Chapter 30

Chemical Injuries

The reader is strongly advised to supplement material in this chapter with the following reference:
US Army Medical Research Institute of Chemical Defense (USAMRICD), Chemical Casualty Care Division. *Medical Management of Chemical Casualties Handbook*. 5th ed. Aberdeen Proving Ground, MD: USAMRICD; 2013.

Introduction

The use of chemical agents in modern history includes the use of riot control agents, pulmonary agents (chlorine and phosgene), and vesicants (mustard) during World War I through the use of vesicants (mustard) and nerve agents by Iraq on Iran in the 1980s. The chemical agents most likely to be used today on the battlefield include nerve agents and mustard. However, with the implementation of various types of medical defenses, chemical casualties can be saved and returned to duty, and mortality can be minimized.

Personal Protection

- Prevention!
  - Avoid becoming a casualty.
  - Protect yourself and instruct your personnel to do the same.
- Prevent further injury of the casualty by instructing him/her to put on the protective mask and MOPP (Mission-Oriented Protective Posture) ensemble, and administer self-aid. If contaminated, tell the individual to remove clothing and decontaminate potentially exposed body surfaces.
- Provide buddy aid by masking the individual, administering antidotes, and spot decontaminating exposed body areas.

- Ensure completeness of the decontamination process to the greatest extent possible at the co-located patient decontamination station.
  - Potential for vapor exposure from an off-gassing residual agent or inadvertent contact with undetected liquid is a hazard for medical personnel.
  - Avoid contamination of the medical treatment facility.

Initial Treatment Priorities

- There is no single "best" way to prioritize emergency treatment for chemical or mixed casualties, although respiratory insufficiency and circulatory shock should be treated first. One workable sequence is shown below.

1. **Treat respiratory insufficiency (airway management) and control massive hemorrhage.**
2. **Administer chemical agent antidotes.**
3. **Decontaminate the face (and protective mask if donned).**
4. **Remove contaminated clothing and decontaminate potentially contaminated skin.**
5. **Render emergency care for shock, wounds, and open fractures.**
6. **Administer supportive medical care as resources permit.**
7. **Transport the stabilized patient to a contamination-free (ie, clean) area.**

Specific Chemical Warfare Agents and Treatment Considerations

Nerve Agents

- Tabun (GA), sarin (GB), soman (GD), cyclosarin or cyclohexyl sarin (GF), and methylphosphonothioic acid (VX).
- **General:** Nerve agents are among the most toxic of the known chemical agents. They pose a hazard in both vapor and liquid states, and can cause death in minutes by respiratory obstruction and cardiac failure.
- **Mechanism of action:** Nerve agents are organophosphates that bind with available acetylcholinesterase, permitting a paralyzing accumulation of acetylcholine at the myoneural junction.

- **Signs/symptoms:** Miosis, rhinorrhea, difficulty breathing, loss of consciousness, apnea, seizures, paralysis, and copious secretions.
- **Treatment:** Each deployed US service member has three **Antidote Treatment Nerve Agent Autoinjectors** (ATNAAs) for IM self-injection in a pocket of the protective mask carrier. Each kit delivers 2-mg injections of atropine sulfate and 600 mg pralidoxime chloride (2-PAMC). Each US service member also carries a 10-mg diazepam autoinjector to be administered by a buddy.
  - Immediate IM or IV injection with:
    - Atropine to block muscarinic cholinergic receptors (may require multiple doses in much greater amounts than recommended by Advanced Cardiac Life Support doses).
    - 2-PAMC (if given soon after exposure) to reactivate cholinesterase.
- **Pretreatment:** Military personnel may have also received pretreatment prior to nerve agent exposure. In the late 1990s, the US military fielded pyridostigmine bromide tablets as a pretreatment for nerve agent exposure (this **reversibly** binds to the enzyme acetylcholinesterase, enhancing the efficacy of atropine against soman).

Vesicants

- Sulfur mustard (HD or H), nitrogen mustard (HN), Lewisite (L), and phosgene oxime (CX).
- **General:** The vesicants (blister agents) are cytotoxic alkylating compounds exemplified by the mixture of compounds collectively known as "mustard."
- **Mechanism of action:** Mustard is an alkylating agent that denatures DNA, producing a radiomimetic effect; and produces liquefaction necrosis of the epidermis, severe conjunctivitis, and, if inhaled, injures the laryngeal and tracheobronchial mucosa.
- **Signs/symptoms:** Skin blisters, moderate-to-severe airway injury (presentation can be delayed), conjunctivitis of varying severity that causes the casualty to believe he/she has been blinded, and mucus membrane burns. No delay with Lewisite; immediate burning of the skin and eyes.

- **Treatment:** Preventive and supportive. Immediate decontamination of the casualty has top priority. Agent droplets should be removed as expeditiously as possible by blotting with Reactive Skin Decontamination Lotion (RSDL) or flushing with water or 0.5% hypochlorite. RSDL is extremely effective at inactivating mustard.
  - Most military forces carry a decontamination powder or liquid that should be used immediately to remove the vesicant.
  - Because mustard tends to be an oily solution, water may spread the agent. Dimercaprol is used by some nations in the treatment of Lewisite. Dimercaprol must be used with caution because the drug itself may be toxic.

