EVALUATION OF TRADITIONAL AND NOVEL RADIOGRAPHIC VERTEBRAL RATIOS IN GREAT DANES WITH VERSUS WITHOUT CERVICAL SPONDYLOMYELOPATHY

PAULA MARTIN-VAQUERO, RONALDO C. DA COSTA

Great Danes are predisposed to osseous-associated cervical spondylomyelopathy (Wobbler syndrome). The first aim of this prospective study was to compare values measured using previously published intravertebral and intervertebral ratio methods and a novel ventrodorsal ratio method in radiographs of clinically normal and affected Great Danes. The second aim was to determine whether these ratios could be used as predictors of sites of spinal cord compression based on magnetic resonance imaging (MRI). Thirty dogs (15 normal, 15 affected) were prospectively enrolled. Lateral and ventrodorsal radiographs were obtained and six measurements were recorded from C3-T1. For each vertebral location, intravertebral ratios and intervertebral ratios were calculated from lateral views, and the ratio of the distance between the articular process joints vs. vertebral body width (novel ventrodorsal ratio) was calculated from ventrodorsal views. Values for these three ratios were compared, by vertebral location and dog group. Intravertebral and intervertebral ratios did not differ between dog groups. The ventrodorsal ratio was significantly smaller in affected Great Danes at C5–6 ($P = 0.005$) and C6–7 ($P < 0.001$). The ventrodorsal ratio was significantly associated with MRI presence of spinal cord compression. For each 0.1 unit increase in this ratio value, there was a 65% decrease in the odds of spinal cord compression being present at that site, independent of vertebral location ($P = 0.002$). Findings from this study supported use of the novel ventrodorsal ratio as an initial radiographic screening method for Great Danes with suspected cervical spondylomyelopathy. © *2014 American College of Veterinary Radiology.*

Key words: cervical spine, dog, radiography, vertebra, wobbler syndrome.

Introduction

CERVICAL SPONDYLOMYELOPATHY (Wobbler syndrome) commonly affects Great Danes.[1–4] Magnetic resonance imaging (MRI) and CT-myelography are routinely used in the diagnosis of this disease.[3,5–7] Before advanced imaging studies are performed, dogs with clinical signs consistent with a cervical myelopathy will often undergo survey radiographs of the cervical vertebral column as an initial screening test.[4,8] In cases of suspected cervical spondylomyelopathy, survey radiographs can help to rule out other differential diagnoses for cervical myelopathies such as osseous neoplasia, discospondylitis, or trauma.[9] In addition, since Great Danes are usually affected with the osseous-associated form of cervical spondylomyelopathy,[3,4] survey radiographs will frequently reveal osteoarthritic changes and sclerosis of the cervical vertebral articular processes.[1,2,4,9] Occasionally, vertebral body malformations may also be found.[1,2,9]

Vertebral measurements and ratios have been previously described as methods for quantifying cervical spondylomyelopathy using cervical radiographs in dogs.[10–14] Similar methods have been reported for quantifying cervical vertebral malformation in horses,[15–17] and cervical spondylotic myelopathy in people.[18–25] When evaluating direct measurements obtained from radiographs, the issue of magnification needs to be considered.[21,23,24] In order to improve accuracy and minimize effects of magnification errors, a ratio method has been proposed. In this method, both the numerator and denominator values are affected by the same magnification factor. Radiographic ratio methods

From the Department of Veterinary Clinical Sciences, College of Veterinary Medicine, The Ohio State University, Columbus, OH, 43210.

This work was performed at the College of Veterinary Medicine, The Ohio State University, Columbus, OH.

Funding sources: This work was supported by the Great Dane Club of America, an Intramural Canine grant from The Ohio State University, College of Veterinary Medicine, and the Award Number Grant UL1TR001070 for The Ohio State University Center for Clinical and Translational Science (CCTS) from the National Center for Advancing Translational Sciences. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Center for Advancing Translational Sciences or the National Institutes of Health.

Address correspondence and reprint requests to Paula Martin-Vaquero, Department of Veterinary Clinical Sciences, College of Veterinary Medicine, The Ohio State University, 601 Vernon L. Tharp Street, Columbus, OH 43210; E-mail: paulagu83@gmail.com

Received November 16, 2013; accepted for publication January 7, 2014.

