

Nerve Agents

**Tabun (GA) CAS 77-81-6; Sarin (GB) CAS 107-44-8;
Soman (GD) CAS 96-64-0; and VX CAS 5078269-9**

Synonyms:

- GA: ethyl dimethylamidocyanophosphate; ethyl N,N-dimethylphosphoramidocyanidate; ethyl dimethyl-phosphoramidocyanidate; dimethylaminoethoxy-cyanophosphine oxide; dimethyl-amidoethoxy-phosphoryl cyanide; EA1205; dimethylphosphoramidocyanidic acid ethyl ester
- GB: isopropyl methylphosphonofluoridate; isopropoxymethylphosphoryl fluoride; trilone; MFI; TL1 618; isopropylmethanefluorophosphonate; T144; T2106; fluoro(isopropoxy)methylphosphine oxide; methylisopropoxyfluorophosphine oxide; zarin
- GD: pinacolyl methylphosphonofluoridate; 1,2,2-trimethylpropyl methylphosphonofluoridate; methyl-pinacolylxyfluorophosphine oxide; pinacolylxymethylphosphonyl fluoride; pinacolylmethyl-fluorophosphonate; 1,2,2-trimethylpropoxyfluoro(methyl)phosphine oxide; pinacolyl methyl-phosphonyl fluoride
- VX: O-ethyl S-(2-diisopropylaminoethyl) methylphosphonothiolate; methylphosphonothioic acid; S-2-(diisopropylamino)ethyl O-ethyl methylphosphonothioate; O-ethyl S-(2-diisopropyl-aminoethyl)methylphosphonothioate; O-ethyl S-(2-diisopropoylaminoethyl) methylthiol-phosphonoate; O-ethyl S-diisopropylaminoethyl methylphosphonothiolate

- **Persons whose skin or clothing is contaminated with nerve agent can contaminate rescuers by direct contact or through off-gassing vapor. Persons whose skin is exposed only to nerve agent vapor pose no risk of secondary contamination; however, clothing can trap vapor.**
- **G-type nerve agents (GA, GB, and GD) are clear, colorless liquids that are volatile at ambient temperatures. VX is an amber-colored, oily liquid with low volatility unless temperatures are high.**
- **Nerve agents are readily absorbed by inhalation, ingestion, and dermal contact. Rapidly fatal systemic effects may occur.**

Description

Nerve agents are the most toxic of the known chemical warfare agents. **They are chemically similar to organophosphate pesticides and exert their biological effects by inhibiting acetylcholinesterase enzymes.** G-type agents are clear,

colorless, and tasteless liquids that are miscible in water and most organic solvents. GB is odorless and is the most volatile nerve agent; however, it evaporates at about the same rate as water. GA has a slightly fruity odor, and GD has a slight camphor-like odor. VX is a clear, amber-colored, odorless, oily liquid. It is miscible with water and soluble in all solvents. It is the least volatile nerve agent. Table 1 lists selected physical properties for each of the nerve agents.

Routes of Exposure

Inhalation

Nerve agents are readily absorbed from the respiratory tract. Rhinorrhea and tightness in the throat or chest begin within seconds to minutes after exposure. Nerve agent vapors are heavier than air. Odor does not provide adequate warning of detection. The estimated LC₅₀ (the product of concentration times time that is lethal to 50% of the exposed population by inhalation) ranges from 10 mg-min/m³ for VX to 400 mg-min/m³ for GA.

Skin/Eye Contact

Nerve agent liquids are readily absorbed from the skin and eyes. Vapors are not absorbed through the skin except at very high concentrations. Ocular effects may result from both direct contact and systemic absorption. The nature and timing of symptoms following dermal contact with liquid nerve agents depend on exposure dose; effects may be delayed for several hours. As little as one drop of VX on the skin can be fatal and 1 to 10 mL of GA, GB, or GD can be fatal.

Ingestion

Ingestion of nerve agents is expected to be relatively rare compared to inhalation exposure or skin contact; however, they are readily absorbed from the GI tract and are highly toxic.

Sources/Uses

Most of the nerve agents were originally synthesized in a search for insecticides, but because of their toxicity, they were evaluated for military use. GA was synthesized in 1936 by a German scientist who synthesized GB 2 years later. During World War II, Germany developed chemical weapons using both GA and GB but never used them. GD was synthesized in 1944 by a German chemist, and VX was synthesized in the early 1950s by a British scientist. Although related organophosphate chemicals are used in medicine, pharmacology, and agriculture, these are not as toxic as the nerve agents. Nerve agents were used by Iraq against Iran and have been used by terrorists. They are known to be included in military stockpiles of several nations, including the United States.

