Toxic pneumonitis caused by inhalation of hydrocarbon waterproofing spray in two dogs

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Case Description—2 dogs were evaluated because of vomiting and lethargy (a Toy Poodle; dog 1) and acute respiratory distress, vomiting, and anorexia (a Chihuahua; dog 2). Dog 1 had been exposed to a commercial hydrocarbon waterproofing spray 24 hours before the development of clinical signs, and dog 2 was examined 18 hours after exposure to a waterproofing spray containing heptane, a highly flammable liquid hydrocarbon.

Clinical Findings—In both dogs, major gastrointestinal tract abnormalities were ruled out but respiratory status worsened. Thoracic radiography revealed a diffuse interstitial pulmonary pattern, and hypoxemia was detected.

Treatment and Outcome—Hospitalization for monitoring and care was required for both dogs. The dogs recovered with supportive care, which included administration of oxygen, fluids, and bronchodilators. Additionally, dog 1 received glucocorticoids via inhalation and supplemental enteral nutrition, whereas dog 2 was treated with an antimicrobial.

Clinical Relevance—The dogs of this report developed hydrocarbon pneumonitis following exposure to waterproofing sprays. Such sprays contain potentially toxic hydrocarbons. The severity of the adverse effects associated with exposure may have been amplified because the dogs were physically small and were exposed to a relatively large amount of aerosolized spray within small areas. Development of chemical pneumonitis in pet animals is best prevented by application of waterproofing sprays in well-ventilated or outdoor areas from which pets have been excluded. With prolonged hospitalization and considerable monitoring and care, affected dogs can recover from these exposures. (J Am Vet Med Assoc 2007;231:74–78)

A 1-year-old 1.6-kg (3.52-lb) spayed female Toy Poodle (dog 1) was evaluated (day 1) because of vomiting and lethargy, the onset of which was attributed by the owners to dietary indiscretion. The owners reported that the dog had eaten half of an egg and 1 to 2 oz of cheese. Physical examination revealed mild dehydration, tachypnea (respiratory rate, 40 breaths/min; reference range, 18 to 34 breaths/min), and signs of abdominal pain. Initial diagnostic procedures revealed no abnormalities in venous blood gas variables; PCV, and plasma electrolytes, plasma total solids, and blood glucose concentrations. Oxygen saturation determined via pulse oximetry while the dog was breathing room air was 96%, and systolic blood pressure (determined indirectly by use of a Doppler blood pressure monitor) was 140 mm Hg. Tachypnea was attributed to abdominal pain. Results of serum biochemical analyses indicated mildly high alkaline phosphatase (159 U/L; reference range, 10 to 150 U/L) and alanine aminotransferase (97 U/L; reference range, 5 to 60 U/L) activities; results of a CBC were within reference limits. Although abdominal radiography revealed decreased detail in the right cranial quadrant, no evidence of pancreatitis or other cause for the gastrointestinal tract signs was identified ultrasonographically. No vomiting occurred throughout the period of hospitalization. Initial treatments included IV administration of isotonic crystalloid solution (120 mL/kg/d [54.5 mL/lb/d]) and buprenorphine* (0.01 mg/kg [0.005 mg/lb], IV, q 8 h). Food and water were withheld.

On the second day of hospitalization, the dog became acutely dyspneic; its respiratory rate was 80 breaths/min, and the SpO² value while the dog was breathing room air was 78%. The dog was transferred to an intensive care unit and placed in an oxygen cage (FIO², 0.4), after which the SpO² improved to 94%. An arterial blood gas analysis was not pursued because of the small physical size and unstable clinical state of the dog. Thoracic radiography revealed a diffuse interstitial pulmonary pattern; no abnormalities in the size of the heart or in the pulmonary vasculature were detected. Primary differentials considered included pulmonary edema (cardiogenic and noncardiogenic) and early aspiration pneumonia. The dog had no clinical signs suggestive of volume overload (ie, weight gain or interstitial edema), and central venous pressure was 0 cm H₂O. Other differentials, including pulmonary eosino-

