Ricin Poisoning
A Comprehensive Review

Jennifer Audi, MD
Martin Belson, MD
Manish Patel, MD, MSc
Joshua Schier, MD
John Osterloh, MD, MS

Growing awareness and concern about ricin, a potent biologic toxin, as a possible terrorist weapon has necessitated a comprehensive review of this poison.1 The Centers for Disease Control and Prevention (CDC) categorizes ricin as a Category B agent (second-highest priority), as it is moderately easy to disseminate, resulting in low mortality but moderate to high morbidity, and requires specific enhancement of the CDC’s diagnostic and disease surveillance capacity.2 Such agents are not routinely encountered, so heightened awareness in the health care community and a strong public health infrastructure are necessary for detection and response. We therefore have summarized the literature on ricin poisoning and provided recommendations for clinicians and public health professionals dealing with a ricin attack against a civilian population.

EVIDENCE ACQUISITION

Using PubMed, we searched MEDLINE and OLDMEDLINE databases from January 1950 to August 2005 using the keywords ricin, ricinus communis, ricinine, plant toxins, castor beans, castor dust, and castor oil. Keywords were used alone and with the modifiers toxicity, poisoning, diagnosis, clinical effects, treatment, warfare, chemical terrorism, and weapon. The Chemical and Biological Information Analysis Center (http://www.cbiac.apgea.army.mil) database was searched for historical and military literature related to ricin toxicity. Book chapters, unpublished reports, monographs, relevant news reports, and Web material were also reviewed to find nonindexed articles.

Results

Most literature on ricin poisoning involves castor bean ingestion and experimental animal research. Aerosol release of ricin into the environment or adulteration of food and beverages are pathways to exposure likely to be exploited. Symptoms after ingestion (onset within 12 hours) are nonspecific and may include nausea, vomiting, diarrhea, and abdominal pain and may progress to hypotension, liver failure, renal dysfunction, and death due to multigang failure or cardiovascular collapse. Inhalation (onset of symptoms is likely within 8 hours) of ricin is expected to produce cough, dyspnea, arthralgias, and fever and may progress to respiratory distress and death, with few other organ system manifestations. Biological analytic methods for detecting ricin exposure are undergoing investigation and may soon be available through reference laboratories. Testing of environmental samples is available through federal reference laboratories. Currently, no antidote, vaccine, or other specific effective therapy is available for ricin poisoning or prevention. Prompt treatment with supportive care is necessary to limit morbidity and mortality.

Conclusion

Health care workers and public health officials should consider ricin poisoning in patients with gastrointestinal or respiratory tract illness in the setting a credible threat. Poison control centers and public health authorities should be notified of any known illness associated with ricin exposure.

Author Affiliations: Centers for Disease Control and Prevention, National Center for Environmental Health, Division of Environmental Hazards and Health Effects, Health Studies Branch (Drs Audi, Belson, Patel, and Schier) and National Center for Environmental Health, Division of Laboratory Sciences (Dr Osterloh), Emory University, Department of Emergency Medicine and Georgia Poison Control Center, Section of Toxicology (Drs Audi, Belson, Patel, and Schier), Atlanta.

Dr Audi is now at the Nebraska Regional Poison Center and the Department of Surgery of the University of Nebraska Medical Center, Omaha.

Corresponding Author: Jennifer Audi, MD, Nebraska Regional Poison Center, 8401 W Dodge Rd, Suite 115, Omaha, NE 68154 (ca7@cdc.gov).

Clinical Review Section Editor: Michael S. Lauer, MD.

We encourage authors to submit papers for consideration as a “Clinical Review.” Please contact Michael S. Lauer, MD, at lauerm@ccf.org.

Context

The recent discoveries of ricin, a deadly biologic toxin, at a South Carolina postal facility, a White House mail facility, and a US senator’s office has raised concerns among public health officials, physicians, and citizens. Ricin is one of the most potent and lethal substances known, particularly when inhaled. The ease with which the native plant (Ricinus communis) can be obtained and the toxin extracted makes ricin an attractive weapon.

