1. Planning and Treatment for Human Radiation Injuries

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Today I am going to talk about planning and treatment for human radiation injuries.

(Slide 1): This slide shows general guidelines in estimating exposure.

When estimating exposure, the source of radiation such as radioactive materials in radiation therapy or isotope production, diagnostic nuclear medicine, explosion of a nuclear weapon, nuclear reactor or accelerator must be considered. Whenever radionuclides are released without control and in large quantities, external or internal contamination may occur in addition to radiation exposure. The type of radiation, such as beta, gamma or neutron, and the distance from the source and the duration of exposure must also be considered. In addition, the time since exposure is important, because it affects prodromal signs and symptoms of radiation sickness that may help indicate the level of exposure. A whole body counter should be used to measure level of exposure. Samples from the wound, urine, feces, the intact skin or nasal swabs should also be counted for determination of internal contamination

(Slide 2): Radiation exposure and contamination should be evaluated and triaged. Acute whole body exposure exceeding 50 Gy is inevitably fatal. Only humanitarian and emotional support will be possible. Exposure to doses of 8 to 10 Gy is severe and causes some characteristic prodromal signs. Patients with mild exposure which is 1 to 2 Gy may have few immediate signs or symptoms.

At the earliest moment, associated injuries such as burns and fractures, should be treated.

(Slide 3): Initial laboratory studies are shown in this slide. Hematocrit, CBC count, type and crossmatch for transfusion and urinalysis should be examined to rule out classic injuries

(Slide 4): Acute radiation symptoms are shown in this slide Early symptoms of lethal radiation exposure are disorientation, weakness, seizures, ataxia and coma. Death usually occurs within 2 days. The prodromal signs of severe exposure are nausea, vomiting and diarrhea. Symptoms include damage to the gastrointestinal mucosa, gastrointestinal bleeding, and sepsis during the first week or 10 days following radiation exposure. Laboratory studies show leukopenia and thrombocytopenia as the bone morrow is depressed. The outcome is usually fatal. The symptoms of mild exposure are nausea, fatigue and vomiting. The signs are dose dependent.

(Slide 5): Treatment of these cases consists of intravenous fluids and electrolytes to replace losses from the gastrointestinal tract. Antibiotics should be administered to combat infection. Low platelet counts should be treated by platelet transfusion. Granulocyte transfusion should be used or G-CSF should be administered for granulocytopenia. Red blood cells should be used to correct anemia. If bone marrow transplantation is considered, it should be done within 10 days after the radiation exposure.

(Slide 6): This slide shows principles of decontamination of an exposure patient.

Handling the casualty by trained teams dressed in protective disposable clothing. Removal of all possible contaminated clothing preferably at the site of the injury and storage of such clothing in appropriate containers that can subsequently be removed by trained teams and stored where they cannot irradiate others.

Transport of the casualty to a first aid center. This center may be treated and decontaminated if necessary.

Collection and storage of contaminated washings from such patients along with contaminated clothing.

Patients should not be denied hospital admission because of contamination, but contamination should be quantified by a trained radiation biology team or a radiotherapist or nuclear medicine physician as soon as possible.

(Slide 7): Using Hiroshima University Hospital as an example, we see that the University Hospital will accept patients with external radiation exposure or with internal contamination, but will not accept patients with external contamination.

(Slide 8): In Hiroshima University Hospital we have the equipment for the disposal of radioactive effluent waste, this is essentially a storage container, but not for the disposal of radioactive solid waste. Unfortunately there are no specially trained staff except for the radiologists. We also have a 78 square meter shielded area designed as a ward for radio isotope therapy. In the event that we had to admit a patient with external contamination this room might be used.

(Slide 9): Thermal injury is the next subject.

(Slide 10): Depth of burn injury is shown in this slide. Depth is estimated by physical appearance, pain, and skin texture or pliability. A first degree burn involves only the thinner outer epidermis layer. Second degree burns are defined as those in which the entire epidermis and variable portions of the dermis layer are heat destroyed. A superficial second burn involves heat injury to the upper third of the dermis. Blister formation is caused by fluid leakage of large amounts of plasma into the interstitium, which lifts up the thin heat-destroyed epidermis. A deep dermal or deep second degree burn extends well into the dermal layer. Blister formation does not characteristically occur. A full-thickness or third degree burn is defined as destruction of the entire epidermis and dermis.

(Slide 11): Although common characteristics of burn injury are shown in this slide, the exact depth of many burns cannot be clearly defined on first appearance. The major difficulty is distinguishing a very deep dermal from a full-thickness burn.

(Slide 12): A deep dermal burn, produced by flames, is shown. The red appearance with deeper whitish area is typical.

(Slide 13): A full-thickness burn of the hand is shown. This damage resembles a glove.

(Slide 14): A chemical burn of the face is shown in this slide. Appearance of skin is light brown from an alkali solution.

(Slide 15): The same patient with a chemical burn of the feet.

(Slide 16): This slide shows the burn injury which is divided into the four phases. The burn patient undergoes a number of dramatic physiologic and metabolic changes over the course of the injury state. It is essential to have a clear understanding of the pathophysiologic differences and the necessary treatment modifications needed over time following the burn.

