

Assessment of acute injuries, exposure to environmental toxins, and five-year health surveillance of New York Police Department working dogs following the September 11, 2001, World Trade Center terrorist attack

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Objective—To determine deployment logistics of New York Police Department (NYPD) working dogs that assisted in relief efforts at the World Trade Center (WTC) site following the September 11, 2001, terrorist attack; establish types and rates of related acute injuries and illnesses; identify environmental toxin exposures; and determine long-term (ie, 5-year) health effects of deployment.

Design—Prospective cohort study.

Animals—27 working dogs.

Procedures—Deployment logistics for the period from September 11, 2001, through May 30, 2002, were determined, and acute health disorders were identified by means of physical examination; a questionnaire; interviews with dog handlers; and toxicologic (blood and hair samples), clinicopathologic, microbiologic (nasal swab specimens submitted for *Bacillus anthracis* culture), and radiographic methods. Long-term health surveillance ended September 21, 2006.

Results—Dogs worked a total of 1,428 days (15,148 hours) at the site. Seventeen of the 27 (62.9%) dogs had health disorders during the first week. Specific conditions included fatigue (incidence rate [events/1,000 active deployment hours], 13.1), conjunctival irritation (13.1), respiratory tract problems (12.4), decreased appetite (10.8), dehydration (10), and cuts (9.3). Only minor hematologic and serum biochemical abnormalities were identified. Bacterial culture of nasal swab specimens did not yield *B anthracis*. Only mild and infrequent health conditions were identified during the 5-year follow-up period. None of the dogs were identified as having chronic respiratory tract disease. Six dogs died of various causes.

Conclusions and Clinical Relevance—Results suggested that acute injuries and illnesses were common among NYPD working dogs deployed to the WTC disaster site, but that long-term health complications were minimal. (*J Am Vet Med Assoc* 2008;233:48–59)

Environmental hazards were an important concern for relief workers following the terrorist attack of September 11, 2001, on the WTC. Building incineration and collapse created a hazardous environment that exposed emergency responders and community residents to a complex mix of toxic chemicals, including

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ABBREVIATIONS

CI	Confidence interval
NYPD	New York Police Department
WTC	World Trade Center

polychlorinated biphenyls and related compounds, heavy metals, trace minerals, and asbestos, and a wide range of pesticides and other toxic agents.^{1–7} Search-and-rescue teams were hindered by massive amounts of physical debris,^{8,9} and Lower Manhattan was blanketed by a massive dust cloud that contained soot, ash, aerosolized coarse and fine particulate matter, and combustible gases.^{2,3,10,11}

Various studies^{4,12–14} have subsequently identified increases in the rates of new-onset illness and the severity of various symptoms of respiratory tract disease among individuals exposed to the WTC site and its immediate vicinity. Given the important role that working

dogs played in the response and relief efforts, the potential health effects on these dogs are also a concern. Previous studies^{15,16} have examined medical and behavioral problems among working dogs affiliated with the Federal Emergency Management Agency and other national organizations and groups that were deployed to the WTC disaster site. Working dogs affiliated with the NYPD were also dispatched to the WTC site, and many of these dogs remained deployed at the site throughout the 37-week cleanup operation. Consequently, some of these dogs were extensively exposed to environmental hazards for prolonged periods. However, epidemiologic studies of health effects in these dogs have not been reported. The purposes of the study reported here, therefore, were to determine deployment logistics of NYPD working dogs that assisted in disaster relief efforts at the WTC disaster site following the September 11, 2001, terrorist attack; establish types and rates of related acute injuries and illnesses; identify environmental toxin exposures; and determine long-term (ie, 5-year) health effects of deployment.

Materials and Methods

Study population—Working dogs affiliated with the NYPD that were actively deployed in search and rescue, cadaver identification, bomb detection, or security activities at the WTC site following the September 11, 2001, terrorist attack were eligible for inclusion in the study. Eligible dogs were identified by contacting municipal and law enforcement agencies in New York City. Thirty-one dogs were initially identified as being eligible for inclusion in the study, and handlers of 27 of these dogs agreed to participate. Consent was obtained from the NYPD and New York City municipal authorities. All dog handlers were NYPD officers. Each dog included in the study had been assigned to, trained by, and paired with the same handler before September 11, 2001. For dogs included in the study, medical history and health status prior to September 11, 2001, was ascertained by reviewing medical records of the Animal Medical Center, which had provided veterinary care for NYPD working dogs.

Study protocol—The study protocol was approved by the Institutional Animal Care and Use Committee of the Caspary Institute at the Animal Medical Center. The study was divided into 2 phases. The first phase involved assessment of deployment logistics, acute injuries and illnesses, and exposure to environmental toxins for the period from September 11, 2001, to May 30, 2002. This interval was chosen because May 30, 2002, marked the official end of WTC cleanup activities. The second phase involved assessment of the health of participating dogs from May 31, 2002, to September 21, 2006.

Assessment of acute health effects and environmental toxin exposure—Shortly after the September 11, 2001, terrorist attack, an emergency triage and command center was set up at Stuyvesant High School, approximately 457 m (500 yards) from the WTC site, to coordinate New York City law enforcement and rescue-and-recovery operations.⁹ Approximately 6 hours after the WTC collapse, a veterinary emergency treat-

ment station was established at the command center for evaluation and treatment of NYPD working dogs. Subsequently, a more permanent veterinary emergency treatment station was established.¹⁵

For all dogs enrolled in the study, a complete examination was performed at the Bobst Hospital of the Animal Medical Center between January 2002 and May 2002. Thirteen dogs were examined during January and February 2002, 12 dogs were examined during March and April 2002, and 2 dogs were examined during May 2002. Procedures performed during each of these scheduled visits included a complete physical examination, collection of blood samples for a CBC and serum biochemical profile, thoracic and abdominal radiography, collection of blood and hair samples for toxicologic evaluations, collection of nasal swab specimens for bacteriologic culture for *Bacillus anthracis*, and an interview with the handler. The primary investigator (PRF) performed all procedures. Specific attention was paid to any illnesses or injuries sustained during active deployment between September 11, 2001, and May 30, 2002. Each handler was asked about the dog's medical and surgical history, training experience, preventative medical care, diet, and health status prior to WTC deployment. Questions were also asked about WTC deployment, including duration of active deployment; use of paw protection; occurrence, nature, severity, and timing of injuries and illnesses sustained during active deployment; and treatment, management, and resolution of those injuries and illnesses. Information about specific clinical signs was elicited by asking handlers whether their dogs had exhibited any of the conditions included in a predetermined list. This included conditions associated with the eyes (ie, redness, tearing, and squinting), skin (ie, erythema, pruritus, laceration, and oozing), urinary tract (ie, hematuria, stranguria, polyuria, and polydipsia), respiratory tract (ie, wheezing, coughing, and nasal discharge), gastrointestinal tract (ie, emesis and diarrhea), and musculoskeletal system (ie, lameness and other injuries). Handlers were also asked whether their dogs had had any change in appetite (increase or decrease) or evidence of fatigue or dehydration. Handlers were encouraged to use calendars, personal notes, and work schedules to obtain information regarding deployment details and injuries and illnesses. Dogs were reexamined as necessary to follow-up any injuries or illnesses that were detected or if the handler or supervisor expressed any health concerns. Additional follow-up information was obtained through telephone conversations and e-mail. During the period from September 11, 2001, to May 30, 2002, dogs were examined 1 to 6 times each (median, 2 times).

