

Chemical, Biological, Radiological, Nuclear, and Explosive Injuries

Background

Pediatric casualties are unavoidable in every conflict. Children are virtually certain to be among the victims of future terrorist attacks, including those potentially involving chemical, biological, radiological, nuclear, and explosive (CBRNE) agents.

Unique Considerations in the Pediatric CBRNE Victim

The saying that “children are not just small adults” is a mantra familiar to all pediatric caregivers. Perhaps nowhere is this more relevant than in the case of pediatric CBRNE victims, who differ from adults in myriad ways that make their care more problematic

- Anatomical and physiological differences
 - Children have a higher surface-area-to-volume ratio than adults, making them more susceptible to transdermal absorption and the effects of volume loss
 - Children have increased minute ventilation, a thinner and less-well-keratinized epidermis, and a less mature blood-brain barrier than adults
- Differences in disease manifestation and severity
 - In some cases, children may be more prone than adults to developing severe disease from a given agent
 - In other cases, children may simply present with different signs and symptoms
 - ▶ Venezuelan equine encephalitis, an incapacitating agent in adults, can be lethal in young children
 - ▶ Melioidosis sometimes causes a parotitis in children, but not in adults
 - ▶ Few, if any, children are immune to smallpox, but many adults may have some degree of residual immunity from long-distant vaccination

- ▶ Radiation injury disproportionately affects rapidly growing tissues, posing a special problem for young children
- Treatment difficulties
 - Many agents routinely used to treat adults are relatively unfamiliar to those who typically care for children (eg, fluoroquinolone and tetracycline antibiotics are rarely used in young children because of possible toxicities and side effects)
 - Many of the drugs recommended for use in infants and children in this chapter are not specifically approved by the US Food and Drug Administration for those indications; in some cases the dosing is extrapolated from adult dosing
- Prophylactic difficulties
 - Certain immunizations approved for adults are not licensed for use in children (eg, anthrax vaccine adsorbed [AVA] is approved only for those 18–65 y old)
 - Some vaccines (eg, vaccinia and yellow fever) have a higher incidence of complications in children
- Developmental considerations
 - Children, who “live closer to the ground,” are less able to flee in an emergency, follow the instructions of public safety personnel, and distinguish reality from fantasy (eg, repeated media broadcasts of an event may be interpreted by young children as multiple events)
 - Children may be more prone to developing posttraumatic stress disorder than adults
- Other considerations
 - Drugs and antidotes are often unavailable in pediatric (liquid) dosing forms, and medical equipment is often unavailable in sizes suitable for children
 - Hospitals may not be equipped to care for large numbers of children

Pediatric Chemical Casualties

- Background. There are hundreds of chemical agents that may be used by terrorists; this chapter deals with those “military-grade” agents that have gained widespread acceptance as potent and viable terrorist threats

- Military-grade agents
 - Nerve agents
 - ▶ Organophosphates that inhibit anticholinesterase
 - ▶ Nerve agents cause acetylcholine to accumulate at the neuromuscular junction, resulting in cholinergic crisis
 - ▶ This category can be divided into persistent nerve agents (eg, VX) and nonpersistent agents (eg, tabun, soman, and sarin)
 - ▶ Signs and symptoms
 - ▷ Symptoms can be summed up by the mnemonic **SLUDGE** (salivation, lacrimation, urination, defecation, gastrointestinal upset, and emesis)
 - ▷ Central effects include ataxia, seizures, coma, and respiratory depression
 - ▶ Laboratory findings: none are available rapidly enough to be of use in the setting of warfare or terrorism
 - ▶ Treatment: the same for children as for adults
 - ▷ Give atropine and pralidoxime chloride (2-PAM Cl) 25 mg/kg (intravenous [IV] or intramuscular [IM]) initially
 - ▷ There is no maximum dose for atropine, although experts recommend an initial dose of 0.05 mg/kg IV or IM, titrating to effect (ie, secretions are dry and the patient no longer shows signs of respiratory distress)
 - ▷ Many experts also feel that adult autoinjectors may be safely used in young children
 - ▷ Seizures should be managed with benzodiazepines (either diazepam [0.3 mg/kg] or lorazepam [0.1 mg/kg] initially, titrating to effect)
 - Blister agents (vesicants)
 - ▶ Cellular poisons widely used in World War I, as well as by the Iraqi Army during the Iran–Iraq war
 - ▶ Mustard and lewisite are the most notable
 - ▶ Signs and symptoms
 - ▷ Burning eyes, skin, and respiratory tract, with higher exposures leading to systemic effects and eventual bone marrow suppression
 - ▷ Mustard gas has a delayed onset of symptoms;

