Caring for Victims of Nuclear and Radiological Terrorism

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After September 11, 2001, we became more aware of our vulnerability and need for clinical information regarding nuclear and radiological terrorism. As clinicians, we should prepare to care for the victims of a nuclear or radiological act.[1,2] Detonation of a nuclear weapon would cause massive fatalities, injuries, and sickness from the initial explosion (with blast, falling debris, and fires) and from the immediate and long-term effects of radiation exposure.

With modern weapon technology, a terrorist could explode a bomb of radioactive materials (such as waste byproducts from a nuclear reactor) wrapped in conventional explosives in any setting and radiation would spread across a defined area with fewer victims than a nuclear bomb, but with similar physical and behavioral results.[3]

As primary care providers, we must consider the manifestations of radiation sickness and syndromes when managing radiological injuries. Assessment and treatment regimens include unique sample handling requirements to avoid self-contamination and further contamination of the environment. Addressing psychological aspects and the needs of pediatric and geriatric populations is also important for effective treatment.

Radiation damage to cell cytoplasm and genetic material injures organs and rapidly dividing tissues (see Table, "Defining Radiation Terms"). Lymph tissue and bone marrow are the most radiation sensitive tissues. The most radiation sensitive organs are the skin, intestines, kidneys, and gonads. Gray units (Gy) measure radiation doses in human tissue and help identify cellular response to exposure as an early or late effect (see Table,"Early Effects of Radiation Exposure").

Radiosensitivity is the susceptibility of cells, tissues,and organs to the harmful action of ionizing radiation. A person's degree of exposure, pre-existing state of health, age, and sex determine the degree of illness. Victims of high dose radiation exposure,those with chronic illness,and pediatric, geriatric, and male victims are more likely to experience negative sequelae than other members of the population (see Figures,"Radiosensitivities by Gender" and "Radiosensitivity by Age").[4]

Protecting Yourself and Others from Contamination

Before offering any care to victims, be sure to protect yourself from contamination, dispose of contaminants, and control the spread of radioactivity. When caring for victims of radiation exposure, use strict isolation precautions. Protective clothing should include disposable scrubs, waterproof shoe coverings, and gowns with all seams taped. Wear a protective hat, mask, and goggles, as well as double gloves taped at the wrists of your gown. A radiation film badge should be worn inside the gown to measure exposure. Enclose a dosimeter in a plastic, zip-locked bag and tape it to the outside of your gown for a direct indication of exposure risk.

People exposed to radiation but not injured must remove and isolate their clothing for decontamination. Isolate contaminated debris and draping materials by placing them in a sealed, airtight container labeled "contaminated–radiation hazard." Victims should cleanse skin and hair with a mild soap and thoroughly rinse body surface and orifices. Ask them to scrub intact skin with a soft brush. For injured patients, first irrigate wounds with normal saline, then have them follow the same clothing removal and washing routine. After decontamination, continue to treat wounds in the usual manner.[5]

Defining Radiation Terms

Absolute risk: The incidence of malignant disease in a population within 1 year for a given dose. It's expressed as number of cases /106 persons/ mREM.

Absorbed dose: The energy transferred from ionizing radiation per unit mass of irradiated material.

Dosimeter: An instrument that detects and measures exposure to ionizing radiation.

Film badge: A pack of photographic film that approximately measures radiation exposure.

Genetically significant dose (GSD): The average gonadal dose of radiation to members of the population who are of childbearing age.

Gray (Gy): A measurement that specifies the amount of exposure as 1 joule/ Kg or 100 rads (=100 rems).

L50/60: A dose of radiation (3-4 Gy) that's expected to cause death within 60 days to 50% of those exposed to it.

Mean lethal dose: A constant related to the radiosensitivity of a cell. Different cell types have different mean lethal doses.

Mean survival time: The average time between radiation exposure and death.

Relative biologic effectiveness (RBE): The ratio of the dose of standard radiation necessary to produce a given effect to the dose of test radiation needed for the same effect.

Skin erythema dose (SED): A dose of radiation usually about 200 rads (=200 rems) or 2 Gy that causes skin redness.

Somatic effects: The effects of radiation, such as cancers and leukemia, limited to an exposed individual.

Threshold dose: The radiation dose below which a person has a negligible chance of sustaining specific biologic damage or the dose at which a response to increasing x-ray intensity first occurs.