(Slide 17): Edema formation in a small wound is maximum at about 6 hours after injury, since blood volume and vascular pressures to the wound are maintained. The degree of systemic hypovolemia caused by fluid loss into a large burn surface will retard the rate of edema formation, with the quantity of subsequent edema dependent on the adequacy of the fluid resuscitation.

Edema formation in nonburned tissues is clearly evident in patients with burns exceeding 30% of the total body surface. Much of the vascular to extravascular fluid shift in nonburn tissue is caused by the burn-induced plasma hypoproteinemia

The rate of loss of plasma volume is the greatest during the first 4 to 6 hours, decreasing substantially by 18 to 24 hours. The degree of hypovolemia is relative to burn size. Hematologic changes will be described later

(Slide 18): Edema formation process is shown in these next four slides. This slide shows the patient upon admission to our ICU.

(Slide 19): The same patient's face became very edematous several hours after the burn.

(Slide 20): On the next day, she was intubated to maintain airway.

(Slide 21): Her face became extremely edematous, especially her lips

(Slide 22): Hematologic changes in small to moderate burns are shown in this slide.

Some hemoconcentration occurs due to a loss of intravascular volume into the interstitium. A hypercoagulable state can be seen in the initial period in moderate burn injuries.

(Slide 23): This slide shows hematologic changes of massive burn There is frequently evidence of hemolysis, particularly after deep third degree burns or any prolonged exposure to a heat source, with increased free plasma hemoglobin and hemoglobinuria. A leukocytosis is also characteristic during this early phase In addition, a marked consumption of platelets, fibrinogen, and plasminogen is seen in the burn wound as well as a marked depletion of hemostatic components.

(Slide 24): The key decisions to be made for treatment are the 5 factors shown in this slide. That is, what type of fluid to use, how much to give, what type of vascular access, what parameters to monitor, when are inotropes required.

First, I am going to explain what type of fluid to use and how much to give

(Slide 25): This slide shows our protocol of resuscitation fluid for adult patients Fluids that contain salt in quantities isotonic with plasma are appropriate for use in resuscitation. Fluid should be free of glucose. Rate of fluid administration is dependent on the rate of loss, the latter being assessed by the perfusion monitors An initial rate can be estimated using the size of the burn relative to body surface area and body weight, which equates to 4 ml/kg/% burn of Lactated Ringer's solution. However, the amount of fluid required is that necessary to maintain perfusion and a formula is only an initial guide. If shock is present on admission, a bolous of fluid should be given.

(Slide 26): This shows our protocol of resuscitation for adult after 24 hours Hypernatremia is commonly seen if water losses from evaporation and urination, exceed sodium losses. The process will correct itself slowly, if sodium intake is decreased and free water is increased. Therefore a 5% glucose containing solution with a low sodium and high potassium content should be initiated.

(Slide 27): This shows our protocol of resuscitation for pediatric patients. It differs from the adult protocol in the fluid amounts and in that colloids are given earlier.

(Slide 28): This slide shows our protocol of resuscitation for pediatric patients after 24 hours. Low sodium-high potassium-glucose containing solutions should be initiated based on Holliday-Segar's equation.

(Slide 29): This shows data on patients from 1987 for the protocols. The patients were divided into three groups according age. Group I consists of pediatric patients with less than 40% thermal burn of body surface area and group II of pediatric patients with more than 40% thermal burn of body surface area Group III consists of adult patients with 40% greater thermal burn of body surface area.

(Slide 30): Results are shown in this slide. Open circles show group I, closed circles show group II, squares show Group III. The total fluid intake, on the Y-axis, was much larger in group I and group II than in group III.

The selection of vascular access will be discussed in the next slide.

(Slide 31): A peripheral vein catheter and/or a central vein catheter through nonburn tissue is the route preferred for fluid administration. A pulmonary artery line is only occasionally needed to monitor the patient during the initial resuscitation period and is removed as soon as it is no longer needed. Monitoring lines are required primarily for the elderly patient or the patient with severe heart disease An intravenous catheter should not be placed through burn tissue unless no other possible route exists, because of the high infection rate.

Which parameters to monitor are shown in the next slide.

(Slide 32): The increased sympathetic function characteristic of this early period makes arterial pressure an insensitive measure of volume status. A minimal level of perfusion pressure must be maintained and therefore blood pressure monitoring is necessary.

Tachycardia is inevitable early postburn due to hypovolemia and catecholamine release from tissue trauma and pain. The degree of tachycardia can be very useful for determining adequacy of volume replacement. The status of renal blood flow is usually an accurate reflection of the adequacy of systemic perfusion during this early phase of injury. A urine output of 0.5 to 1.0 ml/kg/hr normally reflects adequate renal blood flow. Arrhythmias are not common in the young patient as long as oxygenation is adequate, but they become a major concern in the patient over 45 years as a result of the burn stress response. The burn patient is very prone to hypothermia during this early period. A decrease in temperature will lead to further hemodynamic instability and impaired perfusion. The external environment must be altered to allow for maintenance of a normal temperature. The measurement of pH and acid-base balance is also extremely useful for the assessment of tissue oxygenation. A base deficit during this phase usually reflects impaired tissue oxygenation due to hypovolemia or carbon monoxide toxicity. The majority of young patients, even with massive burns, do not require the use of these measurements for initial resuscitation. A selected group of patients who are elderly or have preexistent heart disease with large burn or smoke inhalation, and young patients with massive burn who are not maintaining perfusion despite fluid intake well in excess of predicted, can benefit from this measurement.

