Cervical Spinal Cord: 
Effects of Neck Position in Dogs

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Spring 2004

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Précis

Cervical vertebral malformation/malarticulation (wobbler) syndrome first started to be recognized in the 1960’s. Today it is identified in numerous breeds of dogs with the highest incidence occurring in Doberman Pinchers and Great Danes. There are multiple etiologies that all lead to spinal cord compression which, depending on the extent of the lesion, can lead to severe neurologic signs with a worst case scenario being a nonambulatory animal. Due to the increasing strength of the Human-Animal Bond, people are more concerned about and willing to do what it takes to help their dogs. Therefore, it is becoming more important to understand the disease processes affecting dogs. It has been shown that the compression caused by wobbler syndrome lesions can be increased/decreased based on the position of the neck. The goal of this study was to better understand the changes neck position has on the spinal cord.

Magnetic resonance (MR) images were taken of the cervical spine of ten clinically normal dogs in neutral, extension, and flexion positions. MR is an emerging diagnostic tool with advantages over older imaging modalities, such as radiography and computed tomography, in its ability to distinguish more tissue types and lack of distortion. The MR images were evaluated by measuring the distances between the spinal cord and the vertebral canal as well as the volume of the spinal cord and canal at each cervical intervertebral disc.

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The images showed there was little movement of the spinal cord within the canal with extension and flexion and in only one dog was it great enough for the spinal cord to be
touching the vertebral wall. The average distance between the spinal cord and the vertebra for all positions was found to be 1.78mm. When the data were looked at for each disc space separately the ventral distance increased from the first cervical disc space to the last while the dorsal distance steadily decreased over the same distance. Also noted was that at the location of the first disc space the spinal cord and canal were significantly larger, both in volume and distance. There was no trend for the spinal cord to move ventrally or dorsally with extension or flexion although there was a significant increase in ventral distance (dorsal movement) compared to neutral when the neck was extended. Looking at the volume measurements showed that the volume of the spinal cord and canal paralleled each other the entire distance of the cervical spine.

The data did not support the theory that the spinal cord moves depending on the position of the neck. Previous research however has shown that compressive lesions of the spine can be exaggerated depending on neck position. Therefore the change in severity of compressive lesions, noted by others, with extension and flexion of the neck could be due to factors other than spinal cord movement such as movement of the surrounding ligaments and soft tissues. Due to the small size of this study it is impossible to definitively determine the amount and direction of spinal cord movement. Benefit could be obtained from future studies expanding upon this one to include more dogs, including some affected by wobbler syndrome, in addition to measuring other parameters, such as lateral distances and spinal cord diameters.
TO THE UNIVERSITY HONORS COLLEGE:

As thesis advisor for Allison DeWitt, I have read this paper and find it satisfactory.

James W. [Signature]
Thesis Advisor

February 17, 2004
Date
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Introduction:

Cervical vertebral malformation/malarticulation syndrome, also known as canine wobbler syndrome (wobblers), cervical vertebral instability, cervical spondylomyelopathy as well as other terms, is recognized most commonly in large breed dogs. Doberman Pinchers and Great Danes are two of the most frequently affected and therefore studied breeds. In wobblers, the cervical spinal cord is compressed due to malformations and/or instability of the vertebral column. The lesions found in dogs with wobbler syndrome can be separated into four major abnormalities:

1. Stenosis or narrowing of the vertebral canal. This is most commonly due to malformations of the cranial aspect of the vertebra. Affected vertebra have a rounding of the cranioventral aspect of the vertebral body and a craniodorsal ridge projecting into the spinal cord which together cause instability of the spine and compression of the spinal cord.

2. Malformations of the articular processes. These can occur during development and can encroach upon the spinal canal resulting in spinal cord compression.

3. Intervertebral disc protrusions. In the cervical spine these can cause compression resulting in clinical signs of wobblers. Disc protrusions are most commonly Hansen’s type II where the annulus fibrosis is hypertrophied and presses into the ventral aspect of the spinal canal. Disc protrusions are most
common in adult Doberman Pinchers and the C5-C6 and C6-C7 disc spaces are the characteristic locations.\textsuperscript{2}

4. Hypertrophy of the ligamentum flavum. This occurs when there is instability of the joint. The ligamentum flavum helps support the intervertebral joint and hypertrophies in response to abnormal motion and stresses. Hypertrophy causes compression of the dorsal aspect of the spinal canal.