Objectives

To summarize the literature on ricin poisoning and provide recommendations based on our best professional judgment for clinicians and public health officials that are faced with deliberate release of ricin into the environment.

Literature Acquisition

Using PubMed, we searched MEDLINE and OLDMEDLINE databases (January 1950–August 2005). The Chemical and Biological Information Analysis Center database was searched for historical and military literature related to ricin toxicity. Book chapters, unpublished reports, monographs, relevant news reports, and Web material were also reviewed to find nonindexed articles.

Results

Most literature on ricin poisoning involves castor bean ingestion and experimental animal research. Aerosol release of ricin into the environment or adulteration of food and beverages are pathways to exposure likely to be exploited. Symptoms after ingestion (onset within 12 hours) are nonspecific and may include nausea, vomiting, diarrhea, and abdominal pain and may progress to hypotension, liver failure, renal dysfunction, and death due to multigang failure or cardiovascular collapse. Inhalation (onset of symptoms is likely within 8 hours) of ricin is expected to produce cough, dyspnea, arthralgias, and fever and may progress to respiratory distress and death, with few other organ system manifestations. Biological analytic methods for detecting ricin exposure are undergoing investigation and may soon be available through reference laboratories. Testing of environmental samples is available through federal reference laboratories. Currently, no antidote, vaccine, or other specific effective therapy is available for ricin poisoning or prevention. Prompt treatment with supportive care is necessary to limit morbidity and mortality.

Conclusion

Health care workers and public health officials should consider ricin poisoning in patients with gastrointestinal or respiratory tract illness in the setting a credible threat. Poison control centers and public health authorities should be notified of any known illness associated with ricin exposure.

JAMA. 2005;294:2342-2351

©2005 American Medical Association. All rights reserved.
Ricin. Purified ricin is a white powder that is soluble in water and stable over a wide pH range. It is inactivated by heat, 80°C in aqueous solution for 1 hour, and requires higher temperatures or longer periods for inactivation when in powder or crude forms. It is a protein toxin (ie, toxalbumin) derived from the castor bean plant, *Ricinus communis* (FIGURE 1 and BOX 1) and has a molecular weight of 60 to 65 kDa. Reports on the ricin content of castor beans vary but probably is in the range of 1% to 5%. Ricin is being studied for therapeutic use in cancer chemotherapy, in bone marrow transplantation, and in cell-based research. Experimental evidence suggests that malignant cells are more susceptible to ricin toxicity because they express more carbohydrate-containing surface-lectin binding sites than do nonmalignant cells. Antibody-conjugated ricin targets cancer cells and has been investigated as an immunotherapeutic agent.

**Castor Beans.** The beans are oblong and light brown, mottled with dark brown spots (Figure 1). They are used to produce castor oil that is used in paints, varnishes, and lubricating oils for jet engines, high-speed automobiles, and industrial machinery. Another use of castor oil is as a purgative. Ricin is contained in the bean pulp following the separation of the oil from the beans. No ricin is thought to remain in the oil, and ricin is inactivated during oil extraction if done under heated conditions. Ingested castor beans are generally toxic only if ricin is released through mastication or maceration. The roots, leaves, and seeds of the plants are also used in traditional or folk remedies throughout the world.

**Historical Use of Ricin and Emerging Threats**

The US War Department considered ricin for chemical warfare as early as 1918. Ricin was tested as an inhalational agent in the 1940s. Although never laboratory-confirmed, it was most likely the etiologic agent used in the 1978 assassination of Bulgarian journalist Georgi Markov in Great Britain. In the 1940s in the United States and in late 1980s in Iraq, weapons-grade ricin (ie, purified and inhalable particles that can be aerosolized for a mass attack) was manufactured and tested in animal experiments and in artillery shells in field testing.