When are inotropes required? Inotropic support to supplement fluids is indicated if adequate perfusion cannot be maintained without excessive fluid administration. Poor ventricular function is most commonly seen in the elderly burn patient or the patient with smoke inhalation requiring increased positive pressure. Since improved renal blood flow is a major goal, low-dose dopamine is often very useful.

Now I am going to talk about the postresuscitation phase. During this period cardiopulmonary stability is optimal because wound inflammation and infection have not yet developed. However, cardiovascular changes will only get worse with the upcoming hypermetabolism and sepsis unless the wound is aggressively managed.

(Slide 33): In the postresuscitation phase the hemodynamic response will be quite different from that seen during the resuscitation phase and treatment is considerably different. A 5% glucose containing solution with a low sodium content is the primary initial replacement fluid for evaporative and urinary losses during this period. The addition of 20 to 30 mEq/L of potassium will usually be necessary. Nutrient infusion should begin as soon as the patient becomes glucose tolerant, that is, in the first 48 to 72 hours, while waiting for gastrointestinal motility to return and to begin enteral feeding. The protein deficit caused by the losses into burn tissue and blood loss from wound excisions, should be carefully restored to levels that allow maintenance of adequate oncotic pressure and protein binding. A value for albumin of greater than 2.5g/dl is reasonable. The hematocrit should be kept at least in the low 30s to optimize the carrying capacity and delivery of oxygen to tissues.

(Slide 34): The criteria for early intubation are based on the findings of initial laryngoscopy or bronchoscopy as well as the respiratory function of the patient. The stridor, retraction, respiratory distress, less than 60 mmHg of Pao2, or greater than 55 mmHg of Paco2, indicate the need for immediate intubation.

(Slide 35): This slide shows a 42 year old woman who suffered 74 % burns by fire and her condition with chest x-ray. This patient survived. The most common cause of pulmonary edema is that from fluid shift-induced volume overload, especially in the presence of a smoke inhalation injury. Volume overload is frequently due to a combination of systemic resorption of tissue edema at a rate faster than that which can be cleared by the kidney and a continued excess infusion of salt-containing fluid at a rate faster than needed. This patient required endotracheal intubation and positive pressure ventilation with PEEP.

(Slide 36): Management of the burn wound is shown in this slide. As subeschar edema develops under the burn tissue, pressure increases. The pressure initially impedes venous return, which produces an increase in capillary hydrostatic pressure. Increased pressure markedly accentuates further edema production, raising pressure to a level that then impedes arterial blood flow.

The superficial second degree burn is the most painful and analgesics will be required before any cleaning can be performed. Intravenous narcotics are indicated because of greater safety and better pain control. Chlorhexidine and povidone-iodine are the most commonly used cleaning solutions. Loose tissue, broken blisters, and dirt should

all be gently removed because they add to subsequent infection risk. It is important to wash and gently mechanically debride the wound, not only to remove loose surface devitalized tissue, but also to determine better the true depth of the burn. Wound cleaning must not impair the basics of resuscitation. Use of a hydrotherapy system for initial wound cleaning is only applicable to the moderate burn injury The patient should not be immersed during this period, but rather can be rinsed with water running from head to foot on a slanted board or shower.

(Slide 37): This slide shows a 3 year old boy who suffered 76% burns by fire. This picture was taken when he arrived at our ICU.

(Slide 38): The burn index was 70% and an escharotomy was necessary the next day.

(Slide 39): This shows him playing after 6 months postburn but his fingers had to be amputated.

Management of this phase of a large burn injury is the most complicated of all the phases The remaining wound is now colonized with bacteria and wound sepsis is of prominent concern.

(Slide 40): The typical wound with bacteria is shown in this slide. This patient died from multiple organ failure due to septicemia.

(Slide 41): The objective of nutritional support is to provide the necessary calories for the required energy needs. The energy required is dependent on energy expenditure, which is divided into three components such as basal metabolic rate, muscle activity, and stress-induced energy needs Intubation of the trachea is not without its own complications because the cough mechanism is impaired. In addition, intubation increases the risk of nosocomial infection Therefore, physiological therapy such as pulmonary toilet, removing airway plugs, and postural drainage should be ordered.

ARDS is the name given to the clinical manifestation of a number of indirect lung injury states characterized by dyspnea, severe hypoxemia, and decreased lung compliance with radiographic evidence of diffuse bilateral pulmonary infiltrates.

Motality rate of ARDS caused by burn inflammation and infection is extremely high. The wound, especially in the large burn, cannot be readily excised and closed at this stage of the postburn process. The most important early treatment is prevention, that is, early removal of as much of the potential source as is feasible.

(Slide 42): Our 1992 data is shown in this slide. Seventy four operations were performed on 35 patients during a four weeks postburn period, there were 26 survivors and 9 nonsurvivors.

(Slide 43): This slide shows that the percentage of residual burn area was much smaller in survivors (top) than in nonsurvivors (lower). The patients who still retained residual burn wounds exceeding 40% of the total body surface area for up to 2 weeks postburn, did not survive The data suggests that early surgical excision of the burn wound is safe and improves mortality.