Compressive lesions occur mainly between C3-C7 with the rare lesion at C2-C3. The location of the lesion is highly linked to which type of lesion is present. Hansen’s type II disc lesions occur primarily at C6-C7 followed by C5-C6, whereas, malformation/instability lesions are more frequent at C3-C4 and C4-C5 but can occur at all cervical joints. Multiplicity of lesions is strongly correlated to the type of lesion present. Almost all bone and ligament changes secondary to degeneration occur at more than one location and malformation/instability lesions commonly have more than one site of compression. Disc disease, on the other hand, usually only occurs at one site.\textsuperscript{1,3,4}

Heritability also is implicated as a factor due to the high incidence of wobbler syndrome in specific breeds (i.e. Great Danes, Doberman Pinchers) and the increased prevalence of certain lesions in each breed (instability, disc protrusions) although nothing has been specifically identified yet.\textsuperscript{14,20}

\textit{Clinical Signs:}

The clinical presentation of dogs with wobbler syndrome is variable and dependent on the stage, type, and severity of the disease as well as the duration. Great Danes are
usually presented when young (4-18 mo.) with progressive signs and malformation lesions while Doberman Pinchers can present, either progressively or acutely, typically as adults (5-7yrs) with disc protrusions. To some degree, the spinal cord is capable of accommodation if the onset of compression is insidious. Accommodation is the nervous system’s ability to reroute signals from damaged tissue to unaffected spinal tracts to maintain function. This will minimize or eliminate the clinical signs initially but accommodation occurs over weeks to months and there is a limit to the amount of compensation possible. Clinical signs often noted include hesitation to walk on slick floors, wide gait or stance of the hindlimbs, difficult rising and positioning for elimination, weakness, mild ataxia worse in the hindlimbs, proprioceptive deficits, and can progress to nonambulatory tetraparesis. Dogs may also resist manipulation and movement of the neck preferring to hold it in a neutral or slightly lowered (flexed) position but usually do not show overt pain. Theories regarding the increased severity of hindlimb deficits include the more superficial location of hindlimb tracts and the smaller number of motor tracts going to the hindlimbs. Wobbler syndrome is a progressive disease that will continue to worsen if intervention is not provided.

Diagnosis:

Radiography is the definitive diagnostic test for canine wobblers (Figure 1). Lateral and ventrodorsal radiographic views and myelography are routinely performed with the dog under anesthesia. Plain radiographs can show malformed vertebra, tipping, spinal canal stenosis, changes in disc spaces, and spondylosis but cannot definitively locate sites of spinal cord compression. Myelography can identify disc protrusions, hypertrophic
ligamentum flavum, degree and exact location of compression, as well as abnormalities noted on the plain radiographs. Obtaining lateral views of hyperflexion, hyperextension, and traction have been recommended, but must be used cautiously due to the possibility of worsening spinal cord compression, mainly with flexion and extension.\cite{1,4,5} Computed tomography has also been used and magnetic resonance imaging is gaining in popularity because of its ability to more clearly show and define lesions but is not necessary for diagnosis.

Treatment:

The goals of treatment are reducing compression of the spinal cord and regaining neurologic function, ideally by noninvasive means. Unfortunately, no current therapy is able to meet all of these goals. Spinal tissue has poor regenerating capacity and limited accommodation, and therefore neurologic deficits are often permanent or show only limited improvement. It is also evident that no single specific treatment should be used in all cases of wobblers due to its multiple etiologies and varying results of specific treatments in dogs with similar lesions.\cite{2,6}

Treatment is broken down into two major categories; medical management and surgical treatment. Two reasons medical management is used are to avoid the invasiveness and varying results of surgery, as well as the significant cost and effort of post surgical patient care following spinal surgery. Nonsurgical therapy is best used in dogs who are still ambulatory and have only mild neurologic signs. Medical therapy consists of restricted exercise, cage rest, use of corticosteroids, and application of neck braces. Dynamic
lesions can benefit from cage rest and restricted exercise to decrease motion at the lesion site and slow the progression of the disease. Braces that include the entire neck and cranial thorax can help further immobilize and prevent motion if the dog tolerates the brace. Corticosteroids, used to decrease inflammation, work best in dogs with very mild signs and can occasionally be used as the sole treatment. It is important to remember that dynamic lesions are progressive and medical therapy does not prevent progression or address the underlying cause of the compressive lesion.\textsuperscript{2,6}