In 2003 and 2004, ricin was discovered in a South Carolina mail sorting facility, a mailroom serving US Senator Bill Frist’s office, and inside a letter addressed to the White House. Ricin has also been discovered in the possession of persons affiliated with antigovernment groups and outside the United States in the possession of individuals possibly linked to terrorist organizations.

**Mechanism of Action**

Ricin is a glycoprotein lectin composed of 2 chains, A and B, linked by a disulfide bond. The B chain is a lectin and binds to galactose-containing glycoproteins and glycolipids expressed on the surface of cells, facilitating the entry of ricin into the cytosol. The A chain inhibits protein synthesis by irreversibly inactivating eukaryotic ribosomes through removal of a single adenine residue from the 28S ribosomal RNA loop. References cited in the retrieved articles were also evaluated to find non-indexed reports. Because much information regarding ricin as a chemical warfare agent is not in the peer-reviewed literature, book chapters, unpublished reports, monographs, relevant news reports, and Web material available in the authors’ collections were also reviewed. The information provided herein is our best professional judgment regarding the clinical and public health implications of use of ricin as a chemical warfare agent. These recommendations should be reassessed as new information becomes available.

**EVIDENCE SYNTHESIS**

**Description**

Ricin. Purified ricin is a white powder that is soluble in water and stable over a wide pH range. It is inactivated by heat, 80°C in aqueous solution for 1 hour, and requires higher temperatures or longer periods for inactivation when in powder or crude forms. It is a protein toxin (ie, toxalbumin) derived from the castor bean plant, *Ricinus communis* (FIGURE 1 and BOX 1) and has a molecular weight of 60 to 65 kDa. Reports on the ricin content of castor beans vary but probably is in the range of 1% to 5%. Ricin is being studied for therapeutic use in cancer chemotherapy, in bone marrow transplantation, and in cell-based research. Experimental evidence suggests that malignant cells are more susceptible to ricin toxicity because they express more carbohydrate-containing surface-lectin binding sites than do nonmalignant cells. Antibody-conjugated ricin targets cancer cells and has been investigated as an immunotherapeutic agent.

**Castor Beans.** The beans are oblong and light brown, mottled with dark brown spots (Figure 1). They are used to produce castor oil that is used in paints, varnishes, and lubricating oils for jet engines, high-speed automobiles, and industrial machinery. Another use of castor oil is as a purgative. Ricin is contained in the bean pulp following the separation of the oil from the beans. No ricin is thought to remain in the oil, and ricin is inactivated during oil extraction if done under heated conditions. Ingested castor beans are generally toxic only if ricin is released through mastication or maceration.

The roots, leaves, and seeds of the plants are also used in traditional or folk remedies throughout the world.

**Historical Use of Ricin and Emerging Threats**

The US War Department considered ricin for chemical warfare as early as 1918. Ricin was tested as an inhalational agent in the 1940s. Although never laboratory-confirmed, it was most likely the etiologic agent used in the 1978 assassination of Bulgarian journalist Georgi Markov in Great Britain. In the 1940s in the United States and in late 1980s in Iraq, weapons-grade ricin (ie, purified and inhalable particles that can be aerosolized for a mass attack) was manufactured and tested in animal experiments and in artillery shells in field testing.

In 2003 and 2004, ricin was discovered in a South Carolina mail sorting facility, a mailroom serving US Senator Bill Frist’s office, and inside a letter addressed to the White House. Ricin has also been discovered in the possession of persons affiliated with antigovernment groups and outside the United States in the possession of individuals possibly linked to terrorist organizations.

**Mechanism of Action**

Ricin is a glycoprotein lectin composed of 2 chains, A and B, linked by a disulfide bond. The B chain is a lectin and binds to galactose-containing glycoproteins and glycolipids expressed on the surface of cells, facilitating the entry of ricin into the cytosol. The A chain inhibits protein synthesis by irreversibly inactivating eukaryotic ribosomes through removal of a single adenine residue from the 28S ribosomal RNA loop.
Box 1. Background, Diagnosis, Treatment, and Prevention and Reporting of Ricin Poisoning*

Background

Ricin is a toxin derived from the castor bean plant Ricinus communis. Poisoning can occur via ingestion, inhalation, or injection. Ricin poisoning can have a presentation similar to gastroenteritis or respiratory illnesses. Epidemiologic clues include increased number of patients seeking care, unexpected progression of symptoms, or a credible threat of ricin release in the community. Person-to-person transmission does not occur. Ricin has been procured for use as a terrorist weapon. Inhalation and injection are considered to be the most lethal routes of exposure.

