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Behavioral problems may be associated with multilevel lumbosacral stenosis in military working dogs

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Abstract

Behavioral and spinal problems have been reported to be important causes of early retirement in military working dogs, however studies on possible relationships between these two problems are currently lacking. The aim of this retrospective, observational, cross-sectional study was to test associations between reported behavioral problems and computed tomographic (CT) diagnoses of lumbosacral (LS) stenosis in a sample of military working dogs. *Data archives at a tertiary referral military working dog hospital were searched for dogs that had LS CT scans acquired during the period of June 2013- July 2014, and available medical records.* For each included dog, an observer unaware of CT findings reviewed medical records and recorded dog signalment data. A second observer reviewed medical records and assigned a score of 0 (absent) or 1 (present) for each of 11 behavioral problem categories. A third observer unaware of medical record findings reviewed CT scans and assigned a score of 0 (absent) or 1 (present) for LS stenosis at each of 4 vertebral locations (L4-5, L5-6, L6-7, L7-S1). A statistician selected and performed tests of association. A total of 55 dogs met inclusion criteria. Of these, 21 dogs (38.2%) had recorded behavioral complaints/problems involving behavior in at least 1 of the 10 categories and 44 (80.0%) had CT

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Authorship statement

The idea for the paper was conceived by Tiana Dodd and Jeryl Jones. The experiments were designed by Tiana Dodd, Jeryl Jones, and Ida Holaskova. The experiments were performed by Tiana Dodd, Jeryl Jones, and Ida Holaskova. The data were analyzed by Tiana Dodd, Jeryl Jones, Ida Holaskova, and Meenakshi Mukherjee. The paper was written by Tiana Dodd, Jeryl Jones, Ida Holaskova, and Meenakshi Mukherjee.

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diagnoses of LS stenosis in at least one vertebral location. The number of behavioral problems were significantly associated with number of vertebral locations with LS stenosis (ordinal logistic fit, $p=0.011$) and positively correlated ($\rho = 0.37$, $p = 0.006$). Problems involving behavioral concerns were more likely to be exhibited if dogs had multi-level stenosis (3 vertebral levels, $Kappa = 0.06$, $p>0.05$; Bowker's test statistics 26.26, $P<0.05$). The most common behavior problems in dogs with multi-level stenosis were "unwilling or reluctant to jump up onto objects/into vehicles" (3/8, 38%), "sudden onset of aggressive behaviors" (2/8, 25%), "self-mutilation in the lower back region, tail, or hind legs" (2/8, 25%), "increase in anxiety" (2/8, 25%), "sudden decrease in appetite" (2/8, 25%), "unwilling or reluctant to sit" (2/8, 25%), and "handler-reported unusual behaviors" (2/8, 25%). *Findings from this preliminary study supported inclusion of multi-level LS stenosis in the differential diagnosis list for military working dogs presenting with a recent onset of behavioral problems.*

Keywords

lumbar; spinal; multi-level compression; cauda equina syndrome

Introduction

Evans, et al. (2007) and Moore, et al. (2001) have identified behavioral problems and spinal problems as important causes of early retirement and loss of active duty status in military working dogs (Evans et al., 2007; Moore et al., 2001); however, studies exploring possible relationships between these two problem categories are currently lacking. Jones et al. (2000), Linn et al. (2003), Henderson, et al. (2017), and Mukherjee et al. (2017) have identified lumbosacral stenosis as a common spinal problem in military working dogs (Jones et al., 2000) (Linn et al., 2003; Henderson, 2014 Mukherjee et al., 2017). Predisposed breeds include German shepherd, Belgian malinois, Dutch shepherd, and Labrador retriever.

