Medical and behavioral surveillance of dogs deployed to the World Trade Center and the Pentagon from October 2001 to June 2002

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Objective—To evaluate early medical and behavioral effects of deployment to the World Trade Center, Fresh Kills Landfill, or the Pentagon on responding search-and-rescue (SAR) dogs.

Design—Prospective double cohort study.

Animals—The first cohort included SAR dogs responding to the September 11, 2001, terrorist attacks (deployed), and the second cohort included SAR dogs trained in a similar manner but not deployed (controls). Enrollment occurred from October 2001 to June 2002.

Procedure—Dogs were examined by their local veterinarians; thoracic radiographs and blood samples were shipped to the University of Pennsylvania for analysis. Handlers completed medical and training histories and a canine behavioral survey.

Results—Deployed dogs were older and had more search experience than control dogs. Serum concentrations of globulin and bilirubin and activity of alkaline phosphatase were significantly higher in deployed dogs, independent of age and training. Despite significant differences in several blood parameters, values for both groups were within reference ranges. No pulmonary abnormalities were detected on radiographs, and no significant differences in behavior or medical history were detected between groups.

Conclusions and Clinical Relevance—Within the first year following the September 11 attacks, there was no evidence that responding dogs developed adverse effects related to their work. Mild but significantly higher serum concentrations of globulin and bilirubin and activity of alkaline phosphatase in deployed dogs suggested higher antigen or toxin exposure. These dogs will be monitored for delayed effects for at least 3 years. (*J Am Vet Med Assoc* 2004;225:861–867)

The attacks of September 11, 2001, in New York; Washington, DC; and Pennsylvania resulted in loss of life and destruction that, as an act of terrorism, had not been previously experienced on American soil. Part of the rescue and recovery response included an estimated 250 to 300 **search-and-rescue (SAR)** dogs that were used at 3 major sites.

The site with the greatest damage and requiring the most substantial response was termed ground zero in lower Manhattan, where the **World Trade Center (WTC)** towers and several buildings in the vicinity were destroyed. As a result, 2,829 people were killed,[1] including 343 rescue workers[2] and 1 working dog.[3] The draft report released from the National Center for Environmental Assessment (**Environmental Protection Agency's [EPA's]** national resource center for human health and ecological risk assessment) in October 2002[4] cited particulate matter, asbestos, metals, dioxin-like material, polychlorinated biphenyls, and volatile organic compounds as concerns for acute and potentially chronic complications secondary to deployment exposure. In addition, smoke from fires that burned until mid-December 2001 acted as an irritant and many potential toxins remain unidentified. Search dogs from around the country first arrived at this site on September 11, 2001, when these hazards were thought to be at their highest concentrations. Those dogs left by early October, whereas New York City Police dogs remained at the site well into 2002. The EPA draft report suggests that the contaminant concentrations at ground zero remained high into early 2002.

The second site, Fresh Kills Landfill, was closely linked to the WTC. Located on Staten Island, Fresh Kills was the largest active landfill in the world and had been accumulating refuse for 50 years until March 2001, when it officially closed.[5] The debris from the WTC was transported to Fresh Kills beginning on September 12, 2001, where it was sorted and searched for human remains. The human and canine responders were exposed to hazardous material from ground zero and the landfill itself. The constant sifting of the debris increased the potential for production of airborne particulate matter (mainly asbestos and aerosolized toxins). Monitoring for asbestos by the EPA, however, did not start until early October.[4] Human workers at this site were equipped with respirators and polyethylene suits; the dogs had no protection.

The third site was the Pentagon, where a Boeing 757 crashed into the side of the building, destroying a segment of the outer ring and killing 184 innocent people on the ground and in the airplane as well as 5 terrorists.[6] The public information regarding hazardous materials involved at this site is more limited; however, an EPA monitoring summary from October 9, 2001,

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reported only trace concentrations of asbestos, volatile organic compounds, and other chemicals in the air of the building work zone. In both the building work zone and debris sorting area, however, high concentrations of antimony and arsenic were found in ash and soot.[7] Human workers were required to wear respirators and protective clothing. Again, the dogs had no protection. The dogs were actively searching at the Pentagon from September 11 until September 29, 2001.