Standards and

Guidelines Workplace time-weighted average: GA and GB, 0.0001 mg/m³; GD, 0.00003 mg/m³; VX, 0.00001 mg/m³

General population limits: 0.000003 mg/m³ (all)
over an 8-hour workshift)

Physical Properties

Table 1. Physical Properties of Nerve Agents

Property	Nerve Agent			
	Tabun (GA)	Sarin (GB)	Soman (GD)	VX
Description	clear, colorless, and tasteless liquid	clear, colorless, tasteless, and odorless liquid	pure liquid is clear, colorless, and tasteless; discolors with aging to dark brown	amber colored, tasteless, and odorless oily liquid
Warning properties	Although GA has a slight fruit odor, this cannot be relied on to provide sufficient warning against toxic exposure	none	Although GD has a slight fruity or camphor odor, this cannot be relied on to provide sufficient warning against toxic exposure.	none
Molecular weight	162.3 daltons	140.1 daltons	182.2 daltons	267.4 daltons
Boiling point	(760 mm Hg) = 428 to 475 °F (220 to 246 °C)	(760 mm Hg) = 316 °F (158 °C)	(760 mm Hg) = 332.6 to 392 °F (167 to 200 °C)	(760 mm Hg) = 568.4 °F (298 °C)
Freezing point	-58 °F (-50 °C)	-68.8 °F (-56 °C)	-43.6 °F (-42 °C)	-59.8 °F (-51 °C)
Specific gravity	1.073 g/mL (water = 1.0)	1.089 (water = 1.0)	1.022 (water = 1.0)	1.008 (water = 1.0)
Vapor pressure	0.037 mm Hg at 68 °F (20 °C); 0.057 mm Hg at 77 °F (25 °C)	2.1 mm Hg at 68 °F (20 °C); 2.9 mm Hg at 77 °F (25 °C)	0.4 mm Hg at 77 °F (25 °C)	0.0007 mm Hg at 77 °F (25 °C)
Vapor density	5.6 (air = 1.0)	4.9 (air = 1.0)	6.33 (air = 1.0)	9.2 (air = 1.0)
Liquid density	1.08 g/mL at 77 °F (25 °C)	1.10 g/mL at 68 °F (20 °C)	1.02 g/mL at 77 °F (25 °C)	1.008 g/mL at 68 °F (20 °C)
Flash point	172.4 °F (78 °C)	nonflammable	249.8 °F (121 °C)	318.2 °F (159 °C)
Solubility in water	9.8 g/100 g at 77 °F (25 °C)	miscible	2.1 g/100g at 68 °F (20 °C)	3 g/100 g (miscible below 48.9 °F [9.4 °C])
Volatility	490 mg/m ³ at 77 °F (25 °C)	22,000 mg/m ³ at 77 °F (25 °C)	3,900 mg/m ³ at 77 °F (25 °C)	10.5 mg/m ³ at 77 °F (25 °C)
NAERG#	153	153	153	153

Incompatibilities

Decomposition of GA may produce HCN, oxides of nitrogen, oxides of phosphorus, carbon monoxide, and hydrogen cyanide. Under acid conditions GB and GD hydrolyze to form HF. GB decomposes tin, magnesium, cadmium plated steel, and aluminum. Hydrolysis of VX produces a class B poison.

Health Effects

Manifestations of nerve agent exposure include rhinorrhea, chest tightness, pinpoint pupils, shortness of breath, excessive salivation and sweating, nausea, vomiting, abdominal cramps, involuntary defecation and urination, muscle twitching, confusion, seizures, flaccid paralysis, coma, respiratory failure, and death.

- **Nerve agents are potent acetylcholinesterase inhibitors causing the same signs and symptoms regardless of the exposure route. However, the initial effects depend on the dose and route of exposure.**

Acute Exposure

Nerve agents alter cholinergic synaptic transmission at neuroeffector junctions (muscarinic effects), at skeletal myoneural junctions and autonomic ganglia (nicotinic effects), and in the CNS. Initial symptoms depend on the dose and route of exposure.

Muscarinic effects include pinpoint pupils; blurred or dim vision; conjunctivitis; eye and head pain; hypersecretion by salivary, lacrimal, sweat, and bronchial glands; narrowing of the bronchi; nausea, vomiting, diarrhea, and crampy abdominal pains; urinary and fecal incontinence; and slow heart rate.

