Caudal cervical spondylomyelopathy or wobbler syndrome refers to a collection of disorders that affect the vertebrae, intervertebral disks, and ligamentous structures of the cervical vertebral column, resulting in spinal cord compression. A large variety of lesions with different proposed causes have been attributed to this syndrome. Several different syndromes have been recognized on the basis of signalment of affected animals, diagnostic imaging findings, and treatment. One of these syndromes, disk-associated wobbler syndrome, is a common cause of cervical spinal cord disease in adult to older (typically 4 to 8 years of age) large-breed dogs. In dogs with disk-associated wobbler syndrome, clinical signs of cervical myelopathy with or without clinical signs of caudal cervical spondylomyelopathy (CCSM).
without cervical hyperesthesia are caused by protrusion of 1 or more intervertebral disks, sometimes in combination with ligamentum flavum hypertrophy and rather mild vertebral body abnormalities. The intervertebral disk spaces between the sixth and seventh or between the fifth and sixth cervical vertebrae are most commonly affected. This specific wobbler syndrome typically develops in middle-aged large-breed dogs, particularly Doberman Pinschers. No sex predilection has been demonstrated, although results of several studies suggest a predilection for development of the syndrome in male animals. Although only Doberman Pinschers with CCSM as a consequence of disk-associated caudal cervical spinal cord compression were evaluated in the study reported here, the more general and well-accepted term CCSM will be used.

Despite the proposal of several causative factors, little is known about the pathogenesis or predisposing factors for the development of this disorder. The size of the vertebral canal relative to the spinal cord and the shape of the vertebral canal have been suggested as potential risk factors in several reports. A relative vertebral canal stenosis with or without a funnel-shaped caudal vertebral canal leading to a narrowed cranial orifice is a proposed predisposing factor for the development of clinical signs of CCSM. Cervical spondylotic myelopathy is considered as the human counterpart of CCSM, and absolute stenosis of the vertebral canal is considered an important static risk factor for the development of that disease. Quantification of vertebral canal stenosis in humans has been evaluated in several studies by use of radiography, CT, and MRI. Although CT and MRI are also increasingly used in veterinary medicine, widespread use of either procedure is currently hampered by the high cost and the fact that availability is limited to referral and veterinary teaching hospitals. Although previous studies in dogs have used absolute measurements made on survey radiographs to evaluate the presence of vertebral canal stenosis, it has become evident, especially from human studies, that absolute measurements made on survey radiographs are influenced by radiographic magnification. Because radiographic magnification is influenced by focus-film distance, object-film distance, and subject-related factors, absolute measurements obtained from survey radiographs are difficult to use in clinical practice. This variability, attributable to magnification errors, can be resolved by the use of ratios of different measurements. In human medicine, a ratio between the midsagittal height of the vertebral canal and the VBH has been developed to assess vertebral canal diameter. This relative measurement technique for assessing vertebral canal diameter is independent of radiographic magnification and has improved the sensitivity of cervical radiographic measurements for diagnosis of cervical spinal stenosis in people. Vertebral CBHRs have also been used in horses to distinguish between horses with and without cervical stenotic myelopathy and between affected and unaffected intervertebral disk spaces. The purpose of the study reported here was to determine the radiographic vertebral ratio values that represent vertebral canal stenosis in Doberman Pinschers with and without clinical signs of CCSM. Additionally, we evaluated whether the vertebral canal assessed and age or sex of the dog influenced these dimensions.

Materials and Methods

Inclusion criteria—A computer search of medical records from dogs admitted to the Small Animal Department of the Faculty of Veterinary Medicine at Ghent University between 1998 and 2009 was performed by use of the following terms: Doberman Pinscher and radiology. From this list, all available files of Doberman Pinschers that underwent conventional or digital lateral cervical radiography were selected. Only radiographic views of adult dogs with closed vertebral physes were used; to be included in the study, those radiographic views had to be of good quality with the vertebral column parallel to the support table (wings of the atlas and the lateral borders of the vertebral endplates superimposed on each other) and have sufficient exposure and contrast to allow clear distinction of the bone structures. Grossly abnormal positioning of a vertebra, such as craniodorsal tilting, was considered as an exclusion criterion. To be included in the group of Doberman Pinschers with clinical signs of CCSM, this diagnosis had to be confirmed by myelography, CT myelography, or MRI.