**Abbreviations**

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<tr>
<td>SpO²</td>
<td>Oxygen saturation determined via pulse oximetry</td>
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<td>FIO²</td>
<td>Fraction of inspired oxygen</td>
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<td>BAL</td>
<td>Bronchoalveolar lavage</td>
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philic infiltrates, lymphocytic interstitial pneumonitis, pulmonary thromboembolism, hemorrhage, and idiopathic pulmonary interstitial fibrosis, were considered less likely and were not pursued diagnostically. Aminophylline was administered (10 mg/kg [4.5 mg/lb], IM, q 8 h) in an attempt to improve the dog’s comfort. On auscultation, airway sounds were harsh, but no wheezes were detected. Because of the development of moderate hypokalemia (2.66 mmol/L; reference range, 3.5 to 5.3 mmol/L), oral and IV potassium supplementation were initiated. To address possible development of vasculitis, the crystalloid IV infusion was discontinued and hetastarch was administered (20 mL/kg/d [9.1 mL/lb/d], IV) in an attempt to limit fluid extravasation.

Because no vomiting had occurred and anorexia continued, a nasoesophageal tube was placed for provision of liquid enteral nutrition on the third day of hospitalization. In the morning, the dog was consistently well oxygenated ($SpO_2$, 99%) at an FiO$_2$ of 0.4 and had a respiratory rate of 44 breaths/min; however, the dog remained oxygen dependent. Throughout the day, the respiratory rate increased to a maximum rate of 120 breaths/min. Serial analyses of venous blood gases revealed a progressive respiratory acidosis, and the central-venous partial pressure of carbon dioxide ranged from 54.9 mm Hg (reference range, 35 to 45 mm Hg) on day 3 to a peak of 60 mm Hg on day 5 of hospitalization. The respiratory rate and respiratory effort began to gradually improve after day 3, despite worsening respiratory acidosis. The acidosis did not resolve until day 7 of hospitalization (venous partial pressure of carbon dioxide, 44.5 mm Hg), at which time the dog was also able to maintain normoxemia while breathing room air.

Further discussion with the owner revealed that the dog had been exposed to a commercial hydrocarbon waterproofing spray 24 hours before the development of clinical signs. Two other dogs in the household each had 1 bout of vomiting after that exposure but did not require medical attention. The owner reported using approximately 75% of a bottle of the spray to wash the bathroom floor; however, the door was not completely closed, and the dog had access to the room after the spraying was completed. The owner reported that the spray did not have an odor but that she felt dizzy after using it.

For dog 1, additional diagnostic procedures were considered, such as an endotracheal wash or bronchoscopy with BAL and helical computed tomography. These procedures were not pursued because of the severity of respiratory compromise and the risks associated with anesthesia and invasive procedures. Furthermore, these diagnostic procedures were unlikely to change the course of treatment in a dog affected by toxin inhalation. Supportive care was continued with administration of oxygen, bronchodilators, IV crystalloid and colloid therapy, and enteral nutritional supplementation. Administration of antimicrobials was withheld because sterile inflammation or pneumonitis was the working diagnosis.

On day 5 of hospitalization, the dog was able to sustain a 3-hour period without provision of supplemental oxygen before becoming dyspneic. Radiography revealed that the pulmonary pattern was unchanged. Because of minimal improvement by the end of the fourth day, treatments with albuterol (90 µg, q 12 h) and fluticasone (110 µg, q 12 h) administered via inhalation through a spacer device and face mask adapter were initiated. Clinicopathologic analyses were repeated on the fifth day and revealed mild panhypoproteinemia (albumin, 2.4 g/dL; [reference range, 2.7 to 4.4 g/dL]; globulin, 1.6 g/dL; [reference range, 2.2 to 4.2 g/dL]). Serum alkaline phosphatase and alanine aminotransferase activities were within reference ranges, and no abnormalities were detected via a CBC.

By day 7, the dog’s respiratory rate had decreased to 38 breaths/min and the $SpO_2$ value was 96% while the dog was breathing room air. Thoracic radiographic findings were unchanged. Oxygen supplementation was discontinued. On the eighth day, the nasoesophageal tube was removed because the dog’s appetite returned. The dog was discharged 8 days after the initial evaluation, and the owner was instructed to administer aminophylline (10 mg/kg, PO, q 8 h) and fluticasone (110 µg, q 12 h) and albuterol (90 µg, as needed) via inhalation. Aminophylline treatment was discontinued after 2 weeks, and the fluticasone treatment was discontinued after 1 month. One year later, the dog had no clinical signs and was not receiving any medication.