Food was withheld for 24 hours prior to collection of blood samples for clinicopathologic analyses, and samples were submitted for a CBC,^a serum biochemical profile,^b and detection of heartworm antigen.^c If clinicopathologic abnormalities were detected, follow-up samples were obtained as soon as possible, generally within 1 to 6 weeks. All samples were analyzed by a commercial laboratory^d; reference ranges established by the laboratory were used as guidelines for data interpretation.

Blood and hair samples obtained for toxicologic evaluations were shipped to the California Animal

Health and Food Safety Laboratory and the New York State Animal Health Diagnostic Laboratory. Blood lead concentrations were determined by means of Zeeman graphite furnace atomic absorption.^e Serum zinc, copper, iron, calcium, magnesium, potassium, sodium, and phosphorus concentrations were determined by means of inductively coupled argon plasma emission spectroscopy.^f Owing to the short half-life of arsenic in blood, hair samples were assayed by means of hydride vapor generation–inductively coupled argon plasma atomic emission spectrometry.^f Blood samples were tested for polychlorinated biphenyls by means of gas chromatography with electron capture detection.^g Testing included chemical analysis for aroclors, which are commercial mixtures of individual polychlorinated biphenyls, including aroclor 1016 (detection limit, 0.5 ppm), aroclor 1221 (detection limit, 0.5 ppm), aroclor 1232 (detection limit, 0.5 ppm), aroclor 1242 (detection limit, 0.1 ppm), aroclor 1248 (detection limit, 0.1 ppm), aroclor 1254 (detection limit, 0.1 ppm), aroclor 1260 (detection limit, 0.1 ppm), and aroclor 1262 (detection limit, 0.1 ppm). Qualitative assessments for environmental toxins, residues, and chemicals were performed on plasma by means of liquid–liquid extraction followed by capillary gas chromatography–mass spectrometry.^h Samples were analyzed for specific polycyclic aromatic hydrocarbons, including naphthalene, acenaphthene, anthracene, fluorene, phenanthrene, fluoranthrene, pyrene, benzo(a)anthracene, naphthacene, chrysene, benzo(a)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(c)phenanthrene, and dibenzo(ah)anthracene.

Nasal swab specimens were shipped to the Cornell University Diagnostic Laboratory for testing for *B anthracis*.

Long-term health surveillance—For long-term health surveillance of dogs included in the study, health information was collected at least once a year from May 30, 2002, through September 21, 2006. Dogs were examined between 1 and 10 times (median, 4 times) during this period. At each examination, a complete physical examination was performed, and the handler was questioned concerning any health problems the dog might have had. Additional information was obtained through telephone interviews with handlers or supervisors familiar with the dogs when an examination was not possible. Questions asked during these interviews were the same as those asked during the initial phase of the study. Most physical examinations were conducted at the Bobst Hospital, but a small number of examinations were performed at other local private veterinary practices. In the latter instance, medical records of these examinations were made available to the principal investigator (PRF), who interviewed the handlers. A full necropsy was performed, if possible, on any dog that died during the study period.

Any illness or health condition that occurred for the first time between May 31, 2002, and September 21, 2006, was recorded, except that conditions related to flea or tick infestation or to preventative health care were excluded. Each specific condition was recorded as the date it was first seen or detected, so that for each

dog, each specific condition was counted only once. The cumulative incidence of each specific condition was then calculated.

Historical control data were used to provide a qualitative context for long-term health assessments of participating dogs. A control group was identified by searching the patient database of the Bobst Hospital for dogs examined annually between September 11, 2001, and September 21, 2006. Fifty control dogs were matched to sample population dogs on the basis of age, breed, and sex. This included 16 law enforcement working dogs that had not participated in disaster relief efforts following the September 11, 2001, terrorist attack and 34 pet dogs. Medical records of the control dogs were reviewed retrospectively to identify any illnesses or health conditions that developed during the study period.

Statistical analyses—Categoric and qualitative data were described as percentages. Toxicologic data were summarized as mean and 95% CI of the mean. Other quantitative data were described as median and range or mean and SD, depending on data distribution. For each dog, number of work days was calculated on the basis of documented hours of deployment. A work day was defined as a work shift ≥ 6 hours long during any 24-hour period during which the dog was participating in search-and-rescue activities, cadaver identification, security patrol, or explosives detection at the WTC disaster site. Total hours of deployment were calculated on the basis of total number of work days and duration of individual work shifts for each dog. Cumulative incidence of specific illnesses and health conditions was calculated by dividing the number of dogs that developed that condition during a specific time period by the number of dogs free from that condition in the population at risk at the beginning of the time period. Incidence rates were calculated by dividing the number of occurrences of each specific condition by the total number of hours of deployment and were reported as number of events/1,000 active deployment hours. Poisson exact 95% CIs were calculated for incidence rates. Continuous outcomes were analyzed by means of fixed-factor ANOVA. Two models were used, with the first including only data for dogs enrolled in the study and the second including factors for number of hours deployed during September 2001 and the interaction between dog and number of hours deployed. The Fisher exact test and multiple logistic regression were used to test for associations between the presence of specific health conditions and various factors determined by the authors to be plausibly associated with development of those health conditions. For these analyses, outcome was coded as yes or no, with yes indicating the presence of at least one of several possible health conditions. Candidate explanatory factors that were examined for an association with outcome included previous training, previous medical and surgical problems, preventative medical care, age, sex, body weight, use of paw protection, and time spent in active deployment. The latter included duration of work days during September 2001, total number of days deployed during September 2001, total number of hours deployed during September 2001, total number of days deployed, and total number of hours deployed during

the first week of September 2001. Forward and backward selection methods were used to develop the logistic regression models. For forward selection, factors were entered into the model in order from most to least significant, determined on the basis of their incidence. For backward selection, factors were eliminated from the model in order from least to most significant, determined on the basis of their incidence. Models developed by means of the forward and backward selection procedures were then compared, and fit of the various models was tested with the Hosmer-Lemeshow goodness-of-fit χ^2 statistic. Assumptions underlying the methods were assessed before accepting the results. Results were considered significant if the *P* value was < 0.05. For long-term health surveillance, number of dog years was calculated on the basis of time that each dog was followed up during the period from May 31, 2002, to September 21, 2006. The cumulative incidence for each specific health condition was calculated by dividing the number of dogs that developed the condition during the study period by the number of dogs free from the condition in the population at risk at the beginning of the study period. Incidence rates of specific conditions were calculated by dividing the number of new events by the number of dog-years and were stated as number of events per dog-year. Poisson exact 95% CIs were calculated for incidence rates. Analyses were performed with standard software.¹

Results

Animals—The 27 dogs included in the study had all been involved in relief efforts at the WTC site and immediate vicinity between September 11, 2001, and May 30, 2002. In rare instances, some dogs were also deployed to the Fresh Kills landfill site or other locations in Manhattan. The Fresh Kills landfill site served as the repository for debris from the WTC, including structural wreckage and human remains, and was located on Staten Island.