From Bushong S: Radiologic science for technologists, 7th edition. St.Louis: Mosby Publishing Co., 2001:482-500.
Seeram E: Radiation protection. Philadelphia: Lippincott, 1997:73-92.

Early Effects of Radiation Exposure

Effect	Anatomic site	Approximate minimum radiation dose (Gy) necessary for effect to occur
Chromosome aberration	Entire body	0.05
Hematologic depression	Entire body	0.25
Death	Entire body	1
Gonadal dysfunction	Reproductive organs	1
Skin erythema	Epidermis exposure	2
Epilation	Epidermis exposure	3

From Bushong E: Radiologic science for technologists, 7th edition. St. Louis: Mosby Publishing Co., 2001:482-500. Seeram E: Radiation protection. Philadelphia: Lippincott, 1997:73-92.

Ordering Lab Work

Assign laboratory specimens from patients exposed to radiological contamination to containers labeled with the patient's name,date, time sample was taken,location, and size of sample taken. Retain blood, urine, feces, or other samples taken in the emergency period for pathologists and public health professionals to investigate later. Store and dispose of samples according to the radiation safety guidelines of the institution where you collected the sample.

Immediately order a complete blood count (CBC) and differential for all patients with radiation injury to assess radiation exposure dose and establish a baseline for degree of injury. Select venipuncture sites from noncontaminated areas, if possible, and cover them with a dressing. Repeat the CBC and differential every 6 hours for 48 hours in patients who have had total body exposure.

Perform routine urinalysis in patients with kidney malfunction¾especially for those who have had internal contamination. Patients should wear gloves when collecting their specimens.Label specimen containers with specimen number, date, and time.

If a patient has experienced external exposure, swab body orifices and wounds to detect any internal contamination. Use separate saline or water-dipped swabs to wipe the inner aspect of each nostril,ear, mouth, etc. and place each in a separate container for analysis. If the patient has wounds, save dressings in labeled plastic bags and collect secretions on swabs or directly into a dropper or syringe. If radiological debris is in the wound, use tweezers to transfer the debris to a collection container for placement in a lead storage container.

For patients with internal exposure, collect 24-hour urine and feces specimens for 4 days. Because excreted specimens may have radiological particles,handle them carefully using isolation precautions.[5]

Performing an Acute Assessment in Adults

Radiation reactions and injuries resulting from nuclear blast or radiological dispersion include acute radiation sickness, trauma from the initial blast, and burns of various depths. Survivors near the blast zone will be few. Survivors in the indirect blast zone (the area not immediately damaged by the blast but contaminated) will receive indirect blast and thermal injuries including ruptured eardrums, epistaxis, severe burns, flash blindness, crush injuries, and trauma secondary to flying debris.[5,6]

The government has stockpiled doses of potassium iodide to help prevent thyroid damage in the general population (see Sidebar, "Health Of-

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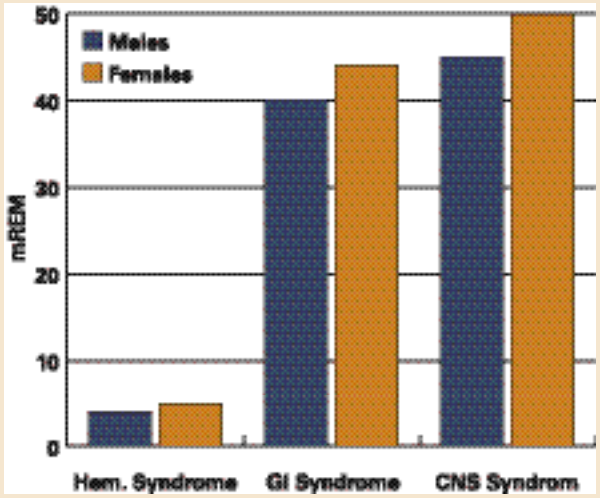
ficials Prepare to Treat Victims with Potassium Iodide"). Otherwise, treatment depends on a patient's presentation and severity of symptoms (see Table, "Acute Radiation Syndrome Treatment Algorithm"). Consult with hematology and radiation specialists early in the course of care,if available. Overall treatment of trauma focuses on airway management, ventilatory support,fluid management, and pain control.