Clinical Findings

Ingestion: Mild poisoning can result in nausea, vomiting, diarrhea, and/or abdominal pain. In moderate to severe poisoning, gastrointestinal tract symptoms can progress (4-36 hours) to hypotension, liver and renal dysfunction, and possibly death. Inhalation: Illness can occur within 8 hours and include cough, dyspnea, arthralgias, and fever, and can progress to respiratory distress and death. Injection: Initial (ie, ≤6 hours) symptoms can include generalized weakness and myalgias; progression of illness (24-36 hours) can include vomiting, fever, hypotension, and/or multiorgan failure and death.

Laboratory Testing

No clinically validated methods are available to detect ricin in biological fluids. Analytic methods for detecting ricin (in blood) and ricinine (in urine) may be available through reference laboratories (the US Army Medical Research Institute for Infectious Diseases and the Centers for Disease Control and Prevention) in an emergency response setting. Centers for Disease Control and Prevention and Laboratory Response Network laboratories conduct tests to detect ricin in environmental samples.

Recommended Treatment

Treatment is mainly supportive and includes intravenous fluid and vasopressors (eg, dopamine) for hypotension. Activated charcoal should be administered to persons with known or suspected ricin ingestion if vomiting has not begun and airway is secure. Gastric lavage may be considered if ingestion has occurred in an hour or less. If a credible threat exists, patients with illness consistent with ricin poisoning should be observed for illness progression. The regional poison control center should be contacted for individualized care and further management.

Prevention and Reporting in the United States

All known or suspected cases of ricin exposure should be reported to the regional poison control center (800-222-1222) and local and state health departments.

*This is a modified version of an original figure in MMWR.1

Toxicokinetics/Toxicodynamics and Clinical Effects in Animals and Humans

Ingestion. Toxicokinetics/Toxicodynamics. There are no literature reports of contained within the 60S subunit. This process prevents chain elongation of polypeptides and leads to cell death (FIGURE 2).2-7 Toxicity results from the inhibition of protein synthesis, but other mechanisms are noted including apoptosis pathways, direct cell membrane damage, alteration of membrane structure and function, and release of cytokine inflammatory mediators. A broad group of bacterial and plant toxins have A- and B-chain protein components, such as diphtheria, ricin, botulinum, and anthrax. Ricin belongs to a group of 2-chain toxins possessing ribosomal–inactivating-protein activity (classified as RIP-II) in their A chains, along with such toxins as shigatoxin, abrin, modeccin, volkensin, and viscumins. Some other plant proteins have no B chain binding component, such as gelonin, trichosantin, and mornodin but possess the catalytic RIP activity and are classified RIP-I.13

The castor bean plant also contains another glycoprotein lectin, the ricin communis agglutinin, which, unlike ricin, is not directly cytotoxic but does have affinity for the red blood cell, leading to agglutination and subsequent hemolysis. Ricin communis agglutinin is not significantly absorbed from the gut and causes clinically significant hemolysis only after intravenous administration.4,5,19,20,36,44,46