Measurements—To improve visualization of the dorsal margin of a given vertebral body, a line connecting the most craniodorsal and most caudodorsal points of the vertebral body was drawn. Measurements were made directly on the neutral lateral radiographs with vernier calipers and a graphite film marker or directly at a workstation with available imaging software. The digital images could be magnified as needed, but all measurements for a given vertebra were made at the same magnification. For the conventional and digital radiographic views, the accuracy of the measurement tool was limited to 0.01 mm. The following measurements were made from the C3 through C7 vertebrae: VBH, VCHm, VChcr, VChcd, and VBL (Figure 1). The VCHm was defined as the distance measured from the middle of the dorsal surface of the vertebral body to the closest point of the spinolaminar line (junction between its laminae and spinous process). The VBH was defined as the distance from the midpoint of the dorsal surface of the vertebral body to the ventral surface of the vertebral body measured parallel to the cranial vertebral endplate. The VChcr was defined as the distance from the most ventrocranial point of the lamina to the craniodorsal border of the same vertebral body; the VChcd was measured perpendicular to the dorsal surface of the vertebral body. The VChcd was defined as the distance from the most dorsocaudal point of the vertebral body to the ventrocaudal point of the lamina of the same vertebra; the VChcd was measured perpendicular to the dorsal surface of the vertebral body. The VBL was defined as the distance from the most dorsocranial to the most dorsocaudal point of the same vertebral body.

From these measurements, the following 3 radiographic ratios were calculated for C3 through C7: CBR, CBHR, and CCHR. The CBHR was defined as VCHm
divided by VBH (Figure 1). This ratio indicates relative vertebral canal stenosis in humans and equids.34,36
The CBLR was defined as VChm divided by VBL. This ratio represents another ratio that is influenced directly by vertebral canal height.36,39 The CCHR was defined as VChcd divided by VChcr (Figure 2). This ratio indicates the shape of the vertebral canal in a lateral view. Ratios > 1 represent a funnel-shaped vertebral canal narrowed cranially in a lateral view.22

All measurements were performed by the same observer (SD), who was unaware of the identity, age, and sex of the dogs; however, the observer was aware of the dogs’ clinical status. Reliability of measurements and ratios was tested by having a second observer (JHS) perform the same measurements on 65 radiographic views that had been reviewed by the first observer. This second observer was unaware of the identity, age, sex, and clinical status of each dog. Only the measurements from the first observer were further used to calculate the ratio values for the different groups of dogs.

Data analysis—The effect of clinical status, assessed vertebrae, sex, and age on the different ratios was evaluated with a mixed model with dog as a random effect by use of statistical software. All ratios were normally distributed according to results of a Shapiro-Wilk test. F tests were used to determine the effects of the different factors. Values of P < 0.05 were considered significant for all analyses although the significance level for multiple comparisons was adjusted by use of the Bonferroni method.

Box-and-whisker plots of the median values, the 25th and 75th percentiles, and the minimum and maximum values of the 3 calculated ratios were created. This was done separately for Doberman Pinschers with CCSM and Doberman Pinschers without CCSM with regard to overall mean values, sex, and individual assessed vertebrae. Receiver operating characteristic curves were generated for CBHR, CBLR, and CCHR for the C5 and C7 vertebrae in Doberman Pinschers with CCSM and Doberman Pinschers without CCSM. An ROC curve helps to distinguish between a normal and abnormal value. Each value on the ROC curve represents a tradeoff between sensitivity (probability that a diagnosis of CCSM is made for a dog with CCSM) and 1-specificity (probability that a diagnosis of CCSM is made for a dog without CCSM). Visual inspection of an ROC curve guides in determining a value with sufficiently high sensitivity and high specificity to discrim-
nate between clinically normal and clinically affected dogs. This value corresponds with the uppermost left point on the curve. In this study, the area under an ROC curve quantified the overall ability of the test (ie, calculation of CBR, CBLR, or CCHR) to discriminate between dogs with and without clinical signs of CCSM. A useless test (no discrimination) has an area of 0.5, and a perfectly useful test has an area of 1.0.