(Slide 44): The major problem with wound infection occurs over the next several weeks. Numerous studies have demonstrated that prophylactic systemic antibiotics in either the minor or major burn are of no benefit in decreasing the rate of wound infection. However, we generally administer prophylactic systemic antibiotics to the patients. Tetanus prophylaxis is required. The indications for topical antibiotics are presented in this slide. The deep wound must be protected from early bacterial invasion, which can rapidly convert the burn to a deeper injury. The use of topical antibiotics that are sufficiently water soluble to penetrate the burn eschar will temporarily control bacterial growth in the wound. A 1% silver sulfadiazine (silvadene) cream is the first choice as an agent to be used on a relatively uninfected deep burn to be applied twice a day. Mafenide (sulfamylon) is a more toxic agent but is the treatment of choice for the deep infected burn of small to moderate size.

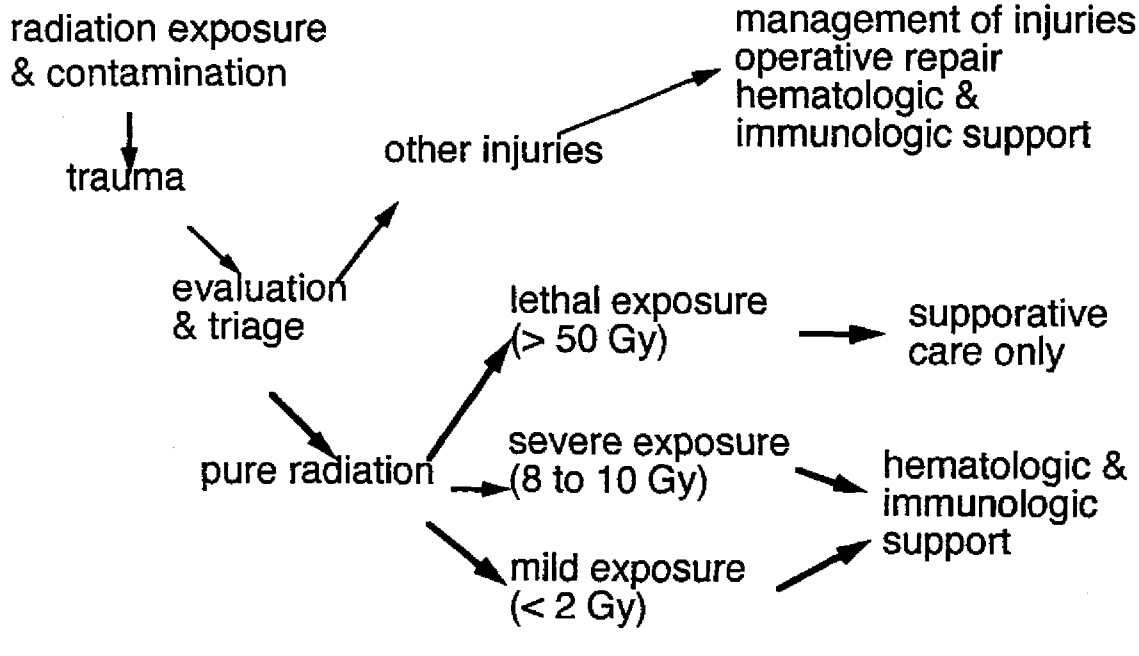
(Slide 45): This concludes my discussion of our burn treatment. The total number of patients from 1980 to 1993 who suffered from burns greater than 15% of burn index or with inhalation injury was 115. The outcome of the patients is shown in this slide. The Y axis represents burn area and the X axis, age. Open dots show survivors and closed dots show nonsurvivors. Squares show the patients with inhalation injury and circles show without inhalation injury. The curve divides the patient's prognosis.

General Guidelines in Estimating Exposure

1. The radiation source
2. The type of radiation
3. The distance from the source
4. The time since exposure
5. Whole body counting
6. Determination of internal contamination

(Slide 1)

Radiation Injuries



(Slide 2)

Initial Laboratory studies

1. Hematocrit
2. CBC and absolute lymphocyte count
3. Type and crossmatch for transfusion
4. Urinalysis
5. Electrolytes, serum enzymes
6. Blood samples for chromosome analysis

(Slide 3)

Acute Radiation Symptoms

dose (Gy)	symptoms	term
> 50 (lethal)	disorientation, weakness seisures, ataxia, coma	death within 48 hours
8 to 10 (severe)	nausea, vomiting diarrhea, high fever gastrointestinal bleeding	7 to 10 days
< 2 (mild)	nausea, fatigue vomiting	

(Slide 4)

Treatment for Radiation Injuries

1. Intravenous fluid and electrolytes
2. Antibiotics
3. Platelet transfusion
4. Granulocyte transfusion
5. Red blood cells
6. Bone marrow transplantation

(Slide 5)

Principles of decontamination of an exposed patient

1. Handling the casualty by trained teams
2. Removal of all possible contaminated clothing
3. Transport of the casualty to a first aid center
4. Collection and storage of contaminated washing
5. Triage of patients who are possibly contaminated with radionuclides outside of a hospital
6. Hospital admission of possibly contaminated patients to a single hospital
7. Decontamination
8. Collection of all excreta, urine, feces, vomitus, and dirty dressings
9. Admission to a ward and continued sampling for radioassay for 24 hours or longer as needed

by K.F.Huebner, C.C.Lushbagh

(Slide 6)