Nicotinic effects include skeletal muscle twitching, cramping, and weakness. Nicotinic stimulation can obscure certain muscarinic effects and produce rapid heart rate and high blood pressure.

Relatively small to moderate vapor exposure causes pinpoint pupils, rhinorrhea, bronchoconstriction, excessive bronchial secretions, and slight to moderate dyspnea. Mild to moderate dermal exposure results in sweating and muscular fasciculations at the site of contact, nausea, vomiting, diarrhea, and weakness. The onset of these mild to moderate signs and symptoms following dermal exposure may be delayed for as long as 18 hours. Higher exposures (any route) cause loss of consciousness, seizures, muscle fasciculations, flaccid paralysis, copious secretions, apnea, and death.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS

Nerve agents cause behavioral and psychological changes in humans. CNS effects include irritability, nervousness, fatigue, insomnia, memory loss, impaired judgment, slurred speech, and depression. High exposures may produce loss of consciousness, seizures, and apnea.

<i>Respiratory</i>	Inhalation of nerve agent vapors causes respiratory tract effects within seconds to minutes. Symptoms include excessive rhinorrhea and bronchial secretions, chest tightness, and difficulty breathing due to constriction of bronchial muscles and mucous secretions. Respiratory failure may occur due to CNS depression.
<i>Cardiovascular</i>	Vagal stimulation may produce bradycardia, but pulse rate may be increased due to ganglionic stimulation, and the effects of hypoxia. Bradyarrhythmias and hypertension may occur.
<i>Gastrointestinal</i>	Abdominal pain, nausea and vomiting are common manifestations of exposure by any route but may be the first systemic effects from liquid exposure on skin. If these symptoms occur within an hour of dermal exposure, severe intoxication is indicated. Diarrhea and fecal incontinence may also occur.
<i>Skeletal muscles</i>	Nerve agents stimulate skeletal muscle producing fasciculations and twitching leading to fatigue and flaccid paralysis. Muscle twitching/fasciculations are clinical identifiers that indicate possible nerve agent exposure.
<i>Metabolic</i>	Profuse sweating may occur.
<i>Ocular</i>	Symptoms may occur from local effects of vapor exposure and from systemic absorption. Pinpoint pupils and spasm of the muscle of visual accommodation (i.e., ciliary muscle) leading to blurred and dim vision, aching pain in the eye, and conjunctivitis are typical effects.
<i>Potential Sequelae</i>	CNS effects such as fatigue, irritability, nervousness and impairment of memory may persist for as long as 6 weeks after recovery from acute effects. Although exposure to some organophosphate compounds may cause a delayed mixed sensory-motor peripheral neuropathy, there are no reports of this condition among humans exposed to nerve agents.
Chronic Exposure	Very little information is available regarding prolonged exposures to low levels of nerve agents.
<i>Carcinogenicity</i>	No information is available regarding the potential carcinogenicity of nerve agents in humans. Limited animal data indicate that nerve agents are not likely to be carcinogenic.
<i>Reproductive and</i>	

Developmental Effects

The limited data available indicate that nerve agents are not reproductive or developmental toxicants.

Prehospital Management

Victims whose skin or clothing is contaminated with liquid nerve agent can contaminate rescuers by direct contact or through off-gassing vapor.

Nerve agents are extremely toxic and can cause loss of consciousness and convulsions within seconds and death from respiratory failure within minutes of exposure.

Atropine and pralidoxime chloride (2-PAM Cl) are antidotes for nerve agent toxicity; however, pralidoxime must be administered within minutes to a few hours following exposure (depending on the specific agent) to be effective. Treatment consists of supportive measures and repeated administration of antidotes.

Hot Zone

Responders should be trained and appropriately attired before entering the Hot Zone. If the proper personal protective equipment (PPE) is not available, or if the rescuers have not been trained in its use, call for assistance in accordance with local Emergency Operational Guides (EOG). Sources of such assistance include local HAZMAT teams, mutual aid partners, the closest metropolitan strike system (MMRS) and the U.S. Soldier and Biological Chemical Command (SBCCOM)-Edgewood Research Development and Engineering Center. SBCCOM may be contacted (from 0700-1630 EST call 410-671-4411 and from 1630-0700 EST call 410-278-5201), ask for the Staff Duty Officer.

Rescuer Protection

Nerve agent vapor is readily absorbed by inhalation and ocular contact and produces rapid local and systemic effects. The liquid is readily absorbed through the skin; however, effects may be delayed for several minutes to up to 18 hours.