To evaluate interobserver agreement, Bland-Altman plots for CBR, CBLR, and CCHR as determined by the 2 observers were constructed. A Bland-Altman plot compares 2 measurement sets by plotting the difference between the 2 measurements on the y-axis and the mean of the 2 measurements on the x-axis. If one method sometimes yields higher values and the other method sometimes yields higher values, the mean differences will be close to zero. If the mean difference is not close to zero, this indicates that the 2 measurement methods are producing different results. By use of these plots, the mean differences between the 2 observers, the SD, and the lower and upper limit of agreement (mean ± SD) are reported.

**Results**

**Animals**—Eighty-one Doberman Pinschers for which CCSM had been diagnosed and 39 Doberman Pinschers with a final diagnosis that was not related to cervical vertebral or spinal cord disease were included. The group of Doberman Pinschers with CCSM consisted of 50 males and 31 females (male-to-female ratio, 1.6); the dogs were 3 to 11 years old (mean age, 6.8 years; median, 6.6 years) and had clinical signs that ranged from only cervical hyperesthesia (n = 15) to ambulatory paraparesis or ataxia with or without cervical hyperesthesia (25), ambulatory tetraparesis or ataxia with or without cervical hyperesthesia (32), and nonambulatory tetraparesis with or without cervical hyperesthesia (9). For these 81 dogs, 59 conventional and 22 digital radiographic examinations had been performed.

The group of Doberman Pinschers without CCSM consisted of 27 males and 12 females (male-to-female ratio, 2.25); the dogs were 1.2 to 11 years old (mean age, 4.1 years; median, 3 years). Radiographic examination of the cervical vertebral column of 16 of these dogs was performed as part of their diagnostic workup. Additional cervical radiography was performed at the owner’s request (n = 5) or after death with the intention that the data be included in this study (4). Radiographic examination was also performed in 14 clinically normal Doberman Pinschers included in a research project investigating the diagnosis and treatment of CCSM. Because the latter 14 dogs were included in prospective research, their inclusion in the present study was in accordance with the guidelines of the Animal Care Committee of the University of Ghent, and written owner consent was obtained prior to enrollment in the study. As part of that research project, these 14 dogs received a complete neurologic examination and low-field MRI of the cervical vertebral column. Of the 25 remaining dogs without clinical signs of CCSM, 16 received a complete neurologic examination; 9 also underwent myelogra-

![Figure 3—Box-and-whisker plots of the CBHRs determined at the C3 through C7 vertebrae in Doberman Pinschers with (n = 81 [white boxes]) and without (39 [striped boxes]) clinical signs of CCSM. Data are expressed for the C3 through C7 CBHR, for individual vertebrae, and by sex. For each box, the horizontal line represents the median value, and the upper and lower boundaries represent the 75th and 25th percentiles, respectively. Whiskers represent the minimum and maximum values. Effect of clinical status and sex was evaluated by use of a mixed model with dog as a random effect. For comparison of the overall CBHR in each group, a value of P < 0.05 was considered significant. For pairwise comparisons of CHHR at each vertebra between affected and unaffected dogs, a value of P < 0.01 was considered significant.](image)

**Table 1—Means values of CBR, CBLR, and CCHR determined at the C3 through C7 vertebrae (overall and individual vertebral values) in Doberman Pinschers with (n = 81) and without (39) clinical signs of CCSM.**