doi: 10.1111/vru.12159

have been used since 1987 as initial screening tests in people suspected of having cervical spondylotic myelopathy.[21] The most commonly reported ratio is one that divides the sagittal diameter of the vertebral canal by the sagittal diameter of the corresponding vertebral body as obtained in lateral radiographs.[21] Lower ratio values are reported in people with cervical spondylotic myelopathy.[21,23] This cervical vertebral ratio is considered a valuable initial screening test of cervical stenosis in people even though it cannot be solely relied upon in the diagnosis of myelopathy.[21,24] Radiographic intravertebral and intervertebral ratios are also routinely used as a screening tool in horses with suspected cervical vertebral malformation.[15–17] Cervical vertebral ratios obtained on lateral radiographs have been investigated as a possible screening tool for cervical spondylomyelopathy in Doberman pinschers with and without clinical signs of the disease.[13,14] The methodologies used in those two studies were slightly different, but the common conclusion was that there were no reliable differences between the vertebral ratios of clinically normal and affected Doberman pinschers and that the ratios had limited clinical application in this breed.[13,14] However, vertebral ratios in dogs have been reported to be breed specific,[12] possibly due to the high variability of body conformation and size present among different breeds. Doberman pinschers and Great Danes have different body sizes and they are affected by different forms of cervical spondylomyelopathy.[4] In Doberman pinschers with disc-associated spondylomyelopathy, ventral spinal cord compressions secondary to intervertebral disc protrusions are most common,[4,26] whereas in Great Danes with osseous-associated cervical spondylomyelopathy, lateral and dorsolateral spinal cord compressions are most frequently reported.[3,6,27,28] Moreover, in osseous-associated cervical spondylomyelopathy the extent of lateral compressions is frequently not appreciated from lateral myelographic views or midsagittal MRI planes.[5,27] Because of these differences, previous studies investigating vertebral ratio values obtained in Doberman pinschers using lateral radiographs cannot be extrapolated to Great Danes.[12,14]

To the authors' knowledge, no prospective studies have compared intravertebral and intervertebral ratios in a population of clinically normal Great Danes vs. Great Danes with cervical spondylomyelopathy. In addition, no studies have described vertebral ratios using ventrodorsal radiographic views in dogs. The first objective of this study was to compare traditional intravertebral ratios, intervertebral ratios, and a novel ratio obtained from ventrodorsal radiographs in clinically normal Great Danes and Great Danes with cervical spondylomyelopathy. A second objective was to determine whether vertebral ratios could be used to predict the sites of spinal cord compression based on MRI in the group of affected Great Danes. We hypothesized that traditional vertebral ratios obtained on lateral radiographs would not differ between clinically normal and affected Great Danes, and that the novel ratio obtained on ventrodorsal views would be significantly different between the two groups.

Methods

Two groups of client-owned Great Danes were prospectively enrolled between April 2011 and October 2012. The investigation was conducted in accordance with the guidelines and with approval of The Ohio State University Clinical Research Advisory Committee and the Institutional Animal Care and Use Committee. Written owner consent was obtained prior to study enrollment. The first group consisted of 15 Great Danes that were defined as clinically normal based on a normal neurologic examination and no prior history of neurologic disease. Only Great Danes 1 year of age or older were eligible for enrollment as normal dogs. The second group included 15 Great Danes with clinical signs and neurologic examination findings consistent with cervical spondylomyelopathy and confirmation of the diagnosis via MRI. The time of onset of clinical signs was recorded. All 30 Great Danes were examined by the two investigators, and underwent complete blood counts, serum biochemical profiles, survey radiographs, and MRI of the cervical vertebral column (Achieva 3.0 Tesla, Philips Healthcare, Best, The Netherlands).

Digital radiographs of the cervical vertebral column were obtained with dogs under sedation. Each dog was sedated with hydromorphone (0.05–0.1 mg/kg IV, West-Ward Pharmaceuticals, Eatontown, NJ) and dexmedetomidine (4–8 mcg/kg IV, Dexdomitor®, Pfizer Animal Health, NY). Lateral views with the cervical vertebral column in neutral position and ventrodorsal views were obtained for all dogs. The radiographic technique was set at 75 kVp, 32 mA, and 40 ms for the lateral views. The ventrodorsal views were obtained with 75 kVp, 160 mA, and 200 ms. Radiographs included from the midbody of C2 to the cranial aspect of T1 with the thoracic limbs directed caudally. The same investigator performed all measurements (P.M.V.). Measurements were made by use of a software program for medical imaging analysis (ClearCanvas Workstation, ClearCanvas Inc., Toronto, ON, Canada). Three measurements were obtained at each vertebral body from C3-T1 and each intervertebral space from C2–3 through C7-T1 on both views. The measurements acquired on lateral radiographs were obtained as previously described in a study performed by one of the authors.[14] The following landmarks were used for the measurements obtained from the lateral views (Fig. 1):

1. *Vertebral body height*—defined as the maximum height of the cranial aspect of the vertebral body determined by