Jones et al. (2000) and Linn et al. (2003) described behavioral traits in military working dogs that were diagnosed with lumbosacral stenosis using computed tomography (CT) and surgery (Jones et al., 2000; Linn et al., 2003). These behavioral traits included lameness, lumbosacral pain, lethargy, reluctance to jump, reluctance to search high ("hupp"), muscle tremors, weakness/paresis, muscle atrophy, dragging toes, conscious proprioception deficits, and ataxia/abnormal gait. In these studies, lumbosacral pain was considered to be present when the dog reacted to palpation of the lumbosacral spine and/or elevation of the tail ("tail jack"). Authors of both studies concluded that early detection and treatment of lumbosacral stenosis was an important factor in the likelihood of return to full active duty. Haverbeke et al. (2008) reported that reluctance to perform working tasks could be a sign of pain in working dogs but initially misinterpreted as "laziness", causing dog handlers to respond with more aversive training techniques (Haverbeke et al., 2008). An improved understanding of possible relationships between concerns involving behavior and lumbosacral stenosis in military working dogs could therefore be helpful for improving early detection so that appropriate treatments could be implemented before further injuries occur. Linn et al. (2003), to our knowledge is the most recent study looking at lumbosacral stenosis and behavioral change or concerns. A limitation to her study is that all dogs were positive for

lumbosacral stenosis. Our study is the first to explore behavioral concerns in a sample that included dogs both positive and negative for lumbosacral stenosis. The objective of this preliminary study was to test potential associations between reported behavioral problems/concerns and CT diagnoses of lumbosacral stenosis in a sample of military working dogs that are both negative and positive for lumbosacral stenosis.

Methods

Dog selection criteria:

The study was a retrospective, observational, cross-sectional design. With approval of the hospital director, data archives of a tertiary referral military working dog hospital (Daniel E. Holland Military Working Dog Hospital, Lackland Joint Base, Texas) were searched for dogs that had a CT scan of the lumbosacral region during the period of June 2013 to July 2014. This sample period was chosen because two prospective research studies had been conducted during this period and had included both clinically affected and clinically normal dogs (Mukherjee et al., 2017; Henderson, 2014). Dogs were excluded from the current study if they had CT evidence of fractures, neoplasia, or previous lumbosacral surgery; or if their medical records were unavailable at the time of the study. A board-certified veterinary radiologist (JJ) made all final decisions for dog inclusion or exclusion.

Data recording:

An undergraduate research student (TD) reviewed medical records for each included dog and recorded descriptions of behavioral concerns or problems (not behavioral diagnoses) identified either before or at the time of CT scanning. A graduate student (MM) reviewed medical records and recorded dog signalment at the time of CT scanning and reason for CT scanning. To minimize bias, the medical record readers were unaware of CT interpretations at the time of data recording. Descriptions of behavioral concerns and complaints were assigned to the following 11 categories: 1) unwilling or reluctant to jump up onto objects/into vehicles; 2) unwilling or reluctant to perform other working tasks; 3) sudden onset of aggressive behaviors; 4) increase in anxiety; 5) laziness; 6) self-mutilation in the lower back region, tail, or hind legs; 7) unwilling or reluctant to sit; 8) sudden decrease in appetite; 9) depression or lethargy; 10) pruritis in the lower back region, tail, or hind legs; and 11) other. For each dog, a score of 0 (absent) or 1 (present) was recorded for each of the 11 behavioral problem categories. For dogs with the behavioral problem category of “other”, the specific description of the behavioral problem was recorded.

A veterinary radiologist (JJ) retrieved and uploaded CT data to an image analysis workstation,^a and used image analysis freeware^b for CT image interpretations. To minimize bias, the CT reader was unaware of medical record findings at the time of CT image reviews. For dogs with more than one CT scan during the study period, only the first CT scan was used for analyses. The radiologist recorded a score of 0 (absent) or 1 (present) for lumbosacral stenosis at each of four vertebral locations: L4–5, L5–6, L6–7, and L7–S1. If a

^aMacPro 12-core with 30 inch Apple Cinema HD display, 1 Infinite Loop, Cupertino, CA

^bOsiriX version 4.1.2, <http://www.osirix-viewer.com>

given vertebral location was not available in the CT scan, the radiologist recorded “NA”, and that vertebral location was excluded from further analyses for that dog. Lumbosacral stenosis was defined as “present” if the following CT characteristics were detected: focal narrowing of the vertebral canal and/or intervertebral foramina due to bony and/or soft tissue encroachment; with associated silhouetting, indentation, and/or displacement of thecal sac or nerve root margins (Jones et al., 1996). The radiologist was allowed to adjust image display settings and reformat images as needed for interpretations.