Ricinine is an alkaloidal toxin also found in the leaves and pericarp of the castor bean plant. Although small amounts of ricinine are found in the castor bean and can be coextracted with ricin, there are no reports of human ricinine poisoning.7 In experimental mice models, ricinine causes convulsions and subsequent death; the mechanism of action is hypothesized to be increased release of glutamate and inhibition of the postsynaptic γ-amino butyric acid receptor subtype A in the brain.46,50
poisoning from ingesting purified ricin. All clinical reports with regard to poisoning refer to castor bean ingestion. The median lethal dose (LD₅₀) in mice is 30 mg/kg, or approximately 1000-fold higher than by injection or inhalation. In previous reports of human castor bean ingestion, the lethal oral dose in humans has been estimated to be 1 to 20 mg of ricin/kg of body weight (approximately 8 beans); but ricin doses estimated from the number of beans ingested may give inaccurate estimates due to variation in the size, weight, and moisture content of the beans; region, season, and period of plant growth at time of harvest of the beans; as well as the degree of mastication, age, and comorbidities.⁵⁻¹⁴,¹⁶,⁵⁰⁻⁵³ The number of beans ingested in reports documenting clinical symptoms (mild to lethal) range from one half to 30.¹⁶,⁵² The minimum number of beans associated with death was 2.¹⁶

Figure 2. Mechanism of Ricin Toxicity

Ricin belongs to a family of 2-chain protein cytotoxins called type II ribosome-inactivating proteins.

It is composed of an A chain that is enzymatically active...

and a B chain that binds the toxin to terminal galactose residues on glycoproteins and glycolipids expressed on the surface of cells.

Some ricin molecules enter the Golgi apparatus and undergo retrograde transport to the endoplasmic reticulum.

Once ricin binds to the cell surface by the B chain, it enters the cell by endocytosis in membrane vesicles and is transported to endosomes.

In the cytosol, the ricin A chain, a glycosidase, inactivates ribosomes by removing an adenine from position 4324 of the 28S rRNA in the 60S ribosomal subunit.

The depurinated rRNA is unable to bind protein elongation factors, and protein synthesis ceases.

A single A chain molecule in the cytosol can inactivate approximately 1500 ribosomes per minute, leading to rapid inhibition of protein synthesis and cell death. Ricin may also mediate other cytotoxic effects (eg, apoptosis).
RICIN POISONING

In animal studies, ingested ricin is absorbed within 2 hours by both lymphatic and blood vessels, accumulates mainly in the liver and spleen, and approximately 20% to 45% is excreted unchanged in the feces up to 72 hours after ingestion.16,55

Clinical Effects. Symptom onset after ingestion is usually within 4 to 6 hours but may be as late as 10 hours.16,51-53,56-63 Initial symptoms are nonspecific and may include colicky abdominal pain, vomiting, diarrhea, heartburn, and oropharyngeal pain. Hematemesis and melena are reported less commonly.16,51,52,56-59 Fluid losses may lead to electrolyte imbalances, dehydration, hypotension, and circulatory collapse.16,51-55,56,58,60 Laboratory abnormalities may include leukocytosis, elevated transaminases and creatinine, elevated liver transaminases, amylase, and serum creatinine. Hemorrhage, anemia, and renal insufficiency, and anemia.16,59,61-63 Postmortem findings of diffuse intestinal hemorrhagic lesions as well as histology consistent with the appearance of apoptotic cell death are seen in both humans and animals.6

Injection. Toxicokinetics/Toxicodynamics. Little published data on human exposure to ricin by parenteral routes exist. The LD50 in mice is approximately 5 to 10 µg/kg.9,66 Minimum lethal doses range from 0.7 to 2 µg/kg in mice and 1 to 1.75 µg/kg in dogs.68 After injection in rodents, the majority of ricin excretion occurs in the urine over the first 24 hours, with less than 2% recovered in feces.69,70 Clinical Effects. The onset of nonspecific signs and symptoms, which may be similar to sepsis (fever, headache, dizziness, nausea, anorexia, hypotension, abdominal pain), can be delayed for as much as 10 to 12 hours, even with high doses.9,67,68 There may also be local tissue damage at the site of the injection. Laboratory abnormalities include elevated liver transaminases, amylase, and creatinine kinase, hyperbilirubinemia, myoglobinuria, and renal insufficiency.71,72 The clinical course may progress to multisystem organ failure.5,9,67,72