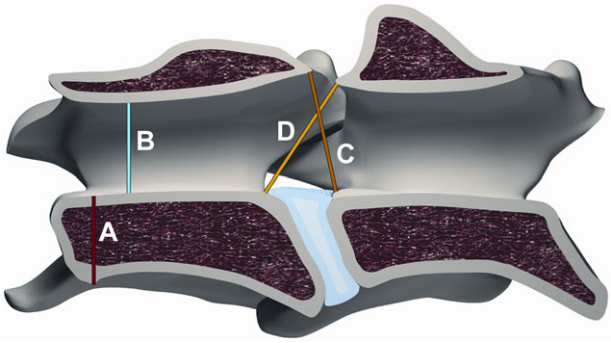

FIG. 1. Locations of traditional radiographic measurements obtained in lateral views. (A) Vertebral body height, (B) minimum intravertebral sagittal diameter, (C and D) locations for the intervertebral measurements for determination of the minimum intervertebral sagittal diameter. (Reprinted with permission from da Costa and Johnson [14]).

a line drawn perpendicular to the path of the vertebral canal.

2. *Minimum intravertebral sagittal diameter*—defined as the minimum diameter of the vertebral canal measured in the cranial third of the vertebral body.
3. *Minimum intervertebral sagittal diameter*—the minimum value of either one of the following two measured was used:

   3.1. A line drawn from the dorsal lamina of the more cranial vertebrae to the dorsocranial aspect of the body of the more caudal vertebrae, or
   3.2. A line drawn from the caudodorsal aspect of the body of the more cranial vertebrae to the cranial dorsal lamina of the more caudal vertebrae.

The following landmarks were used for the measurements obtained from the ventrodorsal views (Fig. 2):

4. *Distance between articular process joints*—measured at the intervertebral space with a line drawn adjacent to the cranial endplate of the caudal vertebral body for that space, extending from the most medial aspect of the right to the most medial aspect of the left articular process joint.
5. *Vertebral body width* —defined as the maximum width of the vertebral body measured in the cranial third of the vertebral body.
6. *Vertebral body length*—defined as a line drawn on the midline of the vertebral body from the cranial endplate to the caudal endplate.

In order to account for radiographic magnification, the following ratios were calculated:

1. Intravertebral ratio[13,14]– defined as the minimum intravertebral sagittal diameter divided by the corresponding vertebral body height.

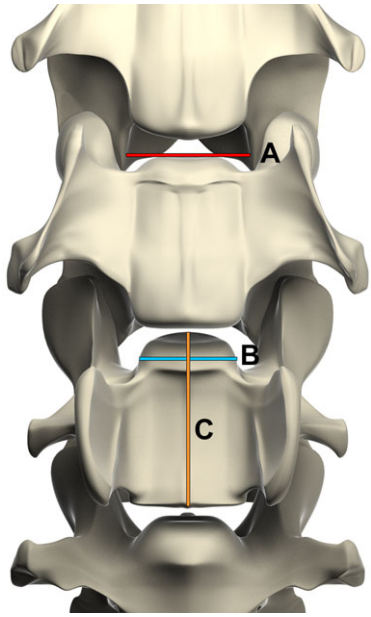

FIG. 2. Locations of radiographic measurements obtained in the ventrodorsal views and used for calculation of the novel ventrodorsal ratio. (A) Distance between articular process joints, (B) vertebral body width, and (C) vertebral body length.

2. Intervertebral ratio[13,14] – defined as the minimum intervertebral sagittal diameter divided by the corresponding vertebral body height.
3. Ratio of the distance between articular process joints – defined as the distance between the articular process joints divided by the vertebral body width.

Intra-observer agreement was tested by repeating all the measurements three times in four dogs (two clinically normal and two affected) at least 1 week apart.

Magnetic resonance imaging studies of the cervical vertebral column were obtained under general anesthesia with dogs positioned in dorsal recumbency. Midsagittal and transverse T2-weighted images were used to record the sites of spinal cord compression. Images were acquired using a turbo spin-echo technique. Repetition time (TR) and time to echo (TE) were as follows: sagittal T2-weighted images, TR = 5000 ms, TE = 110 ms; transverse T2-weighted images, TR = 4000 ms, TE = 120 ms. The field of view was 30 cm in the sagittal plane, and 20 cm in the transverse plane. The number of acquisitions was 2. Slice thickness was set at 3 mm with no interslice interval. The acquisition matrix was 192 × 286 for the sagittal T2-weighted images and 200 × 192 for the transverse T2 weighted images. Five transverse slices were obtained for each intervertebral space from C2–3 to C7-T1. The transverse slices were arranged to pass through the center of each intervertebral space as well as the cranial and caudal end plates of the adjacent vertebral bodies. The MRI studies were reviewed by one of the investigators (P.M.V.) and the sites of spinal cord

compression were recorded. Spinal cord compression was graded as previously described: mild (<25% reduction in the spinal cord diameter), moderate (25–50% reduction), and severe (>50% reduction in the spinal cord diameter).[6]

