Chapter XI, Section B –Thermal Burn

Larry Jones, M.D.

Thermal Injury

INTRODUCTION

Thermal injuries following a nuclear or radiation event are very common. Observations following the atomic blasts revealed that thermal burns were the cause of 60% of the deaths at Hiroshima and 95% of those at Nagasaki [1]. These thermal injuries are the result of 1) a flash burn caused by the immediate radiation of heat and light at the time of the nuclear explosion, and 2) burns from fires caused by that explosion. These fires result from the heat radiated from the explosion as well as fires from the collapse of buildings that damage electrical and natural gas utility supply lines. Interestingly, no casualties were the result of persistent radioactivity of fission products of the bombs. Furthermore, the number of casualties resulting from the blast effect (pressure wave) have been judged negligible when compared to those caused by thermal and mechanical injury.

BURN CARE BASICS

The approach to any patient who has suffered a major burn injury is as currently being taught in the American College of Surgeons Advanced Trauma Life Support Course© and the American Burn Association Advanced Burn Life Support Course© [2,3]. This process begins with a Primary Survey, followed by Initiation of Resuscitation, Secondary Survey and finally Stabilization and Transport to Definitive Care (Figure 1). While history has taught us that burn injuries are common in disaster situations and following terrorist events, the majority of patients will also suffer non-burn trauma injuries as well. These traumatic injuries may be life-threatening and their management must take precedence over definitive management of the burn wound.

Resuscitation

Appropriate fluid resuscitation, with the goal of maintaining organ perfusion while avoiding excessive or inadequate fluid volumes, is critical for patient survival. The fluid resuscitation of a patient suffering a greater than 20% total body surface area burn can be initiated in the field following the guideline in Figure 2. When life threatening injuries have been stabilized and the patient's weight and size of burn have been established, the intravenous fluid rates should be adjusted as outlined in Figure 3. Resuscitation is monitored through measuring urine output, so insertion of an indwelling Foley catheter, or supra-pubic urinary catheter if pelvic injuries contra-indicate a Foley, is important. The goal is to maintain an output of 0.5 cc/kg body weight/hour in patients ages 14 years and above and 1 cc/kg body weight/hour in patients under the age of 14. Output should be titrated by increasing or decreasing the IV administration rate by up to 30%. Administering fluid bolus for a low urine output is not recommended.

The occasional patient may suffer such deep burns that muscle has been injured, resulting in myoglobinuria, observed grossly as a red discoloration of the urine. When this happens, IV administration rates should be increased with the goal being a urine output volume of at least 100 cc/hr until the hemochromogens in the urine have cleared.

Wound Care

Proper care of the burn wound begins with a determination of the size and depth of the wound. Depth is important, since only wounds that are partial or full thickness (second and third

degree) are considered when applying fluid resuscitation guidelines. Superficial, or first degree burns, appear as red, painful but intact skin. This burn will blanch when pressure is applied but return to its normal reddened color. Superficial burns can be treated with systemic anti-inflammatory drugs (NSAIDS) and local moisturizers. They generally become asymptomatic in 24 to 48 hours. Partial thickness, or second degree burns, appear with either intact blistering or, if the blisters have broken, the wound is moist. This painful wound will also blanch when pressure is applied. Because this burn results in a shifting of fluid from the intra-cellular and intra-vascular spaces into the interstitial space, its size must be included in calculating resuscitation fluid requirements. Also, since this is an open wound, an occlusive dressing should be applied to protect it from sources of infection and circulating air currents that stimulate exposed pain nerve fibers. Full-thickness, or third degree burns, appear as dry and discolored skin. The texture of the wound is firm and leathery. While the wound surface is dry, this burn does result in a shifting of fluid and must be counted in the ultimate size of the burn for calculating fluid resuscitation requirements. With full thickness burns, the skin has lost its elastic properties and will not expand as fluid escapes into the soft tissues below the burn. With circumferential full thickness burns of the extremities, the buildup of interstitial fluid under this in-elastic skin can result in tissue pressures that exceed venous, and ultimately arterial perfusion pressures, putting the limb distal to the burn wound at risk for ischemic injury. In similar fashion, a full thickness burn covering the anterior trunk can interfere with normal respiratory mechanics but limiting the movement of ribs and the expansion of the lungs. This situation will lead to a decrease in ventilation and an increase of CO2 in the blood. The treatment for both situations (extremity ischemia and respiratory compromise) is to perform escharotomies through the area of full thickness burn that is causing the problem [4].