Respiratory protection: Pressure-demand, self-contained breathing apparatus (SCBA) is recommended in response situations that involve exposure to any nerve agent vapor or liquid.

Skin protection: Chemical-protective clothing and butyl rubber gloves are recommended when skin contact is possible because nerve agent liquid is rapidly absorbed through the skin and may cause systemic toxicity.

ABC Reminders

Chemical casualty triage is based on walking feasibility, respiratory status, age, and additional conventional injuries. The triage officer must know the natural course of a given injury, the medical resources immediately available, the current and likely

casualty flow, and the medical evacuation capabilities. General principles of triage for chemical exposures are presented in the box on the following page. There are four triage categories: immediate (priority 1), delayed (priority 2), minimal (priority 3), and expectant (priority 4). Clinical signs and effects of nerve agents associated with each of these categories are presented in Table 2.

Before transport, all casualties must be decontaminated. If needed, consult with the base station physician or the regional poison control center for advice concerning management of multiple casualties.

General principles of triage for chemical exposures

- (1) Check triage tag/card for any previous treatment or triage.
- (2) Survey for evidence of associated traumatic/blast injuries.
- (3) Observe for sweating, labored breathing, coughing/vomiting, secretions.
- (4) Severe casualty triaged as immediate if assisted breathing is required.
- (5) Blast injuries or other trauma, where there is question whether there is chemical exposure, victims must be tagged as immediate in most cases. Blast victims evidence delayed effects such as ARDS, etc.
- (6) Mild/moderate casualty: self/buddy aid, triaged as delayed or minimal and release is based on strict follow up and instructions.
- (7) If there are chemical exposure situations which may cause delayed but serious signs and symptoms, then overtriage is considered appropriate to the proper facilities that can observe and manage any delayed onset symptoms.
- (8) Expectant categories in multi-casualty events are those victims who have experienced a cardiac arrest, respiratory arrest, or continued seizures immediately. Resources should not be expended on these casualties if there are large numbers of casualties requiring care and transport with minimal or scant resources available.

1. *Immediate*: casualties who require lifesaving care within a short time, when that care is available and of short duration. This care may be a procedure that can be done within minutes at an emergency treatment station (e.g., relief of an airway obstruction, administering antidotes) or may be acute lifesaving surgery.

2. *Delayed*: casualties with severe injuries who are in need of major or prolonged surgery or other care and who will require hospitalization, but delay of this care will not adversely affect the outcome of the injury (e.g., fixation of a stable fracture).

3. *Minimal*: casualties who have minor injuries, can be helped by nonphysician medical personnel, and will not require hospitalization.

4. *Expectant*: casualties with severe life-threatening injuries who would not survive with optimal medical care, or casualties whose injuries are so severe that their chance of survival does not justify expenditure of limited resources. As circumstances permit, casualties in this category may be reexamined and possibly be retriaged to a higher category.

Table 2. Triage for Nerve Agent Casualties

Category (Priority)	Effects	Clinical Signs
Immediate (1)	Unconscious, talking but not walking, or moderate to severe effects in two or more systems (e.g., respiratory, GI, muscular, CNS)	Seizing or post-ictal, severe respiratory distress or apneic. Recent cardiac arrest.
Delayed (2)	Recovering from agent exposure or antidote	Diminished secretions, improving respiration.
Minimal (3)	Walking and talking	Miosis, rhinorrhea, mild to moderate dyspnea.
Expectant (4)	Unconscious	Cardiac/respiratory arrest of long duration.

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. If trauma is suspected, maintain cervical immobilization manually and apply a decontaminable cervical collar and a backboard when feasible. Apply direct pressure to stop arterial bleeding, if present.

Antidotes

Administration of antidotes is a critical step in managing a nerve agent victim; however, this may be difficult to achieve in the Hot Zone, because the antidotes may not be readily available, and procedures or policies for their administration while in the Hot Zone may be lacking. If the military Mark I kits containing autoinjectors are available, they provide the best way to administer the antidotes. One autoinjector automatically delivers 2 mg atropine and the other automatically delivers 600 mg 2-PAM Cl. Otherwise, administer antidotes as described in Table 3.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Dependant upon available resources, triage of remaining victims should be performed. Victims who are unable to walk may be removed on backboards or gurneys. If these are not available, carefully carry or drag victims to safety. Should there be a large number of casualties, and if decontamination resources permit, separate decontamination corridors should be established for ambulatory and non-ambulatory victims.

Table 3. Recommendations for Nerve Agent Therapy -- Prehospital Management.

