. The burn wound is an ideal substrate for bacterial growth and provides a wide portal for microbial invasion. Microbial colonization of the open burn wounds, primarily from an endogenous source, is usually established by the end of the first week. Infection is promoted by loss of the epithelial barrier, by malnutrition induced by the hypermetabolic response to burn injury, and by a generalized post-burn immunosuppression due to release of immunoreactive agents from the burn wound.

Burn injury leads to suppression of nearly all aspects of immune response. Post-burn serum levels of immunoglobulins, fibronectin, and complement levels are reduced, as well as a diminished ability for opsonization. Chemotaxis, phagocytosis, and killing function of neutrophils, monocytes, and macrophages are impaired. Granulocytopenia is common following burn injury. Cellular immune response is impaired, as evidenced by delayed allograft rejection, anergy to common antigens, impaired lymphocyte mitogenesis, and altered mixed lymphocyte responsiveness. Burn injury results in reductions of interleukin-2 (IL-2) production, T-cell and NK cell cytotoxicity, and helper to suppressor T-cell ration (HSR). Furthermore, infusion of serum from burned to normal patients or animals can transmit some of these immunosuppressive effects.

**Control of Infection**

Although care of the burn wound is not the initial priority, subsequent survival depends upon it. The avascular burn eschar is rapidly colonized by 5 days post-burn, despite the use of antimicrobial agents. If the bacterial density exceeds the immune defenses of the host, then invasive burn sepsis may ensue. When bacterial wound counts are >105 microorganisms per gram of tissue, risk of wound infection is great, skin graft survival is poor, and wound closure is delayed.

The goals of local wound management are the prevention of dessication of viable tissue and the control of bacteria. These are achieved by use of topical antimicrobial agents and/or biological dressings. It is unrealistic
to expect to keep a burn wound sterile. Bacterial counts of less than 103 organisms/gm are not usually invasive and allow skin graft survival rates of >90%.

Antimicrobial therapy is directed by bacterial surveillance through routine tri-weekly sputum, urine, and wound cultures. In addition, punch biopsies for each 18% BSA of burn are obtained qMWF for wound monitoring until the wound is closed. Quantitative wound biopsy is a better determinant of significant pathogens than qualitative surface swabs. Organism identification and in vivo sensitivities to antibiotics are obtained within 48 hours. Agar diffusion assays can also be performed to test susceptibilities to topical antimicrobials. If quantitative biopsies reveal microbial density of >103 organisms/gm, a change in topical therapy is indicated. If bacterial counts are 105, wound infection should be suspected and rapid histologic analysis and gram stain should be performed to confirm this. Wound infection is confirmed by histologic evidence of tissue invasion or clinical sepsis. Systemic antibiotics must be instituted, and the wound excised.

Diagnosis of sepsis in burn patients can be difficult to distinguish from the usual hyperdynamic, hyperthermic, hypermetabolic post-burn state. Blood cultures are commonly negative. Fever spikes are not proportional to degree of infection.

Clinical diagnosis of sepsis is made by meeting at least 3 of the following criteria:
1) burn wound infection (>105 organisms/gm tissue) with histologic or clinical evidence of invasion
2) thrombocytopenia (<50,000) or falling rapidly
3) leukocytosis or -penia (>20,000 or <3,000)
4) unexplained hypoxia, acidosis or hyper/hypoglycemia
5) prolonged paralytic ileus
6) hyper/hypothermia (>39°C or <36.5°C),
7) positive blood cultures
8) documented catheter or pulmonary infection
9) altered mental status
10) progressive renal failure or pulmonary dysfunction

Local evidence of invasive wound infection includes:
› black or brown patches of wound discoloration
› rapid eschar separation
› conversion of wounds to full-thickness
› spreading peri-wound erythema
› punctuate hemorrhagic sub-eschar lesions
› violaceous or black lesions in unburned tissue (ecthyma gangrenosum)

Appropriate systemic antibiotics are administered as indicated. The appropriate use of antibiotics should be based on the following definitions:
● Prophylaxis - A preventative or precautionary measure designed to preserve health and prevent the spread of disease.
● Perioperative - This may also be considered prophylaxis. It is the administration of systemic antibiotics as a protective measure for any type of surgical intervention. The time frame for administration should be short-lived and is limited to 1 to 3 doses, depending on the operative procedure.
● Therapeutic - This is the administration of antibiotics for the treatment of infection. Depending on the infection, therapy may continue for several days.

Systemic antibiotic treatment for burn wound sepsis is continued for at least 72 hours after evidence of sepsis has resolved. If the wounds appear clean, other sources such as the lungs, the kidney, and peripheral veins should be suspected. In the absence of a confirmed organism or site, antibiotic selection should be based on routine surveillance cultures. Empiric antibiotic choice should also be based on sensitivities of the burn facility's endogenous organisms. We use Vancomycin, Imipenem, Timentin or Ceftazidime for coverage against the usual strains of Staph. aureus and Pseudomonas aeruginosa prevalent in our unit. Routine perioperative antibiotics should also take ward-endogenous organisms into account. Post-operative antibiotics are continued until quantitative excisional wound biopsies from surgery are identified.
Blood Cultures - Blood cultures are essential in determining septic episodes. The best time to collect the specimen is before the temperature spikes. A temperature above 39.5 is the body's method for cleansing the blood stream of bacteria. Most bacteria do not survive at prolonged temperature above 39.5. Care must be taken not to contaminate the blood culture bottle. Site selection for collecting the specimen must be meticulously and aseptically cleansed prior to specimen collection. If the site is through a contaminated area, appropriate comments should be made on the request slip.

Ova and Parasites - All burn patients arriving from Mexico, Central America, and South America should receive mebendazole on arrival for 3 days. (The risk of treatment is low, so stool cultures are no longer performed.) Remember, most parasitic cycles occur every 2 weeks. Treat family members as well.