- lewisite exposure manifests more rapidly
- ▶ Laboratory findings: none are available rapidly enough to be of use in the setting of warfare or terrorism
- ▶ Treatment includes rapid decontamination
 - ▷ Soap and water are fine for most casualties; diluted bleach from a standard military decontamination kit is equally effective
 - ▷ Supportive care is the hallmark of therapy, although patients with blister agent burns require less fluid than those with conventional burns
- Pulmonary agents: those intended to prevent or inhibit breathing; used extensively during World War I
- ▶ Chlorine and phosgene are the two primary examples of pulmonary agents in use today; an additional pulmonary agent that can be inadvertently released from burning military vehicles is perfluoroisobutylene
- ▶ Signs and symptoms: the chemical generates hydrochloric acid in the exposed victim and leads to an oxygen free-radical cascade
 - ▷ Upper-airway and conjunctival irritation develops first, followed by wheezing and pulmonary edema
 - ▷ The onset of symptoms within a few hours is an ominous finding
 - ▷ Phosgene smells of newly mown hay
- ▶ Laboratory findings: none are specific, although monitoring blood gases or transcutaneous oxygen saturation may help guide supportive therapy
- ▶ Treatment begins with removing the victim from the area and providing supportive care (oxygen, albuterol, and ipratropium are the mainstays of treatment)
 - ▷ Enforce bed rest for phosgene victims to prevent or help ameliorate pulmonary edema, which usually occurs 4–6 hours postexposure, but may be delayed for up to 24 hours
 - ▷ Because children are shorter than adults and these chemicals are denser than air, pediatric victims will have a proportionately higher exposure than adults in the same attack
 - ▷ Children frequently need higher doses of albuterol than adults; they are much less likely to have adverse

- cardiac reactions to it
 - ▷ Corticosteroids may be required for severe bronchospasm
- Blood agents
 - ▶ Chemicals distributed through the body via blood
 - ▶ Cyanide, a volatile chemical that disperses easily in the air, is the prototypical blood agent
 - ▶ Signs and symptoms: cyanide inhibits cytochrome A3 and halts normal oxidative metabolism, leading to cellular hypoxia and acidosis; it strikes metabolically active tissues hardest, specifically the heart and brain
 - ▷ Toxicity is dose dependent, with mild exposures causing tachypnea, tachycardia, and dizziness
 - ▷ More substantial exposures lead to severe toxicity, which causes seizure, coma, apnea, cardiac arrest, and, eventually, death
 - ▶ Laboratory findings: anion gap metabolic acidosis and elevated mixed venous oxygen saturation
 - ▶ Treatment includes moving the patient to fresh air and administering a cyanide antidote kit
 - ▷ Start by administering 0.33 mL/kg (9 mg/kg) of 3% sodium or amyl nitrite (300 mg/10 mL) IV over 5 minutes (assuming a normal hemoglobin of 12 g/dL), which causes the formation of methemoglobin (which, in turn, binds cyanide ion); dosage can be adjusted based on hemoglobin levels
 - ▷ Follow by administering 1.65 mL/kg (400 mg/kg) of 25% sodium thiosulfate (12.5 g in 50 mL) IV over 10–20 minutes (12.5 g maximum dose; used by the liver to convert cyanide to thiocyanate, which is renally excreted)
 - ▷ Nitrate-induced hypotension, as well as excessive methemoglobin formation, can be hazardous to pediatric patients; **weight-based dosing of antidotes is especially important**
- Riot control agents
 - ▶ Designed to incapacitate victims rather than permanently injure them
 - ▶ Examples include *O*-chlorobenzylidene malononitrile (CS; military-grade tear gas), 1-chloroacetophenone (CN