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Overall C3-C7</th>
<th>Male*</th>
<th>Female†</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBHR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCSM-affected dogs</td>
<td>0.76± ± 0.02</td>
<td>0.73±</td>
<td>0.80±</td>
<td>0.84±</td>
<td>0.79±</td>
<td>0.74±</td>
<td>0.70±</td>
<td>0.72±</td>
</tr>
<tr>
<td>Unaffected dogs</td>
<td>0.84±</td>
<td>0.62±</td>
<td>0.89±</td>
<td>0.92±</td>
<td>0.86±</td>
<td>0.92±</td>
<td>0.90±</td>
<td>0.81±</td>
</tr>
<tr>
<td>CBLR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCSM-affected dogs</td>
<td>0.38±</td>
<td>0.38±</td>
<td>0.39±</td>
<td>0.29±</td>
<td>0.31±</td>
<td>0.38±</td>
<td>0.42±</td>
<td>0.53±</td>
</tr>
<tr>
<td>Unaffected dogs</td>
<td>0.41±</td>
<td>0.41±</td>
<td>0.41±</td>
<td>0.31±</td>
<td>0.33±</td>
<td>0.40±</td>
<td>0.46±</td>
<td>0.55±</td>
</tr>
<tr>
<td>CCHR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCSM-affected dogs</td>
<td>1.36±</td>
<td>1.38±</td>
<td>1.34±</td>
<td>1.20±</td>
<td>1.33±</td>
<td>1.36±</td>
<td>1.38±</td>
<td>1.53±</td>
</tr>
<tr>
<td>Unaffected dogs</td>
<td>1.37±</td>
<td>1.38±</td>
<td>1.35±</td>
<td>1.31±</td>
<td>1.39±</td>
<td>1.35±</td>
<td>1.40±</td>
<td>1.41±</td>
</tr>
</tbody>
</table>

Data are expressed for the C3 through C7 portion of the vertebral column overall, for individual vertebrae, and by sex. Effect of clinical status and sex globally and for different vertebrae separately was evaluated by use of a mixed model with dog as a random effect. For each box, the horizontal line represents the median value, and the upper and lower boundaries represent the 75th and 25th percentiles, respectively. Whiskers represent the minimum and maximum values. Effect of clinical status and sex was evaluated by use of a mixed model with dog as a random effect. For comparison of the overall CBHR in each group, a value of P < 0.05 was considered significant. For pairwise comparisons of CHHR at each vertebra between affected and unaffected dogs, a value of P < 0.01 was considered significant.

*Among the male dogs, 50 had CSSM and 27 were unaffected. Among the female dogs, 31 had CSSM and 12 were unaffected. †For a given ratio, value for the affected dogs differed significantly from the value for unaffected dogs.
phy of the entire vertebral column. The inclusion of the remaining 9 dogs was based on the lack of historical data suggestive of cervical hyperesthesia or myelopathy. For these 39 dogs, 20 conventional and 19 digital radiographic examinations had been performed.

**CBHR**—The mean CBHRs for C3 through C7 overall and for the individual assessed cervical vertebrae were calculated for Doberman Pinschers with and without clinical signs of CCSM (Figure 3; Table 1). The mean CBHRs for C3 through C7 overall were significantly smaller, compared with values for Doberman Pinschers without CCSM. This pattern of difference was evident not only for the comparison of the overall C3-7 CBHRs, but also for the comparisons of the values for the 5 assessed cervical vertebrae separately. A significant ($P < 0.001$ in both groups of dogs) influence of the respective assessed cervical vertebra was detected; C3 had the highest CBHR, and C6 had the lowest CBHR. In both groups of dogs, the CBHR values for male dogs were significantly smaller than the values for female dogs. There was no significant association between the age of the dogs and the CBHR value in Doberman Pinschers with ($P = 0.85$) and without ($P = 0.40$) clinical signs of CCSM. Receiver operating characteristic curves were generated for the C5 and C7 CBHRs in Doberman Pinschers with CCSM and Doberman Pinschers without CCSM (Figure 4). Visual inspection of the ROC curve for the C5 CBHRs in Doberman Pinschers with and without clinical signs of CCSM revealed that a CBHR value of 0.82 corresponded with a sensitivity of approximately 0.5 and a specificity of approximately 0.75. Visual inspection of the ROC curve for the C7 CBHR revealed that a CBHR value of 0.72 corresponded with a sensitivity of approximately 0.85 and a specificity of 0.55.