Urinary Tract Infection (U.T.I.) - If a U.T.I. is suspected as the cause of sepsis, urine must be collected aseptically. Appropriate comments should be made on the request slip. (e.g. Temp. 39.8, clean catch, catheterized, etc.)

Upper Respiratory Infection (U.R.I.) - If a U.R.I. is suspected or evident from clinical signs, an x-ray, sputum, and bronchial washings are essential in order to identify the etiologic agent or infection. However, based on recent mortality studies, the organism isolated from lung abscesses most closely correlated with organisms from the wound, rather than what organisms were isolated from sputum specimens. Spittle is an unacceptable specimen.

Topical Antimicrobials

Currently, a number of topical agents are available to assist in microbial control of the burn wound, including silver sulfadiazine, mafenide acetate, 0.5% silver nitrate, bacitracin/polymyxin B, mupirocin, and Mycostatin. No single agent is totally effective and each has advantages and disadvantages. Almost all agents will affect wound healing and increase metabolic rate.

Silver sulfadiazine (e.g. Silvadene or SSD) is the most commonly used topical antimicrobial agent in burns. Its antimicrobial properties are derived from the dual mechanisms of its silver and sulfa moieties (functional parts), and has a broad spectrum of antimicrobial coverage including gram positive bacteria, most gram negative bacteria, and some yeast forms. Some gram negative organisms (e.g. some Pseudomonas species), do possess a plasmid mediated resistance. Unlike mafenide or silver nitrate, silver sulfadiazine does not hinder epithelialization, although it does hamper contraction of fibroblasts. Furthermore, silver sulfadiazine is painless on application, has high patient acceptance, and is easy to use with or without dressing. Although true allergic sensitivities are rare, many patients will develop a transient leukopenia 3 to 5 days following its continued use secondary to margination of circulating white blood cells. This leukopenia is generally harmless and merits observation, but not cessation of treatment. However, if the white blood cell count drops below 3000, the medication is sometimes withheld until the WBC count returns to >4000-5000. Mafenide acetate 11.2% cream (e.g. Sulfamylon) is one of the oldest effective topical antimicrobial agents. Mafenide has a broad spectrum of antimicrobial activity, including silver sulfadiazine-resistant Pseudomonas and enterococci, but reduced antifungal properties. Its exact mechanism of action is not clear, but thought to be related to its water-soluble sulfa moiety. Mafenide cream is toxic to epithelial cells and fibroblasts. Unlike other topical agents, mafenide has good penetration through the eschar. For this reason mafenide is commonly used on dirty or infected burn wounds, or electrical burns, and on burned ears to prevent chondritis. Following its application, mafenide produces a manful sensation for several minutes, thereby earning its nickname of ‘white lightning’. Mafenide can cause an allergic skin rash. Through carbonic anhydrase inhibition, mafenide can also cause bicarbonate wasting in the kidneys, hyperchloremia, systemic metabolic acidosis and compensatory hyperventilation. To protect against such metabolic abnormalities one can sequentially follow serum electrolyte levels and treat abnormal values with appropriate intravenous replacement therapy. Alternatively, applications of mafenide cream can be limited to no more than 20% of the BSA at any one time. The sites of mafenide applications can then be rotated every 2 hours until the entire burn has been treated.

Petroleum-based antimicrobial ointments such as bacitracin and/or polymyxin B are clear on application, painless, and allow for easy wound observation. These agents are commonly used for treatment of facial burns, graft sites, healing donor sites, and small partial-thickness burns. Povidone iodine ointment has a broad antimicrobial activity, including bacteria, fungi, and some viral forms. Mupirocin (e.g. Bactroban) has improved activity against gram positive bacteria, especially methillin resistant Staph. aureus (MRSA) and
selected enteric bacteria. Gentamicin ointment will select for resistant organisms and diminish effectiveness of its parenteral form, but may be useful in selected cases.

In severely burned patients (>40% BSA), the combination of Mycostatin ointment or powder with other topical agents reduces the incidence of fungal superinfection and improves antimicrobial action. Mycostatin should not be combined with mafenide, however, because both become inactivated. In addition, Mycostatin 5-15 ml given orally 3 times daily reduces alimentary fungal overgrowth. This regimen has markedly decreased the incidence of candida septicemia in our patients.

Topical antimicrobial creams are usually used with closed dressings. This provides for greater patient comfort and less dessication than the open technique. The creams are spread on fine mesh gauze, applied on the wounds, then covered with bulky protective gauze dressing and an elastic compressive wrap. Dressing changes are performed every 8 to 12 hours. At each dressing change, wounds are gently cleaned prior to reapplication. In contaminated or suspicious areas, the wounds are washed with an antimicrobial soap or phosphate buffered 0.25% hypochlorite solution (dilute Dakin's solution). This antimicrobial irrigation reduces septic episodes and hypermetabolic sequelae, and improves subsequent skin graft survival.

**Biological Dressing**

All topical antimicrobial agents adversely affect wound healing, alter metabolic rate, and require reapplication and daily maintenance. Biological dressings have no direct toxins or antimicrobial properties. However, they create a wound environment that prevents dessication, diminishes bacterial proliferation, reduces loss of heat, water, protein and red blood cells, and promotes more rapid wound healing. Biological dressings also reduce burn wound pain. These materials may be organic or synthetic in origin, but good wound adherence is key to function. Organic materials include skin allograft from donors, pigskin (xenograft), and pig dermis (EZ derm). An examples of synthetic covers is Biobrane©.