Signalment—There were 21 (78%) German Shepherd Dogs, 5 (18%) Labrador Retrievers, and 1 (4%) Belgian Malinois. Twenty-five dogs (93%) were male (20 sexually intact and 5 castrated), and 2 (7%) were female (both spayed). Median body weight at the time of study initiation was 35.7 kg (78.5 lb; range, 25.5 to 43.6 kg [56.1 to 95.9 lb]). Median age at the time of study initiation was 3.8 years (range, 2.3 to 8.8 years). Seventeen of the dogs were from the Emergency Service Unit, 5 were from the Explosives Detection Unit, and 5 were from the Narcotics Division. Age did not differ significantly (*P* = 0.56) among these 3 groups.

Health status prior to September 11, 2001—Information on medical and surgical history prior to September 11, 2001, was available for all dogs. All dogs had been kenneled in New York City. Ten of the 27 (37%) dogs had undergone surgical procedures (carpal or tarsal pad laceration, 7; bite wound, 2; cryptorchid castration, 1) prior to September 11, 2001. Additional previous medical conditions included fractured incisors or canine teeth (*n* = 2), atopy (2), and mild hip dysplasia (3). As of September 11, 2001, all immunization and preventative medicine programs were current

for all dogs, and none of the dogs had any evidence of respiratory tract disease or other serious medical or surgical conditions. All dogs were fed the same dry commercial food.¹

Training and experience—At the time of the September 11, 2001, terrorist attack, all dogs were actively engaged in training programs commensurate with their primary roles in law enforcement, such as patrol, search and rescue, explosives detection, and narcotics interdiction. None of these canine-handler teams had urban search-and-rescue certification by the Federal Emergency Management Agency. One dog had previously been deployed to a hurricane disaster site; the remaining 26 had never worked outside the New York City vicinity. Prior to September 11, 2001, none of the dogs had been conditioned to use foot protection while working. Most handlers who tried to have their dogs wear protective booties during early disaster relief efforts reported that their dogs rejected them, and most handlers discontinued their use. Only 3 dogs wore foot protection during the initial deployment period.

Deployment logistics—All 27 dogs were deployed to the WTC site on September 11, 2001, to assist with search and rescue, explosives detection, and security activities. From September 11 through 17, 2001, 24 of the 27 dogs worked 8- to 16-hour shifts at the disaster site, with 10 of these dogs working 6 consecutive days. When anthrax bioterrorism became a paramount concern in New York City during October 2001, some of the dogs were deployed to other locations because of suspected anthrax contamination. During the 262-day period between September 11, 2001, and May 30, 2002, the 27 dogs worked a combined total of 1,428 days, representing 15,148 hours of active deployment (Figures 1 and 2).

When considering the extent of active deployment for each dog, 2 patterns of exposure to the WTC site

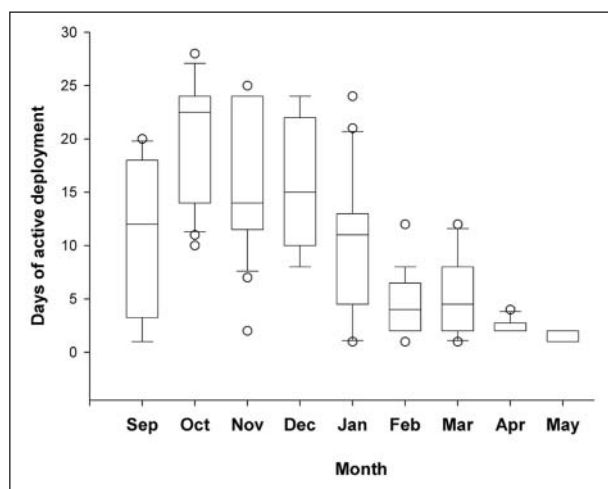


Figure 1—Box plots of total days of active deployment from September 11, 2001, through May 30, 2002, for 27 NYPD working dogs deployed after the September 11, 2001, terrorist attack on the WTC. For each plot, the line in the center of the box represents the median, the lower and upper bounds of the box represent the 25th and 75th percentiles, and the lower and upper whiskers represent the 10th and 90th percentiles. Outlying values are represented as open circles.

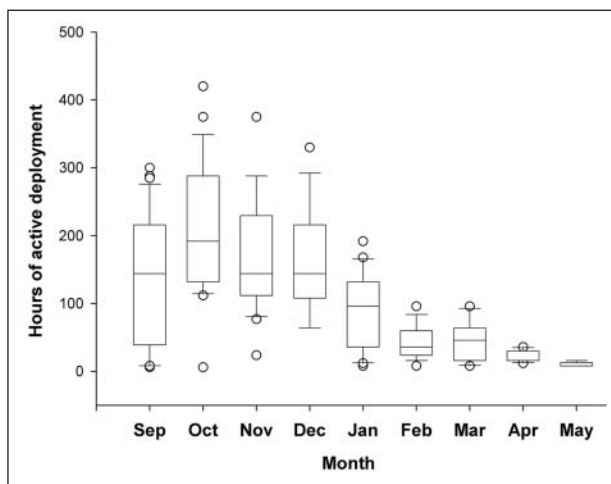


Figure 2—Box plots of total hours of active deployment from September 11, 2001, through May 30, 2002, for 27 NYPD working dogs deployed after the September 11, 2001, terrorist attack on the WTC. See Figure 1 for key.

were evident. Seventeen of the 27 dogs had extensive and prolonged exposure to the WTC site. These dogs were part of the NYPD Emergency Service Unit and participated in search and rescue, cadaver identification, and patrol duties. During the 20-day period from September 11 through September 30, 2001, these dogs worked a combined total of 272 days (median, 18 d/dog; range, 11 to 20 d/dog), representing a combined total of 3,297 hours (median, 188 h/dog; range, 96 to 300 h/dog). During this period, work shifts during each 24-hour period ranged from 8 to 16 hours (median, 12 hours). Subsequently, these dogs worked a combined total of 1,051 additional days at the WTC site from October 1, 2001, through May 30, 2002.

The remaining 10 dogs had relatively brief exposure to the WTC site; their duties included predominantly security and explosives detection. Between September 11 and September 30, 2001, these dogs worked a combined total of 33 days (median, 2 d/dog; range, 1 to 10 d/dog), representing a combined total of 358 hours (median, 14 h/dog; range, 6 to 120 h/dog). During this period, work shifts during each 24-hour period ranged from 6 to 12 hours (median, 9 hours). Subsequently, these dogs worked a combined total of 72 additional days at the WTC site from October 1, 2001, through May 30, 2002.

The 17 dogs with prolonged exposure to the WTC site did not differ from the 10 dogs with brief exposure to the WTC site with regard to number of years of work experience prior to September 11, 2001 (median, 3 years [range, 2 to 8 years] vs 4.1 years [range, 2 to 7 years]; $P = 0.56$); age (median 3.7 years [range, 2.3 to 8.8 years] vs 4.6 years [range, 2.4 to 7.5 years]; $P = 0.77$); body weight (median, 35.9 kg [79.0 lb; range, 31.4 to 42.3 kg {69.1 to 93.1 lb}] vs 34.2 kg [75.2 lb; range, 25.5 to 43.6 kg {56.1 to 95.9 lb}]; $P = 0.45$); or sex distribution (17 males vs 8 males and 2 females; $P = 0.13$). However, dogs with prolonged exposure to the WTC site were deployed significantly ($P < 0.001$) more hours and had significantly ($P = 0.023$) longer work shifts than did dogs with brief exposure to the WTC site.