Statistical analysis were selected and performed by a professional statistician using commercially available software (Stata, version 12.1, Stata Corporation, College Station, TX). A random-effects linear regression analysis model was used to test differences for all the obtained measurements and the three calculated ratios between clinically normal and affected dogs for all the intervertebral levels studied. The linear regression model was adjusted for age, gender, height, and weight. Before running the regression analysis, the ratios were natural log-transformed to stabilize the increased variance inherent in the ratio of two random variables. Results were adjusted for the multiple comparisons by using the Sidak method to preserve the type I error at 0.05. Significance was set at a P value < 0.05. A random-effects logistic regression model was used to evaluate if the calculated ratios were predictive of sites of spinal cord compression as confirmed by MRI in the group of affected Great Danes. The logistic regression model was also adjusted for age, gender, height, and weight. Intra-observer agreement was estimated using the intraclass correlation (rho) among the three replicates of measurements that were obtained for four dogs using a variance components model based on a random-effect linear regression analysis.[29] If rho is close to 1.0 the agreement is excellent, whereas a value of rho close to 0 indicates lack of agreement.

Results

The group of clinically normal Great Danes included seven females (six spayed, one intact) and eight males (seven neutered, one intact). Their median age at the time of study enrollment was 2.3 years (range, 1–6.4 years). The median weight was 52 kg (range, 40.5–73 kg). All clinically normal Great Danes had normal neurological examinations. The group of Great Danes affected with cervical spondylomyelopathy included two spayed females, 12 neutered males, and one intact male. Their median age at the time of study enrollment was 4 years (range, 1–7.2 years). The mean weight was 56.8 kg (range, 42–79.3 kg). The reported median age at the onset of signs for the affected dogs was 1.7 years (range, 0.4–4.2 years). The clinical signs had been present for a mean time of 1.9 years (range, 0–5 years) before enrollment in the study. Fourteen of the 15 affected Great Danes showed ambulatory tetraparesis with proprioceptive ataxia of all four limbs. One affected dog showed a hypertonic thoracic limb gait with ambulatory paraparesis and proprioceptive ataxia of the pelvic limbs. All affected Great Danes had delayed postural reactions involving all four limbs. Mild neck pain was elicited in six affected dogs at the time of examination. Within the affected Great Danes, five dogs had four sites of spinal cord compression each (based on MRI), six dogs had three sites, two dogs had two sites, and two dogs had one site each of spinal cord compression. The sites affected by spinal cord compression (in decreasing order) included C4–5 and C6–7 (12 dogs each), C5–6 (10 dogs), C2–3 (five dogs), C3–4 (three dogs), and C7-T1 (two dogs). The main site of compression was at C6–7 (eight dogs), C4–5 (two dogs), C5–6 (two dogs), and C2–3 and C3–4 (one dog each).

TABLE 1. Comparison of Traditional Vertebral Ratios Obtained on Lateral Radiographs in 15 Clinically Normal Great Danes and 15 Great Danes with Cervical Spondylomyelopathy

Ratio	Intervertebral level	Mean (95% CI)	P value*
Intravertebral ratio	All levels (C2–3 to C7-T1)†		
Normal		0.568 (0.532, 0.605)	0.993
Affected		0. 568 (0.537, 0.600)	
Intervertebral ratio	All levels (C2–3 to C7-T1)†		
Normal		0.754 (0.705, 0.804)	0.933
Affected		0.757 (0.710, 0.803)	

CI = confidence interval.
*P value based on a random-effects linear regression analysis adjusted for age, gender, height, and weight. P value adjusted using the Sidak method to preserve the type I error at 0.05.
† Linear regression did not reveal differences at any of the individual intervertebral levels; thus the results are reported for all levels combined.

No significant differences were present between clinically normal and affected Great Danes for the following absolute measurements: minimum intravertebral sagittal diameter ($P = 0.549$), minimum intervertebral sagittal diameter ($P = 0.706$), vertebral body width ($P = 0.593$), and vertebral body length ($P = 0.913$), at any of the intervertebral levels investigated. The vertebral body height was also not significantly different between groups at any vertebral level, except for the body of C6, which was slightly shorter for affected Great Danes with a mean value of 1.84 cm (95% confidence interval [CI], 1.78–1.90), when compared to normal Great Danes with a mean value of 1.97 cm (95% CI, 1.90–2.05; $P = 0.041$). The absolute measurement of the distance between articular process joints was significantly different at the C5–6 intervertebral space with a mean value of 1.52 cm (95% CI, 1.36–1.68) for affected Great Danes and a mean of 1.90 cm (95% CI, 1.78–2.03) for clinically normal dogs ($P = 0.002$), and also at C6–7 with a mean of 1.54 cm (95% CI, 1.36–1.71) for affected Great Danes and a mean of 1.88 cm (95%, 1.74–2.01) for clinically normal Great Danes ($P = 0.012$).