Fresh skin allograft (also called homograft) has become the 'gold standard' for temporary coverage of the clean open burn wound. Allograft achieves an environmental 'seal' of the burn wound at the graft-wound interface and improves host immune defenses. Allogenous human skin graft can be obtained from fresh cadavers within 18 hours of death or from living relatives to assure that skin cells within the graft are viable. The graft can re-vascularize once adhered to the wound. Allograft provides the best temporary closure of the excised burn wound. However, the Langerhans cells in the transplanted epidermis retain their antigenicity, and the skin allograft will undergo rejection in 7 to 14 days in normal patients. Immunosuppression of major burn patients increases tolerance of the allograft for up to several weeks, allowing prolonged temporary wound closure awaiting permanent skin autograft. Allograft promotes angiogenesis and maturation in underlying granulation tissue. Healing of subsequent skin autograft can be anticipated in areas of good allograft 'take'.

However, fresh skin allograft has a high price tag, a limited supply, a short shelf life (2-3 weeks), and a need for refrigerated storage. Although shelf life may be improved by freezing or lyophilization, these processes diminish cell viability, graft adherence, and protective functions of the altered allograft. Fresh skin allograft should only be used on clean wounds where graft 'take' is anticipated.

Porcine xerograph (heterograft) is nonviable, adheres less than allograft, and does not undergo revascularization by the recipient bed. Xenograft (pigskin) undergoes progressive degenerative necrosis rather than classic rejection. Also, xenograft does not provide the same level of protection from infection as allograft, so pigskin is often embedded with salts of antimicrobial agents to increase its bacteriostatic potential. Febrile responses can be caused by reaction to the treated pigskin or to hidden wound infections, and a fever requires at least temporary xenograft removal.

However, pigskin is well-suited for temporary coverage of full and partial-thickness burn wounds. Pigskin is cheaper and more available than allograft. Its recommended uses include protective coverage of partial-thickness wounds to allow spontaneous healing, temporary coverage of clean granulating wound beds between autografting procedures, and to serve as a 'test graft' to decide suitability for autograft closure. Pigskin should not be used on densely contaminated or non-viable wound surfaces. On deep dermal defects, pigskin should be changed every 3-4 days to prevent infection.
Synthetic biological dressings also provide wound protection from dessication and contamination, increase the rate of wound healing, and reduce patient discomfort. Good wound adherence is needed for success as intervening necrotic tissue or serum results in infection. Diligence in application is essential. When used to cover clean partial-thickness wounds, the dressing detaches as re-epithelialization and keratinization occurs underneath.

Biobrane® is a synthetic, bilaminate membrane with an outer semi-permeable silicone layer bonded to an inner collagen nylon matrix. In-growth of granulation tissue into the inner Biobrane layer increases its adherence. Its elasticity and transparency allows easy drape ability, fuller range of movement and easy wound inspection. Biobrane is suited for use on donor sites, superficial partial-thickness burns, and clean/excised wounds prior to grafting. Biobrane gloves on partial-thickness hand burns reduce discomfort and increase motion, allowing earlier aggressive physiotherapy. Biobrane can also be used to cover meshed skin grafts to prevent slipping and dessication. The major problems with Biobrane are its expense and its lack of inherent antimicrobial properties. Wound infections are not uncommon.

CLOSURE OF THE WOUND

The ultimate solution of burn management is closure of the burn wound through surgical intervention. The alternative burn-care philosophies differ in the timing of the surgical procedure. The conservative approach awaits spontaneous separation of the burn eschar over 3-5 weeks. Topical antimicrobial wound therapy is used for prevention of infection. The resultant granulation bed is then skin grafted. This method advocates maximal preservation of viable tissue. However, conservative treatment increases the risk period for infection, fluid and electrolyte disturbances, and malnutrition. The eschar is separated by the action of bacterial proteolytic enzymes, and the granulation bed is generally heavily colonized. Prolongation of the inflammatory phase of wound healing can result in increased hypertrophic scarring. This method is currently disfavored except for facial burns and small burns (<20% BSA).

The alternative approach involves excisional therapy of the burn wound prior to spontaneous eschar separation. A clinical comparison of conservative versus early excision demonstrated significant reductions in infectious complications and length of hospital stay in the latter group. Excisional therapy may also reduce protein catabolism, immunosuppression, and evaporative water losses. In some cases, early excision can improve cosmesis by reducing hypertrophic scarring.

Timing of excisional therapy is debatable. Some surgeons prefer excision 4 to 14 days post-burn when the acute resuscitation period is well over. This may involve serial excision of various portions of the burn over days to weeks. Other surgeons prefer early excision of the burn wound within 5 days of the injury prior to bacterial colonization of the wound. In experimental models, complete excision of the wound within 24 hours of injury prevented hypermetabolism and immune suppression in the post-burn period. Clinically, in children with greater than 60% BSA burns, excisional therapy resulted in improved survival.

We recommend early excisional therapy of major burn wounds as soon as hemodynamic stability, physiological tolerance, and reliable determination of burn depth are ascertained. In other words, the patient should undergo excisional therapy of full-thickness wounds when surgical risks do not increase risk of mortality nor compromise anticipated functional and cosmetic results. Early accurate determination of burn depth can be difficult. In scald burns, delay of excision for one week reduces blood loss and areas of skin grafting. However, clinical determination of depth in most flame wounds in more readily apparent. For most flame burns, excisional therapy can be completed within 48 hours of admission unless delayed by serious inhalation injury, concomitant injuries, frailty from extremes of age, or pre-existing medical conditions. Partial-thickness flame burns that will spontaneously heal within 14-21 days are not excised. If treated conservatively, deep partial-thickness burns produce poorer scars, more complications, and prolonged hospitalization. If healing takes longer than 21 days, 78% will result in hypertrophic scar formation. Therefore, deep partial-thickness wounds are often treated similar to full-thickness injuries.

