Investigation of potential risk factors for mesenteric volvulus in military working dogs

Shane J. Andrews DVM

Todd M. Thomas DVM, MSpVM

Joe G. Hauptman DVM, MS

Bryden J. Stanley BVMS, MVetSc

From the Department of Small Animal Clinical Sciences, College of Veterinary Medicine, Michigan State University, East Lansing, MI 48824 (Andrews, Hauptman, Stanley); and the LTC Daniel E. Holland Military Working Dog Hospital, Lackland Air Force Base, San Antonio, TX 78236 (Thomas). Dr. Andrews' present affiliation is US Army Veterinary Corps.

Address correspondence to Dr. Andrews (andrewsshanej@gmail.com).

OBJECTIVE
To identify risk factors for mesenteric volvulus (MV) in military working dogs (MWDs).

DESIGN
Retrospective case-control study.

ANIMALS
211 MWDs (54 with and 157 without MV [case and control dogs, respectively]).

PROCEDURES
Medical records (cases and controls) and necropsy reports (cases) were reviewed. Signalment, pertinent medical and surgical history, behavior and temperament characteristics, feeding schedules, and training types were recorded. Weather patterns for regions where dogs resided were researched. Data were evaluated statistically to identify potential risk factors for MV.

RESULTS
Risk factors significantly associated with MV included German Shepherd Dog breed (OR, 11.5), increasing age (OR, 2.0), and history of prophylactic gastropexy (OR, 65.9), other abdominal surgery (after gastropexy and requiring a separate anesthetic episode; OR, 16.9), and gastrointestinal disease (OR, 5.4). Post hoc analysis of the subset of MWDs that underwent gastropexy suggested that postoperative complications were associated with MV in these dogs but type of gastropexy and surgeon experience level were not.

CONCLUSIONS AND CLINICAL RELEVANCE
Data supported earlier findings that German Shepherd Dog breed and history of gastrointestinal disease were risk factors for MV. The MWDs with a history of prophylactic gastropexy or other abdominal surgery were more likely to acquire MV than were those without such history. These findings warrant further study. Despite the association between prophylactic gastropexy and MV, the authors remain supportive of this procedure to help prevent the more common disease of gastric dilatation-volvulus. (*J Am Vet Med Assoc* 2018;253:877–885)

Mesenteric volvulus is a rare and often fatal disorder that involves intestinal rotation around the root of the mesentery and can occur in many animals, most notably horses, cattle, swine, and dogs, as well as people.[1–5] The root of the mesentery includes the cranial mesenteric artery, the intestinal lymphatic vessels, and the extensive mesenteric plexus of nerves that surround the artery.[6] In most reported cases, the cranial mesenteric vessels become obstructed secondary to rotation, leading to ischemic necrosis of the aborad portion of the duodenum; all of the jejunum, ileum, and cecum; the ascending and transverse colon; and the orad portion of the descending colon.[2,7,8] Death is usually attributed to a cascade of vascular obstruction, intestinal anoxia, circulatory shock, endotoxemia, and cardiovascular failure.[9]

Although a specific etiopathogenesis for MV remains unclear, predisposing factors that have been proposed for dogs include breed, vigorous exercise, closed abdominal trauma, recent gastrointestinal surgery, lymphocytic-plasmocytic enteritis, nonspecific gastrointestinal disease, dietary indiscretion, trauma, treatment of ascariasis, parvoviral infection, exocrine pancreatic insufficiency, intussusception, ileal carcinoma, concurrent GDV, and gastrointestinal foreign bodies.[9–18] In people, congenital anomalies of intestinal malrotation are typically identified in infants and children. Intestinal volvulus in adults is rarely reported and is usually associated with a congenital malrotation, congenital adhesions, postoperative adhesions, or gastrointestinal tumors.[1,4,5]

A literature search by the authors revealed that most reports of MV in dogs since 1972 were clinical reports with small sample sizes, apart from 1 case

ABBREVIATIONS

BCS	Body condition score
DOD	Department of Defense
GDV	Gastric dilatation-volvulus
GSD	German Shepherd Dog
MV	Mesenteric volvulus
MWD	Military working dog

series[15] that included 21 dogs that had exocrine pancreatic insufficiency with MV. Clinical signs of MV in dogs include peracute to acute onset of vomiting, mild abdominal distension, and shock; hematochezia and tenesmus are less common.[7,9,17–20] The prognosis is grave, even with early detection and intensive management, with mortality rates ranging from 7 of 12 to 12 of 12.[9,14,17,19,21] More recent reports[16,19] indicate that early recognition and prompt treatment may result in an improved outcome. Among the cases identified in the literature (a total of 72), 14 (19%) involved dogs that survived surgery into the postoperative period.[7,9,16,18–20] Long-term survival was not documented for these patients, except for a single case report of a dog with apparently chronic MV that was still doing well 18 months after surgery.[20]

There is a general consensus that GSDs are at increased risk for MV, compared with other breeds.[15,17,19,21] As the breed most commonly used for MWDs by the US DOD, GSDs comprise approximately 60% (1,440/2,400 in 2016) of the MWD population at any given time. In the 5 years from 2005 through 2009, 8 cases of MV in MWDs were recorded; in the ensuing 5-year period from 2010 through 2014, 31 cases of MV were documented. The total number of MWDs and proportion of GSD were stable during this time (data on file, US DOD). This apparent increase in the incidence of MV in MWDs and the paucity of literature with large sample sizes prompted the authors' investigation. The objective of the study reported here was to evaluate a large number of potential risk factors that might be associated with MV in MWDs, with the intent of improving our ability to identify dogs at risk for the disease. Our null hypothesis was that no factor would be significantly associated with MV.