Patient Age	Antidotes ¹		Other Treatment
	Mild/Moderate Symptoms ²	Severe Symptoms ³	
Infant (0 - 2 yrs)	Atropine: 0.05 mg/kg IM; 2-PAM Cl: 15 mg/kg IM	Atropine: 0.1 mg/kg IM; 2-PAM Cl: 25 mg/kg IM	Assisted ventilation should be started after administration of antidotes for severe exposures. Repeat atropine (2 mg IM) at 5 - 10 minute intervals until secretions have diminished and breathing is comfortable or airway resistance has returned to near normal.
Child (2 - 10 yrs)	Atropine: 1 mg IM; 2-PAM Cl: 15 mg/kg IM	Atropine: 2 mg IM; 2-PAM Cl: 25 mg/kg IM	
Adolescent (>10 yrs)	Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IM	Atropine: 4 mg IM; 2-PAM Cl: 25 mg/kg IM	
Adult	Atropine: 2 to 4 mg IM; 2-PAM Cl: 600 mg IM	Atropine: 6 mg IM; 2-PAM Cl: 1800 mg IM	
Elderly, frail	Atropine: 1 mg IM; 2-PAM Cl: 10 mg/kg IM	Atropine: 2 to 4 mg IM; 2-PAM Cl: 25 mg/kg IM	

1. **2-PAMCl solution needs to be prepared** from the ampule containing 1 gram of desiccated 2-PAMCl: **inject** 3 ml of saline, 5% distilled or sterile water into ampule and shake well. Resulting solution is 3.3 ml of 300 mg/ml.
2. **Mild/Moderate symptoms** include localized sweating, muscle fasciculations, nausea, vomiting, weakness, dyspnea.
3. **Severe symptoms** include unconsciousness, convulsions, apnea, flaccid paralysis.

Decontamination Zone

Rapid decontamination is critical to prevent further absorption by the patient and to prevent exposure to others. Decontaminable gurneys and back boards should be used if possible when managing casualties in a contaminated area. Decontaminable gurneys are made of a monofilament polypropylene fabric that allows drainage of liquids, does not absorb chemical agents, and is easily decontaminated. Fiberglass back boards have been developed specifically for use in HAZMAT incidents. These are nonpermeable and readily decontaminated. The **Chemical Resuscitation Device** is a bag-valve mask equipped with a chemical agent cannister that can be used to ventilate casualties in a contaminated environment.

Rescuer Protection

Personnel should continue to wear the same level of protection as required in the Hot Zone (see *Rescuer Protection* under Hot Zone, above).

ABC Reminders

Quickly ensure that the victim has a patent airway. Maintain adequate circulation. Stabilize the cervical spine with a decontaminable collar and a backboard if trauma is suspected. Antidote administration may be required to allow ventilation. Suction oral and bronchial secretions. Administer supplemental oxygen if cardiopulmonary compromise is suspected. Assist ventilation with a bag-valve-mask device equipped with a cannister or air filter if necessary. Direct pressure should be applied to control heavy bleeding, if present.

Antidotes

Administer antidotes if they have not been administered. If possible, a system should be employed to track antidotes administered. If atropine was previously administered and signs and symptoms have not diminished within 5 to 10 minutes, give a second dose of atropine (2 mg for adults or 0.05 to 0.1 mg/kg for children) (see *Antidotes* under *Hot Zone*, Table 3).

Basic Decontamination

The eyes must be decontaminated within minutes of exposure to liquid nerve agent to limit injury. Flush the eyes immediately with water for about 5 to 10 minutes by tilting the head to the side, pulling eyelids apart with fingers, and pouring water slowly into eyes. There is no need to flush the eyes following exposure to nerve agent vapor. Do not cover eyes with bandages.

If exposure to liquid agent is suspected, cut and remove all clothing and wash skin immediately with soap and water. If shower areas are available, a thorough shower with soap and water should be used. However, if water supplies are limited, and showers are not available, an alternative form of decontamination is to use 0.5% sodium hypochlorite solution, or absorbent powders such as flour, talcum powder, or Fuller's earth. If exposure to vapor only is certain, remove outer clothing and wash exposed skin with soap and water or 0.5% sodium hypochlorite. Place contaminated clothes and personal belongings in a sealed double bag.

In cases of ingestion, **do not induce emesis**. If the victim is alert and able to swallow, immediately administer a slurry of activated charcoal.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

All victims must be decontaminated properly before entering the Support Zone (see *Decontamination Zone*, above).