Surgical Techniques

First described by Janzekovic 20 years ago, tangential excision involves sequential removal of eschar in layers (0.010-0.025 in.) with a dermatome or guarded knife (Goulian, Humby, or Weck) until viable dermis or
subcutaneous fat is reached. An acceptable wound bed is identified by active punctate bleeding. By using this technique, a maximum of viable tissue is preserved and optimal functional and cosmetic results are achieved.

Fascial excision removes all layers of eschar and underlying tissue to the level of fascia. Excision to this plane minimizes bleeding and provides a reliable, clean, vascular bed. Fascial excision is recommended if the subcutaneous fat is burned, and in selected large burns with >60% BSA full-thickness who have high risks for infection, blood loss, or skin graft slough. Fascial excision results in considerable cosmetic deformity. For example, fascial truncal excision sacrifices the breast buds in pre-pubertal females. Therefore, fascial excision is not used except in the worst burns.

The extent of excision is determined by the stability of the patient, the speed of the surgical team, the adequacy of anesthesia, the rate of blood loss, and the availability of skin graft or its substitute. Central venous access, and arterial line, an nasogastric tube, and a Foley catheter are needed for patient monitoring during the procedure. Ketamine is the preferred anesthetic agent in children. If ketamine is used, endotracheal intubation is not always needed. Anticipated blood losses are 0.75 ml/cm² of area of excision during 2-16 days post-burn, or 0.40 ml/cm² if excision is performed during the first 24 hours. Blood losses are minimized by use of tourniquets, pressure, topical thrombin, and topical or subcutaneous epinephrine. Overdoses of epinephrine producing hypertension or paroxysmal tachycardia do occur with injudicious topical use, especially in children. In burns <40% BSA, excision can be completed in a single procedure.

Skin Substitutes

The early excision of the burn wound mandates early wound closure. Preferably, closure is with permanent skin autograft, but closure can also be achieved with skin allograft, other biological dressings, or skin substitutes. Without immediate closure, dessication or infection can increase tissue loss and negate the benefits of early excision. In burns <40% TBSA, wide availability of donor sites permits wound closure with autograft. Sheet grafts are always preferred for their improved cosmetic results. In burns >40% BSA, donor sites are more limited. Many unburned areas, e.g. the face, are unacceptable for graft harvest. By meshing the grafts, better expansion ratios can be obtained for greater surface coverage at the price of reducing cosmesis. Sheet grafts are always used for the face, neck, and hands when available. Mesh expansion ratios larger than 3:1 result in sub-optimal healing and thin, easily damaged skin coverage, so are generally not used. As described by Alexander, we cover our 3:1 meshed skin autografts with 2:1 meshed skin allograft or xenograft to protect the wound beds during healing. As the autograft heals and spreads underneath, the allograft is shed. In massive burns (>70%), donor sites are severely restricted, prompting searches for an acceptable skin substitute.

Unlike biologic dressings, skin substitutes become incorporated permanently, in part or as a whole, into the wound closure. An artificial skin developed by Burke, et al (Integra©) is composed of an outer silastic ‘epidermis’ (0.1 mm thick) and an inner biodegradable bovine collagen glycosaminoglycan (GAG) based dermal analog. The inner surface provides for good wound adherence while the outer layer prevents exogenous bacterial contamination and excessive evaporative losses. After 26-30 days, fibroblasts and collagen at the GCG-wound interface organize into a neodermis. The outer silastic layer is then gently peeled off and replaced with a 0.004 in. thick epidermal graft.

Other dermal replacements include cultured allogenic fibroblasts and/or keratinocytes, decellularized human collagens, and other synthetics similar to Integra©. Clinical trials of these substances are on-going.

Using tissue culture techniques, human epithelial cells can be grown in vitro. Over a period of 2 to 4 weeks, larger confluent multi-layered sheets of cultured keratinocytes are obtainable from a small patch of donor skin (see the policy and procedure manual for exact method of obtaining biopsies), its surface area coverage expanded 100 times or more. Cultured epithelial autograft (CEA) has been successfully used to provide permanent wound closure in massively burned patients. Unfortunately, wounds covered with just epidermis display poor skin function and continued wound contraction. Resultant scars are not optimal. The search for a suitable dermal epidermal skin replacement continues. Combined use of CEA with either allograft cadaver dermis, cultured dermal fibroblasts, or a synthetic dermal analog may provide the ultimate solution for massive skin replacement.

REHABILITATION
Once the patient's survival has been assured, function and cosmesis become the biggest factors for subsequent quality of life. However, if consideration of these goals is not begun in the initial management, the ultimate outcome will be less than desirable despite successful resuscitation and burn wound closure. Rehabilitation of the burn patient should begin during the acute resuscitation period and continue until the patient's scars mature and occupation resumes. Rehabilitation plans are carried out principally by the Occupational and Physical Therapists.

There are principles which must be applied soon after burn to ensure the earliest and optimal rehabilitation of the patient. Rehabilitative care should commence on the day of the injury and the goals of burn patients' rehabilitation are to limit or prevent loss of motion, prevent or minimize anatomic deformities, prevent loss of lean muscle mass, and return the patient to work or normal activity as soon, and as completely, as possible.

Much consideration must be given to a program of rehabilitation for the burn patient, and every patient needs an individually tailored plan of care. There are 4 principles for the rehabilitation of the burn patient:

- The program should start early, preferably the day of injury.
- A program of care should avoid prolonged periods of immobility, and any body part that is able to move freely should be moved frequently.
- Range of motion exercises should be started the day of injury.
- There should be a planned program of daily activity and rehabilitative care. The plan should be reviewed daily as rehabilitative needs change.