There are no prior studies to evaluate the potential long-term medical or behavioral effects of SAR activity in dogs after such large-scale urban disasters. The only study[8] of adverse effects of search activity in SAR dogs in the United States reported medical illness (eg, fatigue, change in appetite, vomiting, and diarrhea) and injuries (eg, foot or skin lacerations and ocular irritation) during and behavioral changes immediately after the 1995 search of the bombed Murrah Federal Building in Oklahoma City. Historically, the focus of long-term studies in humans has been on psychological rather than medical effects of disaster response. Following the September 11 attacks, human medical surveillance of the New York City rescue personnel was initiated. Availability of funding and presence of confounding factors limited these studies; however, the primary causes of morbidity to date have been pulmonary (increased airway reactivity)[9] and psychological sequelae.[a]

Monitoring the SAR dogs that responded to the September 11 attacks is important for 2 major reasons. First, if problems develop in these dogs, training techniques and preventive measures can be developed to safeguard them in the future. Second, as supported by investigations of military working dogs in Vietnam, working dogs may serve as sentinels for human health hazards.[10]

It was hypothesized that adverse medical consequences of searching at any of the 3 sites would result in abnormalities detected via hematologic analysis of blood, serum biochemical analyses, or thoracic radiographs, compared with findings in SAR dogs that were not deployed to these sites. Although many dog handler teams ceased SAR activities after the response to the Oklahoma City bombing and Duhaime et al[8] reported that 33% of the search dogs had subjective behavioral changes during the week after completion of the mission. In working dogs, there has never been an investigation of behavioral abnormalities consistent with **posttraumatic stress disorder (PTSD)** in humans. It was also hypothesized that deployed dogs inadequately prepared for this type and intensity of work would have increased prevalence of negative behavioral traits, compared with control dogs. Subsequent comparison of training history, work conditions, and other variables in the deployed dogs could then prove useful in defining risk factors for the development of adverse behavioral traits. Therefore, the purpose of the study reported here was to evaluate early medical and behavioral effects of deployment to the WTC, the landfill, or the Pentagon on responding SAR dogs.

Materials and Methods

Dogs and handlers—Handlers of SAR dogs that were deployed to the WTC, Fresh Kills Landfill, and Pentagon disaster sites were identified and contacted for enrollment in a health and behavioral study of their dogs that was funded for 3 years, with the anticipation of lifetime surveillance. Because there was no central registry or official record of responding search dog teams, handlers were identified in several ways. The **American Kennel Club (AKC)** shared the deployed handler list they generated, including those who deployed through the **Federal Emergency Management Agency (FEMA)** and several who self-deployed or deployed through a non-FEMA organization. Additionally, a national listing of FEMA-certified handlers was used to enroll nondeployed dogs as control dogs and identify additional deployed individuals who were not on the AKC list. Also, some handlers from the deployed and control groups contacted the research group to enroll after learning of the study through the media or other handlers.

The deployed cohort consisted of the dogs that worked at 1 of the 3 disaster sites. Dogs that did not deploy, but had similar background and training, constituted the control cohort.

Data collection—The deployed and control group handlers were contacted and enrolled through e-mail, telephone, or regular mail. The recruitment period began in October 2001 and ended in June 2002. A pet insurance company[b] initially agreed to donate a 1-year health insurance policy to handlers for dogs that were enrolled in the study, and this company subsequently extended these policies for the life of the deployed dog and the duration of the study for the control dogs. Consent forms were completed for participation in the study.

Samples—In addition to surveys, a subset of deployed and control handlers submitted blood samples and thoracic radiographs from dogs, which were obtained by their local veterinarians. Because of cost constraints, blood sampling and radiographs were only offered to FEMA-deployed dogs and those deployed to the landfill. The FEMA group was chosen because documentation of their training and work was readily available. The landfill group was chosen because of the small number of dogs deployed and the lack of FEMA team representation from this site. All costs associated with collection of these samples were covered by the study. Complete blood counts[c] and serum biochemical analyses[d] were performed by the Clinical Pathology Laboratory at the Matthew J. Ryan Veterinary Hospital at the University of Pennsylvania. Complete thoracic radiographs (right and left lateral and ventrodorsal or dorsoventral) were evaluated by 2 university radiologists, who were blinded to the study groups.