Postmortem findings are consistent in case investigations and animal studies and include focal hemorrhage in the intestines, brain, myocardium, and pleura.9,51,67,71,72 Lymph nodes, kidneys, and intestines may also demonstrate necrosis, hemorrhage, and edema.9,38-41,69,70,73-75

Inhalation. Toxicokinetics/Toxicodynamics. Lung deposition and lethality after ricin inhalation is significantly influenced by particle size. Particles of low micron-size can deposit deeper into the respiratory tract resulting in higher mortality.76 Particles of increasingly larger diameter typically deposit higher in the airways and can be swept up by the mucociliary system and subsequently swallowed.24 The LD50 in mice exposed to ricin of particle sizes less than 5 µm is about 3 to 5 µg/kg.

Monkeys exposed to inhaled ricin developed progressive dyspnea 20 to 24 hours after 21 to 42 µg/kg dosing of 1- to 2-µm particles.77 Three of the 5 monkeys died at 36, 40, and 48 hours. Postmortem findings included diffuse pulmonary edema with multifocal areas of necrosis and inflammation.76-78 All injury was significantly worse in the distal airways and alveoli. Toxicity results from the inhibition of protein synthesis, release of cytokine mediators, and direct injury to the epithelial membrane.76-79 The primary target of toxicity after ricin inhalation are the type I and II pneumocytes.76-78 There was no significant systemic absorption after inhalational exposure and toxicity was primarily limited to the respiratory tract in these animal studies.24,25,76 Clinical Effects. Respiratory failure is likely to be the primary cause of morbidity and mortality in humans after inhaling ricin. Only 1 poorly documented report exists of inhalational ricin poisoning in humans. In the 1940s, 8 persons developed fever, nau- sea, cough, dyspnea, chest tightness, and arthralgias within 4 to 8 hours of presumed inhalational exposure to uncharacterized ricin-containing material.18 Based on this report and animal studies, patients may exhibit respira- tory symptoms as soon as 4 to 6 hours, but delays in the onset of serious symptoms are considered possible up to 24 hours after exposure.18,77

Airborne ricin exposure may also cause an allergic response leading to reactive airway inflammation, rhinitis, and ocular irritation. However, information on allergic reactions to ricin is primarily in persons working in or living near castor bean processing plants.80-85 Allergy patch testing reveals an IgE-mediated inflammatory reaction to ricin although other allergens may be present in the castor bean dust.83,86-89 No cases consistent with direct respiratory tract injury have been reported in the occupational setting, most likely because of the larger particle size of ricin in the castor bean dust or heat inactivation of the plant material.

Dermatologic/Ophthalmologic. An urticarial, IgE-mediated, allergic reaction may occur after handling of the intact castor bean plant or exposure to the castor bean dust or pomace.53,80-89 Irritation and the development of pseudomembranous conjunctivitis after ocular exposure to very low ricin concentrations is reported in animals.3,91

Laboratory Detection

Biological Specimens. In animal studies, ricin has been detected in tissue sections, some tissue specimens, nasal swabs, and fluids by immunologically based methods.53,92,93 Immunologically based methods have been applied to human and animal fluid specimens in the past and have the potential to measure concentrations as low as 0.1 ng/mL (1.54 pmol/L).93-98 However, such applications have not been clinically validated and concentrations after toxic exposures are unknown. Reference laboratories (eg, US Army Medical Research Institute of Infectious Diseases and the CDC) are currently adapting these and other analytic methods for application to human specimens. Matrix-assisted laser desorption-ionization mass spectrometry (MALDI-MS) holds promise as a definitive method for identification in biological specimens. In suspected...
cases, clinicians should collect urine and serum samples and contact their state public health department or CDC for further guidance. Currently, there is no widely available commercial assay for ricin in biological samples. A urine assay for detecting the alkaloid ricin also holds future potential for diagnosing ricin exposure. Because ricin and ricin are extracted from the same plant source, ricinine may serve as a surrogate marker for the presence of ricin. Detection of ricinine up to 48 hours after exposure may be possible with newer methods available at the CDC.