Burns result from the initial explosion and fires started by explosions. Patients with burn injuries are at risk of infection.[7] Initial burn management requires a systematic approach. Consider the six C's; Cool the burn with sterile saline soaks, Cleanse the wound (debride), Cover the burn with sterile dressings (silvadene), Call a burn specialist, provide Chemoprophylaxis with antibiotics for infection, and Comfort with analgesics and psychological support.

Physical findings indicating inhalation injury include coughing, wheezing, dyspnea,facial burns,sooty mucus,and laryngeal edema. Check patients at risk for inhalation burns for carbon monoxide poisoning. Arterial carboxyhemoglobin levels greater than 10% indicate carbon monoxide exposure. Hyperbaric oxygen is the treatment of choice for these patients.[8]

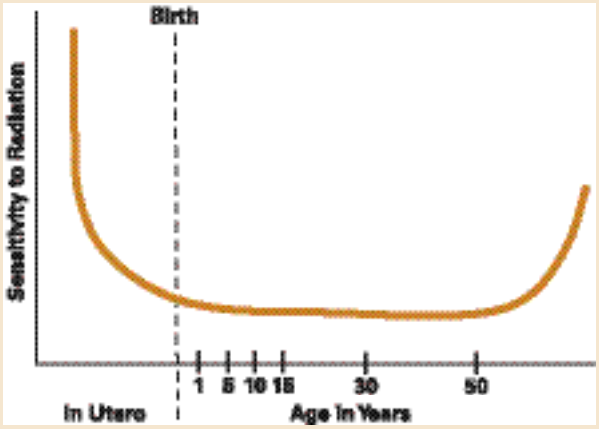
Eye injuries include flash blindness that could result in retinal scarring for people within 12 miles of the blast zone. If the nuclear blast occurs within daylight hours, blindness is temporary (lasting less than 2 minutes). If the blast occurs at night, flash blindness persists for about 30 minutes, with partial recovery within minutes.[9]

Radiosensitivity by Gender (inGy)



(Note: Men require less exposure than women to exhibit symptoms.)

Radiosensitivity by Age



Detecting Acute Radiation Syndrome

The acute sickness caused by irradiation of the whole body (or a significant part of it) is known as acute radiation syndrome and includes a prodromal phase, latent phase, a period of illness and recovery or death. During the prodromal period, which lasts a few hours to 2 days,high dose radiation exposure (> 2 Gy) produces observable somatic effects. Symptoms of acute radiation sickness include nausea, anorexia, vomiting, headache,malaise,diarrhea (possibly bloody), and tachycardia of varying severity. Survivors with bloody diarrhea aren't likely to survive marrow aplasia and injury to vascular and gastrointestinal systems.[10] Other manifestations include temporary loss of hair during a 7- to 14-day period (hair typically regrows within 2 months), skin ulcers, petichiae development, and mucositis (involving the entire GI tract).

A latent period, which is usually short (1-2 days) and symptom free, follows radiation sickness. After the latent period,patients can experience overt illness with visible physiologic changes as detailed below.[11]

Differentiating Among Acute Radiation Syndromes

The development of illness is radiation dose-related and presents with symptoms of major organ injury. Deaths may begin to occur within a week after exposure, peak in 3 to 4 weeks, and taper at 7 to 8 weeks. Deaths may occur during any syndrome with exposure to 1 Gy or more of penetrating radiation. Inhaled plutonium results in acute respiratory failure within one week.[6] The syndromes below are listed in order of development with increasing amounts of radiation exposure.

Hematologic Syndrome

Hematological insult results from exposure to 2 to 10 Gy of radiation with resulting immunological and hematological suppression of the lymph system, spleen and bone marrow. Patients experience anorexia,lethargy, nausea, and vomiting within 6 to 12 hours of exposure, with symptoms subsiding within 36 hours. After initial symptoms subside,patients ex-

perience a latency period with complaints of fatigue. The production of cells necessary for the immune system to function properly diminishes and pancytopenia results. Lymphopenia develops first, followed by neutropenia over 7 to 14 days,and thrombocytopenia within 21 days. Bone marrow suppression requires sophisticated treatment such as blood product replacement, colony stimulating factors and immunosuppression precautions as infection and hemorrhaging develop.

GI Syndrome

GI syndrome results from exposure to 10 to 50 Gy and causes severe damage to epithelial cells lining the intestine, resulting in bloody diarrhea and a compromised immune system,making patients more vulnerable to infection. Bacteremia is a complication of bowel necrosis. Acute treatment includes antibiotics and intravenous hydration.