Acute health effects—None of the dogs died, had a critical work-related injury, or developed a severe work-related illness during the period from September 11, 2001, to May 30, 2002. However, multiple acute injuries and illnesses were identified (Table 1). Most of these injuries and illnesses appeared to be related to exposure to smoke and particulate matter, as signs of most of these conditions developed shortly after exposure to the disaster site. Of particular importance were conjunctival irritation, hyperemia and irritation of the skin and mucous membranes, and respiratory tract problems, including coughing, gagging, and nasal discharge.

At least 1 health condition was identified in 16 of the 17 dogs with prolonged exposure to the WTC disaster site but in only 6 of the 10 dogs with brief exposure to the WTC disaster site. These proportions were significantly ($P = 0.047$) different. Subjectively, injuries and illnesses identified in the dogs with prolonged exposure to the WTC disaster site appeared to be more severe and of longer duration than injuries and illnesses identified in dogs with only brief exposure to the site.

From September 11 through 17, 2001, the incidence rate for all health conditions combined was 92 events/1,000 active deployment hours (95% CI, 74.2 to 112.8 events/1,000 active deployment hours); 18 of the 27 dogs developed 1 or more health conditions during this period, for a cumulative incidence of all health conditions combined of 67%. During the period from September 11 through October 1, 2001, 22 of the 27 dogs developed 1 or more health conditions, for a cumulative incidence of 81%.

From September 11 through 17, 2001, the most common injuries and illnesses were conjunctival irritation and fatigue (Table 1). Conjunctival irritation was generally characterized by severe conjunctival hyperemia, tearing, squinting, and face rubbing. Affected animals were treated by means of gentle irrigation of the conjunctival fornices with eye solution. Although fatigue was commonly reported during this period, no attempts were made to distinguish between weakness, exercise intolerance, and exhaustion, and any dog that was reported by the handler to have reduced physical performance was categorized as having fatigue.

Other injuries and illnesses commonly identified during the period from September 11 to 17, 2001, included respiratory tract problems, decreased appetite and weight loss, dehydration, cuts and abrasions, diarrhea and emesis, and skin problems. Clinical signs associated with respiratory tract problems included coughing, gagging, sneezing, and nasal discharge. Less commonly, tachypnea or exertional dyspnea was reported. None of the affected dogs required evacuation or oxygen therapy.

For dogs with weight loss, the magnitude of documented weight loss during the period from September 11 to October 1, 2001, ranged from 0.9 to 4.1 kg (2.0 to 9.0 lb), representing approximately 3% to 10% of body weight. Weight loss was recorded concurrently with decreased appetite in 8 dogs. One additional dog had weight loss without any reported change in appetite. Seven other dogs had a substantial decrease in appetite, but information on change in body weight was not available.

Table 1—Cumulative incidence of acute injuries and illnesses in 27 NYPD working dogs deployed after the September 11, 2001, terrorist attack on the WTC.

Health condition	September 11–17, 2001			September 11–October 1, 2001	
	No. of affected dogs	Cumulative incidence (%)	Incidence rate* (95% CI)	No. of affected dogs	Cumulative incidence (%)
Fatigue	17	62.9	13.1 (7.7–22.2)	19	70.4
Conjunctival irritation	17	62.9	13.1 (7.7–22.2)	17	62.9
Respiratory tract problems	16	59.2	12.4 (6.9–21)	16	59.2
Decreased appetite	14	51.8	10.8 (5.5–18.4)	16	59.2
Dehydration	13	48.1	10.0 (4.7–18.4)	13	48.1
Cuts and abrasions	12	44.4	9.3 (4.8–17.1)	14	51.8
Diarrhea	9	33.3	7.0 (2.8–13.1)	11	40.7
Skin problems	8	29.6	6.2 (2.8–13.1)	9	33.3
Emesis	6	22.2	4.6 (1.6–10.2)	6	22.2
Weight loss	5	18.5	3.9 (1.1–8.8)	9	33.3
Hematuria and stranguria	2	7.4	0.8 (0.02–3.7)	2	7.4
Lameness	1	3.7	0.8 (0.02–3.7)	2	7.4
Corneal laceration	1	3.7	0.8 (0.02–3.7)	1	3.7

*Expressed as number of events/1,000 active deployment hours.

Of the 14 dogs with cuts and abrasions during the period from September 11 to October 1, 2001, 10 had superficial wounds involving the feet or lower extremities ($n = 7$), trunk (2), or face (1); 2 had full-thickness lacerations requiring suturing (metacarpal pad in 1 dog and the ventral aspect of the chest in the other); and 2 had foot abrasions in combination with chemical or heat burn injuries to the carpal and tarsal foot pads.

Twelve dogs developed diarrhea, emesis, or both between September 11 and October 1, 2001. Characteristically, diarrhea was acute in onset, and affected dogs passed watery feces or feces containing small amounts of blood and mucus and accompanied by straining. Diarrhea generally resolved in 2 to 3 days without treatment, although in 4 dogs, it persisted intermittently for up to 10 days. Emesis occurred infrequently and generally lasted 24 to 48 hours.

Dogs with evidence of dehydration were treated by means of SC administration of fluids. Eight of the 13 dogs with dehydration also had diarrhea, emesis, or both. Dogs that were dehydrated worked significantly ($P = 0.025$) more hours (median, 120 h/dog; range, 64 to 320 h/dog) during the period from September 11 to October 1, 2001, than did dogs that were not dehydrated (median, 60 h/dog; range, 8 to 168 h/dog).

In dogs with skin problems, signs generally developed quickly after dogs began search activities and were characterized by generalized erythredema. The face, external ear canals, ventral aspect of the trunk, and interdigital areas were most severely affected. These dogs were treated by means of frequent bathing and washing, and signs generally resolved in 3 to 5 days. Secondary pyoderma occurred in 4 dogs.

Injuries and illnesses that were identified less frequently included stranguria with hematuria, lameness, and corneal laceration. In both dogs with stranguria and hematuria, clinical signs resolved within 48 to 72 hours. Lameness attributed to hip dysplasia was documented in 2 dogs. One dog had a corneal laceration.

A German Shepherd Dog that reportedly was coughing between September 11 and 17, 2001, had

thoracic radiographic changes consistent with focal bronchopneumonia. The dog was treated with antimicrobials, and radiographic abnormalities had resolved by the time of follow-up thoracic radiography 1 week later. No pulmonary abnormalities were detected in any of the other 18 dogs that underwent thoracic radiography during this period of acute surveillance.

Analysis of potential risk factors for illness and injury—None of the potential explanatory factors considered in the logistic regression analyses were significantly associated with development of acute illness or injury; the lowest P value obtained was associated with total number of hours deployed from September 11 through 17, 2001 ($P = 0.102$). The P value for the Hosmer-Lemeshow goodness-of-fit analysis was 0.984, which indicated that the model was an excellent fit with the data. In most models, severe technical restrictions were encountered because of multicollinearity, meaning that several of the candidate explanatory factors that were examined recorded the same data in different ways.