If any dog died during the study period, a full necropsy was requested. The necropsy protocol included gross examination performed by the attending veterinarian and specified samples shipped to the Michigan State University for histopathologic analysis.

Surveys—Information from handlers was collected via survey instruments. A predeployment and deployment health survey and behavior questionnaire were distributed beginning in October 2001.[e] The health survey requested the complete contact information for the handler and the veterinarian in charge of the SAR dog's care; the SAR dog's complete medical history, including any health problems that developed while deployed; information about the dog's activity, including date of arrival, specific site worked, and disposition during deployment; and information about the dog's SAR training, including length and frequency of such training.

The behavior questionnaire[f] was a recently developed instrument for measuring behavior and behavior problems in dogs. It was tested for reliability and validity on a sample of more than 2,000 companion dogs.[11] The questionnaire measured 11 behavior traits identified by factor analysis, including various forms of aggression and fear; separation-related behavior; excitability; trainability; predatory chasing; and attachment or attention-seeking. In addition, the questionnaire included a list of 24 miscellaneous behaviors that have not yet been validated.

Statistical analyses—For continuous variables, the 2-sample *t* test (normally distributed) or Mann-Whitney test (nonparametric data) was used. For categoric variables, the χ^2 test was used. The relationship between multiple variables was evaluated by use of multivariable linear regression and data transformation as appropriate to achieve normality. To compare the effect of deployment site on hematologic and serum biochemical results, 1-way ANOVA was used. For data that could not be transformed to achieve normal distribution, Kruskal-Wallis ANOVA was used. Because none of these comparisons yielded significant ($P \leq 0.05$) differences, no post hoc testing was used. A power analysis was performed to determine the smallest detectable difference between deployed and control dogs for blood analysis results.[12,g,h] In a post hoc analysis of dogs that worked at the WTC, dogs were grouped according to arrival date for comparisons of blood values. Dogs that arrived on September 11 or 12 were compared with dogs that arrived on September 13 to 17, on September 18 to 24, or after September 24.

Results

Although there was no single central registry of all deployed dogs, 212 deployed handlers were identified and contacted; 101 (48%) handlers enrolled. However, when data collection was terminated for the first year of the study, only 97 health surveys and 95 behavioral surveys from 97 deployed handlers were collected and completed properly for inclusion in the data set. Of the 212 deployed handlers contacted, 111 declined to participate. Ten handlers provided explanations for nonparticipation, including lack of time to complete the study protocol (n = 3), disagreement with the nature of the study (2), dog was currently sick (3), dog died before handler could participate (1), and handler was uncomfortable with the postmortem requirement (1). Seven handlers declined participation without providing a reason, and 25 handlers failed to complete the protocol after agreeing to participate. The remaining handlers (n = 69) could not be reached via their contact information or did not respond to requests for participation. Of the 114 identified control teams, 59 (52%) handlers agreed to participate. At the close of the initial data collection period for this subset, health surveys and behavioral surveys had been collected from 55 controls and were completed properly for the data set.

Handlers were deployed with their dogs (n = 97) to the WTC (61), Pentagon (23), and Fresh Kills Landfill (13) for a median duration of 10, 12, and 7 days, respectively. The median age of deployed dogs was 5.0 years (interquartile range, 3.0 to 7.0 years); control dogs were a median age of 4.0 years (interquartile, range 2.0 to 6.0 years; *P* = 0.02). The deployed dog group consisted of 18 sexually intact males, 37 castrated males, 2 sexually intact females, and 39 spayed females. The control dog group included 8 sexually intact males, 23 castrated males, 4 sexually intact females, and 20 spayed females. The median weight for deployed dogs was 31.1 ± 7.1 kg (68.5 ± 15.6 lb), compared with 32.5 ± 7.7 kg (71.6 ± 17.0 lb) for control dogs (*P* = 0.26). The deployed dog group was composed mostly of German Shepherd Dogs (n = 32 [33%]) and Labrador Retrievers (28 [29%]). Other breeds represented in this group were Golden Retrievers (12 [12%]), mixed breeds (8 [8%]), Border Collies (7 [7%]), and Australian Shepherds (4 [4%]) and a Beauceron (1 [1%]), Belgian Tervuren (1 [1%]), Doberman Pinscher (1 [1%]), English Springer Spaniel (1 [1%]), Giant Schnauzer (1 [1%]), and Rottweiler (1 [1%]). The control dog group was predominantly composed of German Shepherd Dogs (n = 25 [45%]) and Labrador Retrievers (12 [22%]). Other control dog breeds included Airedale Terriers (2 [4%]), Australian Cattle Dogs (2 [4%]), Belgian Malinois (2 [4%]), Hovawarts (2 [4%]), and Golden Retrievers (2 [4%]) and a Belgian Tervuren (1 [2%]), Bloodhound (1 [2%]), Border Collie (1 [2%]), Louisiana Catahoula Leopard Hound (1 [2%]), mixed breed (1 [2%]), Newfoundland (1 [2%]), Rottweiler (1 [2%]), and German Shorthaired Pointer (1 [2%]). Neither the sex distribution nor the breed distribution was different between deployed dogs and control dogs (*P* = 0.39 and 0.30, respectively). Other characteristics of the dogs were tabulated **(Table 1)**. The deployed dogs had more