- gas; eg, mace), and capsaicin (pepper spray)
- ▶ Signs and symptoms
 - ▷ Mild exposure causes eye burning and tearing with eventual blepharospasm
 - ▷ The nose, throat, and upper airway become irritated
 - ▷ In high-dose exposures, victims' skin may blister and they may develop tracheobronchitis (eventually resulting in pulmonary edema)
- ▶ Laboratory findings are nonspecific
- ▶ Treatment for riot control agents is supportive
 - ▷ Begin by moving the victim from the contaminated area and removing potentially saturated clothing
 - ▷ For patients with pulmonary symptoms, provide supplemental oxygen as needed
 - ▷ In patients experiencing airway reactivity or wheezing, use albuterol, ipratropium bromide, and steroids as indicated

Pediatric Biological Casualties

- Background. In 1999, the Centers for Disease Control and Prevention developed a list of infectious and toxic agents that, if employed by terrorists, would pose the greatest threats to public health. "Category A" agents are those deemed to present the greatest risk. All six of these agents also routinely appear at the top of state-sponsored biological weapons threat lists
- Category A agents
 - Inhalational anthrax
 - ▶ Etiologic agent is *Bacillus anthracis*, a gram-positive, spore-forming rod
 - ▶ Signs and symptoms
 - ▷ Inhalational anthrax typically has an incubation period of 1–6 days
 - ▷ A flu-like illness ensues, with fever, myalgia, headache, and cough
 - ▷ A brief intervening period of improvement sometimes follows 1–2 days of these symptoms
 - ▷ The patient rapidly deteriorates; high fever, dyspnea, cyanosis, and shock mark this second phase
 - ▷ Hemorrhagic meningitis occurs in up to 50% of cases

- ▶ Laboratory findings
 - ▷ Sporulating gram-positive bacilli in skin biopsy material (in the case of cutaneous disease) or in blood smears
 - ▷ Chest radiographs demonstrating a widened mediastinum in the context of fever and constitutional signs, and in the absence of another obvious explanation (such as blunt trauma or postsurgical infection)
 - ▷ Confirmation is obtained by blood culture on standard media
- ▶ Treatment and prophylaxis: see Table 38-1
- ▶ Infection control: standard precautions, including use of gloves, gowns, masks, and protective eyewear when contact with blood, body secretions containing blood, or other moist body substances is anticipated
- Plague
 - ▶ Etiologic agent is *Yersinia pestis*, a small safety-pin-appearing, gram-negative bacillus
 - ▶ Signs and symptoms
 - ▷ Symptoms of pneumonic plague include fever, chills, malaise, headache, and cough
 - ▷ Chest radiographs may reveal a patchy consolidation; classic clinical finding is one of blood-streaked sputum
 - ▷ Disseminated intravascular coagulation (DIC) and overwhelming sepsis typically develop as the disease progresses
 - ▷ Meningitis occurs in 6% of cases
 - ▷ Untreated pneumonic plague has a fatality rate approaching 100%
 - ▶ Laboratory findings
 - ▷ Bipolar safety-pin-staining bacilli in Gram or Wayson stains of sputum or aspirated lymph node material
 - ▷ Confirmation is obtained by culturing *Y pestis* from blood, sputum, or lymph-node aspirate
 - ▷ The organism grows on standard blood or MacConkey agar, but is often misidentified by automated systems
 - ▶ Treatment and prophylaxis: see Table 38-1