Surgical therapy encompasses many procedures, but all have similar goals of reducing the compressive lesion and stabilizing the vertebral joint if instability is present. Surgical approaches are divided into ventral and dorsal approaches. The approach used is dependent on the location and type of lesion. Disc lesions are located ventrally, and therefore a ventral approach is usually used. In the ventral approach a slot is made in the vertebral body directly over the lesion which allows the protruding disc material to be removed. When there is a hypertrophied ligamentum flavum, malformed articular processes, and stenosis a dorsal approach is more effective. The most common dorsal approach involves a dorsal laminectomy to relieve pressure on the spinal cord. Once decompression has been achieved, stabilization may or may not be attempted. There are many methods of stabilization including dorsal fixation of articular facets using screws or wire. Ventrally, vertebral body fusion is accomplished by placing cortical or cancellous bone grafts in the disc space and bridging of the unstable vertebral space with Harrington rods or bone screws and orthopedic wire covered with polymethylmethacrylate. Stabilization is only attempted with dynamic lesions and occasionally is the only
procedure done. The post surgical period is also critical and can be taxing on owners, especially those with large breed dogs. Exercise must be restricted and a neck brace is often used. If the animal is nonambulatory, additional care must be taken to prevent pressure sores and soiling. Some sources say the first 6 weeks are the critical period with exercise restrictions lasting for four months. According to another study the post surgical recovery time averaged 4 weeks (range 1-9 wk) for ventral decompression of disc lesions. It is always better to be cautious, thus preventing complications at the surgical site and worsening of clinical signs. Results of surgical treatment vary widely and depend on the method, type of lesion, and severity of clinical signs. Overall, surgical management is successful in stopping the progression and a significant percentage of animals regain some neurologic function.

**Hypothesis:**

In canine wobblers, clinical signs and progression of the disease are due to compression of the fragile, poorly regenerating spinal cord. In Hansen type II cervical disc protrusions, compression is caused by a dorsal bulge of the intervertebral disc pressing on the ventral aspect of the spinal cord. Therefore, the recognition of possible changes within the spinal canal caused by head position becomes important, so that further damage can be avoided, the dog can be as comfortable as possible, and any effect normal spinal conformation may have on the pathogenesis of wobblers. This study investigated the relationship of head position (flexion, extension, and neutral) to changes in the spinal column in normal dogs using magnetic resonance images to observe changes in the distance between the spinal cord and the intervertebral discs. The hypothesis tested was that the spinal cord
Data Collection:

The magnetic resonance images were viewed by a certified radiologist for proper positioning and anatomical abnormalities. Any images with poor positioning were retaken prior to removal of anesthesia. The distance above and below the spinal cord to the inner surface of the vertebra or disc respectively was measured at each intervertebral disc space from C1-C7 (Figure 3). When multiple slices showed the same disc space two measurements were taken and the average used. In the cases where the edge was indistinct no measurement was taken. The distance between the spinal cord and the dorsal and ventral canal was measured in millimeters (mm) for each view; extension, flexion, and neutral. The shape of the spinal cord was noted, looking for any distortion from normal circular appearance. Volume of the spinal canal and spinal cord was also measured (mm$^3$) at each disc space using MR imaging software.