Materials and Methods

Selection of cases and controls

Medical records of MWDs at the LTC Daniel E. Holland Military Working Dog Hospital at Lackland Air Force Base in San Antonio, Tex, were reviewed by 2 investigators (SJA and TMT). The medical record database from January 1, 1990, to December 31, 2014, was searched to identify MWDs with a diagnostic code of mesenteric, intestinal, torsion, or volvulus, alone or in combination. Records identified by the search were then reviewed for a diagnosis of MV on the basis of surgical findings, necropsy records, or both. Following inclusion of an affected MWD (case dog) in the study, records of 3 unmatched MWDs with a similar birth year (control dogs) were arbitrarily selected by an investigator blinded to the identity of individual dogs. For each control record, a specific time point was assigned by selecting a date on the master problem list alternating from the top half and bottom half of the list; this was recorded as an event date to parallel the date of MV for the affected dogs.[22] All control dogs had some medical condition other than MV diagnosed during their lifetime; however, none of the diagnoses were used for exclusion purposes, as the intent was to achieve the most representative sampling of the overall MWD population. Dogs with incomplete medical records were excluded from the study. The date of MV (cases) or the event date (controls) was defined as day 0.

Medical records review

Forty-six potential risk factors were analyzed. These included signalment variables; history of gastrointestinal disease, abdominal surgery (gastropexy and other laparoscopic or open procedures), and aggression; results of behavioral assessments; feeding schedule; BCS; type of training; deployability status; medications administered; and weather. The weather variable was included because associations with weather phenomena have been explored for other gastrointestinal conditions in dogs (eg, GDV)[23–25] but have not been investigated for MV. Behavior was similarly unexplored and could have wide-ranging effects in MWDs by influencing factors such as appetite, activity level, work performance, and repetitive activity when kenneled. Behavior and temperament were therefore evaluated for possible association with MV. Each factor was analyzed for association with MV according to whether the data were nominal, binary, ordinal, discrete, or continuous.

Specification of levels of factors

Nominal factors—Descriptive data (with no numeric value or order) included breed, sex and reproductive status, and training. The training category was assigned as the specific training type or types to which the MWD was assigned; most dogs had dual-purpose training. The training categories included patrol and explosive detector, patrol and drug detector, patrol, tactical explosive detector (ie, explosive detector in a combat environment), specialized search, mine detector, drug detector, explosive detector, combat tracker, improvised explosive device detector, unknown (when information was not available), and untrained (when the MWD was in a training program and had not yet been certified for a task).[26]

Binary factors—The binary data were recorded as yes vs no, unless otherwise indicated. These included history of prophylactic gastropexy; GDV; gastrointestinal disease; abdominal surgery (other than prophylactic gastropexy); abdominal surgery other than, and after, gastropexy in the week immediately prior to MV or the event date; aggression; aggressive temperament; behavior consultation; and diagnosis of a posttraumatic stress–like disorder of dogs (as defined by the US military).[27] Other binary factors analyzed included feeding schedule (once daily vs twice daily; diets primarily consisted of a commercially available food formulated for active or working dogs[a]); whether the dog was receiving medications at the time of MV or on the event date; whether the dog was receiv-

ing NSAIDs at the time of MV or on the event date; breed (GSD vs other); sex (male vs female); and reproductive status (sexually intact vs neutered).

Gastropexy was recorded (as yes) only if the procedure was performed prophylactically. History of GDV was recorded if it occurred prior to the MV date or event date. History of any gastrointestinal disease, regardless of duration, was recorded if ≥ 2 entries were on the master problem list in the dog's medical record. History of other abdominal surgery was recorded if the procedure was performed between the time of prophylactic gastropexy and time of MV or the event date and it had involved a separate anesthetic episode. Abdominal surgical procedures prior to prophylactic gastropexy were extremely rare and were therefore not included; no abdominal surgical procedures other than neutering were recorded for dogs that had no gastropexy.

An MWD was categorized as having a history of aggression on the basis of the initial behavior assessment during the procurement physical examination. This was typically performed when MWDs were approximately 1 to 3 years of age; the initial assessment was done prior to any training and had criteria different than those for aggressive temperament. Aggressive temperament was recorded on the basis of results of standardized semiannual behavior assessments; behaviors considered to reflect aggressive temperament were not training related.[28] The determination of aggressive temperament was recorded if ≥ 2 comments matching the predefined criteria were documented in the record. Behavior consultations were conducted by a board-certified veterinary behaviorist or resident in training addressing unwanted behavior of an MWD per request from the dog's trainer or handler. Any history of such consultation, whether requested because of a single event or multiple events of unwanted signs, was included in the analysis.

Evaluation for posttraumatic stress–like disorder[27] was performed by a board-certified veterinary behaviorist when an MWD returned from deployment to a combat environment or another situation that was deemed stressful. This condition was defined by the US military as the result of a concussive event with any of the following, alone or in combination; physical injury, exposure to a combat environment, or repeated exposure to a combat environment. Behaviorally, MWDs with the condition may have had any combination of the following signs: escape from or avoidance of work-related environments, increased or decreased reactivity to environmental or social stimuli (characterized by increased or decreased motor activity, increased vigilance and scanning, increased autonomic hyperactivity or hyperreactivity, persistent startle reactions, and changes in heart rate and respiratory rate), positive or negative changes in rapport with the handlers (specifically recognition, attentiveness, or responsiveness), evidence of sleep disorders, or impediments in performing critical tasks such as detection, controlled aggression, or obedience.[27] A diagnosis of this condition is made when the behavioral signs continued for ≥ 30 days with no improvement regardless of treatment.