Acceptable or Nonacceptable to Hiroshima University Hospital

	acceptable	nonacceptable
patient with external radiation exposure	○	
patient with internal contamination	○	
patient with external contamination		○

(Slide 7)

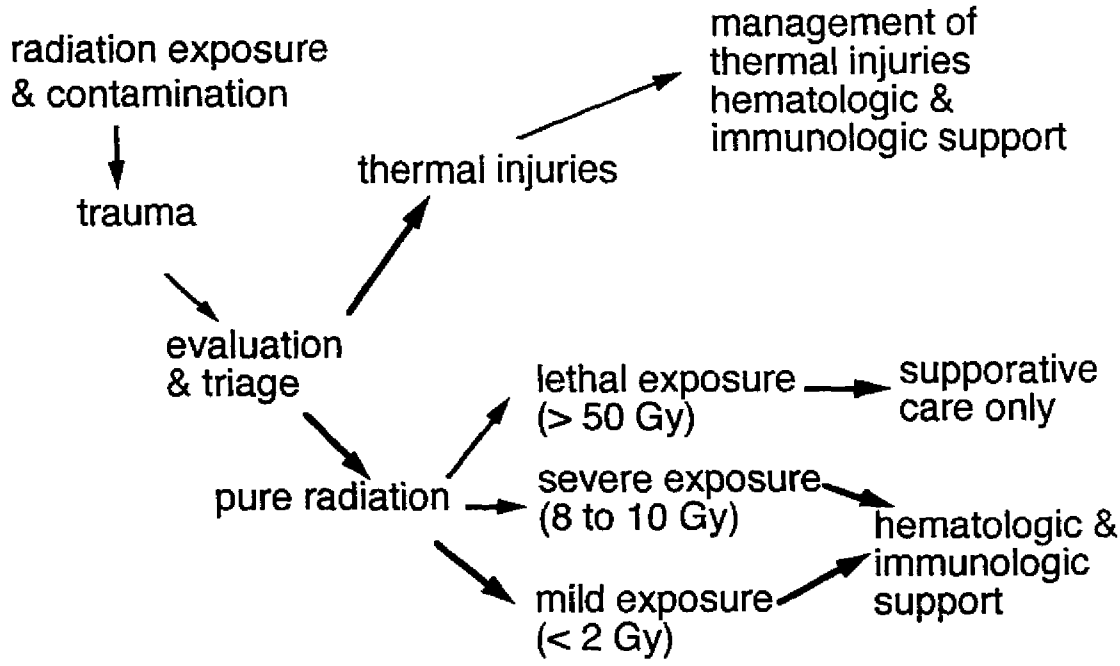
Equipment for Radioactive Waste Disposal

	Yes	No
radioactive solid waste		○
radioactive effluent	#○	

(#the storage of radioactive waste for decay)

(Slide 8)

Radiation Injuries



(Slide 9)

Characteristics of Burn Injury

Cause	Depth (Degree)	Pain	Appearance
Flames			
Flash exposure	Second	Severe	Wet, pink, blisters
Direct contact	Third	Minimal	Dry, white, waxy or brown, black leathery
Chemical			
Acid, alkali	Second Converts to third	Severe	Light brown to light gray

