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Chemical terrorism: Rapid recognition and initial medical management

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INTRODUCTION

Potential actions by terrorist groups span the chemical, biological, radiological, nuclear, and high explosive (CBRNE) threat spectrum [1]. This topic provides guidance for the rapid recognition and initial management of patients exposed to the chemical agents that are most likely to be used in warfare or by terrorists.

Bioterrorism and clinical features and treatment of radiation exposure, including exposure cause by acts of nuclear terrorism, are reviewed separately. (See "Identifying and managing casualties of biological terrorism" and "Clinical manifestations, evaluation, and diagnosis of acute radiation exposure" and "Management of radiation injury".)

Planning and preparation for field and medical response to weapons of mass destruction are beyond the scope of this topic but are reviewed elsewhere [2-11].

BACKGROUND

The use of chemical weapons violates current international law and is governed by treaties administered by the United Nations (UN). Since 1997, the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their

Destruction, or Chemical Weapons Convention (CWC), has been in force. The CWC is administered by the Organisation for the Prohibition of Chemical Weapons (OPCW), in The Hague, Netherlands [12].

Despite international prohibitions against the use of chemical weapons, large amounts of various agents remain available in national stockpiles in several countries, and their use against military and civilian populations has been reported as follows:

- Use of nerve and sulfur mustard [H] agents by Iraq against military targets in Iran and Kurdish villages (eg, Halabjah) in northern Iraq [13,14]
- Terrorist use of sarin (GB) and VX by members of the Japanese cult Aum Shinrikyo [15,16]
- Assassinations using the nerve agent VX by the group Aum Shinrikyo [17]
- Improvised explosive devices rigged to release chlorine gas by Iraqi insurgents [18]
- Use of chlorine in barrel bombs in Syria and Iraq [19,20]
- Use of sarin in Ghouta and Khan Shaykun, Syria [21-25]
- Assassination attempts using Novichok [26,27]
- Risk of chemical agent use in Ukraine [28]

In addition, many chemicals that are commonly used for industrial or commercial purposes are not prohibited by the CWC and have the potential for causing mass casualties.

CHEMICAL AGENT DEFINITIONS

Chemical agents capable of causing mass casualties are described by several categories as follows:

- **Traditional chemical weapons** – Traditional chemical weapons refer to known agents that have been stockpiled by nations for use during war and will be the focus of this topic.

  The North Atlantic Treaty Organization (NATO) has assigned a one- to three-character designation (often called a NATO code) to each of the traditional agents; for agents such as VX (O-ethyl S-[2-(diisopropylamino) ethyl] methylphosphonothioate) and BZ (3-

quinuclidinyl benzilate), this code may be more widely used than the chemical name of the compound.

Categories of chemical weapons include [29,30]:

- Pulmonary agents (eg, chlorine or phosgene [GG])
- "Blood" agents (eg, cyanide compounds [AC])
- Vesicants (blister agents such as sulfur mustard [H] compounds)
- Nerve agents (eg, tabun [GA], sarin [GB], soman [GD], VX, and Novichok, including A-series agents [31]):

  In contrast with so-called first-generation chemical agents (used during World War I), nerve agents include:

  - Second-generation agents (the G-series agents developed by Germany before and during World War II) – These are nonpersistent liquids that evaporate relatively quickly.
  - Third-generation agents (V-series agents, developed by the United Kingdom and the United States shortly after the end of World War II) – These are persistent liquids and are more potent than the G agents.
  - Fourth-generation agents (FGAs), developed by the former Soviet Union beginning in the 1970s as "Novichok" agents and including A-series agents – These are even more persistent than V-series agents.

  The onset of the clinical effects of nerve agents depends on the dose, the state or states (mainly vapor versus liquid), and route(s) of exposure (mainly inhalation versus dermal exposure). Skin exposure to liquid Novichok agents is a special case because of the extremely long latent periods (up to two days), the difficulty of treating symptomatic patients [27], and the importance of actions taken during the latent period.

- Incapacitating agents (eg, the anticholinergic agent, BZ [3-quinuclidinyl benzilate, or QNB])

Some compounds, such as chlorine, phosgene, and cyanide, have been used in war and are also used in industry; these are sometimes termed **dual-use** chemicals.

Although arsenicals (eg, arsine, ethyldichloroarsine [ED], methyldichloroarsine [MD] and phenyldichloroarsine [PD]) have characteristics that would make them attractive as a chemical weapon, they are primarily of historic interest and have not been stockpiled to any great degree [32].

- **Crowd-control agents** – The Chemical Weapons Convention (CWC) also regards crowd-control agents, for example OC (ie, oleoresin capsicum) and CS (o-chlorobenzylidene malononitrile), as weaponized chemical agents. The lay term "tear gas" is sometimes used to refer to some or all of these agents but is not an official military term and, in addition, is a misnomer since these agents are all solids at ambient temperatures and are dispersed as aerosols (eg, smokes or sprays) rather than as gases.

- **Binary chemical weapons** – Binary chemical weapons are not separate compounds; instead the term refers to the practice of developing munitions that hold two immediate precursors to a chemical agent in separate compartments divided by a membrane that ruptures when the round is launched. The precursors mix in flight and generate the desired chemical agent.

  The CWC prohibits several important precursors to chemical agents, but given their availability, synthesis of even complex nerve agents is not beyond the reach of those with graduate-level training in chemistry, as the Aum Shinrikyo cult demonstrated with their nerve agent attacks in the Tokyo subway [15,16]. The simpler chemical agents can be synthesized even more easily or, in the case of dual-use agents, simply purchased or stolen.

- **Toxic industrial chemicals** – Toxic industrial chemicals, or TICs, include a variety of industrial chemicals that have the potential for causing mass casualties including hydrogen fluoride, ammonia, formaldehyde, hydrogen sulfide, phosphine, and sulfuric acid [29,33,34].

  However, serious chemical exposure does not require an industrial source. For example, "detergent suicides," the intentional mixing of common household products to produce toxic compounds such as hydrogen cyanide and hydrogen sulfide, demonstrate how easily toxic chemicals can be made using commercially available substances [35].

  In the United States, local resources to identify TICs or dangerous commercial chemicals primarily reside in fire departments. Decontamination procedures and medical management of TIC or dangerous commercial chemical exposure vary according to agent. Resources to assist the clinician are available online. (See 'Additional

resources' below.)

- **Nontraditional agents** – This term refers to newer chemical agents that have been synthesized and weaponized outside the United States [29]. This category is redefined over time; certain A-series nerve agents, for example, used to be in this category but are now considered traditional agents.

- **Mid-spectrum agents** – Mid-spectrum agents are chemical poisons produced by biological organisms (eg, ricin, T-2 mycotoxins, and botulinum toxin) and are also considered chemical agents by the CWC [36,37]. These agents are discussed separately. (See "Identifying and managing casualties of biological terrorism", section on 'Toxins of concern'.)

RECOGNITION OF CHEMICAL EXPOSURE

The algorithm provides a means of rapid recognition of chemical exposure based upon clinical findings (algorithm 1). The table provides suggested decontamination and management according to chemical agent (table 1).

Recognition of chemical exposure can come from features of the exposure, clinical syndromes, and laboratory testing. Of these, laboratory testing of body fluids or tissues takes too long to play more than a confirmatory role in a mass-casualty incident or to document noncompliance with the United Nations Chemical Weapons Convention Treaty [38]. However, preservation of decontamination fluids and samples of blood, urine, hair, and any foreign material taken from patients is an important forensic consideration during care.

Less commonly, announcements by perpetrators may identify the chemical agent, although confirmation of the agent is often necessary to ensure that a chemical exposure has indeed occurred and to verify that the terrorist claims are true.

Features of chemical exposures — Many of the features of chemical exposures potentially overlap with those of exposures to toxins or weaponized biological agents. Presenting features suggesting a chemical exposure include the following (table 2) [39-41]:

- **Timing** – The sudden onset of symptoms within minutes among multiple exposed patients should suggest the use of chemical agents, especially nerve agents or cyanide [40]. By contrast, biologic agents may take many hours to weeks to become apparent. (See "Identifying and managing casualties of biological terrorism".)

However, the latent period (the length of time between exposure and the appearance of signs or symptoms in casualties) may be more on the order of hours for type II pulmonary, sulfur mustard, or BZ agents. As a general rule, the higher the dose of a chemical agent, the shorter the latent period. Also, skin exposures to liquid nerve agents may require several minutes to several hours for the agent to undergo absorption and produce clinically observable effects.