Ordinal and discrete factors—Data with ordered relationships or other distinct and separate values included number of bite quarantines, BCS, deployment category status, and thunderstorm hours. A bite quarantine was initiated when an MWD bit its handler or another individual in any situation. The number of bite quarantines prior to the date of MV or assigned event date was reported for each dog. The BCS was assigned according to a standardized scoring system[b] (1 to 9) with half-score increments included. Deployment category status was assigned on a scale of 1 to 4 and reflected an assessment of the MWD's fitness for duty to be deployed (by evaluation of health status, presence of chronic disease, dependence on specific diet or medications, and other factors), where 1 = fully deployable and 4 = nondeployable. Total thunderstorm hours were recorded beginning 3 days prior to MV or the event date (ie, day 0); this sum reflected the total duration of thunderstorms that occurred in the region where the dog was housed or deployed, regardless of its activity. These data were recorded as the most recent value up to and including the day of MV or the event date.

Continuous factors—Age, weight, and weather data were all examined as continuous variables. Age and body weight at time of MV or on the event date were recorded and used in the analyses. Weather data were obtained for all dogs at each location for 3 days prior to and on the day of MV or the event date. Absolute measurements of environmental temperature, barometric pressure (recorded and analyzed in millibars and reported as millimeters of mercury, where 1,000 mBar = 750.06 mm Hg), and relative percentage humidity were recorded, and the difference in each variable over each day of interest was calculated as the maximum difference in a 24-hour period.

Statistical analysis

Statistical analysis was performed with a commercial software package.[c] Preliminary univariate analysis of factors was performed with χ^2 (nominal and binary data), Wilcoxon rank sum (ordinal or nonnormally distributed continuous data), or Student *t* (normally distributed continuous data) tests. Normality was assessed by means of a normal probability plot. Factors with $P < 0.30$ on univariate analysis were entered into a multivariate logistic regression model. Multicollinearity of the factors was quantified by means of the variance inflation factor; factors for which the variance inflation factor was > 2.5 were not included in the multivariate analysis. Factors were sequentially deleted from this equation according to the greatest multivariate *P* values. Factors with $P < 0.20$ were retained; all previously deleted factors were then individually added back into the equation and retained if the result was $P < 0.20$. The ORs for development of MV in dogs with a given factor (vs

Table 1—Results of univariate analysis of potential risk factors (nominal data) for MV in a retrospective case-control study that included 211 MWDs with (case dogs; n = 54) and without (control dogs; 157) the disease.

Factor	Cases	Controls	*P* value
Breed			< 0.001
GSD	44 (81.5)	80 (51)	
Dutch Shepherd Dog	0 (0)	3 (1.9)	
Belgian Malinois	6 (11.1)	61 (38.9)	
Labrador Retriever	2 (3.7)	12 (7.6)	
Golden Retriever	1 (1.8)	0 (0)	
Schnauzer	1 (1.8)	0 (0)	
German Shorthaired Pointer	0 (0)	1 (0.6)	
Sex and reproductive status			0.50
Sexually intact male	34 (63)	99 (63.1)	
Neutered male	12 (22.2)	29 (18.5)	
Sexually intact female	0 (0)	6 (3.8)	
Neutered female	8 (14.8)	23 (14.6)	
Training			0.42
Patrol and explosive detector	24 (44.4)	58 (36.9)	
Patrol and drug detector	8 (14.8)	10 (6.4)	
Patrol	5 (9.3)	15 (9.6)	
Tactical explosive detector	1 (1.8)	2 (1.3)	
Specialized search	2 (3.7)	3 (1.9)	
Mine detector	0 (0)	1 (0.6)	
Drug detector	1 (1.8)	6 (3.8)	
Explosive detector	3 (5.6)	15 (9.6)	
Combat tracker	1 (1.8)	1 (0.6)	
Improvised explosive device detector	0 (0)	4 (2.5)	
Untrained	9 (16.7)	38 (24.2)	

Data represent number (%) of dogs. Breed (GSD vs other), sex, and reproductive status (sexually intact vs neutered) were further analyzed as binary factors (***see*** Table 2). Values of $P < 0.05$ were considered significant.

Table 2—Results of univariate analysis of potential risk factors (binary data) for MV in the same 211 MWDs as in Table 1.