Table 1—Variables (median [range]) associated with 97 search-and-rescue (SAR) dogs that were deployed to 3 sites after the September 11, 2001, terrorist attacks and 55 SAR dogs that were not deployed (control dogs).

Variable	Deployed dogs	Control dogs	*P* value
Years of training	5.0 (3.0–6.0; n = 96)	3.5 (1.5–6.0; 53)	0.01
Years active search experience	4.0 (2.0–6.0; 96)	2.5 (1.0–4.0; 51)	0.02
Formal training sessions per month	4.5 (3.1–8.0; 95)	8 (6–12; 51)	< 0.001
Informal training sessions per month	12.0 (8.9–22.1; 93)	14 (8–22; 51)	0.88
FEMA certified (No. reporting)	50 (96)	20 (54)	0.11
Type of search (No.)	Live only (38) Cadaver only (4) Dual (54)	Live only (27) Cadaver only (2) Dual (23)	0.38

FEMA = Federal Emergency Management Agency.

search experience than the control dogs. The deployed dogs enrolled in this study actively searched at the WTC between September 11 and October 6, 2001; at the Pentagon between September 11 and September 29, 2001; and at the Fresh Kills Landfill from September 17 until September 29, 2001. Most of the dogs arrived on site by September 12, 2001 (59% at the WTC and 43% at the Pentagon). During this initial period, airborne hazards were considered particularly high. For all sites, the median number of days spent searching was 10 (interquartile range, 8 to 12 days).

The majority (96%) of deployed dogs and control dogs were trained to find live victims; however, 56% of deployed dogs and 42% of control dogs were also trained to identify cadavers. Only 4 deployed and 2 control dogs were exclusively trained for cadaver search. There were no significant differences in the prevalence of previous medical ($P = 0.241$) or surgical ($P = 0.891$) problems between groups.

Blood samples for CBC and serum biochemical profiles were received from 72 deployed and 52 control dogs. Samples were shipped overnight. There was no difference in the incidence of hemolysis (22/72 vs 14/52) or lipemia (18/72 vs 13/52) in samples obtained from deployed versus control dogs, respectively. There were no significant differences in CBC results between groups except for lymphocyte and eosinophil concentrations, both of which were significantly lower in the deployed dogs ($P = 0.037$ and 0.026, respectively; **Table 2**). All mean or median values for both groups of dogs were within reference ranges. The power of the analysis was sufficient to identify any clinically important changes. To determine whether the work site influenced hematologic results, comparisons were made within the deployed group among the 3 sites; no significant differences were found.

Mean or median serum biochemical values were within reference ranges, although significantly higher serum concentrations of glucose, total protein, globulins, bilirubin, and cholesterol; higher serum activity of alkaline phosphatase; and lower concentrations of potassium, phosphorus, and albumin-to-globulin ratio were detected in the deployed dogs (**Table 3**).

To determine whether the higher globulin concentrations were related to the age or search history of the deployed dogs, a multivariable linear regression was performed. A log transformation of the globulin data was used to achieve normality. The primary predictor of increased globulins was deployment status. Age, years of training, or years of active search did not contribute significantly to the model. In addition, when 2 deployed dogs with clinical disease contributing to hyperglobulinemia (multiple myeloma and systemic aspergillosis) were removed from the analysis, the globulin concentration of the deployed dogs was still significantly ($P = 0.003$) higher than in the control dogs. No biochemical parameter was different among dogs deployed at the 3 sites.