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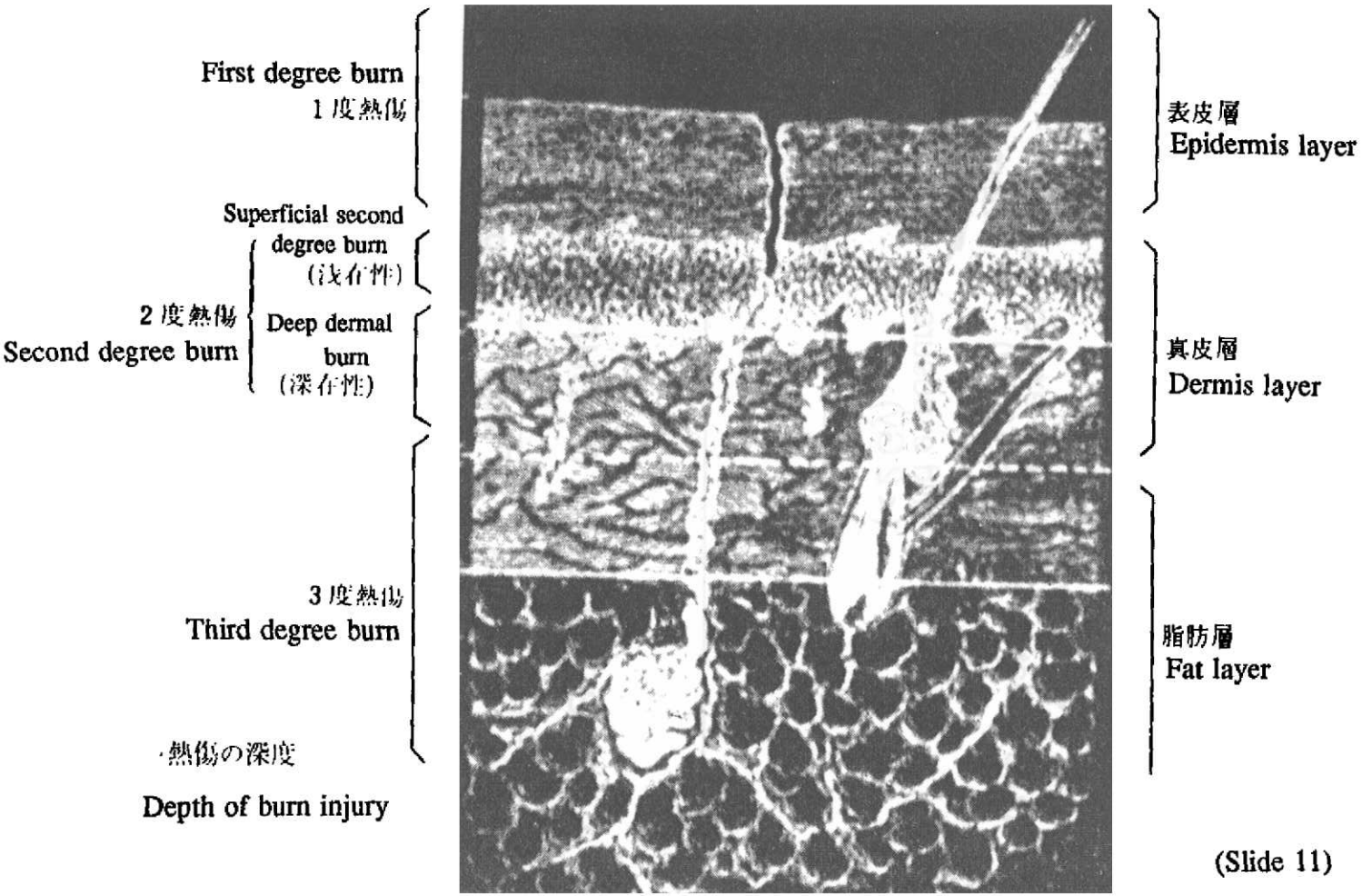
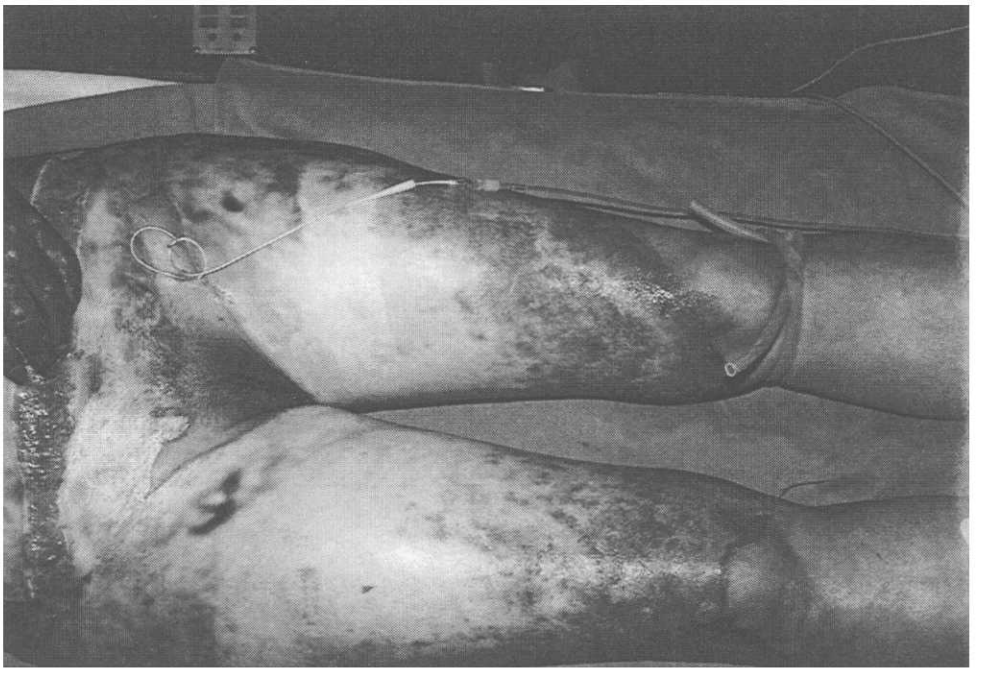

First degree burn
1 度熱傷
Superficial second degree burn
(浅在性)
2 度熱傷
Second degree burn
Deep dermal burn
(深在性)
3 度熱傷
Third degree burn
熱傷の深度
Depth of burn injury
表皮層
Epidermis layer
真皮層
Dermis layer
脂肪層
Fat layer

(Slide 11)