Descriptive analyses:

The undergraduate research student entered signalment data, reasons for CT scanning, behavioral category scores, and CT lumbosacral stenosis scores for each dog into a spreadsheet^c. Frequency values (%) were calculated for categorical data, and averages were calculated for numerical data. Composite behavioral problem scores were calculated for each dog using the sum of scores for each of the 11 behavioral categories. Composite lumbosacral stenosis scores for each dog were calculated using the sum of lumbosacral stenosis scores for the four vertebral locations.

Statistical analyses:

A statistician (IH) selected and performed statistical analyses using commercially available software^d. Associations between composite behavioral problem scores and composite lumbosacral stenosis scores (discrete ordinal categories 0 to 4 for each) were tested using the ordinal logistic fit. Agreement between composite behavioral problem scores and composite lumbosacral stenosis scores grouped in three categories (each 0, 1–2, 3–4) were evaluated using weighted Kappa Coefficient, followed by the Bowker’s test of symmetry of disagreement. Bowker’s test of symmetry is applicable to categorical type of analysis, where all sampled individuals are classified according to two variables (like lumbosacral stenosis and behavioral problems), each with m levels, in a square (m by m) contingency table (see Table 3). For instance, if it is principally hypothesized that the categories of lumbosacral stenosis (0, 1–2, 3–4) are quantitatively associated with categories of behavioral problems (0, 1–2, and 3–4), then the diagonal of such table represents matching of levels of both variables (e.g., dogs with 0 LS have 0 behavioral concerns/problems, dogs with 1–2 LS regions also have 1–2, and dogs with many painful LS regions may exhibit many behavioral issues), where a high percent of observations in cells on the diagonal represents the agreement of the two characteristics. When the diagonal values do not support substantial agreement, the cells of the table in the opposite corners across the diagonal may have a similar numerical pattern, resulting in symmetry of counts around the diagonal. The null hypothesis in the Bowker’s test is that the count across the diagonal is symmetrical. For instance, in Table 3, if 2% of all dogs were without LS and exhibited 3–4 behavioral concerns (upper most right cell with $n=1$), if symmetry of this relationship is expected, 2% of dogs on the opposite spectrum would have 3–4 LS-affected regions and no behavioral concerns (lower most left cell with observed $n=7$). A significant p -value in Bowker’s test indicates evidence of asymmetry.

^cExcel Office for Mac 2011, version 14.4.3

^dSAS Version 9.3; JMP Versions Pro 11; SAS Institute, Cary, NC

Nonparametric correlation analysis (Spearman's rho) was used to compare the number of vertebral locations scored as "present" for lumbosacral stenosis and number of behavioral problem categories scored as "present".

In a secondary analysis, additional effects, including dog's age, weight, and sex on frequency of lumbosacral stenosis, were tested. Variables found to be significant in bivariate analyses were subsequently entered into a multiple logistic regression. A similar approach was used to examine the effects of dog age, weight, sex, and number of regions positive for lumbosacral stenosis on the number of behavioral problems. Representation of various breeds and age groups in the sample was not equal or stratified due to the demographics of hospitalized dogs with CT records.

If at least 10 subjects were not present in each of the breed groups (i.e., with and without LS, with and without behavior problems), breed groups were not included in the logistic regression analyses and the results were evaluated using a pool of all breeds. For all tests, a significance level of $p = 0.05$ was applied.

Results

A total of 55 dogs belonging to four breeds were included in the study (Tables 1 and 2). The majority of the dogs were Labrador retrievers ($n=27$). Other breeds included German shepherds ($n=14$), Belgian malinois ($n=12$), and Dutch shepherds ($n=2$). Thirty-six (65%) of the dogs in this sample had undergone CT scanning as part of previous prospective research studies (Mukherjee et al., 2017, pp. 1–12; Henderson, 2014, pp. 1–56) (Table 1). The Labrador retriever group had the smallest average age (2.96 years) and the smallest average weight (26.76kg). The Belgian malinois group had the greatest average age at the time of CT scanning (6.92 years).