Clinicopathologic and microbiologic findings—Results of CBCs performed on blood samples collected between January and May 2002 were within reference limits, except for mild abnormalities detected in 9 dogs (some dogs had > 1 abnormality). Leukopenia (range, 4.7 to 5.6 $\times 10^3$ WBCs/ μ L; reference range, 6.0 to 17.0 $\times 10^3$ WBCs/ μ L) was identified in 3 dogs, and lymphopenia (range, 830 to 898 lymphocytes/ μ L; reference range, 1,000 to 4,800 lymphocytes/ μ L) was identified in 2 of these 3 dogs. Neutrophilia (12,000 to 14,400 neutrophils/ μ L; reference range, 3,000 to 11,500 neutrophils/ μ L) was identified in 2 dogs. Eosinophilia (range, 1,400 to 1,700 eosinophils/ μ L; reference range, 100 to 1,250 eosinophils/ μ L) was identified in 3 dogs. Monocytosis (range, 1,430 to 1,900 monocytes/ μ L; reference range, 150 to 1,350 monocytes/ μ L) was identified in 4 dogs. Basophilia (280 basophils/ μ L; reference range, < 200 basophils/ μ L) was identified in 1 dog. Additional blood samples were obtained from all 9 dogs with abnormali-

ties, and results of follow-up CBCs were within reference limits, except that 1 dog had persistent leukopenia (4.8×10^3 WBCs/ μ L).

All 27 dogs had negative results for microfilaria. Serum biochemical values were within reference limits, except that serum alanine aminotransferase activity was slightly high (range, 61 to 150 U/L; reference range, 5 to 60 U/L) in 12 (44%) dogs, and serum aspartate aminotransferase activity was slightly high (58 and 60 U/L; reference range, 5 to 55 U/L) in 2 of these 12 dogs. Serum globulin concentration was slightly high in 2 dogs (4.6 and 4.8 g/dL; reference range, 2.8 to 4.5 g/dL). Additional blood samples were obtained from all 12 of the dogs with serum biochemical abnormalities. Results of follow-up testing were within reference limits, except that 3 dogs still had slightly high serum alanine aminotransferase activities. Results of microbial culture of nasal swab specimens for *B anthracis* were negative in all 27 dogs.

Exposure to environmental toxins—Mean blood lead concentration was significantly ($P < 0.001$) higher among the 17 dogs with prolonged exposure to the WTC site than among the 10 dogs with brief exposure to the site (Table 2). The 4 highest blood lead concentrations ranged from 15.6 to 22.6 μ g/dL (reference range, < 10 μ g/dL); none of these 4 dogs had clinical signs compatible with lead toxicosis. There was no significant correlation between the total number of hours deployed during the period of acute health surveillance and blood lead concentration in dogs with prolonged exposure ($P = 0.5$) or in dogs with brief exposure ($P = 0.7$). Twenty-one of the 25 dogs tested had detectable arsenic concentrations in hair (cumulative incidence, 84%), but concentrations were within reference limits in all 21. Arsenic concentrations in the remaining 4 dogs were less than the method detection limit (0.02 ppm). Only 2 dogs had hair arsenic concentrations greater than the background threshold of 0.4 ppm (0.56 and 0.66 ppm, respectively).

Mean serum iron concentration was not significantly ($P = 0.20$) different between dogs with prolonged exposure to the WTC site and dogs with brief exposure. Mean serum zinc concentration was significantly ($P = 0.01$) higher in dogs with brief exposure to the WTC site than in dogs with prolonged exposure, although all dogs in both groups had concentrations within reference limits. There was no significant correlation between total number of hours deployed during the

period of acute health surveillance and serum copper ($P = 0.83$), iron ($P = 0.85$), zinc ($P = 0.67$), or magnesium ($P = 0.85$) concentrations. In all dogs, blood polychlorinated biphenyl concentration was less than the method limit of detection. This included concentrations of aroclor 1016, aroclor 1221, aroclor 1232, aroclor 1242, aroclor 1248, aroclor 1254, aroclor 1260, and aroclor 1262.

One or more environmental toxins were detected in serum samples from 22 of the 27 (81%) dogs. Toxins identified included 3-methyl quinoline (n = 12 [6 dogs with prolonged exposure to the WTC site and 6 with brief exposure]), isoquinoline (11 [7 with prolonged and 4 with brief exposure]), 2-(1-phenylethyl) phenol (9 [8 with prolonged and 1 with brief exposure]), quinoline (6 [4 with prolonged and 2 with brief exposure]), diphenylamine (4 [1 with prolonged and 3 with brief exposure]), surfynol (2 [1 with prolonged and 1 with brief exposure]), and cedrol (1 with prolonged exposure). Quinolone, 3-methyl quinoline, isoquinoline, diphenylamine, surfynol, and 2-(1-phenylethyl) phenol were identified both in dogs with prolonged exposure to the WTC site and in dogs with brief exposure. All serum samples were negative for polycyclic aromatic hydrocarbons, including naphthalene, acenaphthene, anthracene, fluorene, phenanthrene, fluoranthrene, pyrene, chrysene, benzo(a)anthracene, naphthacene, benzo(a)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(c)phenanthrene, and benzo(ah)anthracene.

Long-term health surveillance—One of the 27 dogs was lost to follow-up 15 months after the September 11, 2001, terrorist attack. Twenty of the remaining 26 (76.9%) dogs were still alive at the end of the study period (ie, September 21, 2006). Median age at the end of the study period for dogs that survived was 8.8 years (range, 7.4 to 13.9 years). Six of the 26 (23%) dogs that completed the study died or were euthanized prior to the end of the study period. This included a sexually intact male German Shepherd Dog that developed hemangiosarcoma and died at 8.2 years of age as a consequence of tumor metastasis 389 days after September 11, 2001 (the diagnosis was confirmed at necropsy); a sexually intact male German Shepherd Dog that developed inflammatory bowel disease (plasmacytic-lymphocytic enteritis) unresponsive to treatment that was euthanized at 6.7 years of age 1,229 days after September 11, 2001 (the diagnosis was confirmed at necrop-

Table 2—Results of assessments of blood, serum, and hair samples for environmental toxins in 27 NYPD working dogs deployed after the September 11, 2001, terrorist attack on the WTC.