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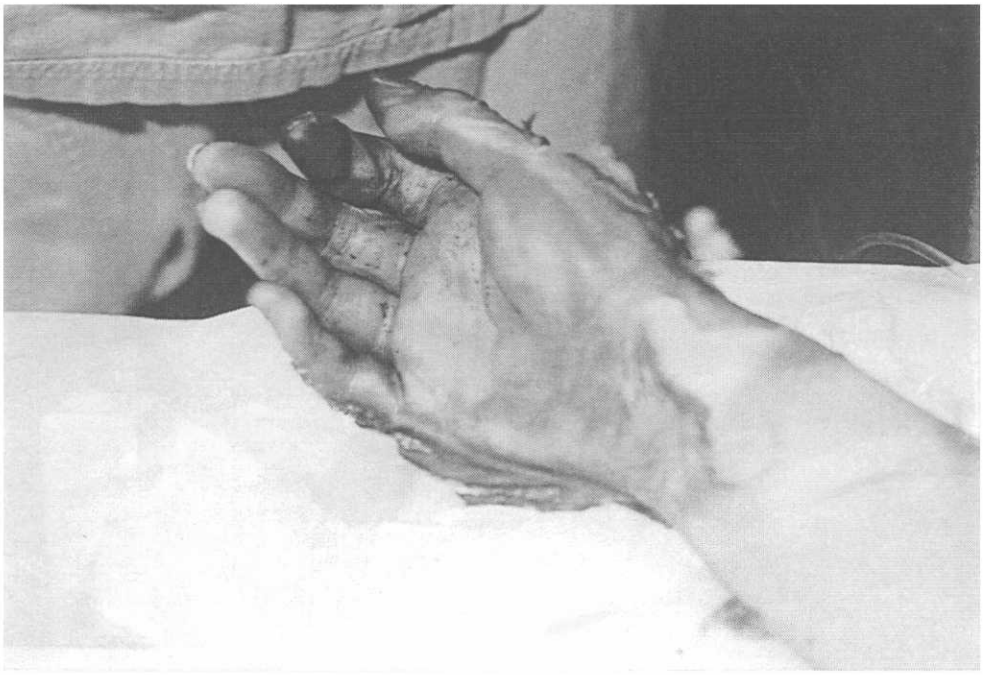

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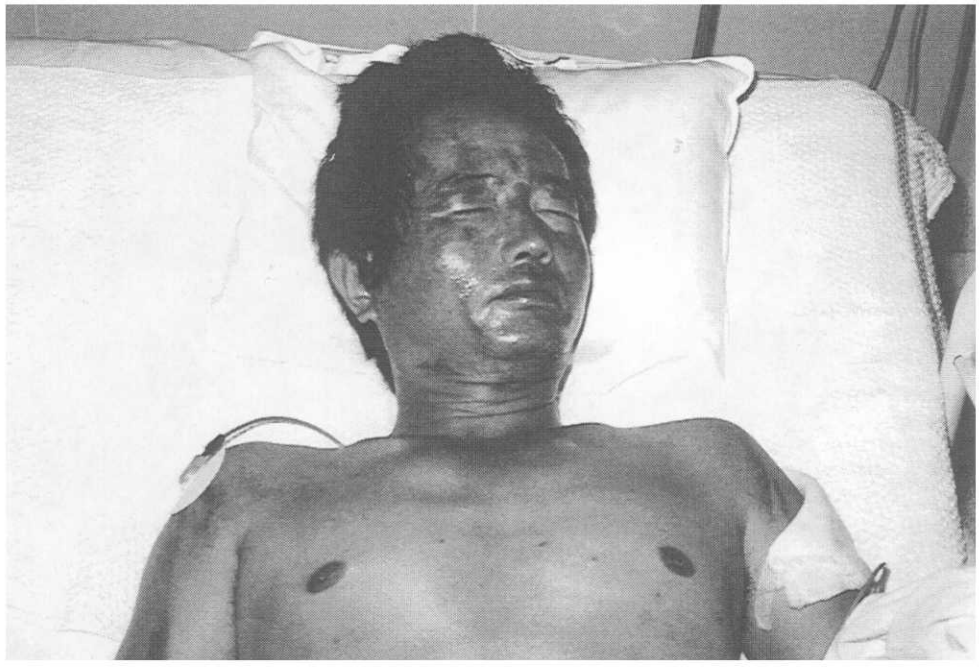

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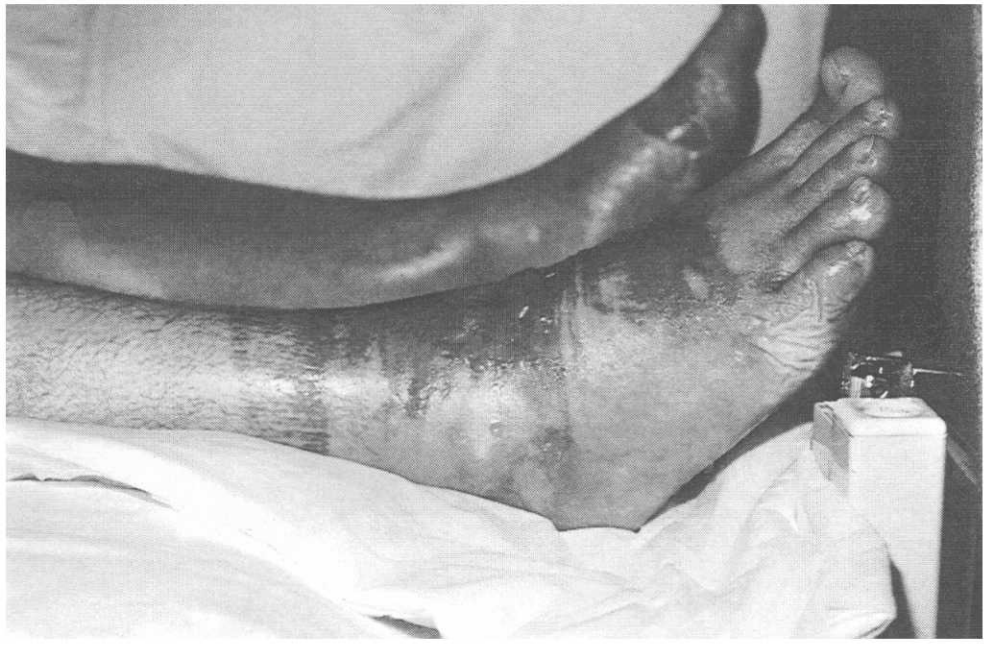