- **Unusual fogs or smokes** – Most chemicals of interest (eg, VX, mustard vapor, phosgene, or chlorine) are heavier than air and stay low to the ground. They may be deployed by an explosive device that causes little or no structural damage. In some instances, the physical characteristics such as odor, taste, or color of the released chemical can help identify it as follows:
  - **Chlorine** – Yellow-green gas with a characteristic chlorine odor [42]
  - **Phosgene** – Colorless gas or white cloud with odor of newly mown or musty hay, grass, or corn [42]
  - **Cyanide** – Odor of bitter almonds (less commonly, of burning rope or of acetylene) (only about 50 percent of people can detect this smell) [42]
  - **Sulfur mustard** – Yellow-brown vapor, yellow liquid, or solid that is odorless or smells like onions, garlic, mustard, or asphalt [43]
  - **Tabun (nerve agent)** – Colorless and tasteless with a slight fruity odor [44]
  - **Sarin (nerve agent)** – Colorless and tasteless, often with a faint fruity odor [44]
  - **Soman (nerve agent)** – Colorless and tasteless with an odor described as sweet, musty, fruity, nutty, or like camphor [44]
  - **VX (nerve agent)** – Amber color, possibly faintly fishy odor, and tasteless [44]
  - **BZ** – Colorless, odorless, and tasteless
  - **Crowd-control agents** – Colorless, odorless, and tasteless in solid form; extremely irritating (bypassing most descriptions of odor) when inhaled in aerosolized form
- **Common clinical findings among multiple patients within a short period of time (minutes to hours)**. (See 'Clinical syndromes' below.)

- **Patients were located near or downwind from the release**.
- **Sentinel case (illness due to an uncommon agent)** – For example, initial casualties with high exposure followed by those exposed to lesser doses or a liquid form of the chemical weapon.
- **Failure to respond to usual therapy** – As an example, patients with exposure to pulmonary agents may have unremitting respiratory failure despite advanced therapies.
- **Unexplained human deaths** – Mass casualties without evidence of trauma suggests a chemical or biological exposure.
- **Unexplained deaths of animals, fish, or plants** – A biological or liquid chemical release may be persistent, although a gas release tends to disperse [40].

Clinical syndromes — The clinical diagnosis of exposure to chemical agents is aided by familiarity with presenting clinical signs and symptoms of chemical weapons exposure and the signs and symptoms that suggest exposure to cholinergic and anticholinergic agents. An algorithm can assist in rapid diagnosis of a chemical weapons exposure (algorithm 1). The table provides suggested decontamination and management according to chemical agent (table 1).

First responders and clinicians must take precautions to protect themselves prior to approaching suspected victims of a chemical weapons exposure and rendering care. (See 'Protection of providers' below and 'Stabilization' below and 'Initial management of specific exposures' below.)

The main toxidromes, or constellations of signs and symptoms that suggest terrorist release of chemical weapons and potential compounds, include the following (algorithm 1) [3,40,41,44]:

- Coma or seizures – Cyanide, hydrogen sulfide, opioids, or, if cholinergic findings are present (eg, miosis, bronchorrhea, wheezing, tearing, vomiting, diarrhea, sweating, fasciculations, or paralysis), nerve agents
- Rapid onset of respiratory distress with eye, nose, or throat irritation – Chlorine or other combination pulmonary agents, type I pulmonary agents (eg, ammonia, other bases, or acids), crowd-control agents, or Lewisite

- Cholinergic findings (eg, miosis, bronchorrhea, wheezing, tearing, vomiting, diarrhea, sweating, fasciculations, or paralysis) – Nerve agents
- Delayed onset of chest tightness and pulmonary edema – Phosgene or other type II pulmonary agents
- Skin erythema, burns, or conjunctivitis – Sulfur mustard agents, phosgene (contact with liquid form), crowd-control agents, hydrogen fluoride, Lewisite
- Disorientation with anticholinergic findings (flushed dry skin, dilated pupils, tachycardia, or hypertension) – BZ
- Rotten-egg odor followed by olfactory paralysis; "knockdown" (sudden collapse); conjunctivitis ("gas eye"); and pulmonary edema – Hydrogen sulfide [45]

By contrast, clinical features consisting of fever, rash, or gastrointestinal bleeding suggest exposure to a biologic agent or toxin (table 2). (See "Identifying and managing casualties of biological terrorism".)

Key questions to answer during a thorough secondary survey in mass-casualty incidents involving chemical agents can be recalled using the mnemonic ASBESTOS as follows:

- **A**: Agent – Is a clinical toxic syndrome (toxidrome) present? What are the results of rapid detection or other features of the release that can identify the exposure? (See 'Rapid detection and ancillary studies' below.)
- **S**: State – Is the chemical exposure caused by a vapor, liquid, aerosol, gas, or combination?
- **B**: Body site of exposure – Was the chemical inhaled, ingested, or dermally absorbed?
- **E**: Effects – What kind of effects are present; local (at or near the body site of exposure), systemic, or both?
- **S**: Severity – How severe is the exposure? What is the severity of the clinical effects?
- **T**: Time course – How long has it been between exposure and onset of symptoms? Is the patient getting worse or better over time?
- **O**: Other diagnoses – What comorbidities does the patient have (eg, asthma)? What is the differential diagnosis for the clinical findings?

- **S**: Synergism – Are there combined effects caused by multiple exposures?

Rapid detection and ancillary studies

Rapid detection — Clues to the identity of a released chemical agent may come from any of the following [46]:

- Announcement by the perpetrators
- Intelligence sources
- Environmental detectors
  - Large-area vapor monitors (eg, M21, Joint Services Lightweight Standoff Chemical Agent Detector)
  - Personal-space vapor monitors (M256A2, ICAD)
  - Liquid detectors (M8 paper, M9 paper)
- Biological sampling of fluid or tissues from those suspected of having been exposed [47]
  - Serum electrolytes, lactate, anion gap, CBC with differential
  - Special tests for specific compounds (usually not fast enough for use in initial treatment; may be useful in later confirmation)
- Clinical suspicion and identification of toxidromes

There are problems inherent in each of these sources; eg, announcements may be deliberately misleading, intelligence may be faulty, false positives and false negatives may be significant with environmental detectors, a given detector may not detect the agent in the state in which it is present, results from laboratory tests may not be definitive or may take too long, and clinical findings may vary for patients with the same exposure.

In many situations, the most reliable initial detector may be clinical recognition of toxidromes. (See 'Clinical syndromes' above.)

Ancillary studies — Patients with significant respiratory distress, regardless of the cause, warrant the following studies:

- Blood gas measurement

- Complete blood count (CBC)
- Chest radiograph

Additional studies obtained in the course of patient care help to confirm the clinical impression and, in some instances, document exposure by a specific agent as follows:

- **Cyanide** (see "Cyanide poisoning", section on 'Laboratory evaluation'):
  - Serum lactate – Elevated
  - Serum electrolytes – Elevated anion gap
  - Arterial and central venous blood gas – Metabolic acidosis, decreased arteriovenous oxygen gradient (usually from a higher-than-usual venous oxygen content)
  - Blood or urine cyanide level – Confirms exposure (rarely if ever available in time to contribute to real-time patient care)
- **Nerve agent** (see "Organophosphate and carbamate poisoning", section on 'Laboratory abnormalities')
  - Decreased red blood cell acetylcholinesterase – Confirms nerve agent exposure and can help guide oxime therapy
  - Decreased pseudocholinesterase – Assists in documenting nerve agent exposure
- **Sulfur mustard** [43]
  - Serial daily CBCs – Leukopenia (typically begins day three to five days after exposure) after an initial leukocytosis
  - Urinary thiodiglycol (investigational) – Elevated
  - DNA and protein adducts (investigational) – Elevated
- **Lewisite** [43]
  - CBC – Hemolytic anemia (large dose exposure)
  - Urinary arsenic – Elevated
  - Urinary 2-chlorovinylarsonous acid (CVAA) (investigational) – Elevated [48]

FIELD INCIDENT RESPONSE

The medical field actions necessary to respond to a chemical terrorism incident are provided in detail by the United States Department of Health and Human Services here. In many civilian jurisdictions, the fire department is in charge of the incident.

Key activities include [49]:

- **Notify local authorities**
- **Establish local on-site incident command**
- **Establish the following control zones and perimeter security**:
  - **Hot zone** – Contaminated area or site of release, entry granted only to properly attired rescuers (first responders)
  - **Warm zone** – Located uphill and upwind of hot zone, this area is designated for decontamination of victims and rescuers (first responders). Personnel performing decontamination and early medical care (first receivers) must be properly attired
  - **Cold (support) zone** – Clean area where victims who are free of external liquid contamination are received and transported to definitive care
- **Ensure protection of first responders and receivers** – Guidelines for personal protective equipment (PPE) to be worn by first responders and first receivers are provided by the United States Occupational Safety and Health Administration.

  Personal protection for first receivers are discussed separately. (See 'Protection of providers' below.)