Factor	Cases	Controls	*P* value
Surgical and medical history			
Prophylactic gastropexy	40/54 (74)	68/157 (43.3)	< 0.001
Other abdominal surgery*	2/43 (4.7)	1/157 (0.6)	0.06
Abdominal surgery ≤ 7 d before MV or event date	3/52 (5.8)	0/157 (0)	0.002
GDV	2/54 (3.7)	3/157 (1.9)	0.46
Gastrointestinal disease	12/52 (23.1)	11/157 (7.0)	0.001
Medications (any) on MV or event date	17/51 (33.3)	23/157 (14.6)	0.003
NSAIDS on MV or event date	7/54 (13)	6/157 (3.8)	0.02
Behavioral history†			
Aggression	3/52 (5.8)	7/157 (4.5)	0.70
Aggressive temperament	3/51 (5.9)	21/156 (13.5)	0.14
Behavior consultation	0/51 (0)	6/157 (3.8)	0.16
Posttraumatic stress–like disorder	0/51 (0)	1/157 (0.6)	0.57
Feeding schedule			0.30
Once daily	2/48 (4.2)	13/149 (8.7)	
Twice daily	46/48 (95.8)	136/149 (91.3)	
Breed			< 0.001
GSD	44/54 (81.5)	80/157 (51)	
Other	10/54 (18.5)	77/157 (49)	
Sex			0.54
Male	46/54 (85.2)	128/157 (81.5)	
Female	8/54 (14.8)	29/157 (18.5)	
Reproductive status			0.60
Sexually intact	20/54 (37)	52/157 (33.1)	
Neutered	34/54 (63)	105/157 (66.9)	

Data represent proportion (%). Not all dogs had all data available.

*History of other abdominal surgery was recorded if the procedure was performed between the time of prophylactic gastropexy and time of MV (cases) or the event date, and it had involved a separate anesthetic episode. †History of aggression or aggressive temperament was recorded during the initial procurement examination and during standardized semiannual behavior assessments, respectively; these behaviors were not related to the dogs' training (eg, for controlled aggressive action). Behavior consultations to address unwanted behaviors were performed by a board-certified veterinary behaviorist or resident at the request of a handler or trainer. Diagnosis of a posttraumatic stress–like disorder as defined by the US military[27] was made by a veterinary behaviorist.

See Table 1 for remainder of key.

without that factor, while controlling for all other factors) are reported with 95% confidence intervals. The OR represents the relative change in odds for the occurrence of MV for presence of a given factor or, for continuous variables, for each (single) unit change in that factor (eg, age). Values of $P < 0.05$ were considered significant.

Results

Records of 54 case dogs affected with MV and 162 unaffected control dogs were selected for review. The records of 5 potential control dogs were excluded because of missing information, leaving 54 case and 157 control dog records in the study. Of the 54

Table 3—Results of univariate analysis of potential risk factors (ordinal and discrete data) for MV in the same 211 MWDs as in Table 1.

Factor	Scale or range	Cases	Controls	*P* value
Bite quarantine	1–5	0.0 (0–3)	0.0 (0–5)	0.11
BCS	1–9	4.5 (3–7)	4.5 (3–6.5)	0.69
Deployment category	1–4	1.0 (1–4)	1.0 (1–4)	0.81
Thunderstorm hours	0–4	0 (0–1)	0 (0–4)	0.20

Data are reported as median (range) and reflect the most recent value up to and including the date of MV or the event date. Bite quarantines were initiated when an MWD bit its handler or another person in any situation. The BCS was reported according to a described system[b] and included half-point increments. Deployment category reflected the MWD's fitness to be deployed, where 1 = fully deployable and 4 = nondeployable. Thunderstorm hours represented the sum of thunderstorm activity hours in locations where MWDs were present, regardless of their activity.

See Table 1 for remainder of key.

Table 4—Results of univariate analysis of potential risk factors (continuous data) for MV in the same 211 MWDs as in Table 1.

Factor	Cases	Controls	*P* value
Age (y)	5.3 (1.6 to 11.2)	4.0 (2 to 11)	< 0.001
Weight (kg)	32.4 (21 to 41)	32.0 (17.5 to 43)	0.82
Environmental temperature (°C)			
Absolute			
Day –3	13.9 (–18 to 31)	18.2 (–17 to 32)	0.006
Day –2	13.8 (–19.5 to 31)	18.3 (–21.5 to 32.5)	0.004
Day –1	13.7 (–24.5 to 31.5)	18.1 (–22.5 to 32)	0.005
Day 0	14.2 (–18 to 1)	18 (–19.5 to 32.5)	0.01
Difference			
Day –3	11.3 (3 to 23.4)	10.9 (0 to 25)	0.66
Day –2	11.3 (2.6 to 25.6)	10.7 (2 to 24.9)	0.43
Day –1	11.7 (2.2 to 25)	11 (1 to 25)	0.29
Day 0	11 (3 to 20.6)	10.3 (1 to 24)	0.36
Atmospheric pressure (mm Hg)			
Absolute			
Day –3	761.8 (739.3 to 770)	761.8 (743.7 to 775.7)	0.90
Day –2	761.5 (745.1 to 777.9)	761.5 (742.2 to 778.5)	0.95
Day –1	761.9 (749.9 to 773.7)	761.8 (743.1 to 779.2)	0.94
Day 0	762.1 (746.2 to 776.3)	762 (747.8 to 774.6)	0.87
Difference			
Day –3	4.73 (2.2 to 17.5)	4.1 (0 to 12.4)	0.26
Day –2	5.25 (0.9 to 15.3)	4.6 (1.5 to 13.5)	0.14
Day –1	4.5 (1.6 to 18.22)	4.8 (1.3 to 13.3)	0.57
Day 0	4.1 (1.4 to 15.3)	4.2 (0.6 to 15.1)	0.72
Humidity (%)			
Absolute			
Day –3	61 (7 to 92)	64.4 (15 to 96.5)	0.16
Day –2	62.4 (6.5 to 90.5)	65.4 (24 to 100)	0.21
Day –1	60.4 (5 to 89)	63.9 (18 to 97)	0.15
Day 0	62.4 (5.5 to 93.5)	65.6 (25.5 to 96.5)	0.17
Difference			
Day –3	41.2 (10 to 73)	44.2 (0 to 89)	0.24
Day –2	41.7 (7 to 73)	42.5 (0 to 89)	0.72
Day –1	43.3 (6 to 71)	42.8 (6 to 77)	0.82
Day 0	42.6 (7 to 75)	43.4 (7 to 77)	0.73