Analysis:

Averages were calculated for ventral and dorsal distances at each disc space for all positions together as well as for extension, flexion, and neutral separately. The spinal cord and canal volumes at each disc space were averaged for the different neck positions. The averages were compared, ventral flexion and extension to ventral neutral, dorsal flexion and extension to dorsal neutral. The averages for all positions together were used to compare dorsal distance to ventral distance. The volume of the spinal cord and canal at C5 were compared for neutral vs. flexion and at C1 compared to all other disc spaces. Paired t-tests were used to compare distances and a P value < 0.05 was considered significant.
Results:

Ten dogs had magnetic resonance images taken between October and December of 2000 and showed no evidence of anatomical abnormalities or disease processes. Physical and neurologic exams were normal for all dogs. Measurements of the distance between the spinal cord and canal ranged from 0 to 4.7 mm for all positions with the overall average being 1.78 mm. Zero distance was measured only on Dog 2’s flexion MR ventrally for C3-C5, and no spinal cord deformation was noted at that location. The average dorsal measurement for all positions was 2 mm with an average of 2.05 mm for flexion and extension, and 1.86 mm for neutral. Ventrally the combined average was 1.58 mm, 1.56 mm for flexion, 1.7 mm for extension, and 1.49 mm for neutral (Table 1). The average distance between the spinal cord and the roof of the vertebral canal was significantly greater (P = 0.012) than the ventral distance although there appears to be a switch around C5 where the ventral distance becomes greater (Figure 4). Comparing individual disc spaces, all were significantly different (P ≤ 0.015) in the neutral position except for C5 (P = 0.069). The average distances for C1 were significantly greater than for all other intervertebral disc spaces (P ≤ 0.004). When comparing flexion to extension for ventral and dorsal distances between dogs at each intervertebral disc space no significant difference was found. There were significant differences when comparing ventral distances between neutral and extension positions at C1-C5 and C7 as well as dorsal C6 for neutral vs. flexion (P values ≤ 0.05) (Figure 5). When looking at the raw data, there were no consistent changes in distances measured and no trends noted.
Looking at the volume of the spinal canal showed that C1 volume was significantly greater than at any other intervertebral space (P = 2.8E-6). The volume of the spinal cord was also significantly greater at C1 (P = 0.02). There appeared to be an increase in both spinal cord and canal size at C5 on flexion which proved to be significant compared to neutral positioning (P = 0.012, 0.01). When comparing the volume of the cord to the canal, except for C1 where the canal was significantly larger, the canal was uniformly larger than the cord.

**Discussion:**

Diagnostic use of magnetic resonance imaging (MR) is becoming more widely recognized and is an advantageous imaging modality of all tissues, but especially soft tissue, bone marrow, joints, vascular structures and neurologic tissues (brain and spinal cord).\(^7,8\) MR creates an image based on unpaired protons, the majority of which are found in hydrogen ions, creating a magnetic dipole. The very large magnet within the MR machine creates a magnetic field with which the hydrogen ions align. Radiofrequency waves cause the hydrogen ions to move out of alignment and give off a signal that varies in intensity. The intensity is dependent on several factors; concentration of protons, the interactions between protons, and the flow of protons. The MR is able to listen to the signals given off by the protons and arranges this into an image. The image formed is a two or three-dimensional computer generated image for the most part based on the distribution of hydrogen ions in the body (Figure 6).\(^7,8\)
The images generated can be $T_1$ or $T_2$ “Weighted” which changes the contrast between different tissues. Weighting is complex and has to do with the time required for the value of the proton to return to 63% of normal ($T_1$) or decrease the magnetization to 37% of original value ($T_2$). Whether $T_1$ or $T_2$ is used is based on the tissues that are being looked at. A substantial advantage to MR imaging is the ability to look at the same image from three planes, sagittal, coronal, and axial, allowing all aspects of an area to be examined.\textsuperscript{7,8} As opposed to radiography, MR does not require the use of contrast medium when looking at the spine, avoiding seizures, and worsening neurologic signs associated with myelography.\textsuperscript{2,8,9} The myelographic appearance of the spinal canal produced by contrast in radiographs is easily achieved by obtaining T2 weighted images with MR. Distortion, a major problem with radiographs is not encountered with MR which makes it ideal for measuring distances.\textsuperscript{7,8}

MR images of normal dogs were used to gain an understanding of changes in spinal cord position that occur naturally and to obtain a baseline against which to compare future studies in wobbler dogs. The information acquired from this study can be extrapolated to dogs with compressive lesions. By measuring the distance between the spinal cord and the inner edge of the vertebral canal the amount of room in which the spinal cord can be displaced and how much space a lesion must occupy before compressing the cord can be determined. The measurements show that the average distance between the cord and canal is 1.78mm. This means the spinal canal has approximately 3.5mm of “extra” space, which a lesion could theoretically occupy prior to compressing the spinal cord. One must
also take into account the dura and surrounding ligaments which also occupy space. A radiographic study of the cervical spinal anatomy measured the sagittal diameter of cervical vertebra in multiple breeds, including breeds known to be predisposed to wobblers. The total diameter in smaller dogs ranged from 7mm to 12mm, where as larger breeds ranged from 10mm up to 20mm in the Great Dane, with the majority being between 12-15mm. By integrating the data it would appear that the spinal cord occupies roughly two thirds of the vertebral canal.