Central Nervous System Syndrome

Central nervous system (CNS) syndrome occurs when a person is within 2.5 miles of a nuclear blast and experiences a Gy exposure greater than 50. Initially, patients experience nausea, vomiting, listlessness, and drowsiness. CNS syndrome progresses to tremors, convulsions,ataxia, and death within hours to a few days of initial radiation exposure. Medical intervention is supportive.[12]

Tallying Long-Term Physical Effects

As a benchmark, keep in mind that "normal medical exposure" to radiation (the recommended maximum dose for x-ray technologists and other radiation workers) is 15,000 milli-radiologic effects in man (mREM) annually. Then, consider that fetal abnormalities and increased cancer risks occur even with one-time exposure of greater than 10,000 mREM. Blood and sperm abnormalities occur at 15,000 mREM and genetic risk can occur at 25,000 mREM of exposure. A 5% risk of death related to cancer and a 1% genetic risk occur with a one-time exposure to 100,000 mREM. People exposed to 250,000 mREM have a 10% risk of cataract development.

Safety guidelines for radiation exposure in women during pregnancy indicate a maximum exposure of 500 mREM. The average background exposure to radiation for people living in the U.S. is 100 mREM annually. In comparison, the average exposure for people within 18 miles of the Chernobyl radiation spill site was 1,500 mREM.

Long-term effects of radiation exposure include amenorrhea, sterility, disturbances in blood cell formation,cataract formation, premature aging, and cancer. Victims are more prone to leukemia and cancers of the skin, breast, lung, and thyroid than other types of cancer. Effects noted after the 1986 nuclear disaster in Chernobyl, Ukraine,include early and pervasive cancer in exposed individuals.[12] When the acute care period after radiation exposure has passed, survivors need counseling about long-term risks.[13]

Consider Psychological Aspects

The possibility of nuclear attack can shatter beliefs about safety and security. Becoming a witness (even if only via television) or victim of terrorism irrevocably changes expectations of life and can cause post-traumatic stress disorder (PTSD).[14] Symptoms of PTSD include hyperarousal, avoidance, and intrusion. Hyperarousal refers to a heightened startle response, intense irritability, and possibly anger. Avoidance manifests as withdrawal from anything or anyone that reminds the victim of the event. Victims may become numb and find any emotions impossible. Intrusions of unwanted and dis-

Health Officials Prepare to Treat Victims with Potassium Iodide

Recent studies of emergency preparedness indicate a need to update training and coordinate the multiple agencies and services responding to the incident.[1,2] Spokesmen from the U.S. Department of Health and Human Services announced that the government has 16 million doses of potassium iodide (KI) and will obtained 6 million more doses in 2002.[3]

Potassium iodide floods the thyroid gland, and may prevent absorption of the radioactive iodine released during a nuclear explosion. It is believed that early treatment with KI in a radiological emergency could offset the potential of thyroid cancer. Local health departments will advise the public how to obtain KI and when to take it. Potassium iodide is available over the counter via the Internet, and if stored in a cool, dark, dry location will maintain potency for at least 3 to 5 years.

For greatest effect, victims should take a single dose of KI as soon as exposed, and within 4 hours of exposure at a dose of 130mg for adults older than age 18, 65mg for children and adolescents ages 3 to 18, 32mg for children 1 month to 3 years old, and 16 mg for newborns up to 1 month old. Children near adult size (150 lbs.) should take the adult dosage regardless of age. Higher than recommended doses do not improve protection and can have adverse side effects. If exposure to radiation persists, additional dosing may be necessary.[4]