Descriptive analyses

Of the 55 included dogs, 44 (80%) had lumbosacral stenosis involving at least one vertebral location and 21 (38.2%) had at least one reported behavioral concern (Table 2). In the group of dogs positive for lumbosacral stenosis, the vertebral location most commonly affected was L4–5 (38/44, 86%), followed by L7–S1 (30/44, 68%), L5–6 ($n=26$) and L6–7 ($n=8$) (Figure 3).

Of the 19 (34.5%) dogs with multilevel lumbosacral stenosis (i.e., involving ≥ 3 regions), 12 (63.2%) had at least one reported behavioral problem. The most frequently reported behavioral problem categories in this sub-population included the following: unwilling or reluctant to jump up onto objects/into vehicles (4/12, 33.3%), and unwilling or reluctant to perform other working tasks (4/12, 33.3%), with less frequent reports of an increase in anxiety and sudden onset of aggressive behaviors (Figure 4). Of the 12 dogs with multi-level lumbosacral stenosis and reported behavioral concerns, there were 8 (66.7%) German shepherds and 4 (33.3%) Belgian malinois.

Statistical analyses:

The number of regions with lumbosacral stenosis (0 to 4) were significantly associated with the number of behavioral problems (0 to 4) (ordinal logistic fit ($p=0.011$, Figure 5A). Furthermore, there was a significant positive correlation between the number of regions positive for lumbosacral stenosis and number of behavioral concerns ($\rho=0.37$, $p=0.006$). Dogs without lumbosacral stenosis and dogs with 1 or 2 regions affected by lumbosacral stenosis exhibited fewer behavioral problems than dogs with 3–4 regions affected by lumbosacral stenosis, suggesting a nonlinear pattern (Figure 5B). Specifically, the median number of behavior problems in categories without and with one or two LS regions was zero, and increased to 1 and 2.5 for 3 and 4 affected LS regions, respectively. Based on this finding, dogs were grouped into 3 lumbosacral stenosis categories for further analyses (0 affected vertebral levels, 1–2 affected vertebral levels, 3–4 affected vertebral levels), and 3 behavioral categories (0, 1–2, 3–4). A 3 by 3 contingency table was then generated (Table 3). An agreement between the number of regions with lumbosacral stenosis and number of behavioral problems was not detected using Kappa agreement (Table 3, Kappa= 0.06, p -value >0.05). However, a shift or a significant asymmetry was identified since proportion of the dogs with 1–2 affected vertebral levels did not exhibit a corresponding number of behavioral problems (Table 3, 0 behavioral problems, 19 dogs; Bowker's test of symmetry of disagreement test statistics 26.26, $p<0.05$). Similarly, there were 7 dogs that had 3–4 affected vertebral levels and did not exhibit any behavioral problems.

In a secondary analysis, the effects of age, weight, and sex on the incidence of lumbosacral stenosis (3 categories) were examined and a significant association was found between age and lumbosacral stenosis ($p<0.05$). Specifically, older dogs had an increased probability of lumbosacral stenosis than younger dogs. On average, dogs with lumbosacral stenosis were approximately 2 years older than dogs without lumbosacral stenosis (23 months, $p<0.05$). Weight and sex did not have a significant effect on incidence of lumbosacral stenosis.

A similar strategy was then performed to determine whether behavioral problems were associated with age, weight, and sex, in addition to number of regions with lumbosacral stenosis. We found that number of regions with lumbosacral stenosis had a significant effect on behavioral problems when adjusted for age, weight, and sex ($p=0.049$) using a multiple logistic regression model.

Discussion

The current study was designed to explore possible associations between two important causes of early retirement in military working dogs, behavioral problems and lumbosacral stenosis. Findings supported our research hypothesis in that the number of behavioral concerns reported was significantly associated and correlated with the number of vertebral locations with lumbosacral stenosis. Most of the behavioral problems identified in dogs of the current study were consistent with previous reports (Jones et al., 2000; Linn et al., 2003; Henderson, 2014). However, to our knowledge, this is the first report also describing reported behavioral concerns such as increased anxiety, loss of appetite and a sudden onset of aggressive behavior in dogs with lumbosacral stenosis.