Lung-Damaging (Choking) Agents

- Phosgene (CG), diphosgene (DP), chloropicrin (PS), and chlorine.
- **General:** Lung-damaging or choking agents produce pronounced irritation of the upper and the lower respiratory tracts. CG smells like freshly mowed hay or grass.
- **Mechanism of action:** CG is absorbed almost exclusively by inhalation. Most of the agent is not systemically distributed, but rather is consumed by reactions occurring at the alveolar–capillary membrane.
- **Signs/symptoms:** CG exposure results in pulmonary edema following a clinically latent period that varies, depending on the intensity of exposure. Immediate eye, nose, and throat irritations may be the first symptoms evident after exposure (choking, coughing, tightness in the chest, and lacrimation). Over the next 2–24 hours, the patient may develop noncardiogenic fatal pulmonary edema.
- **Treatment:**
  - Terminate exposure, force rest, manage airway secretions, oxygen; consider steroids.
  - **Triage considerations** for patients seen within 12 hours after exposure:
    - Immediate care in ICU, if available for patients in pulmonary edema.
    - Delayed: dyspnea without objective signs of pulmonary edema; reassess hourly.

- ♦ Minimal: asymptomatic patient with known exposure.
- ♦ Expectant: patient presents with cyanosis, pulmonary edema, and hypotension. Patients presenting with these symptoms within 6 hours of exposure will not likely survive.

The Cyanogens

- Blood agents: hydrogen cyanide (AC) and cyanogen chloride (CK).
- **General:** AC and CK form highly stable complexes with metalloporphyrins, such as cytochrome oxidase. The term "blood agent" is an antiquated term used at a time when it was not understood that the effect occurs mostly outside of the bloodstream.
- **Mechanism of action:** Cyanide acts by combining with cytochrome oxidase, blocking the electron transport system. As a result, aerobic cellular metabolism comes to a halt.
- **Signs/symptoms:** Seizures, cardiac arrest, and respiratory arrest.
- **Treatment:**
  - o Immediate removal of casualties from the contaminated atmosphere prevents further inhalation.
  - o 100% oxygen.
  - o If cyanide was ingested, perform gastrointestinal lavage and administer activated charcoal.
  - o **Specific antidotal therapy:** Administer sodium nitrite (10 mL of 3% solution IV) over a 3-minute period, followed by sodium thiosulfate (50 mL of 25% solution IV) over a 10-minute period. Sodium nitrite produces methemoglobin that attracts the cyanide; sodium thiosulfate solution combines with the cyanide to form thiocyanate, which is excreted.

Incapacitation Agents

- BZ (3-quinuclidinyl benzilate) and indoles.
- **General:** Heterogeneous group of chemical agents related to atropine, scopolamine, and hyoscyamine that produces temporary disabling conditions with potent CNS effects that seriously impair normal function, but that do not endanger life or cause permanent tissue damage.

- **Signs/symptoms:** Mydriasis, dry mouth, dry skin, increased reflexes, hallucinations, and impaired memory.
- **Treatment:**
  - Immediate removal of firearms and other weapons to ensure safety.
  - Close observation.
  - Physostigmine, 2–3 mg IM every 15 minutes to 1 hour until desired level is attained; maintain with 2–4 mg IV every 1–2 hours for severe cases.

Thickened Agents

- Thickened agents are chemical agents that have been mixed with another substance to increase their **persistency** (persistent agents may remain in the environment more than 24 hours).
- Casualties with thickened nerve agents in wounds are unlikely to survive to reach surgery.
- Thickened mustard has delayed systemic toxicity and can persist in wounds, even when large fragments of cloth have been removed.

Surgical Treatment of Chemical Casualties

- **Wound decontamination—**Initial management of a casualty contaminated by chemical agents will require removal of MOPP gear, as well as initial skin and wound decontamination with available decontaminant before treatment.
  - Bandages are removed, wounds are flushed, and bandages replaced.
  - Tourniquets are replaced with clean tourniquets after decontamination.
  - Splints are thoroughly decontaminated.

Vesicants and nerve agents are potential wound contamination hazards. Cyanogens are so volatile that it is extremely unlikely they would remain in a wound.

Off-Gassing

- The risk of vapor off-gassing from chemically contaminated fragments and cloth in wounds is very low and insignificant.

> Off-gassing from a wound during surgical exploration will be negligible.

Use of RSDL
RSDL inactivates nerve agents and mustard, and can remove an agent that has already begun to penetrate the skin. It is the preferred spot decontaminant for chemical casualties, but is not currently approved for use in eyes or wounds.

WARNING: Concomitant use with bleach may result in an exothermic reaction capable of generating sufficient heat to damage tissue.

Use of Hypochlorite Solution
- Household bleach is 5% sodium hypochlorite; hence, mix 1 part bleach with 9 parts water to create a ~0.5% solution.
- Dilute hypochlorite (0.5%) is an effective skin decontaminant, but the solution is **contraindicated** for use in or on a number of anatomical areas:
  - Eye: may cause corneal injuries.
  - Brain and spinal cord injuries.
  - Peritoneal cavity: May lead to adhesions.
  - Thoracic cavity: Hazard is still unknown, although it may be less of a problem.
- Full strength 5% hypochlorite is used to decontaminate instruments, clothing, sheets, and other inanimate objects.

Wound Exploration and Debridement
Surgeons and assistants should wear well-fitting, thin, butyl rubber gloves or double latex surgical gloves. **Gloves should be changed often** while ascertaining that there are no foreign bodies or thickened agents remaining in the wound.

Wound excision and debridement should be conducted using a no-touch technique. Removed fragments of tissue should be dumped into a container of 5% hypochlorite solution. Superficial wounds should be wiped thoroughly with 0.5% hypochlorite and then irrigated with copious amounts of normal saline.

Following the Surgical Procedure
- Surgical and other instruments that come into contact with possible contamination should be placed in 5% hypochlorite for 10 minutes prior to normal cleansing and sterilization.

- Reusable linen should be checked with the chemical agent monitor, M8 paper, or M9 tape for contamination. Soak contaminated linen in 5% hypochlorite.

For Clinical Practice Guidelines, go to http://usaisr.amedd.army.mil/clinical_practice_guidelines.html