Table 38-1. Recommended Therapy and Prophylaxis for Diseases Caused by Category A Biothreat Agents

| Condition | Therapy | Prophylaxis |
|---|---|--|
| Anthrax, inhalational ^r | Ciprofloxacin [†] 10–15 mg/kg IV q12h | Postexposure (60-day course) |
| | OR | Ciprofloxacin 10–15 mg/kg PO q12h |
| | AND | OR |
| | Clindamycin [†] 10–15 mg/kg IV q8h | Doxycycline 2.2 mg/kg PO q12h |
| | AND | |
| | Penicillin G [§] 400–600k units/kg/d IV ÷ q4h | |
| Anthrax, cutaneous, in terrorism setting ^y | Ciprofloxacin 10–15 mg/kg PO q12h | NA |
| | OR | |
| | Doxycycline 2.2 mg/kg PO q12h | |
| Plague | Gentamicin 2.5 mg/kg IV q8h | Doxycycline 2.2 mg/kg PO q12h |
| | OR | OR |
| | Doxycycline 2.2 mg/kg IV q12h | Ciprofloxacin 20 mg/kg PO q12h |
| | OR | |
| | Ciprofloxacin 15 mg/kg IV q12h | |
| Tularemia | Same as for plague | Same as for plague |
| Smallpox | Supportive care | Vaccination may be effective if given within the first several days after exposure |
| Botulism | Supportive care; antitoxin may halt the progression of symptoms but is unlikely to reverse them | NA |
| Viral hemorrhagic fevers | Supportive care; ribavirin may be beneficial in select cases | NA |

IV: intravenous
 NA: not applicable
 PO: per os (oral)

^rIn a mass casualty setting where resources are severely constrained, oral therapy may need to be substituted for the preferred parenteral option. Patients who are clinically stable after 14 days can be switched to a single oral agent (ciprofloxacin or doxycycline) to complete a 60-day course. Assuming the organism is sensitive, children may be switched

(Table 38-1 notes *continue*)

Table 38-1 notes, continued

to oral amoxicillin (80 mg/kg/day q8h) to complete the course. However, the first 14 days of therapy or postexposure prophylaxis should include ciprofloxacin and/or doxycycline, regardless of age. A 3-dose series of anthrax vaccine absorbed may permit shortening of the antibiotic course to 30 days.

[†]Levofloxacin or ofloxacin may be acceptable alternatives to ciprofloxacin.

[‡]Rifampin or clarithromycin may be acceptable alternatives to clindamycin as drugs that target bacterial protein synthesis. If ciprofloxacin or another quinolone is employed, doxycycline may be used as a second agent (it also targets protein synthesis).

[§]Ampicillin, imipenem, meropenem, or chloramphenicol may be acceptable alternatives to penicillin; they are also effective at penetrating the central nervous system.

[¶]10 days of therapy may be adequate for endemic cutaneous disease. However, a full 60-day course should be used in the setting of terrorism because of the possibility of a concomitant inhalational exposure.

- ▶ Infection control: droplet precautions
- Tularemia
 - ▶ Etiologic agent is *Francisella tularensis*, a gram-negative coccobacillus
 - ▶ Signs and symptoms
 - ▷ Multiple clinical forms of endemic tularemia are known
 - ▷ Inhalational exposure in a terrorist attack would likely lead to pneumonia or typhoidal tularemia, manifest as a variety of nonspecific symptoms (eg, fever, malaise, and abdominal pain)
 - ▶ Laboratory findings
 - ▷ Most findings (pneumonia, leukocytosis) are nonspecific
 - ▷ Confirmation can be obtained by *F tularensis* culture from blood using standard media
 - ▶ Treatment and prophylaxis: see Table 38-1
 - ▶ Infection control: standard precautions (see Category A agents, Infection control)
- Botulism
 - ▶ The etiologic agent is any of seven toxins produced by *Clostridium botulinum*, a gram-positive anaerobic bacterium
 - ▶ Signs and symptoms
 - ▷ A latent period, ranging from 24 hours to several days, is required before clinical manifestations develop
 - ▷ Initial clinical manifestations include cranial nerve dysfunction, manifested as bulbar palsies, ptosis,