Compound	Prolonged exposure group (n = 10)		Brief exposure group (n = 17)		Reference range	P value
	Mean	95% CI	Mean	95% CI		
Blood Lead (μ g/dL)	10.8	2.7	3.1	1.1	< 10	< 0.001
Serum Copper (ppm)	0.7	0.04	0.6	0.05	0.2–0.8	0.13
Iron (ppm)	1.3	0.15	1.5	0.23	0.9–1.2	0.20
Zinc (ppm)	0.7	0.04	0.9	0.09	0.7–2	0.01
Magnesium (ppm)	19.7	0.65	19.4	1.3	18–27	0.58
Hair Arsenic (ppm)	0.12	0.1	0.16	0.12	< 5	0.32

sy); a neutered male Labrador Retriever that developed concurrent immune-mediated hemolytic anemia and immune-mediated thrombocytopenia and died at 10.3 years of age 1,038 days after September 11, 2001; a sexually intact male German Shepherd Dog that developed gastric dilatation-volvulus and died postoperatively at 8.4 years of age 1,832 days after September 11, 2001; a sexually intact male German Shepherd Dog with osteoarthritis that developed debilitating lameness and was euthanized at 9.25 years of age 1,549 days after September 11, 2001; and a sexually intact male German Shepherd Dog that developed osteosarcoma of the scapula and was euthanized at 9.3 years of age 1,835 days after September 11, 2001. By comparison, 11 of the 50 (22%) dogs in the historical control group died or were euthanized during a similar period. This included 2 German Shepherd Dogs with hemangiosarcoma, a German Shepherd Dog with lymphocytic-plasmacytic enteritis, a German Shepherd Dog with gastric dilatation-volvulus, a German Shepherd Dog with pancreatic carcinoma, a German Shepherd Dog with appendicular osteosarcoma, a Labrador Retriever with chronic renal failure, a Labrador Retriever with spinal neoplasia, a German Shepherd Dog and a Labrador Retriever with degenerative joint disease, and a German Shepherd Dog mix with intestinal perforation.

The most common injuries and illnesses documented during long-term health surveillance of the 27 study dogs were skin problems, lameness, lower urinary tract disease, and diarrhea. Skin problems (cumulative incidence, 52%) consisted of acute superficial dermatitis, otitis externa, and skin masses (lipomas and sebaceous cyst); the incidence rate of skin problems was 0.2 events/dog-year (95% CI, 0.11 to 0.33 events/dog-year). By comparison, the cumulative incidence of these skin problems in the historical control group was 42%. Lameness in the study dogs (cumulative incidence, 44%) was associated with osteoarthritis; the incidence rate was 0.12 events/dog-year (95% CI, 0.06 to 0.21 events/dog-year). All affected animals were ≥ 4.5 years old. Treatments for osteoarthritis included dietary management, nutraceuticals, analgesics, and anti-inflammatory agents. The cumulative incidence of lameness associated with osteoarthritis in the historical control group was 36%; all affected animals were > 5 years old. Lower urinary tract disease (cumulative incidence, 33%) was detected in 8 sexually intact male German Shepherd Dogs in the study group. The incidence rate was 0.11 events/dog-year (95% CI, 0.05 to 0.2 events/dog-year). All affected dogs had prostatomegaly and were successfully treated with antimicrobials alone or with antimicrobials and castration. The cumulative incidence of lower urinary tract disease in the historical control group was 16%. All but one of the affected control dogs had prostatomegaly and were sexually intact males; the remaining dog was female and had cystitis. Diarrhea (cumulative incidence, 26%) in the study dogs was generally mild and transient and consistent with both small and large bowel disorders. The incidence rate of diarrhea was 0.08 events/dog-year (95% CI, 0.03 to 0.16 events/dog-year). The cumulative incidence of diarrhea in the historical control group was 38%. For dogs in the study group, skin problems, lameness, and diarrhea were detected throughout the

period of long-term health monitoring, whereas lower urinary tract disease was detected 9 to 20 months after the WTC terrorist attack.

Several other health conditions were identified less commonly in the study dogs during the period of long-term health surveillance. Three dogs developed mild, transient conjunctivitis (cumulative incidence, 11%). A 6-year-old sexually intact male German Shepherd Dog developed duodenal ulcers and septic complications approximately 3 years after September 11, 2001, but responded to medical and surgical management and recovered without complications. A sexually intact male German Shepherd Dog that had allergic dermatitis and pyoderma prior to September 11, 2001, had severe, chronic, relapsing deep pyoderma throughout the surveillance period.

None of the 27 study dogs had clinical signs of respiratory tract disease during the long-term health surveillance period. Thoracic radiography was performed 1 or more times during this period in 21 of the dogs, and findings were unremarkable in all 21. A necropsy was performed on 2 of the German Shepherd Dogs that died, and results of histologic examination of lung specimens were unremarkable.

For 24 of the 27 study dogs, 1 or more blood samples were obtained during the long-term health surveillance period and submitted for a CBC and serum biochemical profile. Results of the CBCs were within reference limits, except for mild abnormalities in 6 dogs (some dogs had > 1 abnormality). Leukopenia (5.7×10^3 WBCs/ μL and 4.4×10^3 WBCs/ μL) was identified in 2 dogs, lymphopenia (880 and 985 lymphocytes/ μL) was identified in 2 dogs, neutrophilia (12,200 and 16,600 neutrophils/ μL) was detected in 2 dogs, and monocytosis (1,450 and 1,620 monocytes/ μL) was detected in 2 dogs. Serum biochemical values were within reference limits, except that serum alanine aminotransferase activity was high in 5 dogs (range, 72 to 112 U/L), serum aspartate aminotransferase activity (58 and 72 U/L) was high in 2 dogs, serum globulin concentration (4.6 and 4.7 g/dL) was high in 2 dogs, and serum cholesterol concentration (348 and 401 mg/dL; reference range, 112 to 328 mg/dL) was high in 2 dogs (some dogs had > 1 abnormality).

Discussion

Results of the study reported here suggested that acute injuries and illnesses were common among NYPD working dogs deployed to the WTC disaster site following the terrorist attack of September 11, 2001, with at least 1 health condition identified in 22 of the 27 (81%) dogs between September 11 and October 1, 2001. The most common injuries and illnesses during this period were fatigue, conjunctival irritation, respiratory tract problems, dehydration, cuts and abrasions, diarrhea, skin problems, emesis, and weight loss and appeared to be related to a combination of exposure to dust, gases, and airborne fine particulate matter and long work hours. However, none of the dogs died, had a critical work-related injury, or developed a severe work-related illness during the 37-week cleanup operation. Long-term (5-year) health surveillance revealed only mild health conditions that occurred at low incidence rates, and none of the dogs had evidence of chronic respiratory

ry tract disease or long-term serum biochemical abnormalities. Analysis of blood and hair samples revealed that several dogs had evidence of environmental toxin exposure; however, the clinical importance of these findings was uncertain. Nineteen of the dogs were still alive and apparently healthy 5 years after the terrorist attack of September 11, 2001.

Results of the present study were somewhat surprising, in that all dogs were deployed to the WTC site during the first 3 weeks after the terrorist attack, when the air was laden with fine particulate matter, including cement, glass, fiberglass, asbestos, and lead,² and combustion of jet fuel and incineration of affected structures had resulted in a variety of toxins, including polychlorinated biphenyls, chlorinated hydrocarbons, and dioxins.^{2,11,17,18} During the subsequent 37-week cleanup operation, fires that burned in the rubble added soot, dust, and volatile organic compounds to the environment, and diesel equipment involved in cleanup efforts produced mutagenic and carcinogenic polycyclic aromatic hydrocarbons.^{7,17-20} In addition, because dogs worked without the benefit of protective masks or garments, they were particularly susceptible to environmental toxins through respiratory, dermal, ocular, and oral pathways.^{2,21}

