Int J Biometeorol
DOI 10.1007/s00484-007-0115-6

ORIGINAL PAPER

Meteorological influence on the occurrence of gastric dilatation-volvulus in military working dogs in Texas

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Received: 14 February 2007 / Revised: 30 May 2007 / Accepted: 16 July 2007

Abstract Gastric dilatation-volvulus (GDV) is a life-threatening condition in dogs and other species in which the stomach dilates and rotates on itself. The etiology of the disease is multi-factorial, but explicit precipitating causes are unknown. This study sought to determine if there was a significant association between changes in hourly-measured temperature and/or atmospheric pressure and the occurrence of GDV in the population of high-risk working dogs in Texas. The odds of a day being a GDV day, given certain temperature and atmospheric pressure conditions for that day or the day before, was estimated using logistic regression models. There were 57 days in which GDV(s) occurred, representing 2.60% of the days in the 6-year study period. The months of November, December, and January collectively accounted for almost half (47%) of all cases. Disease risk was negatively associated with daily maximum temperature. An increased risk of GDV was weakly associated with the occurrence of large hourly drops in temperature that day and of higher minimum barometric pressure that day and the day before GDV occurrence, but extreme changes were not predictive of the disease.

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Keywords Pressure · Temperature · Bloat · Stomach · Dogs

Introduction

Gastric dilatation-volvulus (GDV) is a life-threatening condition in which the stomach dilates and rotates on itself. Vascular compromise can result in stomach wall necrosis, shock, and death, with mortality rates ranging from 23% to 60% (Guilford 1996). This disease can affect many species including man, but is of particular concern in dogs due to its frequency (Van Kruiningen et al. 1974; Glickman et al. 2000).

The physical mechanisms of this disease in dogs are well understood although the etiology is not (Brockman et al. 2000). A variety of risk factors have been proposed: temperament of the dog (excitability), large or giant breed, increased thoracic depth-to-width ratio, and rapid food consumption, as well as the consumption of large volumes of food (Brockman et al. 2000; Schellenberg et al. 1998; Raghavan et al. 2004). Not all of these hypotheses about the cause of the disease, however, explain the clinical findings or the onset of disease.

In most GDV cases, the stomach is distended with gas, and aerophagia, fermentation-putrefaction, chemical gas genesis, and gas diffusion have been suggested as sources of this gas. Bacterial metabolism, presumably related to Clostridia organisms, could result in liberation of CO_2, CH_4, and H_2, but stomach gas analysis in 7 clinical cases determined concentrations similar to atmospheric air (Caywood et al. 1977).

The reason(s) for aerophagia and the progressive distension of the stomach is/are unknown. It has been hypothesized that there is an association between GDV and weather conditions shortly before its occurrence (Herbold et al. 2002; Dennler et al. 2005). Herbold et al. (2002) noted seasonal variation in the occurrence of GDV, but did not find a

statistically significant association between incidence of GDV and meteorologic conditions. Their method, however, used principal components analysis to assess linear combinations of variables and create synoptic days, potentially obscuring the impact of a single weather variable. Dennler et al. (2005), studying dogs in Zurich, Switzerland, reported a statistically significant association between temperature and GDV occurrence, although they noted that the effect was so small that it most likely has no clinical significance. The weather data for their analyses included minimum, mean, and maximum values for daily temperature, humidity, and atmospheric pressure. Hourly changes in these parameters were not investigated.

In humans, an association has been found between changes in barometric pressure and the onset of labor (King et al. 1997) and sudden infant death syndrome (Campbell et al. 2001). Changes in pressure have not been evaluated in previous studies of canine disease. Behaviorists contend that dogs can sense oncoming storms, and a change in barometric pressure is hypothesized to be a biometorological trigger evoking a change in the dog's behavior (Fogle 1992).

As pointed out by Brockman et al. (2000), the assessment of risk factors for GDV is extremely difficult due to the variety of living conditions, e.g., diet, exercise, stress, and housing environment, for affected dogs. Herbold et al. (2002) minimized this variation by studying GDV in military dogs in training in Texas. The Military Working Dog (MWD) Training Center at Lackland Air Force Base (LAFB) houses and trains a large population of large-breed dogs. The dogs are trained 5 days a week to provide security or detect contraband, such as explosives or narcotics, using standard training protocols. They are fed a standard diet, housed in outdoor runs and are under observation 24 h a day. This provides a relatively controlled environment for study of GDV occurrence.