- ▶ photophobia, and blurred vision owing to difficulty in accommodation
- ▶ Symptoms progress to include dysarthria, dysphonia, and dysphagia
- ▶ Finally, a descending symmetric paralysis develops and death may result from respiratory muscle failure
- ▶ No specific laboratory findings
- ▶ Treatment and prophylaxis: see Table 38-1
- ▶ Infection control: standard precautions (see Category A agents, Infection control, page 469)
- Smallpox
 - ▶ Etiologic agent is the Variola virus, a member of the orthopoxvirus family
 - ▶ Signs and symptoms
 - ▶ During the incubation period (7–17 days), the virus replicates in the upper respiratory tract, ultimately giving rise to a primary viremia
 - ▶ Amplification of virus occurs following seeding of the liver and spleen; a secondary viremia then develops
 - ▶ The skin is seeded during secondary viremia, and the classic exanthem of smallpox appears
 - ▶ Clinical illness begins abruptly and is characterized by fever, rigors, vomiting, headache, backache, and extreme malaise; the classical exanthem begins 2–4 days later
 - ▶ Macules are initially seen on the face and extremities
 - They progress in synchronous fashion to papules, then to pustules, and finally to scabs
 - As the scabs separate, survivors can be left with disfiguring, depigmented scars
 - The synchronous nature of the rash and its centrifugal distribution distinguish smallpox from chickenpox, which has a centripetal distribution
 - ▶ Death occurs in 30% of variola major patients
 - ▶ Laboratory findings: classic orthopoxvirus appearance can be seen on electron microscopic examination of material obtained from lesions
 - ▶ Treatment and prophylaxis: see Table 38-1
 - ▶ Infection control: strict airborne and contact precautions

- Viral hemorrhagic fevers
 - ▶ Etiologic agents include a number of ribonucleic acid (RNA) viruses belonging to one of four taxonomic families: the *Arenaviridae*, *Filoviridae*, *Flaviviridae*, and *Bunyaviridae*
 - ▶ Signs and symptoms: the diseases produced by these agents differ considerably in their clinical manifestations, severity, and modes of transmission; however, they share a propensity to cause a bleeding diathesis
 - ▶ No laboratory finding is specific; however, many patients with a viral hemorrhagic fever show evidence of DIC
 - ▶ Treatment and prophylaxis: see Table 38-1
 - ▶ Infection control: contact precautions

Pediatric Nuclear and Radiological Casualties

- Background. Pediatric nuclear and radiological casualties present a divergent scope. Nuclear casualties are those that result from the immediate effects of a nuclear detonation. A so-called “dirty bomb” scatters a radioactive source across an area in a manner similar to local fallout. Because this material is usually from an industrial source, it is “preformed,” and the radiation output decays at a steady half-life rate. Nuclear fission products from detonation decay extremely rapidly. Thus, by 48 hours after the detonation, the dose rate is < 1% of the initial fallout output.

Radiological casualties result from exposure to ionizing radiation and contamination with radioactive material. Ionizing radiation exposure, as a total body injury, may be more hazardous to a pediatric population because of children’s rapid cell turnover rate. Children are also at risk because of their increased metabolism, higher caloric requirements, and baseline respiratory rates. Children have thinner skin and a larger surface-to-mass ratio, increased fluid losses secondary to burns, and are more sensitive to the volume and electrolyte deficits induced by diarrhea, nausea, and vomiting. Small physical mass makes children less tolerant of total-body radiation injury. In industrial accidents, large adults have had

better survival rates than smaller adults

- Medical effects of nuclear detonation
 - Blast
 - ▶ Overpressure results in pulmonary, solid organ, and ear damage
 - ▶ The instantaneous pressure change does not allow for internal stabilization, so pressure gradients that would not ordinarily cause damage result in structural injury
 - ▷ 5 psi is sufficient to rupture eardrums
 - ▷ 15 psi can cause alveolar hemorrhage
 - ▶ Blast winds cause debris entrapment, crush injuries, translocation injury, and missile wounds
 - ▷ Nuclear detonation results in sudden hurricane-force winds sufficient to lift children and displace them into solid structures
 - ▷ Collapsed buildings and other structures can trap children
 - ▷ Disorientation because of sudden destruction of the normal environment, loss of family members, and trauma will diminish normal survival instincts
 - Children will be particularly unable to distinguish potential escape routes
 - Hiding in close quarters may offer immediate comfort, but may result in fatal entrapment
 - Thermal
 - ▶ Partial and full-thickness burns will occur from secondary fires and the direct thermal pulse
 - ▶ After the detonation of a weapon of 10 kilotons or less, most casualties who receive direct infrared burns from the thermal pulse will also receive lethal-dose irradiation
 - ▶ Infrared burns will “mature” like a sunburn and may not be immediately evident
 - ▶ Fires caused by the blast will ignite rubble and cause traditional thermal injuries, which must be treated aggressively (any concomitant irradiation injury will worsen the total prognosis for a patient with combined injuries)
 - ▶ Retinal burns will occur if a child looks directly at the