Once the depth of the burn has been determined, the size (total body surface area, TBSA) must be estimated. This is commonly done through applying the Rule of Nines where areas of the body are assigned a percentage of the total body surface and the extent of the burn in each of those areas can be estimated. (Figure 4) Another, and perhaps simpler way, to determine TBSA is to use the palmer surface of the patient's hand as representing 1% of the body surface, then estimating the extent of the burned body surface.

Partial and third degree burns should be covered with some type of occlusive dressing. If immediate transfer to definitive care is planned, then covering the wound with a clean, dry dressing is all that is needed. If, however, transfer will be delayed for several hours or more, the wound should be cleaned with a mild soap and water, loose epidermis and blisters should be removed and a dressing that includes a topical antimicrobial should be applied.

Burn Center Referral Criteria

The American Burn Association has published a list of situations where referral of the patient to an organized burn center should be made. These criteria, which can be found on Figure 5, are updated from time to time and can be found on the ABA website at www.ameriburn.org [5].

MASS CASUALTY/DISASTER SITUATIONS

The above discussion is meant to be a guide to the basics of burn care and can be uniformly applied to situations where single or small groups of patients are encountered. Those basics can also

be applied to mass casualty situations. However, when mass casualties are encountered, additional principles come into play.

Mass casualty disaster plans

A mass casualty disaster is best defined as the number of patients exceeds the resources available from local and regional hospitals in providing optimal care [3]. This should not be confused with the concept of surge capacity, which is defined as 1.5 times more patients than available hospital specialty beds. For example, a hospital with 10 beds dedicated to burn patients would have a surge capacity of 15.

To properly prepare for a mass casualty incident, management plans must be in place. Those plans should be written through a collaborative effort with local, regional and national experts with local trauma and burn specialists spearheading the project. Many examples of plans, and experiences gained through the use of those plans, can be found [6].

Mass casualty management

The evaluation and triage of patients in a mass casualty situation should be carried out as outlined above, following the Primary Survey/Resuscitation/Secondary Survey approach. However, in a mass casualty scenario resources may become limited and decisions may need to be made about providing for as many patients as possible with those limited resources [7-9]. The American Burn Association has published outcome tables based on data reported to the National Burn Repository (Figure 6) [10]. Such tables define overall survivability when considering the size of the burn wound, the age of the patient, and the presence of an inhalation injury. While these tables are not intended to dictate withholding of care, they can be used by triage officers and healthcare teams in their efforts to provide optimum care to as many patients as possible during a mass casualty event.

Patients from mass casualty disasters very commonly suffer both traumatic as well as burn injuries. Indeed, up to 20% of trauma victims from a disaster scene suffer some degree of burn. However, trauma management must take precedence over burn management in this setting. Adherence to principles taught in the American College of Surgeons Advanced Trauma Life Support and Advanced Burn Life Support Courses will help providers maintain focus in these situations.

Initial burn wound management should be to simply cover the wound with a clean, dry dressing. The dressing of wounds beyond this must take into consideration that the wounds need to be cleansed with clean water and superficial debridement of loosed blistered skin should take place while controlling for pain and anxiety that the patient will experience. Topical dressings of silver sulfadiazine, bacitracin, polysporin, or neosporin are easy to apply and cover with roll gauze. However, in the absence of the traditional burn creams and ointments, topical dressings can be made from chlorine bleach or vinegar, (Figure 7). Dakins solution, which is 1/4 strength chlorine bleach, is commercially available in 473 ml bottles and should be diluted with 477 ml of sterile water in a one liter bottle to make a 1/8th strength solution. To make a 0.25% solution of acetic acid, use commercially available vinegar, which comes as a 5% solution, and mix 3 tablespoons of vinegar to one quart of sterile water (1.5 parts vinegar to 32 parts water or saline). For either acetic acid or

Dakins solution dressings to be effective they must not be allowed to dry out. If these dressings cover a large area of the patient, care must be taken to avoid evaporative heat loss from the patient.

