Chlorine (Cl_2) C 1

Information and recommendations for doctors at hospitals/emergency departments

- **Patients exposed only to chlorine gas do not pose a significant risk of secondary contamination. Patients whose clothing or skin is contaminated with liquid chlorine (boiling point –34°C, -29°F, respectively) can secondarily contaminate rescue and medical personnel by direct contact or through off-gassing chlorine.**
- **Chlorine gas is rapidly corrosive when it comes in contact with moist tissue such as the eyes, skin, and upper respiratory tract causing eye irritation, coughing, chest pain and dyspnea. Laryngospasm and signs of pulmonary edema (shortness of breath, cyanosis, expectoration, cough) may occur.**
- **There is no antidote to be administered to counteract the effects of chlorine. Treatment consists of supportive measures.**

1. Substance information

Chlorine (Cl_2), CAS 7782-50-5
Synonyms: molecular chlorine
Chlorine is, at room temperature, a yellow-green, noncombustible gas with a sharp or pungent odor. Under pressure or at temperatures below -34°C (-29°F), it is a clear, amber-colored liquid. It is a strong oxidizing agent and can react explosively or form explosive compounds with many common substances. Chlorine is only slightly soluble in water, but on contact with moisture it forms hypochlorous acid (HClO) and hydrochloric acid (HCl); the unstable HClO readily decomposes, forming oxygen free radicals. Water enhances chlorine's oxidizing and corrosive effects.

Chlorine is widely used as a chemical reagent in the synthesis and manufacture of metallic chlorides, chlorinated solvents, crop protection products, polymers and synthetic rubbers. It is used as a bleach in the manufacture of paper and cloth; it can be released from hypochlorite-containing household products when they come in contact with acids.

2. Routes of exposure

Inhalation

Most exposures occur by inhalation. Chlorine's odor and irritant properties generally provide adequate warning of hazardous concentrations. However, prolonged low-level exposure may result in olfactory fatigue and tolerance of its irritant effects. Chlorine is heavier than air and may cause asphyxiation in poorly ventilated, low-lying, or enclosed spaces.

Skin/eye contact

Direct contact with liquid chlorine or gas on wet or moist skin causes severe chemical burns, leading to cell death and ulceration.

Ingestion

Ingestion of chlorine is unlikely because it is a gas at room temperature. Solutions that are able to generate chlorine may cause corrosive injury if ingested.

3. Acute health effects

Respiratory

Exposure to low concentrations of chlorine usually causes sore throat and coughing. Rapid development of respiratory distress with chest pain, dyspnea, laryngospasm and pulmonary edema may occur with inhalation of high concentrations of chlorine gas. With exposure to a high concentration of chlorine gas, nausea and vomiting may occur in association with uncontrolled coughing respiratory and cardiovascular failure may occur.

Dermal

Deep burns of the skin and mucous membranes may be caused by contact with concentrated chlorine; disfiguring scars may result. Contact with less concentrated chlorine gas can cause burning pain, redness,

inflammation, and blisters. Contact with liquid chlorine under pressure can result in frostbite.

Ocular — Low gas concentrations cause burning discomfort, spasmodic blinking or involuntary closing of the eyelids, redness, and tearing. Corneal burns may occur at high concentrations.

Dose-effect relationships — Dose-effect relationships are as follows:

Chlorine concentration		Effect
0.31 ppm	-	Odor threshold (some tolerance develops)
0.5 ppm	-	TLV-STEL (USA, NIOSH)
0.5 ppm	-	AEGL I (10 minutes, USA, EPA)
2.0 ppm	-	AEGL II (60 minutes, USA, EPA)
2.8 ppm	-	AEGL II (10 minutes, USA, EPA)
50 ppm	-	AEGL III (10 minutes, USA, EPA)

AEGL I (acute exposure guideline levels): airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
AEGL II: airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious long-lasting adverse health effects, or an impaired ability to escape.
AEGL III: airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Potential sequelae — If the patient survives the initial 48 hours after exposure, recovery is likely. After acute exposure, pulmonary function usually returns to normal in 7 to 14 days. Complete recovery is usual; however, symptoms and pulmonary deficits may persist. Airways hyperreactivity to non-specific irritants may persist, resulting in bronchospasm and chronic inflammation of the bronchi; chlorine-induced reactive airways dysfunction syndrome has been reported to persist for years. Sequelae of the pulmonary tissue destruction and scarring may lead to chronic dilation of the bronchi and increased susceptibility to infection. Chronic or prolonged exposure to chlorine has been associated with increased risk of chronic obstructive pulmonary disease and corrosion of the teeth.

4. Actions

Self-protection — Patients exposed only to chlorine gas do not pose a significant risk of secondary contamination. Patients whose clothing or skin is contaminated with liquid chlorine can secondarily contaminate other people by direct contact or through off-gassing chlorine.

Decontamination — Patients exposed only to chlorine gas who have no evidence of skin or eye irritation do not need decontamination. All others require decontamination.
Patients who are able and cooperative may assist with their own decontamination. If the exposure involved liquid chlorine and if clothing is contaminated, remove and double-bag the clothing.
Assure that exposed skin and hair have been flushed with plain water for at least 15 minutes. If not, continue flushing during other basic care. Protect eyes during flushing of skin and hair.
Assure that exposed or irritated eyes have been irrigated with plain water or saline for at least 15 minutes. If not, continue eye irrigation during other basic care.
Remove contact lenses if present and easily removable without additional trauma to the eye.