A 10-month-old 1.7-kg (3.74-lb) sexually intact female Chihuahua (dog 2) was examined because of acute respiratory distress, vomiting, and anorexia. These clinical signs had developed approximately 18 hours after exposure to a waterproofing spray containing heptane, a highly flammable liquid hydrocarbon. The owner had used an entire bottle of waterproofing spray on a couch inside a small apartment when the dog was present in the same room. A person in the household also required medical attention for respiratory distress after exposure to the spray.

On the day of evaluation, dog 2 had become increasingly lethargic and tachypneic (respiratory rate, 70 breaths/min) but maintained normoxemia ($SpO_2$, 98% [while dog was breathing room air]). Initially, thoracic radiography revealed a moderate interstitial pulmonary pattern within the caudodorsal lung fields (Figure 1).

Figure 1—Lateral radiographic view of the thorax of a 10-month-old Chihuahua that was evaluated because of respiratory distress, vomiting, and anorexia. These clinical signs had developed approximately 18 hours after exposure to a waterproofing spray containing a highly flammable liquid hydrocarbon. A moderate interstitial pattern is evident in the caudodorsal lung fields (image obtained at the initial examination).
Clinicopathologic abnormalities at the initial evaluation included mild hypokalemia (3.5 mmol/L; reference range, 3.7 to 5.8 mmol/L; reference range is different than that reported for dog 1 because of variation between equipment), hyperglycemia (167 mg/dL; reference range, 60 to 110 mg/dL), and mild neutrophilia (13,760 cells/µL; reference range, 2,060 to 10,600 cells/µL). Results of serial analyses of venous blood gases were within reference limits. Treatments initiated on day 1 of hospitalization included ampicillin-sulbactam (23 mg/kg [10.45 mg/lb], IV, q 8 h), aminophylline (10 mg/kg, IM, q 8 h), and IV administration of isotonic crystalloid solution (100 mL/kg/d [45.5 mL/lb/d]). Administration of the antimicrobials was initiated as a prophylactic measure on the basis of a recommendation from the American Society for the Prevention of Cruelty to Animals’ Poison Control Center.

On the second day of hospitalization, SpO₂ (determined while the dog was breathing room air) was 88% but increased to 98% during administration of oxygen (FiO₂, 0.4): The respiratory rate during oxygen supplementation ranged from 30 to 68 breaths/min with moderate inspiratory effort evident at all rates. Although vomiting had ceased, the dog remained anorexic, and treatments (as previously described) were continued. On day 3, radiography revealed a more severe interstitial pattern in the caudodorsal lung fields. Despite provision of inhaled albuterol (90 µg, q 12 h) and nebulization with sterile water, the dog’s respiratory status worsened; respiratory rate increased to 124 breaths/min and SpO₂ was 90% while the dog was receiving supplemental oxygen. Feedings administered via syringe into the oral cavity were started with amounts equivalent to 50% of the dog’s resting energy requirements. Although SpO₂ improved on day 4 (96%; FiO₂, 0.3), the dog remained tachypneic throughout the period of hospitalization.

Subsequent radiographic views obtained on days 5 and 8 revealed marked improvement, but incomplete resolution, of the interstitial lung pattern. Although gradual clinical improvement was evident, the dog was oxygen dependent until the final day of hospitalization (day 8), at which time SpO₂ was 97% while the dog was breathing room air. Dog 2 was discharged, and the owner was instructed to administer amoxicillin trihydrate-clavulanate potassium (17 mg/kg [7.7 mg/lb], PO, q 12 h) for 10 days and aminophylline (10 mg/kg, PO, q 12 h) for 10 days; a further recommendation was to allow the dog to breathe humidified air twice daily. One year later, the dog was not receiving any medications and appeared physically normal according to the owner.