Burn shock resuscitation will be dictated by the number of patients to be treated, the depth of the burn wounds being treated and the available resources. While burns of 20% or greater body surface area usually require intravenous fluid resuscitation as outlined above, burns of smaller size can be adequately treated with oral fluids (Figure 8) [11-13]. The World Health Organization oral hydration solution can be purchased or made by mixing 1 teaspoon of table salt or baking soda and 3 tablespoons of sugar in a liter of water (Figure 9) [12]. End points of resuscitation are as outlined above in terms of hourly urine output.

References

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Figure 1. Elements of Primary and Secondary Surveys [2,3]

Primary Survey

A - Secure the airway while maintaining protection of the cervical spine

B - Make sure the patient is breathing and being oxygenated and ventilated

C - Circulation with hemorrhage control - make sure the heart is effectively pumping intravascular volume. Direct pressure over areas of obvious hemorrhage

D - Disability - Neurologi status as demonstrated by a mini-neurologic exam consisting of the Glascow Coma Score and pupillary size and reaction to light.

Glascow Coma Score

Eye Opening

Spontaneously	4
To command	3
To pain	2
No response	1

Best Verbal response

Oriented	5
Confused	4
Inappropriate	3
Incomprehensible	2
No response	1

Best Motor response

Obeys commands	6
Localizes to pain	5
Withdraws to pain	4
Flexion to pain	3
Extension to pain	2
No response	1

E - Exposure and Environmental control. Totally undress the patient and inspect both anterior and posterior surfaces for injury. Protect from hypothermia.

Initiation of Resuscitation - See table 2 & 3

Secondary Survey

History

Physical exam from head to toe

Complete neurologic exam

Adjunctive tests as appropriate

Transfer to definitive care - Patients with both traumatic and burn injuries should be transferred to trauma centers that also house burn centers. Preference should be made to transfer to centers that have been verified as trauma and burn centers by either the ACS/ABA or a state accrediting agency such as the PTSF.

Figure 2. Fluid resuscitation guide [3]

Before total body surface area has been calculated, but estimated to exceed 20%;

Age $\leq$ 5 years - Ringer's lactate at 125 cc/hour
Age 6 to 13 years - Ringer's lactate at 250 cc/hour
Age $\geq$ 14 years - Ringer's lactate at 500 cc/hour

Figure 3. Consensus Formula for Fluid Resuscitation [3]

When total body surface area has been calculated and weight is known;

Children $\leq$ 30 kg body weight (66 pounds) - 3 cc Ringer's lactate X weight kg X % body surface burn plus Dextrose 5% containing fluid at maintenance based on body weight

Children > 30 kg body weight and up to 14 years of age - 3 cc Ringer's lactate X weight kg X % body surface burn

Patients $\geq$ 14 years of age - 2 cc Ringer's lactate X weight kg X % body surface burn

One half of the calculated amount should be administered over the first 8 hours of resuscitation. However, the titration of the infusion rate to produce and maintain proper urine output is the ultimate goal.