  For a suspected chemical terrorism incident, first responders who are evacuating victims from the hot zone should wear level A personal protective equipment (PPE) consisting of the following [50]:

  - Positive pressure, full face-piece, self-contained breathing apparatus (SCBA)
  - Fully encapsulating chemical protective suit with suit openings sealed with tape
  - Two pairs of chemical resistant gloves

- Chemical resistant boots with a steel toe and shank
- Hard hat, as needed, based upon conditions
- Disposable protective suit, gloves and boots (may be worn over fully encapsulating suit)

- **Identify chemical hazard** (algorithm 1) (see 'Clinical syndromes' above)
- **Determine extent of threat and affected population**
- **Begin patient triage** – Field triage guidance for chemical casualties and the triage algorithms, Simple Triage and Rapid Treatment (START and JumpSTART) and Sort – Assess – Life Saving Interventions (SALT) are discussed in detail here. Additional considerations specific to triage of victims of chemical exposures are discussed below. (See 'Triage' below and 'Special considerations for chemical events' below.)

HOSPITAL INCIDENT RESPONSE

Upon notification of a chemical weapons release, receiving facilities should secure all entrances and hospital grounds, establish a security perimeter, and set up a decontamination zone that is outside the clean parts of the facility. Disaster plans should be activated. Facility incident command and close communication with local emergency management authorities should be established.

Planning and preparation for field and medical response to weapons of mass destruction are beyond the scope of this topic and are provided elsewhere [2-11].

INITIAL MANAGEMENT OF CHEMICAL EXPOSURES

Protection of providers — Providers responding to release of an unknown chemical should wear personal protective equipment (PPE) designed to protect against the highest possible personal threat. The levels of PPE as designated by the Occupational Safety and Health Administration are available here.

Appropriate personal protective equipment for a chemical terrorism event by provider type and location of care include the following [51-53]:

- **First responders** – First responders who enter the site of an unknown chemical release

(the "hot zone") in order to extract casualties and provide field decontamination adjacent to the site of release: Level A [51]. (See 'Field incident response' above.)

- **First receivers (hospital decontamination zone)** – For receivers performing care in the hospital decontamination zone at facilities that meet best practices for emergency planning: Level C, which consists of the following PPE [52]:
  - Powered air-purifying respirator (PAPR) with protection factor of 1000, and fitted with a combination 99.97 percent high-efficiency particulate air (HEPA)/organic vapor/ acid respirator cartridges (both of these items should be approved by the National Institute of Occupational Safety and Health [NIOSH] or similar agency)
  - Double layer protective gloves
  - Chemical resistant suit with openings taped
  - Head covering and eye and face protection (if not already part of the PAPR)
  - Chemical-protective boots
- **First receivers (hospital post-decontamination zone)** – For receivers performing care in the hospital post-decontamination zone at facilities that meet best practices for emergency planning: normal work clothes and PPE as needed for infection control (eg, gowns, gloves, and/or surgical mask) [52].

Once the chemical agent is identified and proper monitoring of hazard levels is in place, additional guidelines may apply. First responders and medical providers should receive communication as defined in their regional emergency management plan from appropriate personnel in the regional incident command center to ensure ongoing compliance with PPE standards during the event.

Triage — In a mass-casualty incident involving chemical agents, casualties will need to be triaged, or sorted, for medical treatment, decontamination, and transport to medical care or evacuation from the site of release.

The paramount question in triage is, "Who can afford to wait?" Most triage categories were developed for trauma patients; however, the general categories of immediate, delayed, minimal, and, in austere conditions, expectant can be adapted to chemical casualties [54].

General triage approaches vary by jurisdiction and include START (simple triage and rapid treatment), SALT (Sort, Assess, Lifesaving Interventions Treatment/Transport), and SMART

tag systems. However, these algorithms have primarily been developed for triage of traumatic injuries and focus on medical sorting. Of these, only SALT has suggestions for antidote administration in the event of a chemical exposure.

Special considerations for chemical events — Triage systems specific to chemical, biological, radiologic, nuclear, and explosive terrorist events have been developed [54-57]. Although beyond the scope of this topic, training in field triage for chemical terrorism is available through the Chemical Casualty Care Division, United States Army Medical Research Institute of Chemical Defense. (See 'Additional resources' below.)

Field triage guidance for chemical casualties and the triage algorithms, Simple Triage and Rapid Treatment (START and JumpSTART) and Sort – Assess – Life Saving Interventions (SALT) are also discussed here.

Proper field triage of patients exposed to chemical weapons has the following differences from traditional mass casualty field triage:

- Time demands are greater.
- Personal protective equipment is needed and makes verbal communication and tactile examination challenging. (See 'Protection of providers' above.)
- Proper assessment of the type and seriousness of the exposure is more difficult.
- Sorting needs to occur for decontamination and evacuation in addition to medical treatment.

Special aspects of triage of victims of chemical weapons exposure also include:

- Trauma is frequently not present.
- Assessment for chemical toxidromes and prompt administration of properly dosed antidotes optimizes outcomes. (See 'Clinical syndromes' above and 'Antidotes' below.)
- Respiratory failure is a serious threat with many exposures and frequently needs to be addressed in the prehospital setting.
- For quick onset chemicals (eg, nerve agents or cyanide), latent periods before symptoms can be very short (seconds to minutes). Thus lives may be saved or lost in the prehospital setting.

- For other chemicals (eg, phosgene or sulfur mustard), latent periods may be very long and exposure may not be recognized.

Special considerations for triage designation of victims of chemical exposure include the following:

- **Immediate** – Immediate casualties are those who cannot afford to wait more than a couple of minutes and **are** likely to survive with local decontamination, initial medical stabilization, and antidote administration given available resources.

  The agents most likely to result in immediate casualties are cyanide and nerve agents; fast-acting antidotes are available for these agents. (See 'Antidotes' below.)

  Impending airway compromise or respiratory distress also requires triage as immediate.

  In addition, any person with suspicious liquid on the skin must also be considered immediate until prompt (local, spot) decontamination has occurred and the patient is reassessed. (See 'Local or spot decontamination' below.)

- **Delayed** – Delayed casualties can wait up to several hours for medical care although if they need rapid local decontamination and prompt field decontamination, they are immediate until local decontamination has been occurred. These patients can obey commands, are not in respiratory distress, have peripheral pulses and no major hemorrhage **but** do have injuries that are more than minor. Typically, these patients cannot walk without assistance.

  In addition to these criteria, patients with exposure to peripherally acting pulmonary agents, vesicants, BZ, and crowd-control agents are typically classified as delayed with respect to medical treatment.

- **Minimal** – Patients who meet all criteria for delayed care AND have only minor injuries are considered minimal once appropriately decontaminated. These patients are typically able to walk and talk.

  For example, patients who have been exposed to nerve agent vapor but then removed from exposure and whose symptoms are now resolving are considered minimal.

- **Expectant/dead** – Expectant patients are those who are **not** likely to survive given available resources. At the scene of a mass casualty chemical exposure, patients who

are not breathing after control of major hemorrhage, opening of the airway, chest decompression, administration of autoinjector antidotes, and, in children, provision of two rescue breaths are classified as dead. Furthermore, patients who have experienced a respiratory or cardiac arrest or continued seizures despite antidote therapy warrant withholding of medical resources if minimal or scant resources are available and there are large numbers of casualties requiring care and transport [58].

Additional considerations for triage of patients with chemical agent exposure include the following:

- Casualties whose only exposure is to vapor assume a lower priority for thorough patient decontamination than those exposed to liquid.
- When the chemical agent has a long latent period, the sorting of patients for evacuation may be different than for medical treatment. As an example, a patient who develops shortness of breath after only four hours of exposure to phosgene may be delayed for medical stabilization but urgent for transport to a pulmonary intensive care unit.
- Respiratory symptoms occurring less than four hours after exposure to a peripherally acting pulmonary agent or to a vesicant imply a high dose and a guarded prognosis. Although these patients would typically be triaged as delayed, the onset of symptoms so soon after exposure indicates a high dose capable of causing death.
- Following a chemical incident, the ratio of casualties presenting with fears of exposure but without objective evidence of toxicity to casualties with objective evidence of poisoning may be as high as 4 to 1, and considerations must be taken to distinguish between these two groups and ensure timely care of the poisoned patients [59].

Stabilization — Medical assessment and life-saving treatment after a chemical weapons exposure frequently must occur during or prior to field or hospital decontamination to ensure patient survival. During this phase of care, key actions include the following:

- **A: Airway** – Maintain an open airway and, if the patient has traumatic injuries, perform cervical spine stabilization.
- **B: Breathing** – Give oxygen for respiratory distress and, if needed, support breathing with bag-mask ventilation followed by endotracheal intubation. Avoid succinylcholine when performing rapid sequence intubation in patients exposed to nerve gas. (See "Organophosphate and carbamate poisoning", section on 'Initial resuscitation'.)

- **C: Circulation** – Establish intravenous access, obtain initial laboratory studies, and give intravenous antidotes.

- **D: Immediate decontamination** – Stop exposure to the chemical agent; actions include application of a gas mask in the field if assisted breathing is not needed, local or spot decontamination of any suspicious liquid on the skin or in wounds, and removing the patient from the source of exposure. (See 'Local or spot decontamination' below.)