<i>ABC Reminders</i>	Quickly ensure that the victim has a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen if cardiopulmonary compromise is suspected. In a severely exposed casualty (unconscious, gasping, or not breathing), the antidotes will be required to allow ventilation. Suction oral and bronchial secretions. Maintain adequate circulation. Establish intravenous access if necessary. Attach a cardiac monitor, as needed. Direct pressure should be applied to stop bleeding, if present.
<i>Antidotes</i>	Administer antidotes if they have not been administered (see <i>Antidotes</i> under <i>Hot Zone</i> , Table 3). Administer atropine (2 mg for adults and 0.05 to 0.1 mg/kg for children) every 5 to 10 minutes until dyspnea, resistance to ventilation, and secretions are minimized.
<i>Additional Decontamination</i>	In cases of ingestion, do not induce emesis. If the victim is alert and able to swallow, immediately administer a slurry of activated charcoal if not given previously.
<i>Advanced Treatment</i>	<p>Intubate the trachea in cases of coma or respiratory compromise, or to facilitate removal of excessive pulmonary secretions. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so. Frequent suctioning of the airways will be necessary to remove mucous secretions.</p> <p>When possible, atropine and 2-PAM Cl should be given under medical supervision to symptomatic patients who have known or strongly suspected nerve agent toxicity (see <i>Antidote</i> sections, above).</p>
<i>Transport to Medical Facility</i>	Patients who are comatose, hypotensive, or seizing or have cardiac dysrhythmias should be treated according to advanced life support (ALS) protocols. Diazepam (5 to 10 mg in adults and 0.2 to 0.5 mg/kg in children) should be used to control convulsions. Lorazepam or other benzodiazepines may be used but barbiturates, phenytoin, and other anticonvulsants are not effective. <p>Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.</p>

Emergency Department Management

Patients whose skin or clothing is contaminated with liquid nerve agent can contaminate rescuers by direct contact or through off-gassing vapor.

Nerve agents are extremely toxic and can cause death within minutes to hours after exposure from respiratory failure.

Atropine and pralidoxime (2-PAM Cl) are antidotes for nerve agent toxicity; however, pralidoxime must be administered within minutes to a few hours following exposure (depending on the specific agent) to be effective. Treatment consists of supportive measures and repeated administration of antidotes.

Decontamination Area

Previously decontaminated patients may be treated or held for observation. Others require decontamination as described below.

ABC Reminders

Evaluate and support the airway, breathing, and circulation. If the patient is apneic, give antidotes immediately (see *Antidote* section below). Intubate the trachea in cases of respiratory compromise. Suctioning may be required for excessive bronchial secretions. If the patient's condition precludes intubation, surgically create an airway. Antidote administration may be required to allow ventilation.

Personal Protection

If contaminated patients arrive at the Emergency Department, they must be decontaminated before being allowed to enter the facility. Decontamination can only take place inside the hospital if there is a decontamination facility with negative air pressure and floor drains to contain contamination. Personnel should wear the same level of protection required in the Hot Zone (see *Rescuer Protection* under *Hot Zone*, above).

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. Remove and double bag contaminated clothing and all personal belongings.

For patients exposed to nerve agent vapor only, remove outer clothing and wash exposed areas including the head and hair with soap and water. For patients exposed to liquid agent, remove all clothing and wash entire body and hair with soap and water or 0.5% hypochlorite followed by a water rinse.

Irrigate exposed eyes with plain water or saline for about 5 to 10 minutes (see Basic Decontamination under Decontamination Zone, above). Remove contact lenses if present and easily removable without additional trauma to the eye.

In cases of ingestion, **do not induce emesis**. If the patient is able to swallow, immediately administer a slurry of activated charcoal if not given previously. (More information is provided in *Ingestion Exposure* above.)

Treatment Area

All patients should undergo decontamination before entering the treatment area (see *Decontamination Area*, above).

ABC Reminders

Evaluate and support the airway, breathing, and circulation (as in *ABC Reminders*, above). Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Triage

Patients who are conscious and have full muscular control will need minimal care. Patients who may have been exposed to liquid must be kept under observation for at least 18 hours.

Patients with a history of possible exposure to vapor only (with no possibility of liquid exposure) who have no signs of exposure by the time they reach the medical facility have not been exposed (because these effects occur within seconds to minutes after exposure). They can be discharged.