- detonation (these burns result when the lens on the retina focuses on the infrared pulse)
- ▶ Total foveal destruction may occur, resulting in permanent loss of usable vision
 - ▷ Flash blindness is a temporary condition lasting several minutes and is due to massive overstimulation of the retinal cells
 - ▷ The brilliance of the detonation, reflected in the atmosphere and off structures, can cause temporary “flash-bulb” effects at distances of tens of miles at night (during daylight, the effect still occurs but at a shorter range)
 - Ionizing radiation exposure
 - Signs and symptoms
 - ▶ Deterministic effects are directly dose-related—the higher the total radiation dose, the more severe the physical effects, the sooner they are expressed, and the more severe the damage
 - ▶ Early nausea and vomiting (within 4–12 h) indicates immune system failure may occur at 5–10 weeks following exposure
 - ▶ Acute local skin erythema in the first hours after the infrared pulse indicates a high probability of lethal injury
 - ▶ Radiation dermatitis is related to effective dose
 - ▷ Erythema occurs at 6–20 Sv (600–1,200 rem)
 - ▷ Exposure to 20–40 Sv will cause the skin to ulcerate in approximately 14 days, starting in the region that received the highest dose and progressing to lower dose areas
 - ▷ Above 3,000 Sv, the skin will blister immediately; this local dose will probably be associated with a lethal radiation injury
 - Laboratory findings
 - ▶ Leukopenia may be seen within 2–4 days of radiation exposure
 - ▶ Anemia and thrombocytopenia are later findings
 - Treatment
 - ▶ The basic clinical management for children is the same

as for adults: relieve nausea and vomiting, manage pain, and control infection

- ▶ The need for acute management is generally limited to patients experiencing dose rates > 1 cGy/h
 - ▶ Treat and prevent neutropenia with cytokines such as filgrastim ($5 \mu\text{g}/\text{kg}/\text{day}$ subcutaneous) or sargramostim ($250 \text{ mg}/\text{m}^2/\text{day}$ subcutaneous) until neutrophil recovery may prevent death from sepsis and lessen the duration of prophylactic antibiotics
 - ▶ Use of broad-spectrum antibiotics is appropriate during the period of absolute neutropenia; specific infections should be treated in accordance with standard practice
- Radiological contamination
 - Contamination evaluation and therapy must never take precedence over treatment of acute injury
 - ▶ Caregivers are not at risk of irradiation from contaminated patients
 - ▶ Normal barrier clothing will significantly limit cross-contamination
 - External contamination usually occurs in the form of dust, which can be washed off the skin and clothing
 - ▶ Signs and symptoms
 - ▷ Most radioactive materials emit α particles, which, when emitted on or near the skin, cause direct cell damage; this becomes evident as the cells migrate to the surface via normal desquamation (ie, " α burns")
 - ▷ Normally there is no initial visible effect because the stratum corneum consists of dead tissue
 - ▶ Laboratory findings: standard radiac instruments (eg, Geiger counter) detect and measure γ radiation
 - ▶ Treatment and prophylaxis: thorough decontamination will prevent further injury and should be undertaken as soon as is practical
 - Internal contamination occurs when children ingest, inhale, or are wounded by radioactive material
 - ▶ Signs and symptoms: normal metabolism of the nonradioactive isotope of the same element determines the metabolic pathway of a radionuclide
 - ▷ Once a radionuclide is absorbed, it crosses capillary