Discussion

Despite the ubiquitous nature of toxins that can be inhaled, there is a paucity of information on hydrocarbon pneumonitis in the veterinary and human medical literature. There is a small number of case reports and case series of affected humans, and there are 2 studies of experimental hydrocarbon inhalation in dogs. Waterproofing sprays contain potentially toxic hydrocarbons, such as heptane or petroleum distillates. Other common hydrocarbons include butane, propane, benzene, and trichloroethylene. Turpentine, kerosene, and gasoline also contain volatile hydrocarbons that are known to have substance-abuse potential. Hydrocarbons are more likely to cause serious respiratory compromise than when used indoors or in areas without adequate ventilation. Both cases described in the present report involved physically small dogs that were exposed to a relatively large amount of aerosolized waterproofing spray within small indoor areas. Outbreaks of respiratory distress after exposure to aerosol sprays in humans are sporadic and typically coincide with changes in the chemical formulas of the sprays. Historically, these outbreaks have led to further changes in compound formulas to create less-toxic sprays.

Hydrocarbons cause a spectrum of clinical syndromes in humans, from mild self-limiting cough and malaise to life-threatening acute respiratory distress syndrome that necessitates provision of positive-pressure ventilation. Systemic signs often include nausea, vomiting, chest pain, transient leukocytosis, and fever. Other signs may include CNS excitation, arrhythmias, bone marrow suppression, and kidney and liver damage. Both dogs of this report inhaled a waterproofing spray, which was subsequently associated with transient vomiting. Dog 1 was lethargic and had high serum alkaline phosphatase and alanine amino-transferase activities that were possibly results of toxin ingestion or metabolism. Dog 2 had neutrophilia, likely a result of toxin-related inflammation. Neither dog was pyretic at initial evaluation or during hospitalization. Respiratory acidosis developed in dog 1 and has been detected after experimentally induced aspiration of kerosene in dogs in a previous study. In dog 1, hypercarbia may have been caused by decreased tidal volume or minute ventilation, increased dead space ventilation, or partial airway obstruction attributable to inflammatory debris. Minute ventilation may have been decreased because of respiratory fatigue that could develop in response to a respiratory rate of 120 breaths/min or because of decreased thoracic wall excursions that could develop in response to pain.

In both dogs, hypoxemia was detected via pulse oximetry; that method was selected because the size of each dog and severity of respiratory distress precluded arterial blood gas analysis. Because pulse oximetry is limited to differentiation between oxyhemoglobin and deoxyhemoglobin, the technic may be inaccurate in animals with methemoglobinemia or carbon monoxide exposure (neither of which were suspected in the dogs of this report).

In humans, the development of pneumonitis after inhalation or ingestion and secondary aspiration of hydrocarbons has been described. Toxic pneumonitis is characterized by dyspnea, hypoxemia, ventilatory dysfunction, decreased alveolar gas diffusion, and diffuse bilateral pulmonary infiltrates detected via thoracic radiography after toxin exposure. The pathogenesis of hydrocarbon pulmonary toxicosis has not been fully elucidated. Common sequelae of lung damage from various toxin exposures in humans have been described. Hydrophilic toxins lead to substantial immediate irritation to the upper portions of the airways (eg, rhinitis and laryngospasm), which limits prolonged exposure of the lower portions of the airways.
In contrast, lipophilic toxins, such as hydrocarbons, are less noxious, resulting in considerable exposure and extensive damage of the lower portions of the airways. Following inhalation, direct toxin-induced damage to the pulmonary parenchyma develops, resulting in loss of the epithelial cell barrier integrity as well as leakage of interstitial fluid into the alveoli. In general, inhaled aerosols primarily damage the tight junctions between epithelial cells, thereby interfering with the mucociliary apparatus and making the respiratory mucosa susceptible to further toxin penetration. This also compromises the affected person’s natural defense against infections. The resultant inflammatory debris can obstruct small airways and cause bronchoconstriction. In an experimental study in which kerosene was instilled into the trachea of dogs, diffuse pulmonary hemorrhage and alveoli filled with inflammatory exudate (neutrophils and macrophages) were detected on histologic examination of lung tissue. Infiltrated leukocytes can generate reactive oxygen species, which cause lipid peroxidation. Another reported mechanism of hydrocarbon damage is direct disruption of pulmonary surfactant. Toxic pneumonitis is diagnosed in humans on the basis of history; symptoms; and findings of thoracic radiography, high-resolution computed tomography, and analysis of BAL fluid. Typically, affected humans develop cough and progressive dyspnea within 1 to 48 hours of toxin exposure. Radiography reveals interstitial and alveolar infiltrates, and high-resolution computed tomography reveals typical bilateral ground-glass opacities and alveolitis. A variety of inflammatory cells can be detected in BAL fluid samples, and results of microbial culture of those samples are typically negative. Though rarely performed, histologic examination of lung biopsy specimens has revealed extensive alveolitis with eosinophils and neutrophil infiltration in exposed humans.