**CBLR**—The mean CBLRs for C3 through C7 overall and for the individual assessed cervical vertebrae were calculated for Doberman Pinschers with and without clinical signs of CCSM (Figure 5; Table 1). The mean CBLRs for C3 through C7 overall were significantly smaller, compared with values for Doberman Pinschers without CCSM. This pattern of difference was not evident for all 5 assessed cervical vertebrae separately. When the vertebrae were assessed separately, the CBLR values for C5, C6, and C7 in the dogs with CCSM were significantly smaller than the values for those vertebrae in dogs without CCSM. A significant ($P < 0.001$ in both groups of dogs) influence of the assessed cervical vertebra was detected; there was a progressive increase in CBLR from the C3 vertebra through the C7 vertebra in both groups of dogs. There was no significant association between the age or sex of the dogs and the overall CBLR for dogs with ($P = 0.98$) and without ($P = 0.58$) clinical signs. Receiver operating characteristic curves were generated for the C5 and C7 CBLRs in Doberman Pinschers with CCSM and Doberman Pinschers without CCSM (Figure 4). Visual inspection of the ROC curve for the C5 CBLRs in Doberman Pinschers with and without clinical signs of CCSM.
CCSM revealed that a CBLR value of 0.39 corresponded with a sensitivity of 0.6 and specificity of 0.65. Visual inspection of the ROC curve for the C7 CBLRs revealed that a CBLR value of 0.54 corresponded with a sensitivity of 0.6 and specificity of approximately 0.55.

CCHR—The mean CCHRs for C3 through C7 overall and for the individual assessed cervical vertebrae were calculated for Doberman Pinschers with and without clinical signs of CCSM (Figure 6; Table 1). The mean CCHR for C3 through C7 overall in male and female dogs with and without CSSM were also calculated. Although there was no significant difference in the overall C3-7 CCHR in Doberman Pinschers with and without clinical signs of CCSM, there was a significantly larger C7 CCHR value in dogs with CCSM than it was in dogs without CSSM. This indicated that there was a more pronounced funnel-shaped vertebral canal at the level of C7 in Doberman Pinschers with CCSM.

In the group of dogs with CCSM, there was a significant (P < 0.001) influence of the assessed cervical vertebra on CCHR; the individual CCHR values increased progressively from C3 to C7. There was no significant association between sex and the CCHR value in either group of dogs. In the group of Doberman Pinschers without CCSM, there was a significant (P = 0.004) influence of age on CCHR; each increase in age of 1 month resulted in an increase in CCHR of 0.0018. Receiver operating characteristic curves were generated for the C5 and C7 CCHR in Doberman Pinschers with and without clinical signs of CCSM revealed a poor ability to discriminate between affected and unaffected dogs. Visual inspection of the ROC curve for the C7 CCHR revealed that a CCHR value of 1.48 corresponded with a sensitivity of 0.8 and specificity of approximately 0.55.

Interobserver agreement for calculation of radiographic ratios—Bland-Altman plots of the 3 assessed radiographic ratios as determined by the 2 observers were constructed (Figure 7). For the CBHR, the mean difference between observers was 0.0034, most individual values of difference were close to zero, and the limits of agreement were ±0.068 (9% and 8% of the mean CBHR value of affected and unaffected dogs, respectively). For the CBLR, the mean difference between observers was 0.0022, most individual values of difference were close to zero, and the limits of agreement were ±0.039 (10% and 9% of the mean CBLR value of affected and unaffected dogs, respectively). For the CCHR, the mean difference between observers was 0.0077, most individual values of difference were close to zero, and the limits of agreement were ±0.140 (10% of the mean CCHR value of both affected and unaffected dogs).

Discussion

In the present study, values of 3 radiographic vertebral body and canal ratios were determined for the C3-7 portion of the vertebral column in Doberman Pinschers with and without clinical signs of CCSM. These ratios were calculated in an attempt to eliminate the effects of magnification in radiographic measurements and of individual variation within the same breed of dog. Because the 2 measurements used to generate each ratio are in the same anatomic plane and are similarly affected by magnification, the ratios are independent of magnification. All 3 evaluated vertebral ratios differed significantly between the dogs with and without CSSM. The results of the present study are in agreement with those of previously pub-
lished studies, suggesting a higher prevalence of vertebral canal stenosis and the presence of a funnel-shaped caudal cervical vertebral canal in Doberman Pinschers with clinical signs of CCSM. However, from the data obtained in the 2 groups of dogs, the constructed ROC curves for the ratios did not provide reliable threshold values that had sufficiently high sensitivity and specificity to discriminate between Doberman Pinschers with and without clinical signs of CCSM.