In the post hoc analysis of dogs that worked at the WTC, blood values from dogs that arrived on September 11 or 12 (n = 26) were compared with values from dogs that arrived later (21; 4 dogs arrived from September 13 to 17, 14 dogs arrived from September 18 to 24, and 3 dogs arrived after September 24). Cholesterol concentration, lymphocyte concentration, and monocyte concentration were significantly higher in the early arrivals; however, as with any post hoc analysis, results should be interpreted with caution.

Although hemolysis was associated with significantly higher bilirubin concentration, there was no difference in degree of hemolysis between groups. Even when samples that were moderately or markedly hemolyzed were omitted, deployed dogs still had significantly higher serum bilirubin concentrations than control dogs. Furthermore, when a bilirubin value of 1.7 mg/dL was omitted for a dog with liver dysfunction (and an eventual diagnosis of systemic aspergillosis), deployed dogs still had significantly higher bilirubin concentrations than control dogs. Serum alkaline phosphatase activity was not related to bilirubin con-

Table 2—Results of CBCs in SAR dogs that were deployed to 3 sites after the September 11, 2001, terrorist attacks and SAR dogs that were not deployed (control dogs).

Variable	Deployed dogs (n = 72)	Control dogs (52)	Reference range
WBC ($\times 10^3/\mu L$)	6.53 (5.48–8.05)	6.86 (5.40–9.38)	5.30–19.8
RBC ($\times 10^6/\mu L$)	7.02 ± 0.721	7.03 ± 0.72	5.83–8.87
Hemoglobin (g/dL)	16.4 ± 1.6	16.5 ± 1.6	13.3–20.5
Hct (%)	49.0 ± 5.1	49.0 ± 5.3	40.3–60.3
MCV (fL)	70.0 ± 3.3	69.8 ± 3.4	62.7–75.5
MCH (pg)	23.5 ± 0.9	23.6 ± 0.7	22.5–26.9
MCHC (g/dL)	33.8 (33.0–34.3)	33.9 (33.4–34.4)	32.2–36.6
RDW (%)	15.1 ± 1.0	15.0 ± 0.8	13.2–17.4
Platelets ($\times 10^3/\mu L$)	185 ± 67	187 ± 76	177–398
Neutrophils (per µL)	4,600 (3,700–5,600)	4,700 (3,700–6,075)	3,100–14,400
Band neutrophils (per µL)	0 (0–0)	0 (0–0)	0
Lymphocytes (per µL)	1,100 (660–1600)*	1,200 (1,100–1,875)	900–5,500
Monocytes (per µL)	385 (210–530)	470 (250–697)	100–1,400
Eosinophils (per µL)	365 (210–540)*	510 (272–698)	0–1,600
Basophils (per µL)	0 (0–0)	0 (0–0)	0–200

Data are expressed as mean ± SD for normally distributed data and median (interquartile range) for nonnormally distributed data.

*Significant ($P \leq 0.05$) difference between groups.

MCV = Mean corpuscular volume. MCH = Mean corpuscular hemoglobin. MCHC = Mean corpuscular hemoglobin concentration. RDW = Red cell distribution width.

Table 3—Results of serum biochemical analyses in SAR dogs that were deployed to 3 sites after the September 11, 2001, terrorist attacks and SAR dogs that were not deployed (control dogs).