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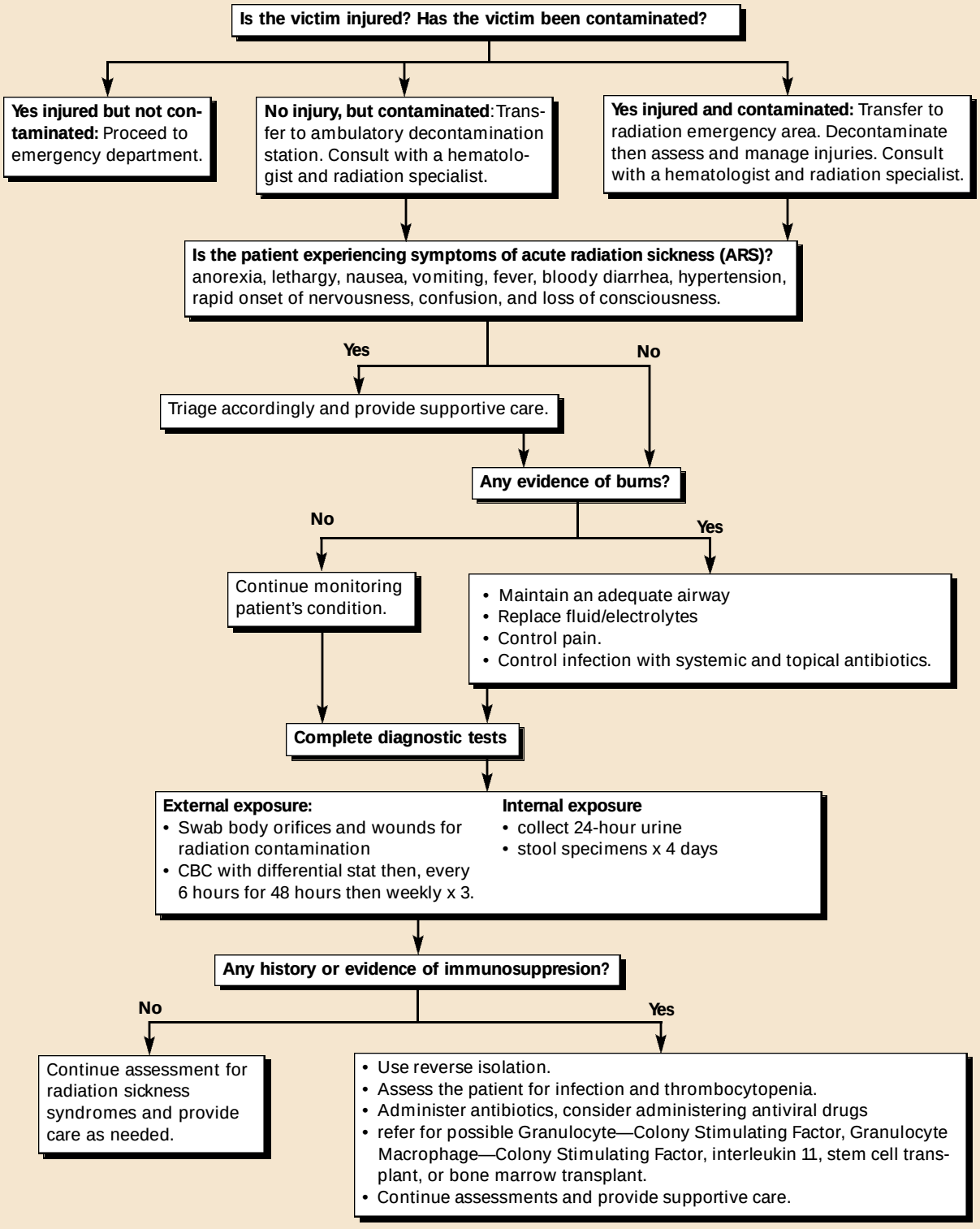
Acute Radiation Syndrome Treatment Algorithm

Follow the algorithm below to help guide your treatment of patients in the hospital setting who have acute radiation syndrome. Clinicians should take isolation precautions described under the subtitle "Protecting Yourself". An initial dosimeter reading should be taken on all patients.



turbingly vivid images or thoughts are highly disruptive. A person with PTSD may re-experience the traumatic event through flashbacks or nightmares, or have other symptoms for months after the trauma.[15] Patients with PTSD also have an increased risk of suicide.[16] The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) lists criteria for PTSD.[17]

Someone with symptoms similar to those of PTSD, but whose symptoms endure less than a month, may have Acute Stress Disorder (ASD).[15] An Immediate Stress Response Checklist (ISRC) to assess the presence of ASD in violently injured children and young adults is in development.[18]

Treatment for PTSD and ASD includes offering support and education concerning available resources and options.[19,20] In one study, debriefing sessions during which victims meet with other victims to talk about their experiences were not as beneficial as expected,leading researchers to consider them inappropriate for direct victims of trauma.[21]