The intravertebral ratio obtained on lateral radiographs was not significantly different between clinically normal and affected Great Danes ($P = 0.993$) at any of the intervertebral levels evaluated (Table 1). Similarly, there were no significant differences in the intervertebral ratio obtained on lateral radiographs between clinically normal and

TABLE 2. Comparison of a Novel Ventrodorsal Ratio‡ in 15 Clinically Normal Great Danes and 15 Great Danes with Cervical Spondylomyelopathy

Intervertebral level	Normal	Affected	*P* value*
C2–3	0.692 (0.640, 0.745)	0.655 (0.597, 0.712)	0.917
C3–4	0.661 (0.609, 0.712)	0.611 (0.559, 0.663)	0.694
C4–5	0.649 (0.596–0.702)	0.589 (0.539, 0.639)	0.474
C5–6	0.717 (0.655, 0.779)	0.584 (0.534, 0.634)	0.005†
C6–7	0.754 (0.684, 0.823)	0.589 (0.537, 0.640)	<0.001†
C7-T1	0.723 (0.647, 0.800)	0.656 (0.590, 0.722)	0.710

Data are presented as mean (95% confidence interval).
*P value based on a random-effects linear regression analysis adjusted for age, gender, height, and weight. P value adjusted using the Sidak method to preserve the type I error at 0.05.
†Indicates statistical significance, $P < 0.05$.
‡Ratio of the Distance between Articular Process Joints and Vertebral Body Width Obtained on Ventrodorsal Radiographs.

TABLE 3. Probability of Spinal Cord Compression Based on the Novel Ventrodorsal Ratio in 15 Great Danes with Cervical Spondylomyelopathy

Ratio value	Probability of compression*	95% CI
0.40	0.910	0.741, 1.080
0.45	0.857	0.630, 1.085
0.50	0.780	0.494, 1.067
0.55	0.678	0.342, 1.013
0.60	0.554	0.192, 0.916
0.65	0.424	0.065, 0.782
0.70	0.303	−0.024, 0.630
0.75	0.204	−0.071, 0.479
0.80	0.132	−0.084, 0.347
0.85	0.082	−0.077, 0.242
0.90	0.050	−0.063, 0.164
0.95	0.030	−0.047, 0.108
1.00	0.018	−0.034, 0.071

CI = confidence interval.
*Probability estimated from a random-effects logistic regression model.

affected Great Danes at any of the intervertebral levels investigated ($P = 0.933$; Table 1). The results of the linear regression analyses for these two ratios were constant across all intervertebral levels; therefore, we report the combined results (Table 1). The ventrodorsal ratio (ratio of the distance between articular process joints vs. vertebral body width obtained on ventrodorsal radiographs) was consistently smaller in Great Danes with cervical spondylomyelopathy. This ratio was significantly different between clinically normal and affected Great Danes at the C5–6 and C6–7 intervertebral spaces, with affected dogs having significantly smaller ratios at these two levels (Table 2).

Of the three ratios investigated, the ventrodorsal ratio was the only ratio significantly associated with the presence of spinal cord compression as confirmed by MRI in the group of affected Great Danes. For each 0.1 unit increase in the value of this ratio, there was a 65% decrease in the odds of spinal cord compression being present at that site independently of the intervertebral level being evaluated (odds ratio = 0.350, 95% CI 0.179–0.683, $P = 0.002$). For a ratio value of 0.40, there was an estimated 91% probability of spinal cord compression being present at that intervertebral site (Table 3, Fig. 3). The intra-observer agreement was high with values over 0.90 for all six measurements obtained (Table 4).

Discussion

In the present study, we found no differences in the traditional intravertebral and intervertebral ratios obtained on lateral radiographs between clinically normal Great Danes and Great Danes with clinical signs of cervical spondylomyelopathy. However, the proposed novel ventrodorsal ratio (ratio of the distance between articular process joints vs. vertebral body width obtained on ventrodorsal radiographs) was consistently smaller in affected Great Danes, with significant differences present at the C5–6 and C6–7 intervertebral spaces. In addition, the ventrodorsal ratio was the only vertebral ratio significantly associated with the presence of spinal cord compression as confirmed by MRI in the group of affected Great Danes. The results obtained from this population of clinically normal Great Danes and Great Danes with cervical spondylomyelopathy support our study hypothesis that vertebral ratios obtained on lateral radiographs would not be different between the two groups, whereas the vertebral ratio obtained on the ventrodorsal views would show differences between groups.