The fact that significantly smaller CBHRs for C3 through C7 were evident in CCSM-affected dogs, compared with findings in unaffected dogs, supported the hypothesis that generalized relative stenosis of the entire cervical vertebral canal often develops in Doberman Pinschers with CCSM. This is in agreement with findings of human and equine studies. In individuals with relative stenosis, the diameter of the vertebral canal is less than that expected for an unaffected animal but does not cause neural compression in itself. This implies that there is decreased available space between the spinal cord and the vertebral canal and that such a change carries an increased risk of becoming clinically important with the development of space-occupying conditions of the vertebral canal, such as age-related intervertebral disk degeneration and protrusion. On the other hand, larger CBHR and CBLR values in unaffected dogs suggest that those dogs have a relatively wider vertebral canal. This may explain why some dogs can tolerate rather severe degenerative abnormalities of the vertebral canal, such as disk-associated cervical spinal cord compression, without developing clinical signs suggestive of cervical myelopathy. It is likely that relative stenosis of the vertebral canal depends not only on the size of the vertebral canal, but also on the size of the spinal cord in the same individual. However, only the vertebral canal can be visualized via survey radiography. In the present study, the overall C3-7 CBHR was significantly larger in female Doberman Pinschers than in male Doberman Pinschers (regardless of whether they did or did not have CSSM). This is in agreement with results of human studies. Another assessed vertebral ratio, the overall C3-7 CBLR, also was significantly smaller in CCSM-affected Doberman Pinschers. Because this ratio is also directly dependent on the vertebral canal diameter, this result further supports the hypothesis of increased prevalence of vertebral canal stenosis in Doberman Pinschers with clinical signs of CCSM.

A funnel-shaped vertebral canal at the level of C6 and C7 is supposed to be a risk factor for spinal cord compression at the narrowed cranial orifice of the respective vertebra. This funnel shape can be identified by use of the CCHR. A larger CCHR is indicative of a more pronounced funnel-shaped vertebral canal (Figure 2). An osteological study, in which the CCHRs among different breeds were compared, revealed that the Doberman Pinscher breed had a higher CCHR than the other evaluated breeds of dog. In the present study, the C7 CCHR in CCSM-affected Doberman Pinschers was significantly higher than that in Doberman Pinschers without clinical signs of CCSM. In agreement with findings of a previous radiographic study, the CCHR value increased from the more cranial to the more caudal cervical vertebrae evaluated in both groups of dogs in the present study. These findings support the hypothesis that a funnel-shaped vertebral canal at the level of C7 is a potential contributing factor for Doberman Pinschers to develop CCSM-associated spinal cord compression at that site. The predilection of the C6-7 intervertebral disk space is possibly further supported by the fact that age-related intervertebral disk degeneration and protrusion in clinically normal Doberman Pinschers develops more frequently at the more caudally intervertebral disk spaces.

The measurements in the present study differed somewhat from those of comparable studies in dogs and horses. In those previous studies, the vertebral body and canal heights were measured from the cranial part of the dorsal surface of the vertebral body and not at the midpoint of the vertebral body and canal. In the study of this report, the midpoint of the dorsal surface of the vertebral body was chosen because measurements of the cranial part of the vertebral canal can be influenced by pathological changes such as narrowing of the cranial orifice, spondylisis deformans, and dorsoventral flattening of the cranioventral border of the vertebral body. Such abnormalities are commonly seen in Doberman Pinschers with CCSM and can also develop in clinically normal Doberman Pinschers. To allow the use of distinct landmarks resulting in consistent measurements, VBL in this study was measured at the dorsal surface and not at the center of the vertebral body as was done in those previous studies.