- **D: Drugs** – Administer antidotes, including autoinjector administration of antidotes in the field prior to establishment of intravenous access; for chemical warfare agents, specific antidotes are only available against cyanide compounds, nerve agents, and BZ. (See 'Antidotes' below.)

- **E: Exposure** – Remove clothing and perform definitive decontamination while avoiding hypothermia, especially in infants, children, and older adults.

These steps need not occur in a strictly chronological order (eg, effective ventilation of an apneic nerve-agent casualty may be impossible before administration of sufficient atropine to break nerve-agent-induced bronchospasm) but should be accomplished nearly simultaneously if possible.

Even in the absence of specific antidotes in the field, general stabilization measures as described may, in many cases, permit casualty survival until definitive treatment can be begun. However, maximum survival following exposures to cyanide and nerve agents requires that antidotes be available to appropriately trained first responders in the field as critical life -saving measures during triage of casualties (algorithm 2) [60-62]. (See 'Triage' above.)

Decontamination — Proper decontamination consists of local or spot decontamination of any liquids on the skin, removal of clothing, and copious irrigation of the skin with lukewarm water and, if available, mild soap. Although mass decontamination may be accomplished in the field, decontamination should also occur at receiving hospitals.

This section provides a basic approach to decontamination. However, proper decontamination requires specialized equipment, extensive training of personnel, and close collaboration between hospitals and regional incident command. Proper setup and performance of decontamination are discussed in detail elsewhere [63].

Local or spot decontamination — Local or spot immediate decontamination of skin should be performed during triage and stabilization (algorithm 2). (See 'Stabilization' above.)

The following agents may be used for spot decontamination [3,63,64]:

- **Reactive Skin Decontamination Lotion (RSDL)** – RSDL is specifically formulated to neutralize the toxicity of the liquid nerve agent VX and blister agents such as sulfur mustard and Lewisite. It acts within seconds of being applied to the skin and is the preferred spot decontamination method for victims of a chemical attack [63,65]. The lotion is packaged on a foam applicator inside a single use pouch. The lotion is applied within three minutes of contamination and rubbed gently on the skin for two minutes, and the nontoxic residue is washed away at a later time (picture 1). Although reasonable to perform, application of RSDL to wounds is considered off label use. Application of RSDL to the eyes is not recommended.

- **Other topical absorbents** – If RSDL is not available, porous material such as activated charcoal, Fuller's earth, clay, tissue paper, flour, or bread, although less effective, may be applied to areas of contaminated skin to adsorb agent followed by irrigation. If an adsorbent is not available, irrigation alone should be performed.

- **Irrigation** – If RSDL is not available, any available adsorbent material (towels, tissue paper, charcoal, bread, clay-rich soil, etc) should be applied, allowed to remain on the skin for 30 seconds to two minutes, and removed by wiping, flushing with water, or (preferably) gentle but thorough washing with soap and water. A dilute bleach solution (0.5 percent hypochlorite, made by mixing one part standard household bleach with nine parts water) may also be used followed by rinsing with plain water. The use of straight bleach (5 percent hypochlorite or greater) is to be discouraged because of potential damage to the skin that may cause increased absorption of the chemical agent. For oily agents, such as sulfur mustard and VX, water plus a mild soap may be more effective than water alone.

Because many chemical agents start damaging or penetrating skin within a couple of minutes of exposure, the importance of immediate decontamination cannot be overemphasized. However, delayed decontamination, even if too late to prevent skin effects such as blistering from vesicants, may prevent continued absorption of the substance and the accumulation of a lethal internal dose [66].

Field decontamination — Mass decontamination is an important aspect of field incident response and often consists of stations for disrobing followed by showering or assisted decontamination. However, in civilian settings, patients might bypass field decontamination stations and report directly to medical facilities for care. Thus, receiving facilities should still

perform definitive decontamination of all exposed patients prior to bringing them into clean areas to avoid contamination. (See 'Field incident response' above.)

The proper setup and performance of field decontamination are discussed in detail elsewhere [63]. Training is available to qualified providers in the United States under the auspices of the Chemical Casualty Care Division of the United States Army Medical Research Institute of Chemical Defense (USAMRICD), Army Chemical Defense. (See 'Additional resources' below.)

Hospital decontamination — Chemical decontamination consists of removal of all clothing and thorough washing of the skin and hair with lukewarm water and soap **before** the patient is brought into the clean area of the emergency department or other parts of the hospital.

Important considerations include [63]:

- Persons performing chemical decontamination at first receiving facilities should wear Level C personal protective equipment (PPE). (See 'Protection of providers' above.)
- Providers assisting with decontamination should ensure that cleansing of the skin does not cause open wounds.
- Water temperature should be controlled so that hypothermia is avoided, especially in infants, children, and older adults.
- Once chemical decontamination has occurred, the patient should be dried, dressed in clean hospital gowns, and escorted or transported into the clean zone of the emergency department.

During chemical decontamination, medical stabilization and treatment may be necessary, particularly for victims exposed to cyanide or nerve agents. Thus, decontamination areas should have supplies and medications necessary to provide initial stabilization while decontamination is performed and medical personnel are outfitted in Level C PPE.

Contaminated patients should **not** be brought into clean areas of receiving facilities (hospitals and emergency departments) because they can sicken staff and contaminate the facility, thereby reducing the capacity of the health care system to respond to the chemical incident [67]. Such patients should be kept outside and undergo decontamination before being brought into the hospital. A security perimeter and lock down of the receiving facility are key actions to prevent inadvertent contamination by such patients.

However, some patients may require emergency medical stabilization before thorough decontamination (see 'Stabilization' above). A complete plan responds to this need by mandating the establishment of an emergency medical treatment station in the "dirty" area after triage but before thorough decontamination.

Each hospital should have a management plan that maximizes the efficiency and efficacy of decontamination. Proposed concept of operations for health care facilities is discussed in detail elsewhere [68].

Important aspects of such planning include [68]:

- Establishment of a designated fixed or rapidly deployed decontamination facility
- Proper training of staff in the donning and removal of Level C PPE
- Triage plan for contaminated patients that separates them into medical and nonmedical decontamination
- Decontamination procedures that maintain privacy and avoid hypothermia
- Secondary triage after decontamination
- Assurance of adequate personnel and supplies to perform simultaneous medical stabilization and chemical decontamination

Initial management of specific exposures — The table provides the mechanism of action, clinical findings, recommended decontamination, and management for chemical weapons exposures (table 1).

Antidotes — Antidotes are available for chemical exposure to nerve agents, cyanide compounds, and BZ. Dosing below is based upon recommendations provided by the United States Department of Health and Human Services [69]. Based upon animal studies, all nerve agent antidotes appear to have bioavailability after intraosseous (IO) administration that is equivalent to intravenous (IV) administration [70]. Thus, the IO route is an option for nerve agent antidote administration, although in a mass casualty situation, IM administration permits more rapid treatment of a greater number of casualties.

Nerve agents — Various autoinjectors are available for the rapid intramuscular (IM) administration of nerve agent antidotes including the following:

- **Mark I kit** (no longer manufactured) – One atropine 2 mg and one pralidoxime 600 mg

autoinjector. Atropine should always be given first.

- **Duodote** – One autoinjector that administers atropine 2 mg with pralidoxime 600 mg simultaneously.
- **Antidote Treatment-Nerve Agent, Autoinjector (ATNAA)** – One autoinjector that administers atropine 2.1 mg and pralidoxime 600 mg simultaneously.
- **Convulsive Antidote, Nerve Agent (CANA)** – One autoinjector containing diazepam 10 mg.

In addition, studies of a midazolam autoinjector to treat children and adults with seizures caused by nerve agents have been funded by the United States Department of Health and Human Services [71]. Midazolam is more rapidly absorbed after intramuscular administration than is diazepam.

Medical personnel should be familiar with the contents and operation of the autoinjector that they will use. Many jurisdictions have stockpiles of nerve agent autoinjectors available for rapid deployment in the event of a nerve agent release. Availability of such stockpiles is essential to an effective response because just one patient with moderate or severe effects of nerve agent exposure can rapidly deplete typical hospital stocks of atropine and pralidoxime.

The correct use of autoinjectors is described here.

Treat adults, including pregnant women, with atropine, pralidoxime, and benzodiazepines based upon clinical effects as follows [72]:

- **Mild effects** – Only selected adults with mild clinical effects warrant treatment as follows:
  - Miosis alone with no respiratory symptoms – No antidote.
  - Miosis and severe rhinorrhea – Atropine 0.05 mg/kg IV, IM, IO (adult maximum 2 mg per dose or one atropine autoinjector containing 2 mg atropine).
  - Do **not** give pralidoxime or benzodiazepines.
- **Moderate effects** – For adults with mild effects **plus** moderate respiratory distress, nausea and vomiting, weakness, and/or muscle fasciculations give the following:
  - Atropine 0.05 mg/kg IV, IM, IO (adult maximum 4 mg per dose or two atropine 2 mg

autoinjectors); double the initial dose and repeat every two to five minutes as needed to control bronchial secretions or bronchospasm and permit ventilation.