Two previous studies investigated the sagittal diameters of the cervical vertebral canal in clinically normal dogs and dogs with signs of cervical myelopathy, including Great Dane dogs.[10,11] Normal ranges were established and it was concluded that the sagittal diameter of the affected dogs frequently fell outside of the reference ranges determined from clinically normal dogs.[11] However, these studies only used lateral analog radiographs to measure the sagittal diameters, no ratios were calculated, and no attempt to control or correct for magnification was made.[10,11] The main advantage of using ratios vs. absolute values is that the ratio method is independent of magnification factors.[21,23] In human neurology, the ratio known as Torg–Pavlov ratio is the most common cervical vertebral ratio used to screen patients with suspected cervical spondylotic myelopathy.[23] Lower ratios are reported in affected individuals when compared to clinically healthy subjects, and a value of <0.82 is considered to indicate absolute stenosis.[23,24] A study reported cervical intravertebral ratios obtained on lateral radiographs from Dobermans and Great Danes that had undergone cervical radiographs and myelography.[12] The study design had some limitations since the clinical status of the dogs enrolled was not reported, only intravertebral ratios were investigated, and the ratios from compressive and noncompressive sites from the same dog were used as unaffected and affected sites, respectively, but no actual control group was used.[12] However, this study was the first to report and

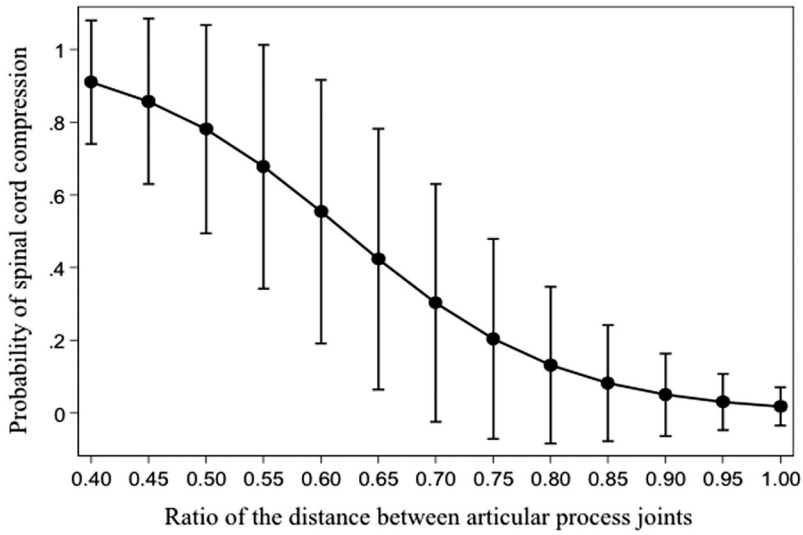

FIG. 3. Dot plot demonstrating the estimated probability of spinal cord compression based on a novel ventrodorsal ratio. Probability estimated from a random-effects logistic regression model.

TABLE 4. Intraclass Correlations for Vertebral Measurements Obtained in 15 Clinically Normal Great Danes and 15 Great Danes with Cervical Spondylomyelopathy

Measurement	Rho	95% CI
Vertebral body height	0.971	0.926–0.991
Minimum intravertebral sagittal diameter	0.946	0.900–0.974
Minimum intervertebral sagittal diameter	0.949	0.905–0.975
Distance between articular process joints	0.950	0.906–0–976
Vertebral body width	0.901	0.819–0.952
Vertebral body length	0.983	0.906–0.976

CI = confidence interval.
Rho = intraclass correlation.

highlight breed-related differences for the vertebral ratios.[12] In horses with cervical vertebral malformation, cervical vertebral ratios are routinely used as a screening tool for the disease, and the intervertebral ratios appear to be more sensitive than the intravertebral ratios at identifying sites of spinal cord compression.[16,17] One recent study investigated the use of vertebral ratios in Doberman pinschers with and without signs of cervical spondylomyelopathy and failed to detect any differences between groups; however, the methodology used in this study was different than the study we report here and only intravertebral ratios were evaluated.[13] Another recent study investigated the use of both intravertebral and intervertebral ratios obtained on lateral radiographs in Doberman pinschers with and without signs of cervical spondylomyelopathy and also failed to identify any differences between the two groups, concluding that these vertebral ratios could not be used as a screening tool for cervical spondylomyelopathy in the Doberman pinscher breed.[14] In our study, we investigated the use of these same intravertebral and intervertebral ratios obtained on lateral radiographs in clinically normal and affected Great Danes, and we also introduced the use of a novel ratio obtained on ventrodorsal views. In Great Danes with osseous-associated cervical spondylomyelopathy, lateral and dorsolateral spinal cord compressions are most commonly recorded.[3,6] As such, the use of ventrodorsal radiographic and myelographic views, as well as dorsal, transverse, and parasagittal MRI planes has been advocated to fully characterize the extent of compression in this form of cervical spondylomyelopathy.[5,27,28] In this study, the ratios obtained on the lateral views revealed no differences between normal and affected Great Danes, whereas the ratio obtained on ventrodorsal views was significantly different at the C5–6 and C6–7 intervertebral sites between groups. Moreover, the ratio of the distance between the articular process joints obtained on ventrodorsal views was the only ratio significantly associated with the presence of spinal cord compression confirmed with MRI in the group of affected Great Danes. These results need to be interpreted with caution given the small sample population and the wide 95% CI noted for the majority of the estimated probabilities of spinal cord compression. However, a ratio of 0.40 appeared to predict the presence of spinal cord compression with a 91% probability and a relatively narrow 95% CI, and may be valuable for clinicians to use as an estimation of the likelihood of spinal cord compression being present at that site. In horses, a study compared vertebral measurements obtained on lateral radiographs with sites of spinal cord compression as confirmed by histopathological evaluation, and revealed that a sagittal diameter ratio of ≤ 0.485 at any intravertebral or intervertebral site correctly classified horses as having cervical vertebral malformation.[17]