The respiratory effects of toxin inhalation can be mild and self-limiting or progress to fulminant noncardiogenic pulmonary edema or acute respiratory distress syndrome. Recommended treatment consists largely of supportive care, including administration of supplemental oxygen; bronchodilators; glucocorticoids (via inhalation or IV routes); and, possibly, antimicrobials. However, to our knowledge, there are no reports of randomized controlled clinical trials to test the efficacies of these treatments, and there is considerable debate regarding the appropriateness of glucocorticoid administration, regardless of route.

In several publications, marked clinical improvement after the institution of treatment with inhaled glucocorticoids in humans with hydrocarbon pneumonitis has been described. In a case series of humans exposed to a fluorocarbon-based waterproofing spray, the only patient who did not receive glucocorticoids developed pulmonary fibrosis. Glucocorticoids have several mechanisms of action, including reduction of macrophage collagenase activity and promotion of type II pneumocyte proliferation. Type II pneumocytes are responsible for production and secretion of surfactant, as well as replacement of damaged type I pneumocytes. Although several reports suggest that a tapering dosage of glucocorticoids provides adequate treatment for hydrocarbon pneumonitis, there are some affected individuals who require continued bronchodilator or glucocorticoid treatment. This may be a result of permanent pulmonary damage, such as fibrosis or proliferation and enlargement of alveolar lining cells. Humans with toxic pneumonitis may be more susceptible to infections and exercise intolerant and may have continued pulmonary function impairment.

In contrast, results of an experimental study of dogs that had kerosene instilled into their lungs do not support the administration of antimicrobials or corticosteroids. In that study, 20 dogs (weight range, 3.8 to 32.3 kg [8.36 to 71.06 lb]) were randomly assigned to a control or treatment group. All dogs received a median lethal dose of kerosene into the trachea, and the treatment group received dexamethasone sodium phosphate (2 mg, IM, q 6 h for 48 h) and ampicillin (25 mg/kg [11.4 mg/lb], IM, q 6 h for 10 days). At the conclusion of the study, there was no significant difference in clinical course, survival, or gross or histologic findings between the treatment and control groups.

The use of bronchodilators in the treatment of toxic pneumonitis in dogs is based on recommendations from the human medical literature. Although it was difficult to determine the direct benefit of this treatment in the dogs of this report, bronchodilators were administered because bronchoconstriction is a known pathologic effect of toxin inhalation in humans. The true benefit of bronchodilators in dogs is best evaluated by pulmonary function testing during intubation, which was not practical in the dogs of this report.

Toxic pneumonitis appears to be an uncommon or infrequently recognized disease in veterinary medicine. Clinical signs, the development of which can be delayed, may be severe and difficult to interpret without a high index of suspicion for toxin exposure. Affected animals can be treated successfully with aggressive supportive measures, including administration of oxygen, bronchodilators, and a tapering dosage of inhaled glucocorticoids; optimization of cardiovascular status; and nutritional support. Both dogs of this report had prolonged periods of hospitalization and required considerable monitoring and care before improvement in clinical status was achieved. Chemical pneumonitis is best prevented by application of waterproofing sprays in well-ventilated or outdoor areas from which pets are excluded. Further research is warranted to elucidate the mechanisms of injury associated with inhalation of waterproofing sprays as well as the efficacy of various treatments.

References