On admission, plans should consider the prevention of skin and muscle contracture and anatomic deformity. The institution of such plans should be individually tailored. Early standing and ambulation and participation in daily living activities is important and all extremities should be actively moved frequently throughout the day. Proper positioning is essential for the prevention of contractures. It has not been uncommon in the past for burned patients to develop contractures of both burned and non-burned joints. The incidence of contractures in healing patients has been significantly reduced through the use of frequent active or appropriate passive motion exercises and proper positioning. Burned patients and their families should be taught the importance of early active exercise and proper positioning during rest and sleep.

Standing and ambulation should be instituted as soon as possible. Such exercise can reduce the loss of muscle mass and help stimulate the appetite. Frequent standing and ambulation will also reduce the risks of pressure necrosis. Additionally, requiring the patient to get out of bed and sit in a chair for some part of the day will increase respiratory tidal volumes and the patient's sense of normalcy.

The joints of all extremities should be frequently moved throughout the 24 hour day, unless there is a strong contraindication (e.g. fracture or open joints). Patients with open wounds from escharotomies or fasciotomies can usually move these parts actively, especially if therapy is instituted early. When early active motion is insufficient or impossible, passive motion is indicated. However, passive motion to an edematous or stiff hand is a delicate procedure, best left to the physical or occupational therapist.

Active exercise to the patient with burns should begin early each day. A schedule of planned activities should be implemented with frequent exercise periods of short duration (3-5 minutes) each hour. If the patient is able to tolerate such a schedule without undue fatigue for 2-3 days, the periods may be slowly increased in duration and decreased in frequency. Long periods of exercise will increase muscle tone and prevent loss of lean mass.

Range of motion can be encouraged by allowing the patient to accomplish all possible activities of daily living himself. Brushing his hair or teeth, feeding himself, ambulating to the bathroom or hydrotherapy room, and assisting with wound care can facilitate active range of motion of the hands, legs and arms and give the patient some measure of control over environment. Any apparatus necessary to make this easier, such as feeding blocks or plate rails should be made available. The use of these tools will allow the patient a sense of accomplishment, improve his self-esteem, and further encourage his participation by decreasing his dependence.

However, even in the most cooperative of patients, programs of active and/or passive range of motion may be insufficient to prevent the development of deformities and contractures. In these situations, proper positioning becomes necessary and important.

While active range of motion is the most important factor in preventing loss of motion, muscle mass, and anatomic deformities; adjunctive measures may also be necessary. Proper positioning is critical for the
maintenance of joint motion. The benefits gained from frequent exercise can be lost after 8 hours sleep in a 'comfortable' position.

Most patients will try to assume comfortable and undesirable positions while at rest. Patients will request, find, or create a pillow for their heads. This position is contraindicated with burn injuries to the lower face and neck. A flexion contracture of the neck is often accompanied by deformities of the lower face. This can be minimized with the neck placed in neutral extension during rest and sleep periods.

Sleeping persons generally assume undesirable positions of their joints. In healthy, mobile persons this is usually not a problem as most will frequently change positions during sleep. However, the discomfort associated with recovery from burns will usually prevent the patient from moving much. It may be difficult for the patient to voluntarily maintain an appropriate position, thereby necessitating the use of splints.

The patient's shoulders should be abducted to 80-90°, with the elbow fully extended, and the wrist extended to 30-40°, thus preventing undesirable position of the small joints in the hand and wrist. With the wrist extended 30-40°, the metacarpophalangeal joint (MCP) will assume a flexed position from the pull of intrinsic muscles. In this position, the interphalangeal joints (IP) will be in mid-flexion or placed in extension (position of rest) and the thumb will be pulled into a mid-abducted position.

Patients resting or sleeping in the supine position will usually maintain the hip and knees in an extended position. However, this may not always be the situation, especially if there are burn injuries to the anterior trunk and thighs, or the posterior thighs and calves. Burns to the lower anterior trunk and thighs tend to pull the hips into flexion, with the knees being intrinsically pulled into flexion as well. If there are concomitant burns to the posterior thighs and legs, knee flexion will be augmented by the contraction of the burned tissue.

Proper positioning will also be modulated by peripheral edema. Any edematous part should be elevated above the level of the heart, to allow for lymphatic drainage. Arms may need to be elevated to encourage venous return. Elastic wraps may be required when the patient is out of bed.

Splinting

Principles and consideration in using splints are the same used in proper positioning. Splints are indicated for the prevention of further damage to exposed structures, nerves, comatose patients, edematous areas, and for the stabilization of minor fractures.

Splints are made from a number of materials, probably most common are the lower temperature, thermoplastic materials. These can be custom fit and molded directly on the patient for optimal fit. Splints should be applied after appropriate dressings have been placed and secured with elastic wraps.

Management of concomitant fracture, if the surrounding area is burned, presents special problems. Simple fractures can usually be maintained immobile within splints. However, more complicated fractures require better stabilization than afforded by splints. Routine cost materials, such as plaster and fiberglass, interfere with proper burn wound management, therefore the most common treatment is external fixation. The pin insertion sites required can be treated with the same topical antimicrobial agents as are being applied to the burn wounds. External fixation allows the wound to be directly visualized and skin grafting can be performed around the pin sites.

Hands and wrists are the areas which require splinting early in the post-burn course. Flexion is considered the position of comfort for the wrist, with the tendency for the MCP joints to hyperextend with flexion of the IP joints, loss of thumb abduction and rotation. These deformities are usually overcome with the wrist splinted into extension. In patients with dorsal hand burns, correction of the wrist flexion will not correct the MCP's hyperextension, the IP's flexion, or thumb abduction. Such burns require splints extending from the midforearm to the fingertips, molded to hold the MCP's in at least 70° flexion, with the IP's almost fully extended and the thumb widely abducted and slightly opposed. As with all splints, it should be worn only when the patient is at rest, and active range of motion encouraged during working hours, of the patient is medically able.