When comparing dorsal to ventral distance there was a trend in all head positions for the dorsal distance to decrease and the ventral distance to increase (from C2 to C7) moving caudally through the cervical spine (Table 1). The dorsal average for all positions was 2mm, significantly greater then the 1.58mm average for ventral distance. With the ventral distances being significantly smaller compared to dorsal distances, disc lesions occurring ventrally should start to displace the spinal cord sooner than would a dorsal lesion, such as a hypertrophied ligamentum flavum. On closer analysis there were significant differences in the ventral and dorsal distances at all intervertebral spaces except C5 where the crossover occurs (Figure 4). Therefore, at C1-C4 the dorsal distance is substantially greater and at C6-C7 the ventral distance is larger. This implies that at C5-C6 and C6-C7 where the majority of the disc protrusions occur spinal cord location is not increasing the risk of compression. Conversely most dorsal articular malformations occur in the more cranial vertebra and would also have more space before compression occurs.
An important finding was that out of ten dogs only one had enough spinal cord movement to have no spinal fluid ventrally from C3-C5 on the flexion view. Visually no spinal cord deformation was occurring and the dog had no adverse neurologic signs. This movement of the spinal cord is in disagreement with previous data in dogs with wobbler syndrome. As shown by myelography a ventral disc protrusion is relieved by flexion and exaggerated by extension.1 This relief could therefore be due in part to an increase in intervertebral space and decreased pressure pushing the disc material into the canal. One could also speculate that possibly the spinal cord when curved expands laterally instead of moving up or down. But it would seem like the spinal cord would also deviated dorsally analogous to what happens when one bends a stick. The data collected in this study did not support this theory. For most positions and measurements there was no significant difference, suggesting that there is little movement of the spinal cord and no consistent deviation one way or the other depending on head position. The only significant findings were the ventral distances when comparing neutral and extension positions (Figure 7). The measured differences were significant for C1-C5 and C7. Opposite of the spinal cord moving ventrally when extended, for C1-C4 and C7 the ventral extension measurements were greater than when in neutral suggesting the cord moved dorsally. Several problems arise in interpreting this data, one of which is the small differences being measured and compared. In order to see the small differences, like the ones you would expect within the vertebra, sample size must be large. In this study only ten dogs were used which limits the ability to detect small changes. Given the data it would appear that no coordinated movement of the spinal cord is observed when the head is extended or flexed. This would lead to the conclusion that the improvement of
compressive lesions seen in wobblers is due solely to movement of surrounding tissues in coordination with flexion and extension.

The first cervical vertebra, known as the atlas, serves a special function in supporting the weight of the skull and acting as the “yes” joint, allowing the head to move up and down. The atlas’s structure is very different from the other cervical vertebrae to allow it to perform these functions. This difference shows up in the distances, both above and below the cord, within C1. The distances for C1 were significantly greater than for all other cervical vertebra (Table 2). This enlargement, along with the different structure, might contribute to the lack of compressive lesions noted at this location. When looking at the internal volume of the atlas it was noted to be substantially larger than all other vertebra, roughly twice the volume. An increase in spinal cord volume was also noted at C1 but was not nearly as large as that of the canal. Most likely the C1 cord enlargement can be attributed to the fact the spinal cord would still be narrowing from the brain stem this high up.