Environmental Specimens. The CDC and Laboratory Response Network laboratories conduct polymerase chain reaction tests and time-resolved immunofluorescence assays to detect ricin in environmental specimens. Cell-based bioassays are sometimes used to confirm intact toxin-killing activity of the ricin in environmental samples. Field immunoassays (so-called Hand-Held Assay, or “smart tickets”) have been available to the military. As with other preliminary testing, confirmatory testing is required. Other field test kits are under development for the US Department of Homeland Security and the various branches of the US military, but commercial distribution is limited.

Immunity
Animal studies have demonstrated the possibility of protection against inhalational and parenteral ricin poisoning through passive immunization (ie, ricin-specific antibodies) or active immunization with a ricin vaccine. Passive immunization affords protection against inhalational ricin if administered prior to exposure; however, the benefit of postexposure immunization remains undefined. Several animal studies have investigated active immunization and demonstrated that adequate levels of ricin-neutralizing protective antibodies would be maintained.

Two preparations of ricin have been used for vaccination: formaldehyde-inactivated ricin (toxoid) and deglycosylated ricin A chain. However, a specific vaccine produced by recombinant technology, RiVax (DOR BioPharma Inc, Miami, Fla), is highly purified and induces high titers of neutralizing antibodies in animals. Phase 1 clinical trials in humans should begin in 2005.

Personal Protective Equipment and Decontamination
The primary hazard from entering a contaminated area involves particulate matter inhalation through primary aerosolization—the period when ricin particles are first made airborne. Ricin inhalational toxicity depends on particle size. In general, particles larger than 10 µm do not reach bronchiolar-alveolar levels and are unlikely to pose a serious inhalational hazard. However, determination of particle size at the scene is usually not possible prior to entry. Other important determinants of inhalational toxicity that war-
Box 3. Decontamination Recommendations for Patients With Ricin Exposure*

**Dermal**

Make the patient “as clean as possible” after life-threatening issues have been addressed.\(^{108,109}\)

- Remove contaminated clothing and jewelry
- Wash skin with soap and copious amounts of water
- Double bag and label belongings as contaminated

**Oral**

- Single dose of activated charcoal\(^ {110}\)
- Gastric lavage is of limited efficacy but can be considered if patient presents within 1 hour of ingestion\(^ {111}\)

**Inhalational**

- Remove patient from exposure
- Gut decontamination is not necessary†

**Environmental Contamination**

- Clean surfaces and clothing with a 0.1% sodium hypochlorite solution for 30 minutes; will inactivate more than 99% of ricin\(^ {1,16,113}\)
- Clean carpets with steam and HEPA filtering\(^ {108,109}\); however, given the paucity of data available, it may be most prudent to remove the contaminated carpet

*Low volatility of ricin and negligible absorption through intact skin poses minimal risk of toxicity to the exposed patient or to a health care worker.
†Unintentional ingestion of ricin after inhalational exposure is unlikely.

Box 4. Acute Toxicity of Ricin: A Dose-Dependent Spectrum of Illness

Ricin is not amenable to dialysis and there is no currently available antidote.\(^ {10}\) The major treatment goals for a patient with oral ricin poisoning are to improve perfusion by aggressive fluid resuscitation, vasopressor therapy, and replenishing electrolytes. Patients should also be monitored and treated for any evidence of myoglobinuria and renal failure. For inhalational exposure, general supportive treatment may include oxygen, bronchodilators, endotracheal intubation, and supplemental positive end-expiratory pressure as needed.