By contrast with findings of the present study, exposure to airborne particulate matter contained in the toxic plume of material released into the atmosphere over Lower Manhattan has been linked to respiratory tract disease and other health disturbances in people.^{4,12,22} The irritant effects of these contaminants were determined in toxicologic experiments in which rodents subjected to WTC dust samples containing 100 µg of fine particulate matter (< 2.5 µm in diameter) developed pulmonary inflammation.²³ In addition, airway hyperresponsiveness and reduced pulmonary function have been reported in workers involved in rescue and recovery efforts at the WTC site.²⁴⁻²⁷

Most of the acute injuries and illnesses identified in the dogs described in the present report developed during the first week of recovery efforts, when the incidence rate for all health conditions combined was 92 events/1,000 active deployment hours, with only a marginal increase in the cumulative incidence of disease during the subsequent 2 weeks. A similar morbidity pattern attributed to exposure to smoke, dust, and debris was recorded in human victims and relief workers.^{4,22,24,28} By comparison, a combined incidence rate of 17 events/1,000 dog-search hours was recorded for 96 dogs associated with the Federal Emergency Management Agency and various private organizations that were involved in search-and-recovery efforts following September 11, 2001, at the WTC, Pentagon, or Fresh Kills landfill.²⁹ These dogs, however, had to travel from multiple locations to reach New York City, and only 59% had arrived on site by September 12.¹⁶ Among New York City firefighters who responded to the WTC disaster, bronchial hypersensitivity was substantially greater in those who were present on the morning of September 11, compared with those who arrived later within the first 2 days.²⁵ The more immediate deployment of dogs in the present study likely contributed to the higher morbidity rate, compared with the previous study.²⁹

The extent of deployment of dogs in the present study was notable. During the 37-week period of relief and cleanup activities following September 11, 2001, these 27 dogs worked a median of 11 to 22.5 days per month for 5 consecutive months and, overall, were deployed for a combined total of 1,428 days. In comparison, a study²⁹ of 61 other search-and-rescue dogs that also participated in WTC relief activities found that those dogs worked a median of 10 days, with deployment ranging from 1 to 25 d/dog. During relief efforts associated with the Oklahoma City bombing, 74 dogs worked a combined total of 491 days.³⁰

Incidences of various injuries and illnesses cannot be directly compared among the various groups of working dogs that participated in WTC relief activities, but certain observations may be informative. Respiratory tract problems were common among dogs in the present study, with an incidence rate during the first week of 12.4 events/1,000 active deployment hours. By contrast, the incidence rate of respiratory tract problems among search-and-rescue dogs in a previous study²⁹ was 2.0 events/1,000 hours. Conjunctival irritation was identified during the first week of disaster relief efforts in 17 of the 27 (69%) dogs in the present study, with an incidence rate of 13.1 events/1,000 active deployment hours, whereas ocular problems were observed in only 8 of the 96 (8%) dogs in the previous study.²⁹ Skin problems were identified in 8 of the 27 (29%) dogs in the present study, with an incidence rate of 6.2 events/1,000 active deployment hours, but pruritus or erythema was identified in only 11 of 96 (11%) dogs in the previous study,²⁹ and neither ocular nor skin problems were listed as common problems in these dogs. Differences between the present study and this previous study may reflect differences associated with time of arrival at the WTC site relative to collapse of the towers, duration of deployment, and the nature of work activities performed or may be a result of differences in data collection. Dogs in the present study appeared to have been deployed earlier and used more extensively, as a group, than were dogs in the previous study, which could have been a factor in the high incidence of acute respiratory tract, ocular, and skin abnormalities.

The normal daily routines of dogs included in the present study were substantially disrupted during initial disaster relief efforts, with extended consecutive work shifts, in particular, affecting their eating and sleeping patterns. This factor, coupled with the increased exertion and activity, appeared to contribute to fatigue, gastrointestinal tract disorders, dehydration, and weight loss in many dogs.

Assessment of bulk, undisturbed, settled dust samples from various locations in Manhattan during September and October 2001 revealed the presence of a number of toxicants,⁵ and monitoring of exposed firefighters revealed significant increases in blood or urine concentrations of potentially fire-related chemicals.³¹ Because working dogs engage in activities that often compel them to work and breathe close to the ground, dogs in the present study could have been expected to have had particularly high exposure to dust

and soot that covered the WTC site and vicinity. Thus, to help detect exposure to environmental toxins, blood and hair samples were collected for toxicologic assessments.

Hair has been confirmed to be a useful specimen for confirming low-level dietary or environmental exposure to inorganic arsenic,³² and low concentrations of arsenic were detected in hair samples from 21 of 25 dogs in the present study. However, in all dogs, concentrations were less than the upper reference limit, and only 2 dogs had hair arsenic concentrations greater than the background threshold of 0.4 ppm. In addition, hair arsenic concentrations were not significantly different between dogs with prolonged exposure to the WTC site and dogs with brief exposure, suggesting that exposure to arsenic was not a major concern for these dogs during disaster relief efforts.

In contrast, blood lead concentrations were significantly higher among dogs in the present study with prolonged exposure to the WTC site than among dogs with only brief exposure. Mean blood lead concentration for dogs with prolonged exposure was higher than the upper reference limit, with the 4 highest blood lead concentrations ranging from 15.6 to 22.6 µg/dL. However, none of these dogs had clinical signs compatible with lead toxicosis, and the difference in lead concentrations between the 2 groups was clinically unimportant. Blood lead concentrations were also found to be significantly increased in firefighters who responded to the WTC collapse.³¹

Analysis of bulk samples of settled dust collected from Lower Manhattan after September 11, 2001, revealed only low concentrations of polychlorinated biphenyls,⁵ and in all of the dogs in the present study, blood polychlorinated biphenyl concentrations were less than the limit of detection. Comparison of polychlorinated biphenyl concentrations in ambient water samples collected before and after September 11, 2001, suggested that concentrations of this toxicant were not significantly increased following the terrorist attack.⁶

Although no polycyclic aromatic hydrocarbons were detected in serum samples from dogs in the present study, a variety of other environmental toxins were identified. In particular, quinoline, 3-methyl quinoline, isoquinoline, diphenylamine, surfynol, and 2-(1-phenylethyl) phenol were identified both in dogs with prolonged exposure to the WTC site and in dogs with brief exposure. Polycyclic quinones such as quinoline, 3-methyl quinoline, and isoquinoline may be formed from photochemical oxidation of polycyclic aromatic hydrocarbons in the atmosphere.³³ These compounds can be found in coal tar vapors, fossil fuels, shale oil, creosote wood preservatives, and manufactured dyes and are intermediates in the manufacture of other products, polymers, and agricultural chemicals.³⁴⁻³⁶ Metabolites of polycyclic aromatic hydrocarbons were detected in urine from New York City firefighters who responded to the WTC disaster.³¹ Polycyclic aromatic hydrocarbons and other semivolatile organic compounds including quinoline analogues are considered carcinogenic or mutagenic.^{34,35,37} In the experience of one of the authors (JGE), some of these chemicals have been detected in serum from young, apparently healthy

German Shepherd Dogs, but their medical importance is undetermined.