Data are given as median (range). Overall ranges of values for environmental temperature, atmospheric pressure, and humidity were –24.5° to 31.5°C (cases) and –22.5° to 32.5°C (controls), 739.3 to 777.9 mm Hg (cases) and 742.2 to 779.2 mm Hg (controls), and 5% to 93.5% (cases) and 15% to 100% (controls), respectively. Age and body weight were determined on the date of MV or the event date. Differences in weather measurements reflect the maximum difference in each 24-hour period. Atmospheric pressure was calculated in millibars and reported as millimeters of mercury, where 1,000 mBar = 750.06 mm Hg. Day 0 for weather-related data was the date of MV or the event date.

See Table 1 for remainder of key.

MWDs with MV, 50 (93%) died or were euthanized shortly after the diagnosis. Twenty-eight (52%) case dogs had the diagnosis confirmed during exploratory laparotomy, and the remaining 26 (48%) had the diagnosis confirmed on necropsy. Thirteen (24%) of 54 dogs were found dead in their kennels, and 41 (76%) were brought to a veterinary treatment facility for evaluation. Results of univariate analysis for case and control dogs were summarized **(Tables 1–4)**.

On multivariate logistic regression analysis, the GSD breed, increasing age, history of prophylactic gastropexy, history of gastrointestinal disease, history of other abdominal surgery, and NSAID administration at the time of MV (or event date) were associated with increased odds of MV. Increasing absolute humidity on day –1 (with the date of MV or event considered day 0) was also significantly associated with this outcome. The ORs, 95% confidence intervals, and *P* values generated in the analysis were reported **(Table 5)**.

Post hoc analysis of case and control dogs that had undergone prophylactic gastropexy was performed to investigate potential associations of the following variables with the outcome of interest: type of gastropexy (incisional, laparoscopy-assisted, or right paracostal grid), surgeon experience level (board-certified, residency-trained board-eligible, resident, intern, or general practitioner), and postoperative complications. All reported postoperative complications from gastropexy procedures were included in the analysis, regardless of severity. Of the 108 MWDs that had undergone gastropexy, 40 (37%) developed MV. The type of gastropexy (incisional, 26/108 [24%]; laparoscopy-assisted, 15/108 [14%]; or right paracostal grid, 67/108 [62%]) and surgeon experience level were not associated with development of MV on univariate analysis ($P = 0.29$ and $P = 0.07$, respectively). The presence of postoperative complications from prophylactic gastropexy surgery was significantly ($P < 0.001$) associated with development of MV. Recorded complications included dehiscence, improper gastropexy site (in 1 control MWD), seroma, and incisional infection. Incisional infections were the most common type of complication associated with prophylactic gastropexy surgery (4/108 [4%] dogs). On multivariate logistic regression analysis, presence of postoperative complications was associated with development of MV ($P = 0.01$) but experience level of the surgeon was not ($P = 0.19$).

Discussion

The present study included data from 54 MWDs with and 157 dogs without MV (case and control dogs, respectively), representing, to the authors' knowledge, the largest collection of MV-affected dogs in a single study to date. Over the last several decades, a number of putative risk factors for MV have been identified.[15,16,18,19] Data from the present study confirmed the impact of several previously reported risk factors for MV including breed (GSD), increased age, and history of gastrointestinal disease. Additional risk factors identified in this study included a history of prophylactic gastropexy and a history of other abdominal surgery.

To further underscore the importance of breed, 61 of 157 (39%) control dogs in the present study were Belgian Malinois (another common breed of MWD), whereas only 6 of 54 (11%) case dogs were of this breed. The male sex is predominant among MWDs and comprised 46 of 54 (85%) cases and 128 of 157 (82%) controls. Despite several previous reports[9,17–19] that identified males as being affected more commonly than females, we found no significant association between sex or reproductive status and development of MV. Consistent with earlier reports,[18,19,21] most of the case dogs in our study were adults (median age, 5.3 years; range, 1.6 to 11.2 years).

The stresses and demands associated with MWD training programs and subsequent assignments were considered as possible risk factors for developing MV, similar to the way stressful events have been identified as predisposing to other gastrointestinal malpositionings such as GDV.[29] Previous reports[3,9] have also associated MV with vigorous activity, and it has been established that substantial physiologic movement and displacement of the intestine occurs during physical activity. We identified no association

Table 5—Results of multivariate logistic regression analysis of potential risk factors for MV in the same 211 MWDs as in Table 1.

Factor	OR	95% confidence interval	*P* value
GSD breed (vs all others)	11.5	3.1–42.0	< 0.001
Age	2.0	1.6–2.8	< 0.001
Surgical and medical history (yes vs no)			
Prophylactic gastropexy	65.9	10.4–417.6	< 0.001
Other abdominal surgery	16.9	1.0–298.3	0.05
Gastrointestinal disease	5.4	1.1–25.7	0.04
NSAID administration at time of MV or event date	5.2	0.9–30.4	0.07
Absolute humidity on day –1	0.96	0.93–0.99	0.01

All factors with values of $P < 0.20$ in the analysis were reported. For continuous variables (age and humidity), the OR represents the relative change in odds for the occurrence of MV for each unit change in that factor. For example, the odds of developing MV were increased 2-fold for each 1-year increase in age.