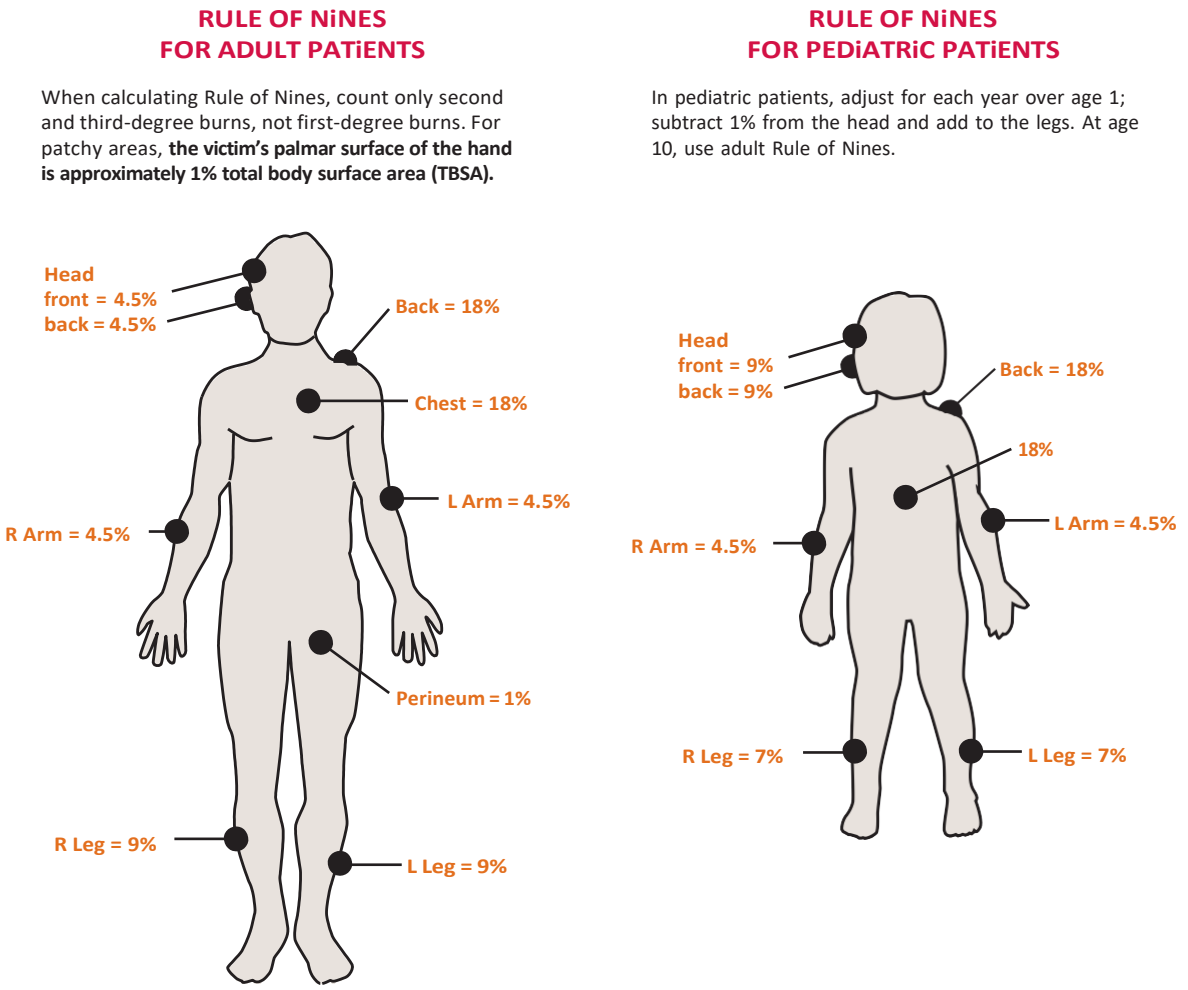

Figure 4. Rule of Nines to estimate burn body surface area. (Reprinted by permission of The Ohio State University).