**Diagnosis, Management, Disposition, and Prognosis**

**Recognition of the ricin poisoned patient will likely be difficult due to similarities with more commonly encountered illnesses (Box 4).** Diagnosis will rely on the clinician’s suspicion in the context of a credible ricin threat or in the context of an outbreak of severe gastrointestinal or respiratory illness.\(^ {1,16,115}\)

**Diagnosis.** Oral ricin exposure will lead to a syndrome resembling foodborne, chemical or infectious gastroenteritis (Box 4). Following exposure, onset of gastrointestinal symptoms may occur within a few hours of exposure, mimicking some infectious and chemical agents. A dose-dependent spectrum of illness may be expected ranging from mild symptoms to profuse diarrhea (possibly bloody), dehydration, hypotension, and multisystem organ failure. Severe gastrointestinal illness or a rapid progression should heighten the suspicion for ricin exposure. Similarly, rapid progression of severe respiratory illness over 12 to 24 hours, after unknown inhalational exposures, may increase the concern for ricin although a number of noxious chemicals can produce injury in this time frame (Box 4).

**Management.** No specific treatment protocols exist for ricin exposures; treatment is largely symptomatic and supportive. To prevent further systemic absorption of unknown toxic substances, a single-dose of activated charcoal should be considered for non-vomiting patients, even though adsorption of ricin by charcoal is unknown (Box 3).\(^ {110}\) Once the patient begins to vomit, gut decontamination is unlikely to be beneficial. Although controversial, gastric lavage may be considered for patients presenting within 1 hour from ingestion.\(^ {111}\)

Ricin is not amenable to dialysis and there is no currently available antidote.\(^ {10}\) The major treatment goals for a patient with oral ricin poisoning are to improve perfusion by aggressive fluid resuscitation, vasopressor therapy, and replenishing electrolytes. Patients should also be monitored and treated for any evidence of myoglobinuria and renal failure. For inhalational exposure, general supportive treatment may include oxygen, bronchodilators, endotracheal intubation, and supplemental positive end-expiratory pressure as needed.

**Disposition and Prognosis.** In the setting of a credible threat or suspicion of ricin poisoning, all symptomatic patients should be admitted to the hospital. The clinical course after ingestion and inhalation typically progresses over 4 to 36 hours, and monitoring in an intensive care unit may be warranted. Patients who re-
main completely asymptomatic for 12 hours after oral or inhalational exposure to ricin are unlikely to develop toxicity and may be discharged to home with appropriate precautions. Experimental animal evidence suggests a possibility of delayed respiratory symptoms at 20 to 24 hours after ricin inhalation; thus, all discharged patients should be instructed to return immediately to the emergency department if symptoms develop. Recognition and treatment of ricin exposures may vary with age, other constitutional factors, and underlying disease states; susceptibility factors are unknown (Figure 2).

**CONCLUSION**

Recent threats of ricin release and procurement of ricin as a terrorist weapon highlight the need for clinicians and public health officials to be vigilant for illness suggestive of ricin exposure. Clinical manifestations of ricin poisoning will vary depending on the routes of exposure. In the setting of a credible threat, clinicians should consider ricin poisoning in patients presenting with gastrointestinal or respiratory tract illness, especially in the setting of progressively worsening symptoms and organ dys-
RINIC POISONING

function. To facilitate early diagnosis and reduce further morbidity and mortality, poison control centers, public health and local law enforcement agencies should be notified of any known illness associated with ricin exposure or outbreak of illness consistent with ricin poisoning.

Author Contributions: Dr Audi had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Financial Disclosures: None reported.

Funding/Support: No outside or commercial funding source was provided for the development and completion of this manuscript.

Disclaimer: The findings and conclusions in this report are those of the study and do not necessarily represent the views of the Centers for Disease Control and Prevention, the Agency for Toxic Substances, and Disease Registry. This article did receive clearance through the appropriate channels at the Centers for Disease Control and Prevention prior to submission.

Acknowledgment: We thank Carol Rubin, DVM, MPH, Chief Health Studies Branch, National Center for Environmental Health, CDC; Max Kifer, MS CIH, Assistant Director for Emergency Preparedness, National Institute for Occupational Safety and Health, CDC; and Jerry Thomas, MD, Medical Toxicologist, Division of Laboratory Sciences, CDC.

REFERENCES