We assessed interobserver agreement by use of Bland-Altman plots in the present study. How large the differences in any of the 3 assessed radiographic ratios can be without causing concern is a question of judgment (ie, a clinical question, not a statistical one). This decision will vary for different clinical applications. It was concluded that interobserver agreement was good for each of the 3 assessed ratios determined in the present study. The mean differences were always close to zero, most individual values of difference were situated around zero (low variability), and the limits of agreement did not exceed 10% of the mean values. Although the ranges in limits of agreement for the different ratios suggested that the assessed measurements could be considered reliable, whether they should also be considered clinically acceptable for the purposes of this study should be considered. Compared with the mean values of CBHR and CBLR in dogs without CCSM, values in the dogs with CSSM differed by only 9% for CBHR and 7% for CBLR. The fact that the limits of agreement were close to or even exceeded these differences raises doubt regarding the clinical usefulness of these ratios in individual dogs. The greatest variability was noted for the CCHR. This can probably be explained by the superposition of the caudal articular facets in survey radiographic views, which can complicate correct identification of the anatomic landmarks.

Although vertebral body and canal ratios may have potential use as a screening tool for dogs that are at risk for developing clinical signs associated with CCSM, there are several reasons to believe that this is currently inappropriate. Except for the aforementioned limitation
concerning accurate interobserver agreement, the box-and-whisker plots created from the study data revealed considerable overlap of ratio values between clinically affected and unaffected dogs. Furthermore, the constructed ROC curves did not indicate that the ratio values had both high sensitivity and high specificity. For these reasons, screening Doberman Pinschers for relative vertebral canal stenosis by use of the ratios calculated in the present study is not recommended and may result in misdiagnosis of stenosis in many dogs that will never develop clinical signs. The 3 ratio values were influenced by the vertebra under assessment. Therefore, it is only possible to compare values between different dogs for the same vertebra. Although the use of the calculated ratios allows the comparison of vertebral body and canal dimensions of dogs of different size and conformation, only Doberman Pinschers were included in the present study. It is suggested that vertebral body and canal ratios are breed specific and that cervical vertebral ratios derived from data collected for one breed should not be extrapolated to other breeds. Additional studies are warranted to confirm this hypothesis. In the present study, conventional and digital radiographic views of Doberman Pinschers with and without clinical signs of CCSM were examined. Currently, little is known about the accuracy of these imaging techniques when used to perform linear vertebral body and canal measurements in veterinary medicine or the agreement between the derived measurements. However, results of several endodonic studies in humans have indicated comparable accuracy for these imaging techniques when used to perform linear root-canal measurements and obtain agreement between the derived measurements.

We recognize several limitations of the present study. The first observer (SD) was not blinded to clinical status of the dogs, which could be a potential cause of observer bias. Second, because of the retrospective nature of the study, not all unaffected Doberman Pinschers underwent a neurologic examination and advanced medical imaging to exclude presence of disease. Additionally, the unaffected Doberman Pinschers did not subsequently undergo neurologic evaluation at predetermined times to exclude the development of clinical signs at a later time. Because of the latter, there is no information currently available about the predictive value of the calculated ratios. Therefore, well-designed prospective studies with neurologic reassessments, combined with follow-up medical imaging of dogs at predetermined time points, are warranted.

The results of the present study suggested that Doberman Pinschers with clinical signs of CCSM have generalized vertebral canal stenosis combined with a funnel-shaped vertebral canal at the level of the C7 vertebra significantly more often than do Doberman Pinschers without clinical signs of CCSM. Although the ratios calculated in the study can provide additional information about contributing risk factors and pathogenesis of CCSM in Doberman Pinschers, the authors believe caution should be taken in the clinical application of these ratios in individual dogs. Although the differences in ratio values between affected and unaffected dogs were significant, there was considerable overlap in values in box-and-whisker plots, the limits of agreement approached or exceeded the ratio differences between the 2 groups of dogs as determined by the Bland-Altman plots, and we were unable to identify reliable threshold values to distinguish clinically affected dogs from unaffected dogs. More studies are needed to compare ratio values obtained for Doberman Pinschers with those of dogs of other breeds, to evaluate the positive predictive value of the calculated vertebral ratios, and to assess the correlation of these ratios with values determined via CT or MRI in dogs with vertebral canal stenosis.

References

18. Seim HB. Diagnosis and treatment of cervical vertebral instabil-