The high number of Labrador retriever military working dogs in the current study's sample was most likely due to the fact that one of the prospective research studies conducted during our sample period was focused on this breed (Mukherjee et al., 2017). This previous prospective study had also purposefully selected an equal number of males and females for inclusion and this was most likely the reason that the current study identified more females with lumbosacral stenosis than previously reported (Jones et al., 2000; Linn et al., 2003). The majority of Labrador retrievers with lumbosacral stenosis in the current study did not have behavioral problems. However, most of these dogs were young at the time of CT scanning (2 years of age) and it is unknown whether any of them later developed behavioral concerns or further clinical lumbosacral signs. The asymmetry found (Table 3) indicates that behavioral concerns are more likely when 3 vertebral levels are affected for dogs in this study (n=19 dogs).

Our study identified L4–5 as the most common vertebral location with CT evidence of lumbosacral stenosis. This finding was not consistent with previous military working dog studies by Linn et al. (2003) and Jones et al. (2000), possibly because the L4–5 vertebral region was not evaluated in these studies (Linn et al., 2003; Jones et al., 2000). We recommend that the L4–5 region be included in CT scans of military working dogs presenting for suspected lumbosacral stenosis.

One of the limitations of the current study was the use of medical record entries as the basis for assigning dogs to broad, descriptive behavioral categories. Medical record entries can be subjective and operator dependent. However, this also reflects current standard clinical practice. Another limitation of the current study was insufficient sample sizes in some of the subgroups for a complete assessment of possible outside effects on results of the tests of association. We also recognize that other musculoskeletal diseases may be present in this population. Accordingly, the association findings in the current study need to be considered as preliminary and interpreted with caution and within the context of this study.

Conclusions:

Findings from the current study provided preliminary evidence that multi-level lumbosacral stenosis should be considered as a differential diagnosis in military working dogs presenting with a recent onset of reported behavioral concerns, especially for German shepherds. In addition to previously reported behavioral problems in dogs with confirmed lumbosacral stenosis, other problems such as loss of appetite, increased anxiety, and increased aggression may warrant further study as additional possible early markers for multi-level lumbosacral stenosis in this breed.

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Highlights:

- 21/55 military working dogs (38.2%) had recorded behavioral problems
- 44/55 military working dogs (80.0%) had CT diagnoses of LS stenosis
- The number of behavioral problems was associated with the number of LSS locations
- Behavioral problems were more likely if dogs had multi-level LSS (3 levels)
- Behavioral problems were more likely if dogs were German shepherd breed

Figure 1:

This mid-sagittal, soft tissue window, CT image illustrates a dog that was scored as absent (0) for lumbosacral stenosis at each of four vertebral locations.

Figure 2:

This mid-sagittal, soft tissue window, CT image illustrates a dog that was scored as present (1) for lumbosacral stenosis at four vertebral locations (multi-level stenosis).

Figure 3:
Distribution of affected vertebral locations in dogs that were positive for lumbosacral stenosis.

Figure 4.

Percentages of behavioral problems recorded in the 12 dogs with multi-level stenosis. Dogs were included in more than one category if they had more than 1 behavioral problem. The length of each bar represents the proportion of the 12 dogs that exhibited the particular behavioral problem. The distribution demonstrates that behavioral problems with highest incidence were “unwilling or reluctant to jump up onto objects/into vehicles” (33%), “unwilling or reluctant to perform other working tasks” (33 %), while “depression or lethargy” and “pruritus or hair loss in lower back region, tail or hind legs” were the least frequent problem (1/12, 8% for each).

Figure 5:

(A) Mosaic plot of the association of incidence (y-axis) and proportion of behavioral problems (bottom legend bar) in dogs with lumbosacral stenosis at 0, 1, 2, 3 or 4 vertebral locations (x-axis) (n=55 dogs). A significant association was identified with the ordinal logistic regression (p-value = 0.01). (B) Graph demonstrating that the detected quantitative relationship of behavioral problems and lumbosacral stenosis was non-linear in shape, namely, the median number of behavioral problems (y-axis) increased after at least 3 lumbosacral vertebral locations were affected by lumbosacral stenosis (x-axis). This change is illustrated with dark markers and bold reference lines.

Table 1:

Summary of medical record findings for the 55 military working dogs included in this study, by breed category.