Splints are frequently applied to freshly grafted extremities to maintain position for optimal graft take. In these cases, splints are applied in the operating room after dressings are applied. Range of motion should be curtailed to the affected extremity for 4-5 days; after which active, and then passive, range of motion can be instituted. Usually within 7-10 days, the patient should be able to perform active range of motion.

Control of Scarring

Studies have demonstrated that the application of pressure dressings can decrease hypertrophic scarring. Hypertrophic scarring can be defined as an elevated scar with a Swiss cheese-like appearance. This
type of scar is a consequence of inappropriate collagen deposition within the wound during healing. Hypertrophic scarring is known to occur more frequently in darker complected individuals, however, the true etiology is unknown. Elastic wraps, stockinette with elastic reinforcement, or custom made garments should be applied to all burn-injured areas to decrease hypertrophic scar formation.

During the acute post-burn period, elastic wraps can be applied to the healing wounds. Stockinette with elastic reinforcement can be used after most wounds have healed, but some spots remain open. Measurements for elastic garments should be made just prior to discharge and stockinette can be used until their receipt.

Elastic garments should be worn 24 hours a day over all burned areas until the scar fully matures. Two garments should be made for each patient, so a clean one will be available after the daily bath. Scar maturation usually occurs within 1-2 years post-injury, occasionally longer, and is signaled by loss of scar erythema and a softening of the scar tissue. Until the scar matures, there is the potential for the formation of hypertrophic scars and subsequent joint contracture.

**Psychosocial Recovery**

Concern with the psychosocial aspects of burn recovery begins with the admission of the acute patient and continues throughout that patient's recovery and rehabilitation. The cognitive and emotional status of the patient and of the patient's family play an important role in the success or failure of burn treatment at every stage of recovery.

Although everyone interacts with the patient, the psychosocial aspects of treatment are managed by team members with expertise in these areas.

Of particular concern in pediatric burns is the case of injury in which there is some reason to suspect abuse or neglect. Whenever the origin of the burn seems suspicious, it is extremely important that the reasons for suspicion be documented and the child be carefully examined for signs of past injuries (e.g. long-bone x-rays). The child should not be discharged until such a discharge has been approved by the protective services in the child's community and/or by our Family Services staff.

Because the psychological well-being of the patient is tightly intertwined with the physical, good communication among team members is of the utmost importance. Members of the family services staff attend morning rounds, discharge planning conferences, rehabilitation rounds and all other multi-disciplinary conferences. In addition, a staff member is always on-call.

**INHALATION INJURY**

Inhalation injury is evident in over 30% of hospitalized burn patients and in 20-84% of burn-related mortalities. Heat can result in damage and edema to the upper airway, but uncommonly produces injury below the vocal cords except with steam burns. Acute asphyxia can occur due to environmental oxygen consumption by the fire or by reduction in oxygen transport from carbon monoxide poisoning. Smoke inhalation induces a multitude of physiologic changes. Lung vascular permeability is increased, promoting pulmonary edema. De-activation of surfactant in the pulmonary alveoli reduces pulmonary compliance, increases ventilatory work, and adds to metabolic demands. The majority of tissue damage attributed to inhalation injury is mediated by a chemical injury from incomplete combustion products carried by smoke, including aldehydes, oxides, sulfur, nitrogen compounds, and hydrochloric gases. This chemical damage to the lower airways and parenchyma is propagated by polymorphic neutrophils (PMN's) and leukokinesis. In severe injuries, desquamation of small airways along with inflammation produces airway costs. Areas of atelectatic lung tissue alternating with compensatory emphysematous regions leads to acute pulmonary insufficiency and bronchopneumonia.

Diagnosis of inhalation injury should be suspected in patients with facial burns, singed nasal hair, cough, carbonaceous sputum, or evidence of upper airway edema, including hoarseness, stridor, or wheezing. Pulmonary injury should be considered in any patient with history of burn in a closed space, loss of consciousness, or altered mental status. In unconsciousness, protective reflexive laryngospasm to pulmonary irritants is lost and lung parenchymal injuries tend to be more severe. Arterial blood gases and carboxyhemoglobin content should be determined, but may be misleading if initially normal. Diagnosis of inhalation injury is best confirmed by fiberoptic bronchoscopy which detects airway edema, mucosal sloughing,
Chest x-ray is an insensitive initial test, as parenchymal changes may not be evident for 48-72 hours. Currently, fiberoptic bronchoscopy is the gold standard for evaluation of inhalation injuries, providing more frequent and earlier diagnosis. In addition, there are xenon lung scopes which evaluate alveolar air trapping from obstruction, and extravascular lung water determinations which assess parenchymal fluid levels. Each can identify parenchymal lung injury and help differentiate upper airway and parenchymal inhalation damage. However, no studies accurately quantify the extent of inhalational damage, or prognosticate for parenchymal injuries.

Inhalation injury can be divided into three clinical phases: acute pulmonary insufficiency, pulmonary edema, and bronchopneumonia. Acute pulmonary insufficiency occurs between 0 and 36 hours post-burn due to acute asphyxia, carbon monoxide poisoning, bronchospasm, upper airway obstruction, and/or severe parenchymal damage. Pulmonary edema is seen 6-72 hours post-burn. Bronchopneumonia occurs most commonly 3-10 days post-injury.

Treatment of inhalation injury should begin at the scene with immediate administration of 100% oxygen. Carbon monoxide poisoning produces asphyxia by binding competitively to hemoglobin and reducing oxygen carrying capacity. Hemoglobin has a 210 times greater affinity for carbon monoxide than oxygen. On room air, carboxyhemoglobin (CO-Hgb) has a half-life of about 4 hours in the bloodstream. The half-life is reduced to 20 minutes when breathing 100% oxygen. If oxygen supplementation is started promptly, anoxic cerebral injuries are reduced. Levels of CO-Hgb greater than 15% are clinically significant, and levels above 40% can produce coma.