- Pralidoxime 25 mg/kg IV, IO, or IM (adult maximum single dose 1 g IV; 2 g IM or two pralidoxime 600 mg autoinjectors) with or after atropine, may repeat within 30 to 60 minutes as needed up to a total dose of 45 mg/kg, then again every 12 hours for up to two doses as needed for persistent weakness or high atropine requirement; continuous infusion may be needed to control severe muscarinic symptoms.

  Pralidoxime is initially reconstituted to 50 mg/mL (1 g in 20 mL sterile water) for IV or IO administration, and the total dose infused over 30 minutes, or it may be given by continuous infusion (loading dose 25 mg/kg over 30 minutes, then 10 mg/kg per hour).

- Do **not** give benzodiazepines.

- **Severe effects** – For adults with moderate effects **plus** coma, seizures, apnea, or paralysis (or for anyone with (a) significant respiratory distress or (b) systemic effects), give the following:

  - Atropine 0.1 mg/kg IM only (adult maximum 6 mg per dose or three atropine 2 mg autoinjectors).

  - Scopolamine adult dose: 1 mg IM, IV, or via inhalation as a single dose with the initial dose of atropine.

    Pediatric dosing (based upon preoperative parenteral dosing):

    - Children 6 months to 3 years: 0.15 mg IM, IV, or via inhalation as a single dose with the initial dose of atropine.
    - Children over 3 to 6 years: 0.3 mg IM, IV, or via inhalation as a single dose with the initial dose of atropine.
    - Children over 6 years of age to puberty: 0.6 mg IM, IV, or via inhalation as a single dose with the initial dose of atropine.

    Scopolamine is a tropane alkaloid that penetrates the CNS at lower doses than atropine. Based upon animal models, when given early enough, it can prevent nerve-agent-associated seizures and may be synergistic with atropine for the treatment of muscarinic symptoms [73-75]. It does **not** replace atropine (which is still useful in treating muscarinic effects outside the CNS), but even a small dose of

scopolamine can significantly reduce the total dose of atropine needed to treat a nerve-agent casualty and permit conservation of atropine during a large chemical event.

Although optimal dosing of scopolamine after nerve agent exposure in humans is unknown, the suggested single adult dose of 1 mg is chosen to conserve atropine while avoiding delirium. This dose is conservative given that, in healthy unexposed adults, delirium may occur at parenteral scopolamine doses of ≥1.5 mg.

Scopolamine is currently not widely available in the United States and is not approved by the US Food and Drug Administration (FDA) for nerve agent exposure, although when available it could be given off label where a physician-patient relationship exists.

- Pralidoxime 45 mg/kg IV, IO, or IM (adult maximum single dose 2 g IV and 2 g IM or three pralidoxime 600 mg autoinjectors) with or after atropine. May repeat after 60 minutes as needed up to 2 g IV, then again every 12 hours for up to two doses as needed for persistent weakness or high atropine requirement; continuous infusion may be needed to control severe muscarinic symptoms.

- Benzodiazepines, options include:

  Diazepam 0.3 mg/kg (maximum 10 mg) IV, IO OR lorazepam: 0.1 mg/kg IV, IO, IM (maximum 4 mg) OR midazolam: 0.2 mg/kg (maximum 10 mg) IM OR two to three diazepam 10 mg (convulsive antidote, nerve agent [CANA]) autoinjectors.

- **Dosing in infants and children** – When possible, weight-based dosing should be given to children up to the adult maximum doses described above and according to clinical effects.

  For children with severe, life-threatening nerve agent toxicity who lack intravenous access, and for whom more precise mg/kg IM dosing would be logistically impossible, suggested autoinjector dosing guidelines for atropine, pralidoxime, and valium by weight are as follows [69]:

  - **≤25 kg** – One atropine 2 mg and pralidoxime 600 mg autoinjector; IM valium 5 mg (do not use autoinjector)

  - **26 to 50 kg** – Two atropine 2 mg and two 600 mg pralidoxime autoinjectors and one valium 10 mg autoinjector

- **≥50 kg** – Three atropine 2 mg, three pralidoxime 600 mg, and two to three valium 10 mg autoinjectors

- **Dosing in older adults** – Dosing should be adjusted in frail older patients as follows:
  - **Mild effects** – Atropine (maximum dose 1 mg or one atropine 1 mg autoinjector)
  - **Moderate effects** – Atropine as for mild effects; pralidoxime 10 mg/kg IM or one pralidoxime 600 mg autoinjector
  - **Severe effects** – Atropine 2 to 4 mg (one or two atropine 2 mg autoinjectors); Pralidoxime 25 mg/kg (two to three pralidoxime 600 mg autoinjectors; and valium 5 to 10 mg every 15 minutes (total maximum dose 25 mg) or two valium 10 mg autoinjectors

- **Management of liquid exposure to Novichok** – Individuals with skin exposure to liquid Novichok can be very difficult to treat once they become symptomatic [27,31], but the long latent periods (up to two days) following this kind of exposure present a unique opportunity for presymptomatic management. Those who may have been exposed in this manner need to be identified, sequestered, and decontaminated by showering and with reactive skin decontamination lotion (RSDL). Cholinesterase monitoring should begin, and the Chemical Casualty Care Division of the United States Army Medical Research Institute of Chemical Defense (USAMRICD) should be contacted. Specialized consultative advice can be found at USAMRICD. (See 'Additional resources' below.)

Cyanide — Availability of treatment varies by region and hospital. Immediately below is a series of antidotal management recommendations, based upon treatment availability, for patients with **probable** cyanide exposure (see "Cyanide poisoning", section on 'Suspected cyanide intoxication'):

- For patients where hydroxocobalamin is available, it is administered as follows:
  - Hydroxocobalamin 70 mg/kg IV over 15 minutes (15 mL/minute) (5 g is the standard and maximum adult dose). The Cyanokit contains 2.5 g (one reconstituted vial). In patients <40 kg, the initial dose may be repeated once, but total dose should not exceed 5 g (two vials).

- For patients without contraindication to nitrites (eg, carbon monoxide toxicity), and where hydroxocobalamin is not available, use combinations of amyl nitrite and sodium

nitrite to induce methemoglobinemia, and sodium thiosulfate to act as a sulfur donor as follows:

- Amyl nitrite inhaled by the patient (held under the patient's nose or via the endotracheal tube) for 30 seconds of each minute, for three minutes
- Sodium nitrite 10 mg/kg IV **AND**
- Sodium thiosulfate (25 percent) 1.65 mL/kg IV (maximum dose 12.5 g)

- Where 4-dimethylaminophenol (4-DMAP) or dicobalt edetate is available, they are options **only** when other antidotes are **not** available, but should only be given after consultation with local critical care, military and/or toxicology experts. They are only for parenteral, not intramuscular, administration.

BZ (3-quinuclidinyl benzilate) — Most patients with anticholinergic toxicity do well with supportive care alone, but some may benefit from antidotal therapy with physostigmine. One approach is as follows (see "Anticholinergic poisoning", section on 'Antidotal therapy with physostigmine for severe toxicity'):

- Consider treating mild to moderate agitation with benzodiazepines alone (eg, lorazepam), although physostigmine is more effective for this purpose than are benzodiazepines; **do not** use phenothiazines or butyrophenones (eg, haloperidol).
- Patients who manifest **both peripheral** (eg, dilated pupils, dry mouth, and/or flushing) **AND moderate central** (moderate to severe agitation/delirium or seizures) anticholinergic toxicity **without contraindications** to physostigmine (eg, widened QRS on electrocardiogram) should receive the following dose: 0.5 to 2 mg (0.02 mg/kg IV, up to a maximum of 0.5 mg per dose in pediatric patients); physostigmine should be given by slow IV infusion, generally over five minutes. Benzodiazepines (eg, lorazepam) may also be administered as needed for seizures.

Because physostigmine is uncommonly used and unfamiliar to many clinicians, it is best given after consultation with a medical toxicologist or regional poison center, if possible. In the United States, call 1-800-222-1222 to be connected to the nearest poison control center. Contact information for poison centers around the world is provided separately. (See 'Additional resources' below.)

Crowd-control agents — Most patients who have been exposed to crowd-control agents such as OC (oleoresin capsicum, pepper spray), CS (o-chlorobenzylidene malononitrile), and

CN (mace) have mild effects and do well with removal from exposure and supportive care as needed. However, serious ocular and respiratory effects can occur [76-79]. Skin blisters from irritant or allergic contact dermatitis can result in 12 hours to a week after exposure if decontamination is delayed or incomplete [80]. Allergic contact dermatitis and tracheobronchitis may also occur with repeated exposure to CS [81].