Variable	Deployed dogs (n = 72)	Control dogs (52)	Reference range
Glucose (mg/dL)	96 ± 12*	85 ± 16	65–112
BUN (mg/dL)	16.6 ± 4.0	16.1 ± 3.8	9.0–33.0
Creatinine (mg/dL)	1.2 (1.1–1.4)	1.2 (1.1–1.3)	0.7–1.8
BUN:creatinine	13.6 (11.2–16.3)	13.5 (11.8–15.2)	NR
Phosphorus (mg/dL)	4.1 ± 0.6*	4.4 ± 0.8	2.8–6.1
Calcium (mg/dL)	10.2 (9.9–10.6)	10.2 (9.8–10.4)	9.8–11.7
Sodium (mmol/L)	146 (145–149)	147 (145–148)	140–150
Potassium (mmol/L)	4.4 ± 0.3*	4.6 ± 0.4	3.9–4.9
Chloride (mmol/L)	117 (115–119)	118 (116–120)	109–120
Enzymatic CO_2 (mmol/L)	22 (20–23)	21 (19–23)	17–28
Total protein (g/dL)	6.3 ± 0.6*	6.1 ± 0.5	5.4–7.1
Albumin (g/dL)	3.0 (2.9–3.2)	3.1 (2.9–3.3)	2.5–3.7
Globulin (g/dL)	3.2 (2.9–3.4)*	2.9 (2.7–3.2)	NR
Albumin:globulin	1.0 (0.9–1.1)*	1.1 (1.0–1.2)	NR
ALT (U/L)	46 (36–67)	46 (37–57)	16–91
AST (U/L)	34 (28–39)	34 (31–40)	23–65
Alkaline phosphatase (U/L)	51 (35–78)*	43 (34–55)	24–174
GGT (U/L)	13 (11–15)	13 (11–15)	7–24
Total bilirubin (mg/dL)	0.3 (0.2–0.4)*	0.2 (0.1–0.3)	0.3–0.9
Cholesterol (mg/dL)	218.5 ± 58.5*	194.9 ± 41.1	128.0–317.0
Anion gap (mmol/L)	13 (11–14)	12 (11–14)	12–16
Calculated osmolality (mOsm/kg)	284 ± 6	283 ± 4	NR

NR = Not reported. ALT = Alanine aminotransferase. AST = Aspartate aminotransferase. GGT = Gamma glutamyl transaminase.
See Table 2 for remainder of key.

centration. There was no relationship between age and bilirubin concentration or serum alkaline phosphatase activity. Conversely, age was positively related to cholesterol concentration. Thoracic radiographs (3 views) were evaluated, and no clinically relevant pulmonary abnormalities were identified in either group.

The behavioral survey was completed by handlers of deployed (95 completed) and control dogs (55 completed). There were no significant differences between the 2 groups for any of the 11 main behavioral traits, although the control dogs obtained significantly less favorable scores on 3 of the miscellaneous (unvalidated) behaviors, including eating its own or other animals' feces ($P = 0.03$), being nervous or fearful of going up or down stairs ($P = 0.01$), and pulling excessively hard on leash ($P = 0.005$). To overcome possible confounding effects of differences in breed composition between the groups, the analysis was repeated for German Shepherd Dogs only (29 deployed and 22 control German Shepherd Dogs were included in the behavioral analysis); deployed German Shepherd Dogs were given significantly higher (more favorable) scores for trainability.

Despite rumors of numerous SAR dog deaths, only 1 dog was confirmed to have died during the search period. This Port Authority of New York dog was killed during the collapse of the WTC Tower Two.[3] During the enrollment period (October 2001 to June 2002), there was 1 death in the deployed group and no deaths in the control group. In addition, information was received regarding the death of 2 other deployed dogs that were not enrolled in the study.

Discussion

The major long-term consequences of disaster response in humans are psychological and physical sequelae. There are no prior reports of either in SAR dogs. Although it was hypothesized that more medical or behavioral problems would be detected in the deployed dogs, compared with the control dogs, there were no clinically important differences between the groups at this time. The deployed dogs were older and had more experience than the control dogs. Both groups were composed predominantly of German Shepherd Dogs and Labrador Retrievers. Almost all dogs in both groups were trained to find live victims. The younger, less experienced control dogs spent more time in formal training than the older, more experienced deployed dogs.

Dogs responding to the September 11 disasters arrived soon after the attacks. The dogs were exposed to potential hazards, which were present in highest concentrations in the first few days after the attacks at the Pentagon and WTC. The exposure at the landfill was less likely to have been influenced by the temporal proximity to September 11; the material was constantly being sorted, aerosolizing any hazards that might have otherwise settled at ground zero.