Antidotes and Other Treatments

Patients exposed to vapor who have miosis and rhinorrhea will need no care unless (a) they have eye or head pain or nausea and vomiting; under these circumstances topical atropine or homatropine in the eye should relieve the symptoms and the patient can be discharged within an hour or so; or (b) the rhinorrhea is very severe; under these circumstances, atropine IM (2 mg in adults and 0.05 mg/kg in children) should relieve this and the patient can be discharged in an hour or so. Topical atropine and homatropine should not be used routinely for miosis because they cause visual impairment for about 24 hours. See Table 4 for other antidote and treatment recommendations.

Table 4. Recommendations for Nerve Agent Therapy -- Emergency Department Management.

Patient Age	Antidotes		Other Treatment
	Mild/Moderate Symptoms ¹	Severe Symptoms ²	
Infant (0 - 2 yrs)	Atropine: 0.05 mg/kg IM or 0.02 mg/kg IV; 2-PAM Cl: 15 mg/kg IV slowly	Atropine: 0.1 mg/kg IM or 0.02 mg/kg IV; 2-PAM Cl: 15 mg/kg IV slowly	Assisted ventilation as needed. Repeat atropine (2 mg IM or 1 mg IM for infants) at 5 - 10 minute intervals until secretions have diminished and breathing is comfortable or airway resistance has returned to near normal. Phentolamine for 2-PAM induced hypertension: (5 mg IV for adults; 1 mg IV for children) Diazepam for convulsions: (0.2 to 0.5 mg IV for infants 5 years; 1 mg IV for children >5 years; 5 mg IV for adults)
Child (2 - 10 yrs)	Atropine: 1 mg IM; 2-PAM Cl: 15 mg/kg IV slowly	Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IV slowly	
Adolescent (>10 yrs)	Atropine: 2 mg IM; 2-PAM Cl: 15 mg/kg IV slowly	Atropine: 4 mg IM; 2-PAM Cl: 15 mg/kg IV slowly	
Adult	Atropine: 2 to 4 mg IM; 2-PAM Cl: 15 mg/kg (1 g) IV slowly	Atropine: 6 mg IM; 2-PAM Cl: 15 mg/kg (1 g) IV slowly	
Elderly, frail	Atropine: 1 mg IM; 2-PAM Cl: 5 to 10 mg/kg IV slowly	Atropine: 2 mg IM; 2-PAM Cl: 5 to 10 mg/kg IV slowly	

1. **Mild/Moderate symptoms** include localized sweating, muscle fasciculations, nausea, vomiting, weakness, dyspnea.

2. **Severe symptoms** include unconsciousness, convulsions, apnea, flaccid paralysis.

Inhalation Exposure

Ventilatory support is essential. Following low-dose exposure, administration of antidotes and supplemental oxygen may be adequate. Suction secretions from the nose, mouth, and

respiratory tract. Marked resistance to ventilation is expected due to bronchial constriction and spasm. Resistance lessens after administration of atropine.

Skin Exposure

Skin must be decontaminated within minutes following exposure to nerve agent. Because of the high toxicity, rapid absorption, and volatility, it is unlikely that a patient brought to a medical facility will have nerve agent on the skin. However, some nerve agent may remain in the hair or clothing and should be decontaminated if not previously done (see *Basic Decontamination*, above).

Eye Exposure

Severity of miosis cannot be used as an indicator of the amount of exposure or effectiveness of the antidotes. Maximum miosis may not occur until an hour or more after exposure. If severe eye pain or nausea and vomiting occur, protect eyes from bright light and consider topical administration of atropine or homatropine. Test visual acuity.

Ingestion Exposure

Do not induce emesis because of the risk of pulmonary aspiration of gastric contents which may result from abrupt respiratory arrest, seizures, or vomiting. If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal. If the patient's condition is evaluated within 30 minutes after ingestion, consider gastric lavage. (Gastric contents should be considered potentially hazardous by skin contact or inhalation and should be quickly isolated.)

Laboratory Tests

Routine laboratory studies for all admitted patients include CBC, glucose, and serum electrolyte determinations. Chest X-ray and pulse oximetry (or ABG measurements) are recommended for severe exposures. Symptomatic and asymptomatic patients suspected of significant exposure should have determinations of red blood cell (RBC) cholinesterase activity, the most useful test for nerve agent poisoning. Severe symptoms of toxicity are usually present when more than 70% of RBC cholinesterase is inhibited. However, there is no correlation between cholinesterase activity and severity of topical signs and symptoms (e.g., miosis, rhinorrhea, dyspnea). If this test is not available, plasma cholinesterase can be measured.