Risk factors for serious injury include exposure in an enclosed space, underlying pulmonary disease (eg, asthma or chronic obstructive pulmonary disease), and delivery by projectile mechanisms. Since these compounds are solids, and since one method of dispersion is their forceful ejection from canisters, ocular effects can include impaction of particles in the cornea. High doses (high concentrations and high durations of exposure) in confined spaces can lead to pulmonary edema and fatal acute lung injury.

There is no antidote for these agents. Treatment begins with removal from exposure. Contact lenses should be removed before eye irrigation. The clinician should perform copious irrigation of eyes and skin with water or normal saline. Inform the patient that transient worsening of pain with water or saline is normal. Hypochlorite (bleach) solutions, which can cause additional skin damage and, in the case of CS (o-chlorobenzylidene malononitrile), can generate toxic epoxides, are contraindicated.

Symptomatic management is as follows (table 1) [76,82]:

- Respiratory distress – If respiratory symptoms do not resolve with removal from exposure and fresh air, patients should receive supplemental oxygen (humidified, if available). Further care is determined by the presence of upper or lower airway findings:
  - Upper airway (stridor, drooling, hoarseness, or laryngospasm):
    - Inhaled racemic epinephrine for stridor or upper airway obstruction
    - Pulmonary toilet (frequent suctioning)
    - Bronchoscopy for severe upper airway obstruction
  - Lower airway (wheezing):
    - Inhaled short-acting beta-2 agonists (eg, albuterol)
    - Systemic corticosteroids (eg, oral prednisolone or dexamethasone, or intravenous prednisolone)

- Eye exposure – Patients with significant eye pain, tearing, and blepharospasm warrant the following treatment:
  - If no signs of penetrating or serious blunt eye injury, provide topical ophthalmic anesthetic (eg, proparacaine 0.5 percent, one drop to each eye)
  - Perform irrigation for at least 20 minutes with fresh water or normal saline (see "Topical chemical burns: Initial assessment and management", section on 'Eye exposure')
  - Perform a complete ocular examination, including fluorescein staining to identify corneal abrasions or other injuries to the eye (see "Approach to diagnosis and initial treatment of eye injuries in the emergency department")

ADDITIONAL RESOURCES

The following resources provide a means of rapid notification of a chemical weapons attack within the United States and access to specific medical guidance and consultation:

- **Emergency Federal Hotline** (United States) – Federal chemical and biological hotline (US Government Response Center): 1-800-424-8802
- **Chemical Hazards Emergency Medical Management (CHEMM)** – An interactive online and downloadable clinical guide.
- **Centers for Disease Control and Prevention** – The physician's telephone line is (404) 639-3311. The CDC also provides a website that addresses all hazards preparedness and medical care, including both bioterrorism and chemical terrorism.
- **Army Chemical Defense** – The United States Army Medical Research Institute of Chemical Defense (USAMRICD), at Aberdeen Proving Ground, Maryland is an important source of current research and clinical data and consultation concerning the medical response to chemical-warfare agents.

  The Chemical Casualty Care Division (CCCD; 410-436-2230) is the USAMRICD division responsible for training, education, and clinical consultation. The CCCD provides comprehensive courses, a variety of training materials, and consultative services.

  The United States Army also has developed clinical practice guidelines for initial response and medical management of chemical, biological, and radiological nuclear

injury.

- **US Food and Drug Administration (FDA)** – The FDA has an excellent counterterrorism website that provides up-to-date information on antidotes for chemical agents, including pediatric dosing as it is validated. The main telephone number for the drug center at the FDA is (301) 594-5400, in Rockville Maryland. The Chemical and Bioterrorism Office at the FDA is located in CDER (Center for Drug Evaluation and Research). The telephone number for the FDA counterterrorism office is (301) 827-7777.

- **Chemical biological incident response force** – Following the 1995 Tokyo subway attack, the United States Marine Corps formed the Chemical Biological Incident Response Force (CBIRF) based near Washington, DC [83]. The CBIRF will deploy anywhere in the United States and provide capabilities for agent detection and identification, casualty search and rescue, personnel decontamination, and emergency care and stabilization of contaminated personnel. They can decontaminate 200 casualties per hour, and they have been trained and equipped to identify 120,000 toxic industrial chemicals. The CBIRF can be requested by local, state, or federal agencies. Contact information is available here.

- **American Academy of Pediatrics (AAP)** – Pediatric considerations during a chemical terrorism event are discussed in a technical report from the AAP [84].

Regional poison control centers — Regional poison control centers in the United States are available at all times for consultation on patients with known or suspected poisoning, and who may be critically ill, require admission, or have clinical pictures that are unclear (1-800-222-1222). In addition, some hospitals have medical toxicologists available for bedside consultation. Whenever available, these are invaluable resources to help in the diagnosis and management of ingestions or overdoses. Contact information for poison centers around the world is provided separately. (See "Society guideline links: Regional poison control centers".)

Society guideline links — Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Chemical terrorism".)

SUMMARY AND RECOMMENDATIONS

- **Chemical agent definitions** – Chemical compounds capable of creating mass

casualties include (see 'Chemical agent definitions' above):

- Traditional chemical agents (pulmonary agents, "blood" agents [cyanide compounds], vesicants [blister agents], nerve agents, and the anticholinergic agent BZ)
- Nontraditional agents
- Toxic industrial chemicals (TICs)
- Crowd-control agents
- Mid-spectrum agents (biological toxins) (see "Identifying and managing casualties of biological terrorism", section on 'Toxins of concern')

- **Recognition of chemical exposure** – Recognition of a chemical weapons release is based upon the following (see 'Recognition of chemical exposure' above):
  - Incident features that suggest a chemical exposure (table 2)
  - Clinical syndromes among casualties (algorithm 1)
  - Confirmation using rapid detection methods and clinical laboratory studies
- **Field incident response and decontamination** – Key medical actions in the field include protection of first responders (Level A personal protection equipment [PPE] as defined by OSHA [https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.120AppB.]) patient triage, spot decontamination, administration of antidotes to victims of suspected cyanide or nerve gas exposure (algorithm 2), and field decontamination. (See 'Field incident response' above and 'Local or spot decontamination' above and 'Field decontamination' above.)
- **Hospital incident response** – Upon identification or notification of a chemical weapons release, receiving facilities should secure all entrances and hospital grounds, establish a security perimeter, and set up a decontamination zone that is outside the clean parts of the facility. Disaster plans should be activated. Facility incident command and close communication with local emergency management authorities should be established. (See 'Hospital incident response' above.)
- **Initial management** – Initial hospital management of patients with chemical weapons exposure warrants the following actions:

- Protection of first receivers prior to decontamination (Level C PPE as defined by OSHA [https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.120AppB]) (see 'Protection of providers' above)
- Triage with immediate stabilization of airway, breathing, and circulation and, for victims of cyanide or nerve agent exposure, antidote administration (see 'Triage' above and 'Stabilization' above and 'Antidotes' above)
- Spot decontamination (see 'Local or spot decontamination' above)
- Definitive decontamination based upon the specific exposure (table 1) (see 'Hospital decontamination' above)
- Agent-specific medical care and administration of antidotes (table 1) (see 'Initial management of specific exposures' above and 'Antidotes' above)

- **Additional resources** – Several online resources provide additional information on the response to a chemical weapons release including access to specific medical guidance and consultation. (See 'Additional resources' above.)