At this early point in the study, the biochemical and hematologic differences found between control and deployed dogs were not considered clinically important, although they may represent early markers of subtle effects of the search response. Although all values were within reference ranges, significantly higher serum globulin concentration and associated higher total protein concentration and lower albumin-to-globulin ratios may have been the result of increased exposure to antigens at the disaster sites in the deployed dogs. This finding is consistent with the lack of relationship between globulins and age or previous search experience; however, it is possible that multiple other measured or unmeasured factors contributed to this difference between groups. In addition, the higher bilirubin concentration and alkaline phosphatase activity in the deployed dogs is consistent with an increased antigenic load, toxin exposure, or other hepatic insult. The higher cholesterol concentration of the deployed dogs was significantly and positively related to age and therefore may be explained by the older age of the deployed dogs.

Stress can result in hyperglycemia, lymphopenia, and eosinopenia, but the hematologic profile typically includes neutrophilia, and monocytosis,[13] which were not detected in the deployed dogs. Both the eosinophil concentration and blood glucose concentration are dynamic values, and a single sample may be influenced by the immediate stress of a veterinary visit and may not be representative of a chronic stressed state.

The absence of pulmonary abnormalities on thoracic radiographs is consistent with the study findings of human responders that developed coughing within 24 hours of exposure at the WTC.[9] Thoracic radiography is an insensitive tool for the early diagnosis of pulmonary malignancies. During the first two thirds of the course of a neoplastic disorder, the tumor nodules are too small to be recognized radiographically.[14,15] Additionally, expected lung lesions from chronic irritation caused by inhaled particulate matter or development of neoplasia would be a delayed change.

In humans, it takes at least 20 years[16] to develop mesothelioma after chronic asbestos exposure. In a report[17] that associated asbestos and mesothelioma in dogs, the mean age of affected dogs was 8.0 ± 1.9 years. The shorter life span of dogs results in a relatively shorter latency for cancer development, compared with humans. Therefore, the deployed dogs may provide an early indication of asbestos exposure in all rescue workers. In addition, silicosis may be evident in the dogs prior to the humans. These conditions emphasize the potential for dogs to act as sentinels of human disease as they did in Vietnam.[10]

Although behavioral trait profiles were not different between groups, the control dogs had evidence of problematic behavior with respect to some of the unvalidated miscellaneous questionnaire items. These results, together with the higher trainability score of the deployed German Shepherd Dogs, suggest a slight initial sampling bias toward behaviorally superior dogs among the deployed group, rather than any improvement or change in behavior after deployment. However, because predeployment data on these dogs were not available, the latter possibility cannot be excluded at this stage.

In human rescue workers, severe symptoms of PTSD are experienced by as many as 1 of every 3 rescue workers.[18] The lack of baseline behavioral data on the dogs did not allow us to identify stress-induced behavioral changes, however subtle, such as fear or aggression that would suggest postdeployment effects. It is also recognized in humans that symptoms of PTSD are most commonly evident within 6 months[19] of the traumatic event, but occasionally may not be obvious for several years.[20] Therefore, changes in the behavioral profile may still provide valuable information about the effects of SAR work in general and, more specifically, in association with the September 11 response. Because of the strong human-animal bond between the handlers and dogs, it is also possible that PTSD of the handler may actually cause physical or behavioral problems in the dogs. As part of a related study, a team of psychologists is monitoring the enrolled canine handlers.

The ability to identify abnormalities in the deployed dogs was limited in several ways. First, there was no predeployment evaluation of the dogs. Therefore, subtle changes in behavior, hematologic values, serum biochemical values, or radiographs in individuals cannot be identified. The data reported here, however, will serve as a baseline to identify changes over time. Second, although 97 deployed dogs were enrolled, if the prevalence of disease was low, there would be insufficient power to identify an association. There was potential for unrecorded conditions, such as lack of food, environmental factors, and sample handling or other unanticipated physiologic factors, to contribute to the observed differences in blood results between groups; however, systematic bias attributable to any of these factors seems unlikely. The nature of the survey data also introduced error. Despite aggressive recruitment attempts, some handlers were not identified and surveys were not completed until 9 months after the attacks. Most responses were designed to be yes or no; however, numerical reports such as duration of work shifts and time rested were subject to great variability. Additionally, medical problems may have developed in some dogs after completion of the initial survey, and this information will not be available until the second-year survey is completed. In addition, the limited response rate may have introduced a bias into our results because dogs belonging to nonparticipating handlers may have different problems. For example, the offer of health insurance may have encouraged handlers of dogs with a medical problem to enroll; alternatively, handlers of dogs that developed problems may also have been so overwhelmed by the dog's medical problems that they did not feel able to participate. Additionally, less qualified handlers may have been reticent to document problems in their dogs, whereas full-time handlers (eg, police officers) were often too busy to complete the paperwork. It is impossible to predict the exact nature of the bias that this limited enrollment may have introduced. To limit this bias, however, the study team recorded and confirmed any known adverse event (obtained through the media, the SAR community, or the handler) in deployed dogs whether or not they were enrolled in the study.