Breed Number (%)	Sex Number (%)	Age (yrs) Range (median)	Weight (kg) Range (median)	Reason for CT Scanning Number (%)
German shepherd 14 (25%)	Female: 4 (29%) Male: 10 (71%)	2.08–8.00 (6.67)	26.31–40.19 (31.41)	Research: 6 (43%) Suspected LS disease: 5 (36%) Other: 3 (21%)
Labrador retriever 27 (49%)	Female: 15 (56%) Male: 12 (44%)	1.17–6.33 (2.96)	19.05–33.75 (26.76)	Research: 24 (89%) Suspected LS disease: 2 (7%) Other: 1 (4%)
Belgian malinois 12 (22%)	Female: 7 (58%) Male: 5 (42%)	5.00–14.00 (6.92)	22.59–44.27 (28.26)	Research: 5 (42%) Suspected LS disease: 5 (42%) Other: 2 (16%)
Dutch shepherd 2 (4%)	Female: 1 (50%) Male: 1 (50%)	4.67–6.58 (5.63)	29.48–37.19 (33.34)	Research: 1 (50%) Suspected LS disease: 0 (0%) Other: 1 (50%)

Table 2:

Summary of lumbosacral stenosis and behavioral problem status findings for the 55 military working dogs included in this study, by breed category.

Breed, Number (% of Total)	Lumbosacral Stenosis Status Number of dogs (% of breed, 95% CI)	Behavioral Problem Status Number of dogs (% of Breed and LS Status, 95% CI)	
		Absent	Present
German shepherd 14 (25%)	Absent: 0 (0%, 0.66–26.76)	0 (0%, N/A)	0 (0%, N/A)
	Present: 14 (100%, 73.24–99.34)	3 (23.08%, 5.71–51.18)	11 (78.57%, 48.82–94.29)
Labrador retriever 27 (49%)	Absent: 9 (33%, 17.24–53.99)	7 (77.78%, 40.19–96.05)	2 (22.22%, 3.95–59.81)
	Present: 18 (67%, 46.01–82.76)	16 (88.89%, 63.93–98.05)	2 (11.11%, 1.95–36.07)
Belgian malinois 12 (22%)	Absent: 1 (8%, 0.44–40.25)	1 (100%, 5.46–89.22)	0 (0%, 10.78–94.54)
	Present: 11 (92%, 59.75–99.56)	6 (50%, 24.56–81.86)	5 (45.45%, 18.14–75.44)
Dutch shepherd 2 (4%)	Absent: 1 (50%, 2.67–97.33)	0 (0%, 10.78–94.54)	1 (100%, 5.46–89.22)
	Present: 1 (50%, 2.67–97.33)	1 (100%, 5.46–89.22)	0 (0%, 10.78–94.54)
Total	Absent 11 (20%, 10.87–33.37)	8 (73%, 39.32–92.67)	3 (28%, 7.33–60.68)
	Present 44 (80%, 66.63–89.13)	26 (59%, 43.31–73.30)	18 (41%, 26.70–56.69)

Table 3:

Table illustrating relationships between number of behavioral problems and number of vertebral locations with lumbosacral stenosis for the 55 military working dogs included in this study.

Number of Vertebral Regions with Lumbosacral Stenosis	Number of Reported Behavioral Problems			
	0	1–2	3–4	Total
0	8 (14.55%)	2 (3.64%)	1 (1.82%)	11
1–2	19 (34.55%)	6 (10.91%)	0 (0%)	25
3–4	7 (12.73%)	8 (14.55%)	4 (7.27%)	19
Total	34	16	5	55

The diagonal of the table is identified by bold numbers (**8**, **6**, and **4**), representing matching of levels of both variables (eg: 8 dogs with 0 LS and 0 behavioral problems). The values in the lower corner (**19**, **7** and **8**) identify dogs that had 1–2, or 3–4 LS-affected areas, yet, exhibited none or only 1–2 behavioral problems. On the contrary, the values in the upper corner of the table (**2**, **1**, and **0**) represent the low or none behavioral problems in dogs with none or 1–2 number of LS areas. This asymmetry in the table was quantified (Bowker's test of symmetry of disagreement test statistics 26.26, $p < 0.05$) and could be interpreted as known stoic behavior of dogs.