Initial treatment — Therapy will be empiric; there is no antidote to be administered to counteract the effects of chlorine.
The following measures are recommended if the concentration dose is 2.8 ppm or greater (depending on time exposed), symptoms, e.g. eye irritation or pulmonary symptoms have

developed, or if no concentration dose can be estimated but exposure has possibly occurred:
- **Administration of oxygen**
- **Administration of 8 puffs of beclomethasone (800 µg beclomethasone dipropionate) from a metered dose inhaler.**

Patients with severe clinical respiratory symptoms (e.g. bronchospasms, stridor) should be treated as follows:
a) Nebulized epinephrine (adrenaline): Mix 2 mg of epinephrine (2 ml) with 3 ml saline 0,9%. Administer via nebulizer mask.
b) Intravenous administration of 250 mg methylprednisolone (or an equivalent steroid dose) is recommended.

Patients with clinical signs of a toxic lung edema (e.g. foamy sputum, wet crackles) should be treated as follows:
a) Start CPAP-therapy (Continuous Positive Airway Pressure Ventilation).
b) Intravenous administration of 1000 mg methylprednisolone (or an equivalent steroid dose) is recommended.

Intubation of the trachea or an alternative airway management should be considered in cases of respiratory compromise. When the patient's condition precludes this, consider cricothyrotomy if equipped and trained to do so.

Note: Efficacy of corticosteroid administration has not yet been proven in controlled clinical studies.

If signs of hypoxemia or severe inhalation exposure are present, humidified supplemental oxygen should be administered.

Intubation of the trachea or an alternative airway management should be considered in cases of respiratory compromise. When the patient's condition precludes this, consider cricothyrotomy if equipped and trained to do so.

If chlorine gas or chlorine generating solutions have been in contact with the skin, chemical burns may result; treat as thermal burns: adequate fluid resuscitation and administration of analgesics, maintenance of the body temperature, covering of the burn with a sterile pad or clean sheet. If liquefied compressed gas is released and contacts the skin, frostbite may result.

After eye exposure chemical burns may result; treat as thermal burns. Immediately consult an ophthalmologist.

Note: Any facial exposure to liquid chlorine should be considered as a serious exposure.

Further evaluation and treatment

To the standard intake history, physical examination, and vital signs add pulse oximetry monitoring and a PA chest X-ray. Spirometry should be performed. Routine laboratory studies should include a complete blood count, blood glucose and electrolyte determinations.

Evidence of pulmonary edema - hilar enlargement and ill-defined, central-patch infiltrates on chest radiography - **is a late finding that may occur 6 to 8 hours or later after exposure. The chest X-ray is typically normal on first presentation to the emergency department even with severe exposures.**

Patients who have possible exposure or who develop serious signs or symptoms should be observed for a minimum of 24 hours and reexamined frequently before confirming the absence of toxic effects. Delayed effects are unlikely in patients who have minor upper respiratory symptoms (mild burning or a slight cough) that resolve quickly.

If oxygen saturation is less than 90 % or if it appears to drop, immediately check arterial blood gasses and repeat the chest X-ray.

If blood gasses begin to show deterioration and/or if the chest X-ray begins to show pulmonary edema start oxygen supplementation.
In case of worsening clinical signs (especially tachypnea >30/min with a simultaneous decrease of the partial pressure of carbon dioxide) CPAP-therapy (Continuous Positive Airway Pressure Ventilation) should be started within the first 24 hours after exposure.
In case of a pulmonary edema fluid intake/output and electrolytes should be monitored closely. Avoid net positive fluid balance. Central line or Swan-Ganz catheterization might be considered, to optimize fluid management.
As long as signs of pulmonary edema are present, intravenous administration of methylprednisolone (or an equivalent steroid) should be continued in intervals of 8-12 hours.

Prophylactic antibiotics are not routinely recommended but may be used based on the results of sputum cultures. Pneumonia can complicate severe pulmonary edema.

Patient release/ follow-up instructions

Clinically asymptomatic patients exposed to a concentration **of less than 2.8 ppm** (depending on the period of time exposed) as well as patients who have a normal clinical examination and no signs or symptoms of toxicity may be discharged after an appropriate observation period in the following circumstances:

a) The evaluating physician is experienced in the evaluation of individuals with chlorine exposure.
b) Information and recommendations for patients with follow-up instructions are provided verbally and in writing. Patients are advised to seek medical care promptly if symptoms develop or recur.
c) The physician is comfortable that the patient understands the health effects of chlorine.
d) Site medical is notified, so that the patient may be contacted at regular intervals in the 24-hour period following release from the emergency department.
e) Heavy physical work should be precluded for 24 hours.
f) Exposure to cigarette smoke should be avoided for 72 hours; the smoke may worsen the condition of the lungs.

Patients who have serious skin or eye injuries should be reexamined in 24 hours.
Post discharge spirometry should be repeated until values return to the patient’s baseline values.

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