The purpose of this study is to use an expanded case and climate dataset to determine if there is a significant association between hourly-measured temperature and/or atmospheric pressure and the occurrence of GDV in the population of MWD at LAFB. We have particular interest in examining the effect of air pressure, specifically low air pressure or a dramatic change in air pressure. If meteorological extremes are associated with GDV occurrence, and if such extremes can be forecasted, then owners of at-risk dogs could alter feeding amounts or frequency in the 24-h period of weather changes and decrease GDV risk.

Materials and methods

Study population

Our study population included all MWD housed at LAFB from 1 January 1993 through 31 December 1998 that were diagnosed with GDV. This expanded the previously reported data (Herbold et al. 2002) by 1 year and 11 GDV cases. The data for these dogs include breed, sex, date of birth, weight, age at the time of diagnosis, and the date that the dog was diagnosed with GDV.

Meteorological data

Weather data for the 6-year study period were obtained from the National Climatic Data Center for Kelly Air Force Base, located immediately adjacent to LAFB. The data set contained hourly measurements for surface temperature (°C) and (mean sea level) atmospheric pressure (hPa), and the hourly change in these variables was calculated. The daily maximum and minimum measurements were determined for surface temperature and atmospheric pressure, and the greatest hourly increase and decrease observed among all possible hourly changes in a given day were also recorded for temperature and pressure.

Statistical methods

Incidence rates with 95% confidence intervals were calculated via assumption of a binomial distribution for proportions. Univariate logistic regression models were fit to the data to estimate the probability of a day being a GDV day, given certain temperature and atmospheric pressure conditions for that day or the day before. These conditions were daily maximum and minimum temperatures, daily maximum and minimum atmospheric pressures, maximum observed hourly temperature increase, maximum observed hourly temperature decrease, maximum observed hourly pressure increase, and maximum observed hourly pressure decrease. Estimated odds ratios were calculated by exponentiation of the regression coefficients. The corresponding 95% confidence intervals were calculated by exponentiation of the endpoints of the respective intervals of the 95% logodds ratios. Categorical time series analysis was not used because there was no presumed strong correlation between outcomes (GDV events) over time; the disease is not contagious between animals. The predictive value of meteorological variables associated with increased disease risk was assessed by determining the percent of GDV days significantly associated with extremes (upper quartile) for that variable.

Results

There were a total of 59 dogs that were diagnosed with GDV in the MWD population at LAFB from 1993–1998. Two dogs were diagnosed with GDV on both 2 November 1996 and 1 November 1997, resulting in a total of 57 GDV

days. Thus, disease events were recorded on 2.60% of the days in the study period (95% CI: 1.98–3.36%). The months of November, December, and January included 19.3%, 15.3%, and 12.3% of the total cases, respectively, whereas the smallest percentage of cases occurred in June and August (3.5% in each month).

Disease risk was most significantly associated with daily maximum temperature. The risk of GDV was significantly reduced by approximately 2–3% for each degree increase in maximum daily temperature on the GDV day or the day before GDV occurred ($p<0.02$) (Table 1). Risk of GDV occurring on a particular day was also reduced by 2% for each degree increase in the maximum hourly rise in temperature observed on that day ($p=0.055$).

Risk of GDV was increased by the occurrence of large hourly drops in temperature that day and by higher minimum barometric pressure that day and the day before ($p=0.049$–0.058). Point estimates indicating the greatest increase in disease risk (4.2–4.6% increase) were less strongly associated with large hourly drops in barometric pressure on the day preceding GDV occurrence or the day of GDV occurrence ($p=0.09$–0.11). Extreme drops in barometric pressure, i.e. lower quartile of observed hourly drops in pressure, were not reliable predictors of a GDV occurrence ($p>0.20$).

Discussion

This study investigated the association between hourly-recorded measurements in air temperature and/or atmospheric pressure with the occurrence of GDV in a large population of military working dogs in Texas. The data used for this study expanded the data set employed by Herbold et al. (2002) with an additional year of weather and additional cases of GDV. A significant seasonal predilection for GDV occurrence in the late autumn and early winter was previously noted, and was also present in the additional data in our study. The months of November, December, January, and February in south Texas are a period in which the surface weather can be relatively more volatile, owing to southward intrusions of polar air.