While the use of advanced imaging modalities remains necessary in order to confirm the presence and extent

of spinal cord compression in canine cervical spondylomyelopathy, not all affected dogs can be referred to specialty practices, often due to owners' financial constraints and/or availability. Survey radiographs obtained at the primary care veterinarian may be the only imaging method pursued in some affected dogs. The results of this study highlight the importance of obtaining ventrodorsal radiographic views in cases of suspected osseous-associated cervical spondylomyelopathy, as well as provide clinicians with a novel vertebral ratio that may be used as an initial screening test in Great Danes with suspected cervical spondylomyelopathy, especially if no advanced imaging method is going to be pursued. The authors' believe that, in order for the novel ventrodorsal vertebral ratio described in this study to be of value as a screening test, it is of vital importance to obtain good quality ventrodorsal radiographs under sedation so optimal positioning can be achieved. In this study, sedation and positioning were kept consistent across all dogs enrolled, in order to minimize the influence of radiographic technique on the vertebral ratios results.

A limitation of this study is the relatively small study population. An additional limitation is the lack of a gender-matched population, since the prevalence of male dogs was higher in the affected group. Given that this was a prospective study, the owners of affected dogs were offered the possibility of being enrolled in the study whenever the patients presented to our clinic, independent of the gender of the affected dog. In order to control for this, adjustments for gender were made in the statistical models used to analyze the data.

In conclusion, findings from the current study indicated that traditional intravertebral and intervertebral ratios obtained on lateral survey radiographs were unable to differentiate between Great Danes with and without clinical signs of cervical spondylomyelopathy. On the other hand, the novel ratio of the distance between articular process joints vs. vertebral body width obtained on ventrodorsal radiographs was able to make this differentiation. Findings therefore supported the use of the ventrodorsal ratio as a screening method in Great Danes with suspected cervical spondylomyelopathy. Future studies are needed to evaluate the positive predictive value of this novel ratio obtained on ventrodorsal radiographic views using a larger population of giant-breed dogs with osseous-associated cervical spondylomyelopathy confirmed by advanced imaging. In addition, long-term follow-up longitudinal studies, where survey radiographs are obtained in Great Dane puppies that are followed clinically and radiographically over time may reveal if the ratio obtained on ventrodorsal views is different between puppies that eventually develop signs of the disease and those that do not.

ACKNOWLEDGMENTS

The authors wish to express our gratitude to Tim Vojt (College of Veterinary Medicine, The Ohio State University) for assistance with illustrations and Gary Phillips (Center of Biostatistics, The Ohio State University Medical Center) for assistance with statistical analysis.

REFERENCES

1. Trotter EJ, de Lahunta A, Geary JC, Brasmer TH. Caudal cervical vertebral malformation-malarticulation in Great Danes and Doberman Pinschers. J Am Vet Med Assoc 1976;68:917–930.

2. Olsson SE, Stavenborn M, Hoppe F. Dynamic compression of the cervical spinal cord. A myelographic and pathologic investigation in Great Dane dogs. Acta Vet Scand 1982;23:65–78.

3. Gutierrez-Quintana R, Penderis J. MRI features of cervical articular process degenerative joint disease in Great Dane dogs with cervical spondylomyelopathy. Vet Radiol Ultrasound 2012;53:304–311.

4. da Costa RC. Cervical spondylomyelopathy. Vet Clin North Am Small Anim Pract 2010;40:881–913.

5. Lipsitz D, Levitski RE, Chauvet AE, Berry WL. Magnetic resonance imaging features of cervical stenotic myelopathy in 21 dogs. Vet Radiol Ultrasound 2001;42:20–27.