Surfynol is a surfactant commonly used as a foam destabilizer³⁶ and was detected in serum samples from 2 of the dogs in the present study; 1 of these dogs had prolonged exposure to the WTC site, and 1 had only brief exposure. Foaming agents were used to control fires at the WTC, and surfynol may have been an ingredient in these compounds. Diphenylamine was detected in serum samples from 1 dog with prolonged exposure and 3 dogs with brief exposure to the WTC site. This compound is used in manufacturing rubber tires and dyes, stabilizing nitrocellulose explosives and celluloid, and manufacturing bridged diphenyl fungicides.³⁶ Cedrol was detected in 1 dog in the present study. Cedrol is a constituent of various cedar wood conifers and has been used as a fragrance in foods, soaps, detergents, cosmetic creams, and lotions.³⁶ The source of exposure for the dog in the present study was not known. The chemical 2-(1-phenylethyl) phenol was detected in serum samples from 8 dogs with prolonged exposure to the WTC site and 1 dog with brief exposure. This compound is listed by the US Environmental Protection Agency as a chemical in commerce³⁸ and is a component of some compounds in the class of phenolic benzotriazoles, which are used in manufacturing polycarbonate resins and polyethylene phthalate polymers. These agents are potent UV light absorbers and constitute an important class of industrial additives for polymers and light-stabilized coatings, including polycarbonate polyesters, polystyrenes, acrylics, polyvinyl chloride, and thermoplastic polyesters.³⁹ At the WTC site, they were likely released from burning plastics, furniture, laminates, and office materials. A number of chemicals that were thought to be the products of burnt plastic materials were identified from firefighters who responded to the WTC site.³¹

The use of working dogs in military, law enforcement, and public health roles places these animals at risk for exposure to biological and toxic agents. Bio-monitoring has been advocated to assess exposure and protection strategies.³¹ When an outbreak of anthrax was identified in New York City in October 2001, many of the dogs in the present study were reassigned from disaster relief activities at the WTC site to monitoring activities at various sites suspected to be contaminated with anthrax. Therefore, dogs in the present study were screened for nasal carriage of *B anthracis*; results were negative in all dogs.

Although acute respiratory tract problems were common during the first 3 weeks of disaster relief work in dogs in the present study, long-term health surveillance did not reveal any clinical evidence of chronic respiratory tract disease, and results of thoracic radiography were unremarkable. Moreover, pulmonary lesions were not detected in the 2 dogs that died and underwent necropsy. This apparent absence of chronic respiratory tract disease was unexpected, particularly in view of reports^{4,12,22,24,40,41} that respiratory tract disease developed in people exposed to airborne pollutants from the WTC site. Although the reason for the apparent lack of chronic respiratory tract disease among dogs in the present study was not apparent,

certain dissimilarities have been reported between animal and human responses to inhalant toxicants. These include anatomic differences between human and animal airways, differences in the response to inhaled mediators of inflammation, and differences in lung defense mechanisms.⁴²⁻⁴⁴

Six dogs died during the long-term health surveillance portion of the present study, with the cause of death attributed to a different disease in all 6 dogs. Five of the deaths were associated with hemangiosarcoma, osteosarcoma, inflammatory bowel disease, gastric dilatation-volvulus, and degenerative joint disease, and dogs in the historical control group also died of these conditions. Thus, although we cannot say with certainty that none of the deaths in this study were related to exposure to the WTC site, we believe that age, sex, breed predispositions to certain diseases, and other factors played larger roles. For example, all dogs with lower urinary tract disease in the present study were sexually intact male German Shepherd Dogs that had prostatomegaly. Prostatic disease is reported to be a common finding in sexually intact male dogs, especially German Shepherd Dogs, and in older male dogs.⁴⁵⁻⁴⁷ Similarly, most of the dogs with lower urinary tract disease in the historical control group were sexually intact males. Three of the 5 chronic disease conditions reported both in study dogs and in the historical control group—degenerative joint disease, skin disease, and diarrhea—were among the most common disorders reported in a large series of dogs examined at private veterinary practices.⁴⁵

Analysis of CBC and serum biochemical profile results in the present study revealed few abnormalities. These findings were generally consistent with results reported for other search-and-rescue dogs deployed at the WTC site,¹⁶ in which CBC and serum biochemical profile results were generally within reference ranges. A few dogs in the present study had mild alterations in hematologic or serum biochemical variables, but none of these were considered clinically important.

The present study had several important limitations. Some health conditions may have been underreported or misreported by dog handlers and their supervisors or may not have been detected by the primary investigator. Although the study population comprised a cohort of dogs that was exposed to the WTC site for a prolonged period, the total number of dogs studied was low and may not have been sufficient to detect adverse health effects or subclinical disease associated with WTC-site exposure. The types, composition, and concentration of environmental toxins that these dogs were exposed to were unknown and likely changed over time,^{2,11} and the clinical importance of environmental toxins detected in serum samples from these dogs remains unresolved. Further, the time between exposure and collection of samples for analysis of environmental toxin exposure was uncontrolled, making it difficult to establish associations between time or extent of exposure and toxin concentrations. It is possible that some of the environmental compounds that were inhaled or absorbed during initial relief efforts may have been metabolized, excreted, or modified

during the interval between exposure and collection of blood samples for analysis. These chemicals could also have been altered during blood storage or as a result of microbial degradation or photochemical dechlorination. Moreover, the composition of chemicals identified by means of capillary gas chromatography–mass spectroscopy and liquid–liquid extraction techniques may have been altered in some instances as a result of thermal breakdown during injection through the hot port used for capillary analysis. Additionally, hair and blood samples may have been unsuitable for detecting exposure to certain chemicals. Results of CBCs and serum biochemical profiles were interpreted in relationship to laboratory reference ranges, and although most of these values were within reference limits, no attempts were made to identify changes in values over time. Only a single nasal swab specimen was obtained from each dog to test for exposure to *B anthracis*, meaning that assessment for this pathogen was limited. The present study did not include a prospective matched control group, owing to financial constraints. A historical control group was used to create a context for qualitative comparisons of chronic health conditions identified in the study dogs. However, limitations associated with use of historical control animals are recognized.⁴⁸ Moreover, the present study did not resolve whether recorded deaths and diseases were specifically related to exposure to the WTC disaster site.

Even with these limitations, we believe the present study provides important information that may assist in planning for the use of working dogs in disaster relief efforts, aid in assessing potential hazards associated with prolonged relief efforts, and help determine risks in environments characterized by large building collapse and incineration. Because early arrival and long duration of work at the WTC disaster site were associated with acute disease risk, long-term medical monitoring should be continued to determine whether these dogs remain healthy or develop late-onset health conditions.

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- a. Cell Dyne 3500, Abbott Diagnostics, Santa Clara, Calif.
 - b. Hitachi 747-100, Hitachi 717 Roche Diagnostics, Indianapolis, Ind.
 - c. PetChek, IDEXX Laboratories, Westbrook, Me.
 - d. IDEXX Laboratories, Westbrook, Me.
 - e. Analyst 800 atomic absorption spectrophotometer, Perkin Elmer, Shelton, Conn.
 - f. ARL, Accuris Model, Thermo Optek Corp, Franklin, Mass.
 - g. Autosystem gas chromatograph with ECD, Perkin Elmer, Shelton, Conn.
 - h. Agilent 5973 mass selective detector, Agilent Technologies, Palo Alto, Calif.
 - i. SAS for Windows, version 9.1, SAS Institute Inc, Cary, NC.
 - j. Eukanuba veterinary diet adult, Iams Co, Dayton, Ohio.
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