In our study, disease risk was reduced with high maximum daily temperatures, as well as reduced with large hourly increases in temperature. This finding from regression models corresponded with tabular frequencies showing fewer GDV cases occurred in the summer months of June through August.

Parameters with point estimates indicating increased risk, but with weaker statistical association, of GDV included large hourly decreases in temperature, large hourly decreases in barometric pressure, and higher minimum daily pressure. Such temperature and pressure changes are most likely associated with synoptic-scale weather fronts. Consistent with the noted seasonal predilection, fronts are most common in south Texas in the late fall through winter seasons, owing to the southerly position of the mean polar jet stream during this time (e.g., Peixoto and Oort 1992). The low magnitude of risk and statistical association however resulted in poor predictability of disease occurrence.

Although anatomical and behavioral factors have been identified which predispose dogs to GDV (Brockman et al. 2000; Schellenberg et al. 1998; Glickman et al. 2000), it remains unclear what factors actually trigger a disease event, i.e. why did GDV occur on a particular day? The sizeable population (>300) of large-breed dogs at the single

Table 1 Unadjusted odds ratios and 95% CIs (univariate logistic regression) for temperature and barometric pressure as risk factors for gastric dilatation-volvulus (GDV) in a population of military working dogs

	Day before a GDV diagnosis			Day of a GDV diagnosis		
Parameter	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Temperature - daily maximum	0.979	0.962–0.996	0.016	0.974	0.964–0.999	0.002
Temperature - daily minimum	0.992	0.976–1.009	0.344	0.994	0.978–1.011	0.510
Temp - daily max increase per h	0.986	0.966–1.005	0.148	0.980	0.959–1.001	0.055
Temp - daily max decrease per h	1.015	0.995–1.035	0.139	1.021	1.000–1.043	0.050
Pressure - daily maximum	1.024	0.980–1.067	0.289	0.996	0.953–1.041	0.864
Pressure - daily minimum	1.041	0.999–1.086	0.058	1.043	1.001–1.088	0.049
Pressure - daily max increase per h	0.974	0.929–1.021	0.272	0.961	0.912–1.012	0.122
Pressure - daily max decrease per h	1.046	0.993–1.101	0.090	1.042	0.991–1.097	0.110

OR=odds ratio; *CI*=confidence interval; OR reported per 1°C change (temperature) or 1 mb change (pressure).

location in this study provided an unique opportunity to investigate the relationship between meteorological parameters and the occurrence of GDV in these dogs. If specific weather changes or extremes could be identified with a strong association with increased GDV risk in the population, then feeding practices (a known predisposing factor) might be changed until such forecasted events have passed. Regrettably, such meteorological parameters were not identified and may indicate the involvement of unidentified non-meteorological risk factors which might trigger this disease, or failure to identify primary meteorological risk factors of statistical and clinical significance.

Gastrointestinal disturbances, i.e. colic, in horses has been previously reported by Barth (1982) to increase during certain weather phases, notably the inflow of cold air following low pressure. The equine study suggested a close association between disturbances in intestinal motility and changes in climatic environment. Different manifestations of colic were included, however, and the distinction between alterations in gut motility and changes in animal behavior that might influence motility via neuroendocrine regulation is challenging at best.

The potential mechanism(s) by which a change in barometric pressure alters canine behavior is/are unknown, as it is not determined how dogs 'sense' meteorological events in advance of humans. Sensing of adverse weather may promote a change in activity levels in dogs, and fearful or excitable behavior as well as rapid eating have been previously identified as risk factors for GDV (Glickman et al. 1997). Additionally, such factors may have as-yet-undefined interaction with one another, further increasing the risk of disease. If meteorological parameters, e.g. rapid drops in atmospheric pressure, could be determined which predict increased GDV risk with reasonable accuracy, then owners of dogs predisposed to this life-threatening disease could potentially reduce or control their dog's food intake when these weather changes occur and diminish the risk of disease. This study, however, was not able to define those parameters nor prove their predictive ability.

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