See Tables 1 and 4 for remainder of key.

between presumed stress level (as determined by diagnosis of posttraumatic stress–like disorder,[27] temperament and aggression factors, or vigorous activity [per training category]) and development of MV in the present study.

We found that MWDs with a history of prophylactic gastropexy were more likely to develop MV (OR, 65.9; $P < 0.001$). The link between gastropexy and MV in this study was unexpected and, in the authors' opinions, should be interpreted cautiously. The 2 most common surgical procedures performed on an MWD are neutering and prophylactic gastropexy, and these were therefore included as factors for analysis. Historically, GDV has been a common cause of death or reason for euthanasia in the MWD population.[30] Thus, in 2001, the US military began to implement a prophylactic gastropexy policy for all MWDs in their early adult years. This program was rolled out over several years and resulted in an apparent reduction in the incidence of GDV. From 1990 through 2000, 116 cases of GDV were recorded; from 2001 through 2009, 95 cases of GDV were recorded; and from 2010 through 2016, 11 cases of GDV were recorded (data on file, US DOD). It was during this time that the incidence of MV subjectively increased, with 6, 12, and 48 cases of MV recorded during the years 1990 through 2000, 2001 thorough 2009, and 2010 through 2016, respectively.

The authors are unsure how or why a gastropexy might predispose to MV. A potential reason for the increased odds of MV following prophylactic gastropexy is that impaired gastrointestinal motility due to the gastropexy may hinder physiologic movement or disrupt the natural resolution of a subclinical intestinal volvulus once it has occurred.[16] Fifty of 54 (92%) case dogs died or were euthanized because of MV in our study, and all had a necropsy performed in which proper location of the gastropexy (gastric antrum attached to right abdominal wall, caudal to the last rib) was confirmed. Further analysis revealed no association between the type of gastropexy performed and the occurrence of MV, suggesting that incisional, laparoscopy-assisted, and right paracostal grid all remain acceptable methods of gastropexy in MWDs. Experience of the surgeon performing the gastropexy, evaluated on the basis of training, was also not associated with MV in this subset of dogs ($P = 0.19$). Most complications associated with prophylactic gastropexy occurred in the postoperative period (typically ≥ 1 year prior to MV) and thus were not considered to be clinically relevant. Further studies to investigate any association between gastropexy and MV are indicated.

A history of GDV was not associated with development of MV in our population of MWDs. As postulated in previous literature,[18] however, a history of gastrointestinal disease did have a significant ($P = 0.04$) association with this outcome (OR, 5.4). Previous gastrointestinal diseases included stress-induced colitis, inflammatory bowel disease, exocrine pancreatic insufficiency, ileus, pancreatitis, food allergy or intolerance, and nonspecific gastrointestinal disease. Previous studies[9,11–15,17,18] have identified lymphocytic-plasmocytic enteritis, treatment of severe ascariasis with piperazine, parvoviral infection, exocrine pancreatic insufficiency, intussusception, and ileal carcinoma in dogs with MV. These conditions are all associated with altered intestinal motility, which may also be a common underlying predisposing factor for MV. Abdominal surgery performed for other reasons at some time after a prophylactic gastropexy was also found to be a risk factor for MV in this study (OR, 16.9; $P = 0.05$). Abdominal surgery is known to cause a transient ileus and adhesions.[31] Results of studies[1,4,5,11,32] in human and canine patients have suggested that intestinal adhesions might impair normal gastrointestinal peristalsis and motility, although no report of abdominal adhesions (other than gastropexy) was found in the necropsy reports of dogs in the present study. Previous reports[13,18] have also indicated that gastrointestinal surgery, concurrent GDV, and gastrointestinal foreign bodies may be associated with MV in dogs. The relationship between gastrointestinal disorders, gastrointestinal motility, and gastrointestinal transit time has been researched for decades, without a clear consensus. Wireless motility devices or capsules have previously been used to assess variations in gastrointestinal motility and transit times in dogs.[33–35] Further prospective studies including the use of wireless motility devices in MWDs could provide useful data to investigate whether there is a relationship between gastrointestinal motility and the risk of MV in these dogs, and may lead to an understanding of how preexisting gastrointestinal disease is related to this outcome.

Whether feeding schedules are linked with gastrointestinal malpositioning has been debated for decades, and we elected to test for an association between MWD feeding schedules and MV. From approximately 2001 and continuing through the present study, MWDs have primarily been fed on a twice-daily schedule, and these dogs typically receive a commercially available diet formulated for their active lifestyle. A small number of MWDs are fed specialized diets because of specific clinical diagnoses. The present study found no associations between feeding on a once-daily or twice-daily basis and development of MV. Body condition has been identified as a predisposing risk factor for GDV,[29] and for this reason BCS was included in our investigation of MV, but no association was detected. In evaluating medications administered on the date of MV (or event), an association was found between NSAID treatment and the outcome of interest on univariate analysis; however, this was nonsignificant in the final multivariate analysis.