Maintenence of the airway is critical. If early evidence of upper airway edema is present, then intubate early. Airway edema increases over 12-18 hours. Prophylactic intubation without good indications should not be done, as intubation may otherwise increase pulmonary complications in burn patients. Fluid resuscitation should not be restricted. Although over-hydration can increase pulmonary edema, inadequate hydration increases the severity of pulmonary injury by sequestration of PMN's. Bronchodilators are used to reduce lower airway bronchospasm. Many patients who require intubation due to airway edema will also need mechanical ventilatory support for parenchymal damage, as indicated by criteria similar for other critically ill patients. Treatment for pulmonary edema generally necessitates ventilatory support with increases in tidal volume, oxygen supplementation, and positive end-expiratory pressure (PEEP). Adequate oxygenation is assured by serial ABG's. Chest x-rays help document pulmonary progression. Chest physiotherapy, early ambulation, and appropriate use of PEEP help to reduce post-injury atelectasis, consolidation, and pneumonia. Serial bronchoscopies with lavage can be useful for clearing of mucus plugs. Prophylactic antibiotics for inhalation injury are not indicated.

The nebulization of various substances has been demonstrated to allocate some of the adverse symptomatology following inhalation injury. In addition to bronchodilators, heparin is indicated for patients with abnormal ABG's or inpsissated mucous secretions. Heparin (10,000 units) in 3 ml of normal saline may be administered every 4 hours via endotracheal or tracheostomy tube. In severe cases, the heparin can be augmented with Mucomyst (n-acetyl-cysteine) treatment (3-5 ml 20% soln.) every 4 hours, timed so that either heparin or Mucomyst is administered every 2 hours. Bronchopneumonia is the most common cause of sepsis in the burn patient. Pneumonias that develop within the first week are most commonly aureus. Pneumonias occurring after one week are more likely due to resistant gram negative bacteria, e.g. Pseudomonas or Klebsiella. Systemic antibiotic regimens are based on serially monitored sputum cultures, bronchial washings or transtracheal aspirates. Chest physiotherapy is an important adjuvant treatment for bronchopneumonia. We do not use hyperbaric oxygen therapy as has been suggested and corticosteroids are strictly contraindicated.

**ELECTRICAL INJURIES**

Electrical injuries account for only 3-5% of all burn admissions. Low-voltage burns most commonly involve the oral commissure in infants and toddlers due to sucking on the female end of live extension cords or biting electrical cords. These low-voltage injuries cause little tissue destruction and are best managed conservatively with intraoral splinting. A significant late complication may be hemorrhage from the labial artery.

On the other hand, high-voltage electrical injuries are classified as major burns due to associated massive tissue damage. On average, high-voltage cutaneous involvement is only 10-15% BSA, but this visible injury is
only a small portion of the overall tissue destruction. The human body serves as a volume conductor to electricity. Current flow is therefore concentrated in the extremities by their narrowing. Since bone has the highest resistance to electrical current, conduction through bone produces the greatest amount of heat. For this reason, damage to muscle by electricity is greatest at tendonous attachments and periosteal regions. Massive muscle destruction causes myoglobinemia. Precipitation of myoglobin in the renal tubules can produce acute tubal necrosis and acute renal failure. In addition, high-voltage electrical burns are commonly associated with dislocations, fractures, vertebral injuries, myocardial damage, neurologic sequelae, and intra-abdominal injuries due in part to concomitant trauma. The most common cause of early mortality is cardiopulmonary arrest due to induced fibrillation.

Treatment of the high-voltage electrical victim should include prompt initiation of aggressive fluid resuscitation, serial assessment of distal vascular integrity, and urgent surgical intervention for fasciotomies and muscle compartment explorations. If the urine is rose-pigmented from haemochromogens, the urine output should be maintained at 100-125 ml/hr (1-2 ml/kg/hr) in adults, or twice the normal hourly rate in infants and young children, until gross pigment is cleared. The urine can be alkalized by IV administration of sodium bicarbonate to help prevent myoglobin precipitation. In severe injuries, IV mannitol (12.5 gm in an adult) is given in addition to aggressive fluid replacement to help promote an osmotic diuresis. Early use of other diuretics is contraindicated. Development of compartment syndromes should be anticipated. Deeper muscle groups sustain the greatest injury. Intraoperative exploration, decompression, and debridement is an essential part of early treatment. Serial technetium-99m stannous pyrophosphate muscle scans can be useful in assisting determination of progressive muscle damage.

Initial assessment of high-voltage patients would also include a careful neurologic examination, cardiac evaluation, and a skeletal survey. Vertebral fractures are frequent due to falls or forceful muscular contractions. All patients should have an electrocardiogram and serum CPK-MB determinations. In the patients without history of unconsciousness or cardiac arrest who have normal EKG's and myocardial isoenzymes, routine cardiac monitoring is not needed. Two-thirds of patients will have early neurological changes on initial exam, although long-term neurologic complications are rare. Late formation of cataracts following major electrical injuries has been documented.

CHEMICAL BURNS

Chemical burn injuries are uncommon. These are not hyperthermic, but are due to tissue reactions to noxious substances, including oxidizing agents, reducing agents, corrosives, protoplasmic poisons, desiccants, and vesicants. In general, chemical injuries are deeper than they initially look. The key to treatment of most chemical burns is early and continued copious irrigation of the insulted skin surface. Wounds can be most easily irrigated with water, while a balanced saline solution is preferable for irrigation of mucosal surfaces or eyes. Dilution and not neutralization is paramount. Misdirected attempts at neutralization of acid or alkali burns can produce exothermic damage as well. Deep alkali burns should be irrigated for 24 hours. Initial copious hydrotherapy is indicated for all chemical burns except those caused by dry-line, phenol, concentrated sulfuric acid, sodium metal, and muriatic acid; which either are not miscible with water or react with water exothermically.