Figure 5. Burn Center Referral Criteria[4]

A burn center may treat adults, children, or both. Burn injuries that should be referred to a burn center include the following:

- Partial-thickness burns of greater than 10 percent of the total body surface area.
- Burns that involve the face, hands, feet, genitalia, perineum, or major joints.
- Third-degree burns in any age group.
- Electrical burns, including lightning injury.
- Chemical burns.
- Inhalation injury.
- Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality.
- Burns and concomitant trauma (such as fractures) when the burn injury poses the greatest risk of morbidity or mortality. If the trauma poses the greater immediate risk, the patient's condition may be stabilized initially in a trauma center before transfer to a burn center. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
- Burns in children; children with burns should be transferred to a burn center verified to treat children. In the absence of a regional pediatric burn center, an adult burn center may serve as a second option for the management of pediatric burns.
- Burn injury in patients who will require special social, emotional, or rehabilitative intervention.

	Burn Size (%TBSA)									
Age, yrs	0 – 10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91+
0-1.99	Very High	Very High	Very High	High	Medium	Medium	Medium	Low	Low	Low
2-4.99	Outpatient	Very High	Very High	High	High	High	Medium	Medium	Low	Low
5-19.9	Outpatient	Very High	Very High	High	High	High	Medium	Medium	Medium	Low
20-29.9	Outpatient	Very High	Very High	High	High	Medium	Medium	Medium	Low	Low
30-39.9	Outpatient	Very High	Very High	High	Medium	Medium	Medium	Medium	Low	Low
40-49.9	Outpatient	Very High	Very High	Medium	Medium	Medium	Medium	Low	Low	Low
50-59.9	Outpatient	Very High	Very High	Medium	Medium	Medium	Low	Low	Low	Low
60-69.9	Very High	Very High	Medium	Medium	Low	Low	Low	Low/ Expectant	Low/ Expectant	Low/ Expectant
70+	Very High	Medium	Medium	Low	Low	Low/ Expectant	Expectant	Expectant	Expectant	Expectant

Figure 6. Triage decision table for burn victims based on anticipated outcomes compared with resource allocation. 1 = OUTPATIENT: survival and good outcome expected without requiring initial admission; 2 = VERY HIGH: survival and good outcome expected (survival 2:90%) with limited/short-term initial admission and resource allocation (straightforward resuscitation, LOS :514 –21 days, 1–2 surgical procedures); 3 = HIGH: survival and good outcome expected (survival 2:90%) with aggressive care and comprehensive resource allocation, including aggressive fluid resuscitation, admission 2:14 –21 days, multiple surgeries, prolonged rehabilitation; 4 = MEDIUM: survival 50 –90% and/or aggressive care and comprehensive resource allocation required, including aggressive resuscitation, initial admission 2:14 –21 days, multiple surgeries, prolonged rehabilitation; 5 = LOW: survival <50% even with long-term, aggressive treatment and resource allocation; 6 = EXPECT- ANT: predicted survival 10% or less even with unlimited, aggressive. treatment. (From [10]Saffle JR, Gibran N, Jordan M. Defining the ratio of outcomes to resources for triage of burn patients in mass casualties. JBCR 2005; 26(6): 478-82. DOI: 10.1097/01.bcr.0000185452.92833.c0. Reprinted with permission from Lippincott Publishers).

Figure 7. How to Make Dakin's (Sodium Hypochlorite) Solution

Supplies:

- Sodium hypochlorite solution 5.25% (Clorox® or similar household bleach).
- Be sure to use unscented bleach. Do not recommend use scented bleach or any of the ultra bleach products that are more concentrated and thicker.
- Sodium bicarbonate (baking soda)
- Clean tap water or filtered water
- Clean pan with lid
- Sterile measuring cup and spoons (glass ore metal)
- Sterile jar with sterile lid

Sterilize Equipment

Place the equipment in a dishwasher and run them through a wash cycle with the dishwasher set on the highest hot water and heat settings. If a dishwasher is not available, you can boil the equipment in rapidly boiling water for 5 minutes. Make sure the equipment is totally submerged in the boiling water. Remove the equipment with a pair of metal tongs and place on a paper towel to dry.