6. da Costa RC, Echandi RL, Beauchamp D. Computed tomography myelographic findings in dogs with cervical spondylomyelopathy. Vet Radiol Ultrasound 2012;53:64–70.

7. da Costa RC, Parent JP, Dobson H, et al. Comparison of magnetic resonance imaging and myelography in 18 Doberman pinscher dogs with cervical spondylomyelopathy. Vet Radiol Ultrasound 2006;47:523–531.

8. Parent J. Clinical approach and lesion localization in patients with spinal diseases. Vet Clin N Am Small Anim Pract 2010;40:733–753.

9. Sharp NJH, Wheeler SJ, Cofone M. Radiological evaluation of 'wobbler' syndrome – caudal cervical spondylomyelopathy. J Small Anim Pract 1992;33:491–499.

10. Wright JA. A study of the radiographic anatomy of the cervical spine in the dog. J Small Anim Pract 1977;18:341–357.

11. Wright JA. The use of sagittal diameter measurement in the diagnosis of cervical spinal stenosis. J Small Anim Pract 1979;20:331–344.

12. Drost WT, Lehenbauer TW, Reeves J. Mensuration of cervical vertebral ratios in Doberman pinschers and Great Danes. Vet Radiol Ultrasound 2002;43:124–231.

13. De Decker S, Saunders JH, Duchateau L, et al. Radiographic vertebral canal and vertebral body ratios in Doberman Pinschers with and without clinical signs of caudal cervical spondylomyelopathy. Am J Vet Res 2011;72:958–966.

14. da Costa RC, Johnson JA. Intervertebral and intravertebral ratios in Doberman pinscher dogs with cervical spondylomyelopathy. Vet Radiol Ultrasound 2012;53:518–523.

15. Moore BR, Reed SM, Biller DS, et al. Assessment of vertebral canal diameter and bony malformations of the cervical part of the spine in horses with cervical stenotic myelopathy. Am J Vet Res 1994;55:5–13.

16. Van Biervliet J. An evidence-based approach to clinical neurology questions in the practice of equine neurology. Vet Clin Equine 2007;23: 317–328.

17. Hahn CN, Handel I, Green SL, et al. Assessment of the utility of using intra- and intervertebral minimum sagittal diameter ratios in the diagnosis of cervical vertebral malformation in horses. Vet Radiol Ultrasound 2008;49: 1–6.

18. Burrows EH. The sagittal diameter of the spinal canal in cervical spondylosis. Clin Radiol 1963;14:77–86.

19. Murone I. The importance of the sagittal diameters of the cervical spinal canal in relation to spondylosis and myelopathy. J Bone Joint Surg Br 1974;56:30–36.

20. Ogino H, Tada K, Okada K, et al. Canal diameter, anteroposterior compression ratio, and spondylotic myelopathy of the cervical spine. Spine 1983;8:1–15.

21. Pavlov H, Torg JS, Robie B, Jahre C. Cervical spinal stenosis: determination with vertebral body ratio method. Radiology 1987;164:771–775.

22. Blackley HR, Plank LD, Robertson PA. Determining the sagittal dimensions of the canal of the cervical spine. The reliability of ratios of anatomical measurements. J Bone Joint Surg Br 1999;81:110–112.

23. Yue WM, Tan SB, Tan MH, et al. The Torg–Pavlov ratio in cervical spondylotic myelopathy: a comparative study between patients with cervical spondylotic myelopathy and a nonspondylotic, nonmyelopathic population. Spine 2001;26:1760–1764.

24. Prasad SS, O'Malley M, Caplan M, et al. MRI measurements of the cervical spine and their correlation to Pavlov's ratio. Spine 2003;28: 1263–1268.

25. Suk KS, Kim KT, Lee JH, et al. Reevaluation of the Pavlov ratio in patients with cervical myelopathy. Clin Orthop Surg 2009;1:6–10.

26. da Costa RC, Parent JM, Partlow G, et al. Morphologic and morphometric magnetic resonance imaging features of Doberman Pinschers with and without clinical signs of cervical spondylomyelopathy. Am J Vet Res 2006;67:1601–1612.

27. Rendano VT, Smith LL. Cervical vertebral malformation-malarticulation (wobbler syndrome) – The value of the ventrodorsal view in defining lateral spinal cord compression in the dog. J Am Anim Hosp Assoc 1981;17:627–634.

28. Abramson CJ, Dennis R, Smith K, Platt SR. Radiographic diagnosis – lateralized vertebral osseous compression causing cervical spondylomyelopathy in a Great Dane. Vet Radiol Ultrasound 2003;44:56–58.

29. Searle SR, Casella G, McCulloch CE. Variance components. New York: Wiley, 1992.