Extensive measurements of weather-related variables were also made. Among 24 measures of absolute values and changes in environmental temperature, barometric pressure, and percentage humidity at each dog's location over a 4-day period including the day of MV or the event date (day 0), no associa-

tions were found, with the exception of absolute percentage humidity on day –1. Given that there was no pattern to any other weather variable measurements between case and control MWD locations, we suspected this single difference might be attributable to a type I error.

Limitations of the present study included its retrospective, records-dependent nature. In addition, we did not evaluate any hematologic values, histopathologic data, or genetic factors that could potentially have contributed to identification of additional risk factors. Further, it is important to recognize that 1 population of MWDs may not be representative of the larger population of MWDs or of dogs with MV in general. Additional studies are needed to investigate not only the potentially predisposing factors identified in this study, but whether factors specific to gastrointestinal motility, familial tendencies, and breed-specific conditions or anatomy may have contributory or protective roles. Although all MWDs are typically monitored closely whether on duty or off duty and kenneled, the data obtained by this study provide a basis for more specific monitoring of MWDs with the identified risk factors for MV. Despite the association between MV and gastropexy, we remain supportive of this procedure for prophylaxis against the much more common disease of GDV.

Acknowledgments

No third-party funding or support was received in connection with this study or the writing or publication of the manuscript. The authors have no conflicts of interest to report.

The views expressed in the article are those of the authors and do not reflect the official policy or position of the Department of the Army, DOD, or the US Government.

Presented in abstract form as a poster presentation for the Small Animal Surgery Residents' Forum at the American College of Veterinary Surgeons Surgery Summit, Seattle, October 2016.

Weather data were obtained and collated for MWDs worldwide by 14WS/WXCP 14th Weather Squadron, DOD Applied Climatology, Asheville, NC. The authors thank Col. Cheryl Sofaly, Lt Col. Jennifer Hiniker, Maj. Margaret Hanson, Isabel Castro-Perez, Robyn Miller, Jeff Cutrer, and Anne Pack for technical assistance.

Footnotes

a. Science Diet High Energy, Hill's Pet Nutrition Inc, Topeka, Kan.
b. Purina Body Condition System, Nestle Purina Inc, Largo, Fla.
c. SAS, version 9.4, SAS Institute Inc, Cary, NC.

References

1. Talbot CH. Volvulus of the small intestine in adults. *Gut* 1960;1:76–80.
2. Ellison GW. Intestinal obstruction In: Bojrab MJ, ed. *Disease mechanisms in small animal surgery*. Philadelphia: Lea & Febiger, 1993;255–256.
3. Van Kruiningen HJ. Intestinal volvulus. In: *Comparative gastroenterology*. Springfield: Charles C. Thomas, 1982;90–103.
4. Dietz DW, Walsh RM, Grundfest-Broniatowski S, et al. Intestinal malrotation: a rare but important cause of bowel obstruction in adults. *Dis Colon Rectum* 2002;45:1381–1386.
5. Gamblin TC, Stephens RE Jr, Johnson RK, et al. Adult malrotation: a case report and review of the literature. *Curr Surg* 2003;60:517–520.
6. Evans H, de Lahunta A. The digestive apparatus and abdomen. In: *Miller's anatomy of the dog*. 4th ed. St Louis: Saunders, 2013;281–337.
7. Carberry CA, Flanders JA. Cecal-colic volvulus in two dogs. *Vet Surg* 1993;22:225–228.
8. Evans H, de Lahunta A. The abdomen, pelvis and pelvic limb. In: *Miller's guide to the dissection of the dog*. Philadelphia: Saunders, 1980;175–255.
9. Shealy PM, Henderson RA. Canine intestinal volvulus. A report of nine new cases. *Vet Surg* 1992;21:15–19.
10. Brown DC. Small intestine. In: Tobias KM, Johnston SA, eds. *Veterinary surgery: small animal*. St Louis: Elsevier, 2012;1513–1541.
11. Jasani S, House AK, Brockman DJ. Localised mid-jejunal volvulus following intussusception and enteroplication in a dog. *J Small Anim Pract* 2005;46:398–401.
12. Halfacree ZJ, Beck AL, Lee KC, et al. Torsion and volvulus of the transverse and descending colon in a German Shepherd Dog. *J Small Anim Pract* 2006;47:468–470.
13. Matushek KJ, Cockshutt JR. Mesenteric and gastric volvulus in a dog. *J Am Vet Med Assoc* 1987;191:327–328.
14. Parker WM, Presnell KR. Mesenteric torsion in the dog: two cases. *Can Vet J* 1972;13:283–284.
15. Westermarck E, Rimaila-Parnanen E. Mesenteric torsion in dogs with exocrine pancreatic insufficiency: 21 cases (1978–1987). *J Am Vet Med Assoc* 1989;195:1404–1406.
16. Gagnon D, Brisson B. Predisposing factors for colonic torsion/volvulus in dogs: a retrospective study of six cases (1992–2010). *J Am Anim Hosp Assoc* 2013;49:169–174.
17. Harvey HJ, Rendano VT. Small bowel volvulus in dogs; clinical observations. *Vet Surg* 1984;12:91–94.
18. Nemzek JA, Walshaw R, Hauptman JG. Mesenteric volvulus in the dog: a retrospective study. *J Am Anim Hosp Assoc* 1993;29:357–362.
19. Junius G, Appeldoorn AM, Schrauwen E. Mesenteric volvulus in the dog: a retrospective study of 12 cases. *J Small Anim Pract* 2004;45:104–107.
20. Spevakow AB, Nibblett BM, Carr AP, et al. Chronic mesenteric volvulus in a dog. *Can Vet J* 2010;51:85–88.
21. Cairó J, Font J, Gorraiz J, et al. Intestinal volvulus in dogs: a study of four clinical cases. *J Small Anim Pract* 1999;40:136–140.
22. Hennekens CH, Buring JE. Case-control studies. In: *Epidemiology in medicine*. Philadelphia: Lippincott Williams & Wilkins, 1987;132–152.
23. Herbold JR, Moore GE, Gosch TL, et al. Relationship between incidence of gastric dilatation-volvulus and biometeorologic events in a population of military working dogs. *Am J Vet Res* 2002;63:47–52.
24. Moore GE, Levine M, Anderson JD, et al. Meteorological influence on the occurrence of gastric dilatation-volvulus in military working dogs in Texas. *Int J Biometeorol* 2008;52:219–222.
25. Dennler R, Koch D, Hassig M, et al. Climatic conditions as a risk factor in canine gastric dilatation-volvulus. *Vet J* 2005;169:97–101.
26. Secretary of the Air Force. *DOD military working dog (MWD) program*. Air Force instruction 23–126_IP. Army regulation 700–81. Washington, DC: Department of the Air Force, 2011.
27. Canine PTSD Blue Ribbon Panel. *Canine PTSD Blue Ribbon Panel*. Lackland Air Force Base, Tex: LTC Daniel E. Holland Military Working Dog Hospital, 2011.
28. Burghardt WF Jr. Behavioral considerations in the management of working dogs. *Vet Clin North Am Small Anim Pract* 2003;33:417–446.
29. Glickman LT, Glickman NW, Schellenberg DB, et al. Multiple risk factors for the gastric dilatation-volvulus syndrome in dogs: a practitioner/owner case-control study. *J Am Anim Hosp Assoc* 1997;33:197–204.
30. Moore GE, Burkman KD, Carter MN, et al. Causes of death or reasons for euthanasia in military working dogs: 927 cases (1993–1996). *J Am Vet Med Assoc* 2001;219:209–214.
31. Boscan P, Cochran S, Monnet E, et al. Effect of prolonged general anesthesia with sevoflurane and laparoscopic surgery on gastric and small bowel propulsive motility and pH in dogs. *Vet Anaesth Analg* 2014;41:73–81.
32. Di Cicco MF, Bennett RA, Ragetly C, et al. Segmental jeju-