Making the Solution:

1. Wash your hands well with soap and water.
2. Measure out 32 ounces (4 cups) of water. Pour into the clean pan.
3. Boil water for 15 minutes with the lid on the pan. Remove from heat.
4. Using a sterile measuring spoon, add ½ teaspoonful of baking soda to the water.
5. Measure bleach according to the chart and add to the prepared water:

	Dakin's ¼ (0.125%) Strength	Dakin's 1/8 (0.0625%) Strength
Clorox Bleach	1 Tbs + 2 tsp (=5 tsp = 25 ml)	2 ½ tsp (12.5 ml)
Water	32 oz. (~946 ml)	32 oz. (~946 ml)

6. Place the solution in a sterile jar. Close it tightly with the sterile lid.
7. Cover the entire jar with aluminum foil to protect it from light.
8. Throw away any unused portion 48 hours after opening. Unopened jars can be stored for one month after you have prepared them.

Precautions:

- Keep out of the reach of children.
- **Do not swallow**

Storage:

- Keep the solution stored at room temperature.
- Cover jar with aluminum foil to protect it from light.
- Be sure the jar lid is tight for storing.

Figure 8. *Oral Hydration Solutions Compared to IV Solutions*

Beverage	Carbohydr	Na+	Cl-	K+	Buffe	Osmolality	Use
	mM (%						
WHO ORS	*111 (2.0)*	*90*	*80*	*20*	*30*	*331*	*Cholera*
Gatorade[UK]	*~250 (4.5)*	*20*	*20*	*3*	*3*	*280*	*Sports*
Pedialyte[UK]	*139 (2.5)*	*45*	*35*	*20*	*30*	*250*	*Dehydratio*
Rehydralyte[UK]	*139 (2.5)*	*75*	*65*	*20*	*30*	*325*	*Dehydratio*
Fox's Na Lactate	*0*	*161*	*0*	*0*	*161*	*321*	*Burn*
Mayer's	*0*	*85*	*63*	*0*	*29*	*160*	*Burn*
Monafo's HLS	*0*	*300*	*200*	*0*	*100*	*600*	*Burn shock*
Liquidsorb[UK]	*222 (4.4)*	*60*	*44*	*4*	*28*	*-370*	*Burn*
Jiang's Burn	*252 (5.0)*	*48*	*28*	*0*	*20*	*347*	*Burn*
Ricelyte	*(3.0)*	*50*	*45*	*25*	*34*	*200*	*Dehydratio*
AstroAde (NASA)	*0*	*164*	*76*	*0*	*40*	*253*	*PV*
IV Solutions							
Lactated Ringer's	*0*	*130*	*109*	*4*	*28*	*270*	*PV*
0.9% NaCl	*0*	*154*	*154*	*0*	*0*	*308*	*PV*
Plasmalyte-R	*0*	*140*	*98*	*5*	*50*	*294*	*PV*
							expansion

(From [12]Kramer GC, Michell MW, Oliveira H, Brown TLH, Herndon D, Baker RD, et al. Oral and enteral resuscitation of burn shock the historical record and implications for mass casualty care. Open access Journal of Plastic Surgery,www.eplasty.com; 10: 458-74.)

Figure 9. *Oral Resuscitation Formulas–Kitchen or Homemade WHO ORS, Sodium enriched Gatorade and sugar enriched LR*

Base ingredient	Volume	Sugar	Salt	Baking
Clean water	*1 liter*	*8 tsp*	*1/2 tsp*	*1/2 tsp*
Clean water	*1 quart*	*9 tsp*	*2/3 tsp*	*2/3 tsp*
Gatorade	*Quart*	*no addition*	*Add 1/4*	*Add 1/4*
Lactated Ringers	*1 liter*	*8 tsp sugar or*	*no*	*no*
Note: Non- sterile — use only not for IV use!				

(From [12]Kramer GC, Michell MW, Oliveira H, Brown TLH, Herndon D, Baker RD, et al. Oral and enteral resuscitation of burn shock the historical record and implications for mass casualty care. Open access Journal of Plastic Surgery,www.eplasty.com; 10: 458-74.)