The most successful interventions for patients with PTSD are cognitive-behavioral therapy (CBT) and drugs. Sertraline (Zoloft),paroxetine (Paxil), and fluoxetine (Prozac) are examples of selective serotonin reuptake inhibitor (SSRI)used in this condition. Eye Movement Desensitization and Reprocessing (EMDR) may also help relieve symptoms of PTSD. In an EMDR session, moving light is used to induce rapid eye movement. Events and reactions to them are processed during REM sleep, which is thought to enable processing traumatic events.[16]

Caring for Pediatric Patients

Caring for burns is an immediate focus for pediatric victims of radiation exposure. Increased body surface area to mass ratio and skin maturity mean that children receive full-thickness burns in 0.5 second, compared with 1.8 seconds for adults.[22] Burns involving 10% or more of a child's body surface are critical burns requiring hospitalization. Burns of the hands, feet,face, eyes,ears, and genitalia are major burns that a burn specialist should see.[23] The number of children receiving major burns in a terrorism strike, however, could overwhelm acute care facilities. Clinicians may find themselves unable to refer to a burn specialist and responsible for care. Concerns for pediatric burn patients include insuring adequate airway, fluid and electrolyte replacement,infection control, and pain management.[22]

Immediately order a complete blood count (CBC) and differential for all patients with radiation injury to assess radiation exposure dose and establish a baseline for degree of injury. If a patient has experienced external exposure, swab body orifices and wounds to detect any internal contamination. For patients with internal exposure, collect 24-hour urine and feces specimens for 4 days Deaths may begin to occur within a week after exposure, peak in 3 to 4 weeks.

Wound sepsis,along with acute radiation sickness,place a child at increased risk for death and require aggressive treatment. Burns colonize early with gram-positive organisms (primarily Staphylococcus) and change to gram-negative organisms such as Pseudomonas aeruginosa by the third day after the trauma.

Good nutritional support, excision of necrosed tissue, skin grafts, and topical antimicrobial treatment can decrease the chances of fatal infection.[22] However, radiation exposure creates a limited window in which to perform procedures such as debridement and grafts without increasing significantly the possibility of death.[24] Systemic antibiotics may be necessary.

Nuclear blasts accompanied by flying debris yield increased catastrophic outcomes when children are involved. Babies with open cranial sutures or fontanelles may experience permanent damage to the skull and brain secondary to being struck with high velocity debris. Children's bones are porous,pliable, and susceptible to buckling, bending, and breaking.[22] Fractures with blood loss are more significant for a young child,particularly with care delays due to decontamination. Understanding the dependency of blood volume on age and body weight is crucial to recognizing life-threatening blood loss.[25] The clinical course of hematopoietic damage in radiation syndromes may be the same as with adults, but be aware of age-specific blood counts in children, which you can verify in a pediatric hematology reference.

Compared with adults, children's smaller fluid reserve combined with a greater body surface area to mass ratio leads to rapid dehydration and shock from vomiting and/or diarrhea.

Become familiar with basic fluid requirements for children to avoid fluid overload. Most guidelines require initial IV fluid replacement followed by oral rehydration. Consult a pediatric reference to determine speed of fluid replacements.

Be sure to adequately address pain. Some clinicians express concern about medicating children with opioids. Narcotics are no more dangerous for children than they are for adults. Respiratory depression is uncommon and addiction is rare.[26] One study of pediatric burn patients found a significant dose dependent association between morphine received during a child's hospitalization and reduction of PTSD symptoms post hospitalization.[27]

Because children's vision continues to develop until age 9, loss of vision resulting from retinal burns or flash blindness that extends for weeks or months raises concern of permanent loss.[28] Studies show that early cataracts develop in

children exposed to radiation.[11]

Consider the psychological injury to children after nuclear terrorism. Children who have witnessed the injury or death of family and friends will experience emotional trauma. Injuries resulting in permanent or temporary loss of sight will magnify the psychological trauma. The decontamination process, including seeing adults in hazardous material suits, could frighten children.

If you haven't cared for children recently, review basic principles of growth and development, and pediatric communication to effectively provide care and gain the child's trust and cooperation. Assess all children for PTSD and manage them accordingly.

Long-term effects of radiation exposure in children reveal an increased incidence of thyroid cancer and leukemia. In a developing embryo and fetus, radiation exposure causes a period of intense cell proliferation, differentiation, and migration with the developing nervous system particularly sensitive to ionizing radiation.