- membranes through passive and active diffusion mechanisms and is distributed throughout the body
- ▷ The rate of distribution to each organ is related to organ metabolism, the ease of chemical transport, and the affinity of the radionuclide for chemicals within the organ
 - ▷ The liver, kidney, adipose tissue, and bone have higher capacities for binding radionuclides due to their high protein and lipid makeup
 - ▷ Nursing mothers should discontinue breast-feeding when internal contamination is suspected
 - ▷ Inhaled particles $< 5 \mu\text{m}$ in diameter may be deposited in the alveoli and microbronchioles
 - Larger particles will be cleared to the oropharynx by the mucociliary apparatus, where they will be swallowed and processed through the digestive tract
 - Soluble particles will either be absorbed into the bloodstream directly or will pass through the lymphatic system
 - Insoluble particles, until cleared from the alveoli, will continue to irradiate surrounding tissue
 - ▷ Most radioisotopes in nuclear weapons, such as plutonium, uranium, radium, and strontium, are insoluble and, when ingested, pass through the gastrointestinal tract unabsorbed
 - ▷ Certain radioactive elements, such as cesium (a potassium analogue) and iodine, are readily absorbed
 - ▷ Avoiding contaminated food by eating only packaged foods significantly decreases internal contamination by this route; infants, with their predilection for placing items in their mouths, must be removed from contaminated areas
 - ▷ Skin is impermeable to most radionuclides, but any element that is in a water-soluble form may pass through; skin is particularly vulnerable to water containing tritium as the hydrogen moiety
 - ▷ Open wounds provide a direct route for absorption
 - Wounds should be carefully examined with an appropriate radiation detector after the surrounding

- skin is cleaned
- Wounds and burns create a portal for any particulate contamination to bypass the epithelial barrier
- Thorough irrigation and cleansing is mandatory to diminish uptake by this route
- ▶ Laboratory findings
 - ▷ Standard radiac instruments (eg, Geiger counter) detect and measure γ radiation; many also detect and measure α and β activity
 - ▷ These instruments are hand held and have a range of several feet
- ▶ Treatment and prophylaxis: mobilizing or chelating agents should be initiated as soon as practical when the probable exposure is judged to be significant
 - ▷ Gastric lavage and emetics can be used to empty the stomach promptly and completely after the ingestion of poisonous materials
 - ▷ Purgatives, laxatives, and enemas can reduce the residence time of radioactive materials in the colon
 - ▷ Ion exchange resins may limit gastrointestinal uptake of ingested or inhaled radionuclides (like Prussian blue)
 - ▷ Ferric ferrocyanide (Prussian blue) and alginates have been used in humans to accelerate fecal excretion of cesium-137
 - The recommended dose of Prussian blue for children is 1 g orally (PO) tid
 - Treatment should continue for a minimum of 30 days
 - ▷ Blocking agents, such as potassium iodide, must be given as soon as possible after radioiodine exposure
 - Neonates: administer 16 mg ($\frac{1}{4}$ of a 65-mg tablet OR $\frac{1}{4}$ mL of the solution; **use caution**, concentrations of potassium iodide solutions vary by manufacturer)
 - 1 month–3 years old: administer 32 mg ($\frac{1}{2}$ tablet OR $\frac{1}{2}$ mL of solution)

- Older children: administer 65 mg (1 mL of solution)
- ▷ Mobilizing agents are more effective the sooner they are given after the exposure to the isotope (see below)
- ▷ Propylthiouracil (PO, 5–7 mg/kg/day divided tid) or methimazole (0.5–0.7 mg/kg/day divided tid) may reduce the thyroid's retention of radioiodine
- ▷ Chelation agents may be used to remove many metals from the body
- ▷ Edetate CALCIUM disodium (CaEDTA), diethylenetriaminepentaacetic acid (DTPA), dimercaprol, and penicillamine can all be used to chelate various heavy metal radioisotopes (seek formal consultation before initiating any of these complex therapies)

Toxicology Consultation

- Available by e-mail at: toxicology.consult@us.army.mil
- Other links to the teleconsultation pages within Army Knowledge Online (www.us.army.mil)
 - Deployed providers briefing (<https://www.us.army.mil/suite/files/19174202>)
 - Case studies (<https://www.us.army.mil/suite/files/19174257>)
 - Reference materials (<https://www.us.army.mil/suite/files/19174300>)