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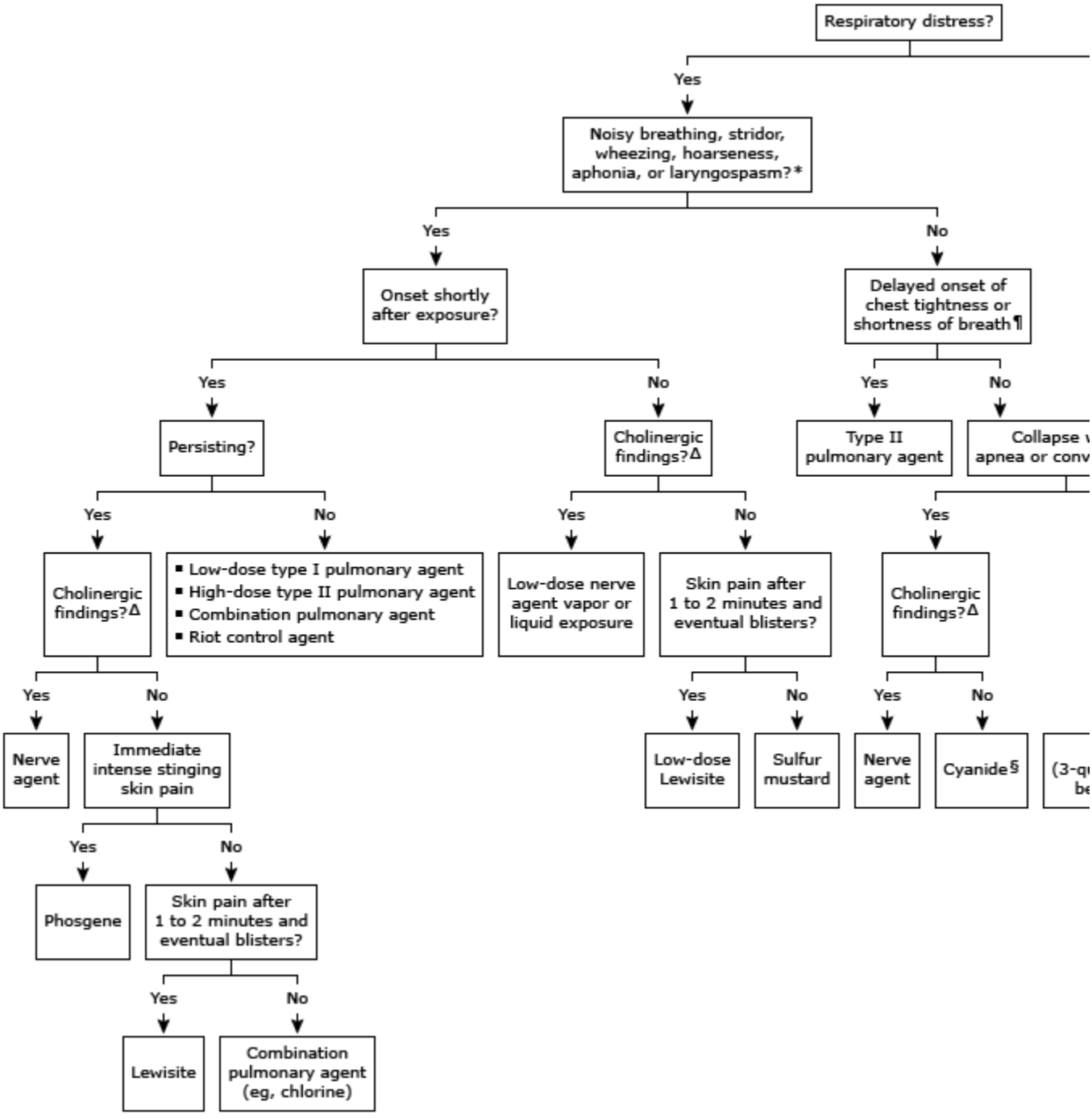
Topic 2020 Version 55.0

GRAPHICS

Algorithm for the clinical diagnosis of a chemical weapons exposure



* Signs of upper airway (central compartment) irritation consistent with type I (eg, hydrogen chloride or combination (eg, chlorine) pulmonary agent exposure.

¶ Signs of pulmonary edema (peripheral compartment) suggesting type II pulmonary agent exposure (e

Δ For example, miosis, nausea, vomiting, diarrhea, bronchorrhea, sweating, twitching, fasciculations, we

◇ For example, dilated pupils, dry mouth, flushing, dry skin, tachycardia, delirium, hallucinations.

§ May also have flushed skin and normal or dilated pupils.

Graphic 90159 Version 5.0

Recognition and initial treatment of chemical weapons exposure

Chemical	Mechanism of action	Clinical findings	Decontamination*
Nerve agents: ▪ Tabun (GA) ▪ Sarin (GB) ▪ Soman (GD) ▪ Cyclosarin (GF) ▪ VX (O-ethyl S-[2-(diisopropylamino)ethyl] methylphosphonothioate)	Anticholinesterase: Muscarinic, nicotinic and CNS effects	Cholinergic crisis◇ with either: a) Sudden collapse, coma, apnea, and convulsions OR b) Progression from local effects (see below) to generalized systemic effects (fasciculations, coma, seizures, paralysis): ▪ Local effects from vapor inhalation: Miosis, rhinorrhea, salivation, difficulty breathing ▪ Local effects from liquid on skin: Local sweating, twitching, and fasciculations	Vapor: ▪ Move to fresh air ▪ Remove clothes ▪ Wash hair Liquid: ▪ Remove clothes ▪ Use Reactive Skin Decontamination Liquid for spot decontamination ▪ Irrigate skin with water or soapy water ▪ Irrigate eyes and wounds with sterile saline or water
Cyanide (AC)	Cytochrome oxidase inhibition: Cellular anoxia, lactic acidosis	▪ Tachypnea ▪ Coma ▪ Seizures ▪ Apnea	Fresh air Skin: Soap and wat‡er

Pulmonary, type I (central, eg, hydrogen chloride, hydrogen fluoride) or combination agents (eg, chlorine)	Type I: Various mechanisms causing irritation (including irritative laryngospasm) and partial to total airway obstruction Combination: In addition to type I, various reactions causing fluid leakage and pulmonary edema	Type I: ▪ Airway noise (coughing, sneezing, hoarseness, inspiratory stridor, wheezing) ▪ Irritation of eyes, nose, and throat ▪ Irritative laryngospasm Combination: ▪ Type I findings ▪ Delayed onset chest tightness or shortness of breath	Fresh air Skin: Irrigate with water
Type II pulmonary agents (eg, phosgene [GG]) or combination agents (eg, chlorine)	Type II: Various reactions causing fluid leakage and pulmonary edema	Delayed onset chest tightness and shortness of breath Combination, rapid	Fresh air Skin: Irrigate with water

	Combination: In addition to type II effects, various mechanisms causing irritation (including irritative laryngospasm) and partial to total airway obstruction	onset of : ▪ Airway noise(coughing, sneezing, hoarseness, inspiratory stridor, wheezing) ▪ Irritation of eyes, nose, and throat ▪ Irritative laryngospasm	
Crowd-control agents: ▪ CS (o-chlorobenzylidene malononitrile) ▪ CN (mace) ▪ OC (oleoresin capsicum, pepper spray)	Alkylation Release of substance P (OC)	Eye: Tearing, pain, blepharospasm Nose and throat irritation Type I pulmonary effects if very concentrated exposure Bronchospasm	Fresh air Skin: Flush with water or soapy water Eye: Water or normal saline irrigation Avoid bleach

Mustard compounds (eg, sulfur mustard [H])	Alkylation	Skin: Erythema, vesicles Eye: Inflammation Respiratory tract: Inflammation	Skin: Soap and water Eyes: Water (only effective if done within minutes of exposure)
Lewisite (L)		Skin: Erythema, vesicles Eye: Inflammation Respiratory tract: Inflammation	Skin: Soap and water Eyes: Water (only effective if done within minutes of exposure)
BZ (3-quinuclidinyl benzilate)	Competitive antagonism of acetylcholine at muscarinic receptors	Anticholinergic effects: ▪ Peripheral: • Dilated pupils • Dry mouth • Flushed skin • Tachycardia • Hypertension • Absent bowel sounds • Urinary retention ▪ Central: • Delirium	Irrigate skin with water or soapy water

		• Seizures	

CNS: central nervous system.

* Decontamination, especially for patients with significant nerve agent or vesicant exposure, should be performed by health care providers wearing adequate personal protective equipment. For first receiving facilities (eg, hospital emergency departments), this consists of nonencapsulated, chemically-resistant body suit, boots, and gloves with a full-face air purifier mask/hood. Refer to UpToDate topics on chemical weapons for more information regarding the proper performance of decontamination of chemically exposed patients.

Δ Emergent supportive of chemical exposures should always include the ABCDDs: Airway, Breathing, Circulation, immediate Decontamination (meaning immediate local, or spot decontamination of any suspicious liquid on the skin or in wounds), and Drugs (including specific antidotes).

◇ Signs of cholinergic crisis include miosis, bronchorrhea with wheezing, copious salivation, lacrimation, diaphoresis, vomiting, and diarrhea.

§ Intraosseous route is likely equivalent to intravenous for administration of antidotes. Refer to UpToDate topics on intraosseous infusion.

¥ Inhaled ipratropium bromide (500 mcg inhaled, may repeat once) may complement parenteral atropine administration for the treatment of bronchospasm. ‡Administration of scopolamine may help preserve atropine in the setting of large numbers of patients with severe nerve gas exposure. For scopolamine dosing refer to UpToDate topics on chemical terrorism.

† High flow nasal cannula and noninvasive positive pressure ventilation should be avoided in patients with upper airway obstruction after combination agent (eg, chlorine) exposure.