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Phases of the Burn Injury

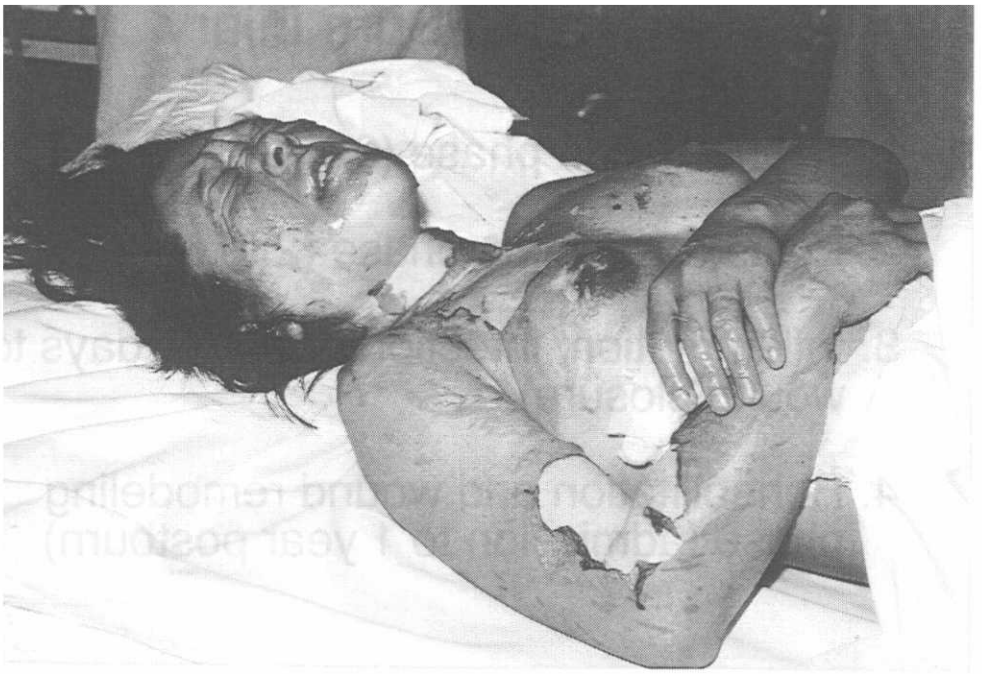
1. Resuscitation phase (0 to 36 hours)
2. Postresuscitation phase (2 to 6 days)
3. Inflammation, infection phase (7 days to wound closure)
4. Rehabilitation and wound remodeling phase (admission to 1 year postburn)

(Slide 16)

Pathophysiology of Burn Shock

1. Burn Edema
2. Changes in Nonburn Tissue
3. Systemic Hemodynamic Changes
4. Hematologic Changes

(Slide 17)



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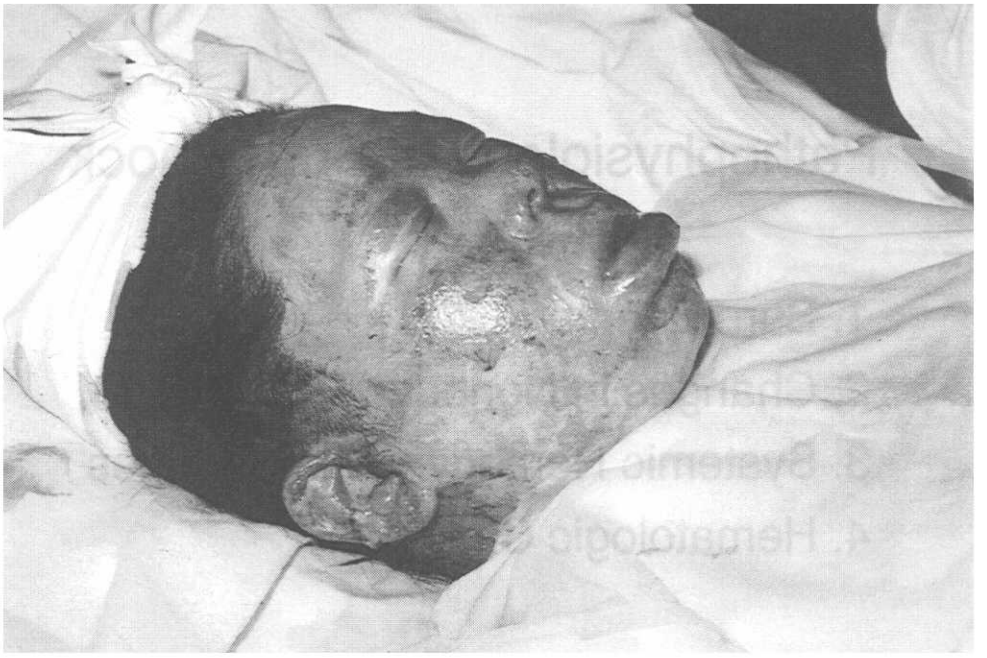

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