nal entrapment, volvulus, and strangulation secondary to intra-abdominal adhesions in a dog. *J Am Anim Hosp Assoc* 2011;47:e31–e35.
33. Gazzola KM, Nelson LL. The relationship between gastrointestinal motility and gastric dilatation-volvulus in dogs. *Top Companion Anim Med* 2014;29:64–66.
34. Boillat CS, Gaschen FP, Gaschen L, et al. Variability associated with repeated measurements of gastrointestinal tract motility in dogs obtained by use of a wireless motility capsule system and scintigraphy. *Am J Vet Res* 2010;71:903–908.
35. Boillat CS, Gaschen FP, Hosgood GL. Assessment of the relationship between body weight and gastrointestinal transit times measured by use of a wireless motility capsule system in dogs. *Am J Vet Res* 2010;71:898–902.

From this month's *AJVR*

Corneal thickness, endothelial cell density, and morphological and morphometric features of corneal endothelial cells in goats

Natalia Coyo et al

OBJECTIVE
To determine corneal thickness (CT), endothelial cell density (ECD), and morphological and morphometric features of caprine eyes and to assess effects of aging on these variables.

SAMPLE
27 healthy eyes of 19 Murciano-Granadina goats.

PROCEDURES
Goats were classified into 2 age groups (kids, 14 months old [14 eyes]; and adults, 7 to 10 years old [13 eyes]). The ECD and CT were calculated in the central cornea and 4 peripheral quadrants. Mean cell area (MCA), pleomorphism (percentage of hexagonal cells), and polymegathism were evaluated in the central cornea.

RESULTS
Median values for kids were determined for ECD (3,831 cells/mm^2; interquartile range [IQR], 3,669 to 4,011 cells/mm^2), CT (608 μm; IQR, 573 to 655 μm), MCA (255 μm^2; IQR, 243 to 272 μm^2), pleomorphism (80.53%; IQR, 78.83% to 83.30%), and polymegathism (19%; IQR, 18% to 22%). Median values for adults were determined for ECD (2,101 cells/mm^2; IQR, 1,966 to 2,251 cells/mm^2), CT (706 μm; IQR, 670 to 730 μm), MCA (466 μm^2; IQR, 425 to 507 μm^2), pleomorphism (67.80%; IQR, 65.50% to 70.00%), and polymegathism (21%; IQR, 15% to 26%). Values differed significantly between the 2 groups for all variables, except polymegathism. For both groups, the dorsal and temporal quadrants were the thickest and thinnest, respectively. Ventral ECD was the lowest for both groups.

CONCLUSIONS AND CLINICAL RELEVANCE
ECD decreased with age, whereas MCA, pleomorphism, and CT increased. Moreover, differences among regions of the cornea indicated that the central cornea should not be considered as representative of the entire cornea. (*Am J Vet Res* 2018;79:1087–1092)

October 2018

See the midmonth issues of *JAVMA* for the expanded table of contents for the *AJVR* or log on to avmajournals.avma.org for access to all the abstracts.