Graphic 90716 Version 10.0

Clinical findings of chemical and biological terrorist agent exposure

	Chemical agent	Toxins	Biologic agents
Timing of symptoms	Often rapid onset (minutes to days)*	Delayed (hours to days)	Delayed (days to weeks)
Unusual fog or smoke	Not necessarily*	No	No
Multiple simultaneous victims with similar symptoms	Common, geographically concentrated	Common, geographically concentrated	Less likely, may be geographically dispersed
Fever	No	No	Yes
Respiratory distress	Often	Often	Often
Rash	No	Rare	Frequent
Vesicles	Sulfur mustard, Lewisite, and, less commonly, riot-control agents	T-2 exposure only	Some agents
Bleeding	Uncommon	Some cases	Many agents
Neuromuscular effects (eg, seizures, weakness)	Cyanide or nerve agents	Botulinum exposure	No
Failure to respond to typical therapy	Depends upon severity of exposure¶	Sometimes$^{\Delta}$	Yes (eg, multi-antibiotic resistant organisms)
Unexplained human deaths	Yes	Yes	Yes
Unexplained deaths of animals, fish, or plants	Yes	Yes	Yes

* Exposure to some liquid forms of chemical weapons may take many hours to be absorbed and cause symptoms. Morever, chemical vapors may be invisible.

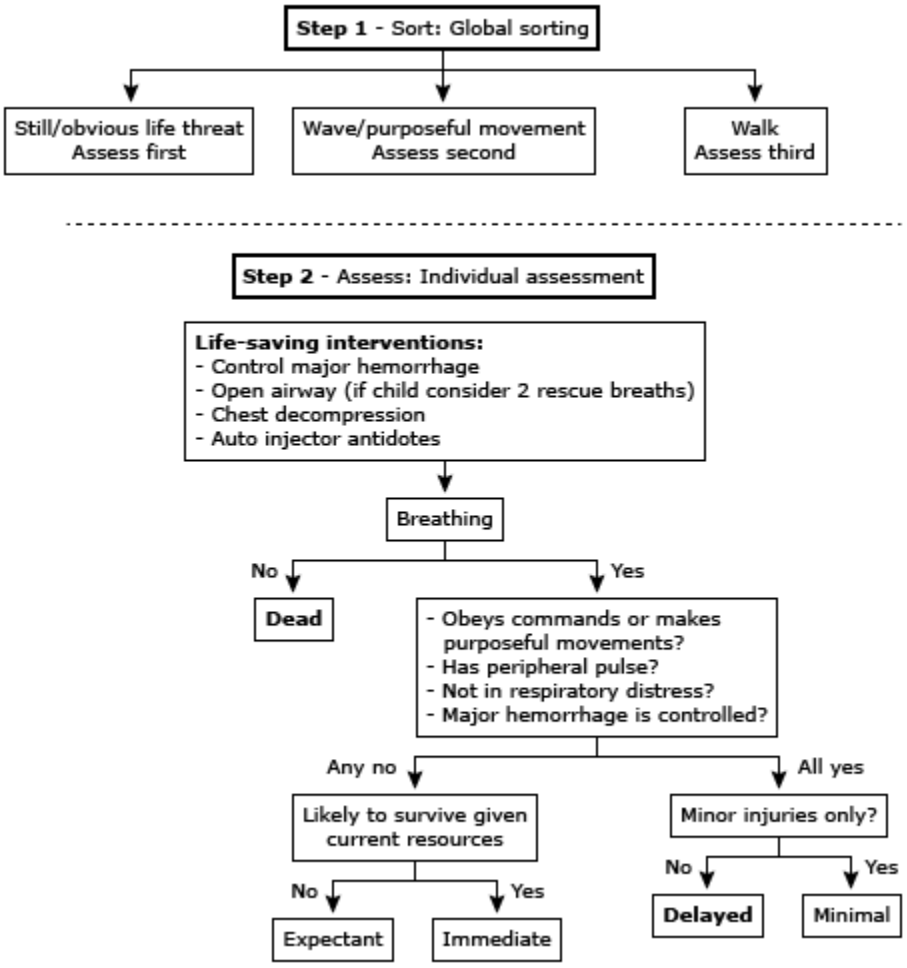
¶ For example, victims exposed to pulmonary agents may have unremitting respiratory failure despite the use of advanced therapies.

Δ For many toxins, therapy is mainly supportive and may be ineffective if the dose is high or recognition has been delayed.

Data from: Madsen JM. Toxins as weapons of mass destruction. A comparison and contrast with biological-warfare and chemical-warfare agents. Clin Lab Med 2001; 21:593.

Graphic 90149 Version 5.0

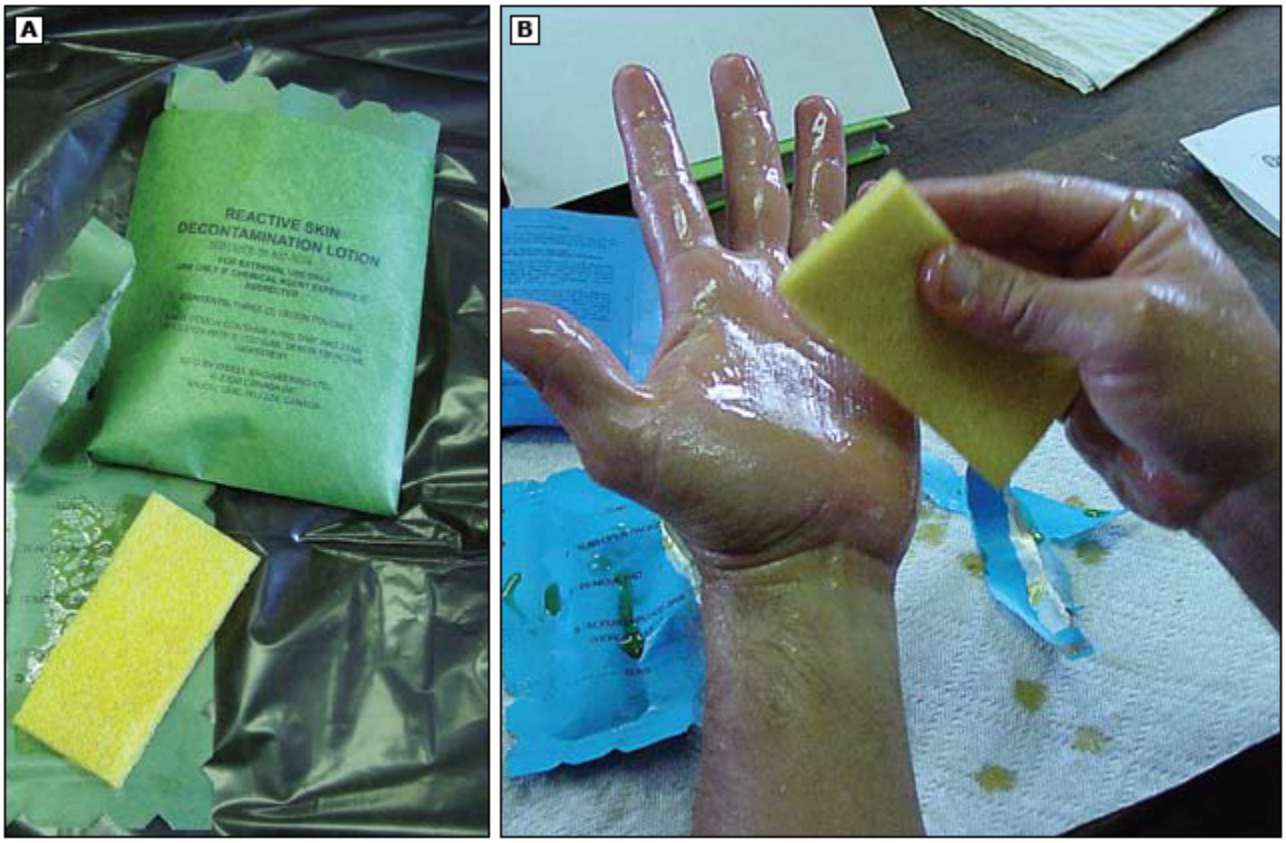
SALT mass casualty triage algorithm



SALT mass casualty triage: concept endorsed by the American College of Emergency Physicians, American College of Surgeons Committee on Trauma, American Trauma Society, National Association of EMS Physicians, National Disaster Life Support Education Consortium, and State and Territorial Injury Prevention Directors Association. Disaster Med Public Health Prep 2008; 2:245. Copyright © 2008 Society for Disaster Medicine and Public Health, Inc. Reprinted with the permission of Cambridge University Press.

Graphic 90283 Version 3.0

Reactive skin decontamination lotion (RSDL)



RSDL lotion is packaged on a foam applicator inside a single use pouch. The lotion is applied within three minutes of contamination, and the non-toxic residue is washed away at a later time. Application of RSDL to wounds or the eyes is considered off label use.

Photo of RSDL® (KBDO individual use decontamination packet) reproduced with permission from Emergent BioSolutions. Originally published in: Braue EH, Boardman CH, Hurst CG. Decontamination of chemical casualties. In: Medical Aspects of Chemical Warfare, 2nd edition, Tuorinsky SD (Ed), United States Department of the Army, Office of the Surgeon General at TMM Publications, Borden Institute, Washington, DC, 2008.

Graphic 90991 Version 1.0

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