Besides irrigation, 'antidotes' are often helpful for burns from hydrofluoric acid, phenol, and white phosphorous. Hydrofluoric acid (HFA) causes liquefaction necrosis of the subcortaneous tissue and can penetrate to bone. Systemic complications of HFA toxicity include hypocalcemia and pulmonary edema. HFA wounds are covered with a 10% calcium gluconate solution mixed to a slurry with a water soluble ointment, or infiltrated if excruciatingly painful. Phenol is an acidic alcohol which produces local coagulation and systemic toxicity in large doses, including fatal arrhythmias. Acute phenol burns are treated topically with polyethylene glycol solution irrigation. White phosphorus is contained in grenades and anti-personnel mines. Once particles are imbedded in skin, white phosphorus causes burn by both chemical and thermal reactions, as particles are spontaneously ignited with prolonged exposure to air. Patients should be submerged in water until imbedded particles can be surgically debrided. The skin is washed with a solution of 5% sodium bicarbonate, 3% copper sulfate, and 1% hydroxy cellulose to blacken the particles and aid earlier identification. Prolonged exposure to copper sulfate solution can induce coagulopathies.
CONCLUSIONS

Successful management of the acute burn patient requires prompt aggressive fluid resuscitation, metabolic/nutritional support, control of bacterial infection, anticipation and prevention of complications, timely closure of the burn wound, and early initiation of rehabilitation therapy. Burn shock must be adequately treated. Post-burn malnutrition must be prevented. In the post-burn stress response, all major organ systems are affected. Closure of the wound is essential for correction of the pathophysiologic post-burn derangements. In essence, management of the burn patient is a race against time, as rapidity of wound closure is inversely related to mortality. This race must be tempered, however, with thoughtful considerations of ultimate function, cosmesis, and quality of life.

PAIN MANAGEMENT

Utilize fentanyl, morphine or dilaudid IV dosing or PCA as needed and appropriate. Utilize short and long acting narcotics to manage pain once oral medications have been instituted. Don’t forget about nausea control and bowel management. Those with histories of drug abuse may have higher requirements and the acute burn phase is not the appropriate time to limit narcotics.

MANAGEMENT OF ITCH DUE TO INFLAMMATORY RESPONSE IN BURN SCAR AREA

1) Use moisturizing body shampoo and lotions to alleviate itching due to dry, scaly skin.
2) Topicals:
   a. Preparation H: Astringent properties relieve itch.
   b. Benadryl Cream: Sometimes helpful in relieving itch.
   c. Hydrocortisone 1% Cream: Low potency corticosteroid. Used only in very resistant cases because of corticosteroid necrotizing local effect.
      - Need Attending Staff approval -
3) Diphenhydramine (Benadryl):
   a. Sedating properties useful in calming patient, thus relieving itch.
   b. Antihistamine properties useful in management of itch due to morphine histamine release.
   c. May cause hyperactive paradoxical effect.
   d. Dose: 1.25 mg/kg/dose PO q6h.
4) Hydroxyzine (Atarax):
   a. Literature states hydroxyzine most effective antihistamine for chronic urticaria.
   b. Dose: 0.5 mg/kg/dose PO q6h.
5) Cyproheptadine (Periactin):
   a. Phenothiazine side effects useful in producing sedation and itch management at bedtime.
   b. Dose: 0.1 mg/kg/dose PO q6h.
6) Loratidine (Claritin):
   a. Non-sedating antihistamine.
   b. Dose: Children > 6 years of age = 10mg.

REHABILITATION SERVICES

Basic Treatment Procedures

Splinting - Pressure - Positioning - ROM/Strengthening - Ambulation
Activities of Daily Living (ADL’s)
Splinting
Static Splint: Have no movable parts and maintain joint in one position.
Preventative: Prevents deformities. Usually we allow patient to be free of splint wear during ADL’s and
dressing changes.
Protective: Post-operative to prevent disruption of newly applied skin grafts.
Supportive: Immobilize, protect, and position damaged tendons and joints.
Corrective: To gradually/serially correct a contracture by assisting to maintain joint following active and passive exercises.
Dynamic Splinting: Applies specific force in a place of motion through elastic traction while allowing the patient some motion of the joint. These splints should be considered for those joints that demonstrate the most resistance to passive stretch and positioning. Splints that are commercially available work best when this problem occurs over large joints.
ADL's: We provide adaptive equipment as needed, and train patients in achieving maximum independence in performing activities of daily living.
Focus on splinting should be on those motions that are most difficult to regain:

<table>
<thead>
<tr>
<th>Neck extension/rotation</th>
<th>MCP flexion</th>
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<tbody>
<tr>
<td>Shoulder flexion/abduction</td>
<td>IP extension of the hand</td>
</tr>
<tr>
<td>Elbow/Knee extension</td>
<td>Ankle dorsiflexion</td>
</tr>
<tr>
<td>MPT flexion</td>
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Positioning
Positioning is one of the fundamental practices necessary for successful burn patient rehabilitation. Positioning in bed and in sitting is important.
Pressure
Pressure is used as treatment of scar management and can vary by use of:
Ace Bandages - Tubigrip - Interim Garments (pre-fabricated) - Custom Garments - Coban (elastic woven wrap that can be used for the hand and fingers as a temporary glove).
When a healed burn surface is able to tolerate a minimal shearing force, a tubular bandage or garments can be used. Tubular bandages may be used as an interim compression device or used as a definitive appliance.
Inserts: Due to body makeup, inserts are sometimes necessary to achieve adequate pressure in certain body areas. These devices help to apply even pressure over the scar.

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