Teratogenesis and its degree of complications relate to the fetal stage of development and radiation dose at the time of exposure. Even preconceptual exposure to low doses of ionizing radiation can contribute to congenital malformation.[29,30] Risks to the unborn child are greater early in pregnancy and include spontaneous abortion, neonatal death, congenital defects of the nervous system, mental retardation, growth retardation, physical anomalies and malformations, a higher susceptibility to infectious and noninfectious diseases, and malignancies.[29,30,31]

Caring for Geriatric Patients

Older adults (usually defined as over age 65) are particularly vulnerable to the aftermath of a nuclear event because of physiological changes related to aging, the presence of co-morbidities, and a lack of physiologic reserves to recover from injuries and sequelae. In addition to radiation burns, the elderly may suffer from fractures and injuries by debris due to mobility limitations.

Consider age-related changes in the respiratory system when providing airway management and ventilatory support. Elderly people are at risk for dehydration related to symptoms of acute radiation sickness and reduction of total body water, making fluid management very important.[32] More so than healthy younger adults, older people also experience hematopoietic syndrome because immune system function diminishes with age.[33]

Due to lack of physiologic reserves, the elderly are less likely to survive extensive body surface area burns. With other complications, elderly people will likely develop respiratory problems.

When ordering drugs for elderly patients, consider changes in metabolism and excretion. Use antiemetics judiciously because of their depressant and anticholinergic actions.[33] Titrate analgesics considering possible deleterious effects on respiration and mobility.[32]

Elderly people, with and without cognitive impairment, may experience confusion after a traumatic event. It may be difficult to distinguish confusion from cognitive impairment, so allow extra time for the elderly to process events. If feasible, volunteers or minimally injured people may provide reality orientation.[34] An elderly person's extent of exposure, type of injury, pre-event health, existing chronic and environmental conditions, coping skills, and social support will influence his or her survival.

Caring for burns is an immediate focus for pediatric victims of radiation exposure. Increased body surface area to mass ratio and skin maturity mean that children receive full-thickness burns in 0.5 second, compared with 1.8 seconds for adults. Burns involving 10% or more of a child's body surface are critical burns requiring hospitalization. Consider age-related changes in the respiratory system when providing airway management and ventilatory support. Elderly people are at risk for dehydration, making fluid management very important.

Preparing for the Worst

As clinicians, we must plan for the possibility of a nuclear attack. Understanding decontamination protocol, the types of illness that follow radiation exposure, and the treatment to provide are key to offering safe and effective care for patients while protecting ourselves and others. In the event of a nuclear or radiological attack, we'll want to do everything our skills allow to help the victims.

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4. **New discount procedure:** Take 75¢ off the price of each test if submitting two or more tests at a time from any issue.
5. **Fax-back service:** Fax your test (credit card orders only) to 732-255-2926 and we'll fax back your CE certificate within 2 business days. Provide a fax number for a location where confidential information will be safe (home/workplace). Faxes sent to a workplace will be accompanied by a cover letter. We aren't responsible for faxes not received due to malfunctioning machine on receiving end. A CE certificate will be mailed after attempts to fax have failed.
6. **Take tests on-line** at http://www.nursingcenter.com/prodev/ce_online.asp and have them processed immediately.

The passing score for tests is 70%. If you pass, a certificate for earned contact hours will be awarded by Lippincott Williams & Wilkins. You'll also receive an answer sheet with the rationale for each correct answer. If you fail the test, you can take the test again for free. For questions about test results, contact Lippincott Williams & Wilkins, CE Dept., 345 Hudson St., New York, N.Y. 10014; 1-800-933-6525, ext. 332.

Provider Information:

This continuing nursing education (CNE) activity for 1.0 contact hours is provided by Lippincott Williams & Wilkins, which is accredited as a provider of continuing education in nursing by the American Nurses Credentialing Center's Commission on Accreditation and by the American Association of Critical-Care Nurses (AACN 9722; category A). This activity is also provider-approved by the California Board of Registered Nursing, provider #CEP11749, for 1.0 contact hours. Lippincott Williams & Wilkins is also an approved provider of CNE in Alabama (#ABNP0114), Florida (#FBN2454), and Iowa (#75)*. All of its home study activities are classified for Texas nursing continuing-education requirements as Type 1. Your certificate is valid in all states.

*In accordance with Iowa Board of Nursing administrative rules governing grievances, a copy of your evaluation of this CE offering may be submitted to the Iowa Board of Nursing.

TEST RESULTS MUST BE POSTMARKED BY FEBRUARY 28, 2005.