In an attempt to provide a measure of the degree of training, certification information was requested. It is difficult to compare training because the standards for certification vary considerably. The FEMA certification standards are the most consistent standards published[21] for both the performance of the dog and the handler, but it is difficult to compare training among other non-FEMA dogs.

The evaluation of the SAR dogs' respiratory system was limited to radiographs, which are insensitive to functional changes; however, of 3 dogs in which cough was reported during deployment, only 1 dog (deployed at the landfill) was reported to have clinical signs compatible with persistent increased airway reactivity.[i] No information was available on the prevalence of cough in workers at the landfill. In human workers at ground zero, the likelihood of developing cough was related to exposure; the workers present at the time of collapse composed the highest risk group. The moderate risk group included responders present in the first 2 days after the collapse of the WTC; most dogs fit into this category. Additionally, like the dogs, 78% of the human responders did not regularly use respiratory protection. However, of the 10,116 responders evaluated, 3% of the 6,958 with moderate exposure developed a cough. It is possible that our limited sample size contributed to the absence of chronic cough in the study dogs.[9]

Although validated for companion dogs and designed to be completed by anyone reasonably familiar with a dog's typical behavior, the behavioral survey has not been validated specifically for SAR dogs. Temperament traits considered advantageous in SAR dogs, such as high energy and high drive, are not necessarily the same as those deemed suitable for either companionship or other working roles, and it is not yet known whether the behavior of these dogs can be compared reliably with other canine populations. Also, although the survey covers a wide range of salient canine behaviors, it is possible that it fails to measure specific behaviors that are of critical importance to evaluating SAR dogs and their responses to stress.

This is the first large-scale study evaluating SAR dogs. These data can be used to establish reference values for the dogs, help to standardize training protocols, and provide a central database to monitor the health of these dogs. Tracking the dogs and keeping a record of possible risk factors from the time of deployment will help identify the medical hazards of SAR work and the associated risk factors. Importantly, these dogs may also serve as sentinels for human disease.

The lack of clear adverse medical or behavioral effects of the September 11 response is encouraging. It must be emphasized, however, that the time period required for development of neoplasia or other diseases may be substantial. Greater values for globulin concentration, bilirubin concentration, and alkaline phosphatase activity in the deployed dogs, compared with the control dogs, may represent evidence of increased exposure to antigens or toxins. It is unknown whether this exposure could lead to any adverse sequelae during the next several years. The acute exposure to concentrated airborne hazards and the intense nature of the search activity are both unprecedented. Continued vigilance is warranted for the benefit of the SAR dogs and the human responders.

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[a] Alvarezn J, Hunt M, Moser R, et al. Psychological sequelae in canine search and rescue handlers after September 11th. Poster presented at the 36th Annual Meeting of the Association for the Advancement of Behavior Therapy, November 2002; Reno, Nev.

[b] Veterinary Pet Insurance Co, Brea, Calif.

[c] Cell Dyne 3500, Abbott Diagnostics, Santa Clara, Calif.

[d] Vitros System Chemistry 250, Johnson & Johnson Clinical Diagnostics, Rochester, NY.

[e] Copies of the medical and behavioral surveys are available from the corresponding author.

[f] Canine Behavioral Assessment & Research Questionnaire (CBARQ), James A. Serpell, PhD, University of Pennsylvania School of Veterinary Medicine, Philadelphia, Pa.

[g] SigmaStat for Windows, version 2.03, SPSS Inc, Chicago, Ill.

[h] StatView, version 5.0.1, SAS Institute Inc, Cary, NC.

[i] Shearer T, Shearer Pet Hospital, Columbus, Ohio: Personal communication, 2001.

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