Disposition and Follow-up

Patients exposed to nerve agent vapor who have only miosis and/or mild rhinorrhea when they reach the medical facility do not need to be admitted. All other patients who have had exposure to nerve agent should be hospitalized and observed closely.

Delayed Effects

Effects from skin exposure to liquid nerve agent may not develop for up to 18 hours following exposure.

Patients who have inhalation exposure and who complain of chest pain, chest tightness, or cough should be observed and examined periodically for 6 to 12 hours to detect delayed-onset bronchitis, pneumonia, pulmonary edema, or respiratory failure.

Formaldehyde poisoning can cause permanent alterations of nervous system function, including problems with memory, learning, thinking, sleeping, personality changes, depression, headache, and sensory and perceptual changes.

Follow-up

Patients who have severe exposure should be evaluated for persistent CNS sequelae. Patients should be advised to avoid organophosphate insecticide exposure until sequential RBC cholinesterase activity (measured at weekly to monthly intervals) has stabilized in the normal range, a process that may take 3 to 4 months after severe poisoning (see *Follow-up Instructions*, included with the *Nerve Agent Patient Information Sheet* below).

Reporting

Other persons may still be at risk in the setting where this incident occurred. If a public health risk exists, notify your state or local health department or other responsible public agency.

Nerve Agents Patient Information Sheet

This handout provides information and follow-up instructions for persons who have been exposed to nerve agents.

What are nerve agents?

Nerve agents are chemical warfare agents, similar to but much more potent than organophosphate insecticides. They are colorless to amber-colored, tasteless liquids that may evaporate to create a gas. GB and VX are odorless, while GA has a slight fruity odor, and GD has a slight camphor odor.

What immediate health effects can result from exposure to nerve agents?

Nerve agents are extremely toxic chemicals that attack the nervous system. As little as one drop to a few milliliters of nerve agent contacting the skin can cause death within 15 minutes. Nerve agent exposure can cause runny nose, sweating, blurred vision, headache, difficulty breathing, drooling, nausea, vomiting, muscle cramps and twitching, confusion, convulsions, paralysis, and coma. Symptoms occur immediately if you inhale nerve agent vapor but may be delayed for several hours if you get nerve agent liquid on your skin.

Can nerve agent poisoning be treated?

There are antidotes for nerve agent poisoning but they must be administered quickly after exposure. Immediate decontamination is critical and hospitalization may be needed.

Are any future health effects likely to occur?

Complete recovery may take several months. After a severe exposure with prolonged seizures, permanent damage to the central nervous system is possible.

What tests can be done if a person has been exposed to nerve agents?

Activity of a blood enzyme called acetylcholinesterase can be measured to assess exposure and recovery.

Where can more information about nerve agents be found?

More information about nerve agents can be obtained from your regional poison control center; the Agency for Toxic Substances and Disease Registry (ATSDR); your doctor; or a clinic in your area that specializes in toxicology or occupational and environmental health. Ask the person who gave you this form for help locating these telephone numbers.

Follow-up Instructions

Keep this page and take it with you to your next appointment. Follow *only* the instructions checked below.

Call your doctor or the Emergency Department if you develop any unusual signs or symptoms within the next 24 hours, especially:
dizziness, loss of coordination, loss of memory
coughing, wheezing, or shortness of breath
nausea, vomiting, cramps, or diarrhea
muscle weakness or twitching
blurred vision

No follow-up appointment is necessary unless you develop any of the symptoms listed above.

Call for an appointment with Dr. _____ in the practice of _____.
When you call for your appointment, please say that you were treated in the Emergency Department at _____ Hospital by _____ and were advised to be seen again in _____ days.

Return to the Emergency Department/ _____ Clinic on (date) _____ at _____ AM/PM for a follow-up examination.

Do not perform vigorous physical activities for 1 to 2 days.

You may resume everyday activities including driving and operating machinery.

Do not return to work for _____ days.

You may return to work on a limited basis. See instructions below.

Avoid exposure to cigarette smoke for 72 hours; smoke may worsen the condition of your lungs.

Avoid drinking alcoholic beverages for at least 24 hours; alcohol may worsen injury to your stomach or have other effects.

Avoid taking the following medications: _____

You may continue taking the following medication(s) that your doctor(s) prescribed for you: _____

Other instructions: _____

• Provide the Emergency Department with the name and the number of your primary care physician so that the ED can send him or her a record of your emergency department visit.

• You or your physician can get more information on the chemical by contacting: _____
_____ or _____, or by checking out the following Internet
Web sites: _____;

Signature of patient _____ Date _____

Signature of physician _____ Date _____