Another anomaly was seen in the volume of the canal and cord at C5 on flexion views (Figures 8 and 9). The data shows that the volume significantly increases at C5 on flexion only. Due to the fact that both the canal and cord are involved, the change could be attributed to artifact. Perhaps the cross-section was not perpendicular and increased the measured distances. The fact that the increase is consistent between all dogs would go against artifact and suggest that maybe during flexion the main bending within the neck occurs at C5 leading to a greater increase in volume. Going back the study of
sagittal diameters no increase seems apparent in the diameters of C₅ compared to the other cervical vertebra.¹¹ It was also interesting to see the volume difference between the canal and cord remained consistent throughout the cervical vertebra (Figure 10). This suggests that developmentally there is good correlation between the size of the cord and the space which it occupies, conceivably mother nature’s way of trying to prevent spinal cord compressions. It would be interesting to follow the volume through the rest of the spine to see if at the thoracic and lumbar intumescences there is corresponding increase in spinal canal diameter.

**Summary:**

By looking at data of normal large breed dogs that are not predisposed to wobblers one cannot automatically assume that the anatomy would be the same as those that are predisposed and therefore direct correlations are hard to make. Important information could be obtained by expanding this study to include Dobermans that have wobblers and those that do not to compare the intervertebral anatomy. From the data measured in this limited study the spinal cord did not consistently move up or down with flexion and extension of the neck, except possible dorsal cord movement with extension. Previous studies have shown via myelography that neck positioning can have a significant effect on the amount of compression produced by a dynamic lesion.¹⁴,⁹,¹³,¹⁸ Since spinal cord movement does not seem to be the cause of relief of spinal compression with head movement other factors such as, soft tissue stretching, increased distance between vertebral bodies, and possibly lateral expansion of the cord could be the source of
decompression. Another interesting finding is the change in cord position as one moves caudally which could have implications concerning the size of lesion needed to cause compression if it is dorsal or ventral. Finally the large size of C₁ is most likely a consequence of the functions performed by the vertebra and has the positive effect of decreasing the occurrence of compression. The spinal cord is a very delicate structure with complex and indispensable functions that must be protected. The cord is contained within a hard bone tunnel to prevent damage but due to the requirement of movement the spinal canal cannot be complete. This is a strength preventing the spinal canal from snapping in half but produces inherent weaknesses. Through these intervertebral areas tissue is able to press upon the spinal cord and cause compression. The importance of studying the vertebral canal is evident due to the severe consequences of spinal cord compression. If better methods of correcting compressive lesions are found and the ability to prevent lesions in the future by breeding for “normal” conformation is obtained then much will have been gained.
Figure 1: Lateral radiographs of the cervical spine of a dog. IA: Plain radiograph of a normal spine, IB: Myelography of a disc protrusion. Notice how the contrast outlines the spinal cord and the compressive lesion at C4-C5 where the contrast column fades.

Figure 2: Dog positioned for a cervical MR.
Figure 3A is a MR image showing where the cross-section (fig. B) is. Fig. 3B is an image of C2-C3 taken from a dog with the neck in neutral position. Fig. 3C is an enlargement of the vertebra showing the dorsal and ventral measurements taken. The gray density between the measurements is spinal cord, below which is the disc.
Table 1:

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<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
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Table 1: Average distances between spinal cord and vertebra for dorsal (D) and ventral (V). Measurements for each head position and intervertebral disc as well as the overall average distance for each position.

Figure 4:

Figure 4: A graphical representation of the average dorsal and ventral measurements with the neck in neutral position for each intervertebral disc space. Notice the crossover at C₅.
Figure 5: Average ventral distances between spinal cord and vertebra at each intervertebral disc while head was positioned in neutral and extension. Significant differences were found for C1-C5 and C7.

Figure 6: A picture of Washington State Universities magnetic resonance imaging machine.
Figure 7: Average measurements of the ventral distances for extension and neutral positions. The distances were significant for C₃-C₅ and C₇.

Table 2: Average volume measurements of the spinal cord and canal at each intervertebral disc space. Notice the canal and cord are significantly larger at C₁ compared to all other disc spaces.
Figure 8: Comparison of spinal cord size between flexed, extended, and neutral head positions, notice spike at C5 in the flexed position.

Figure 9: Vertebral canal volume at each disc space, notice large volume of C1 and spike at C3 for flexion.
Figure 10: Volume measurements for the spinal cord and canal in the neutral position, notice the large volume of C1 canal compared to the cord as well as the correlation between the canal and cord sizes throughout the cervical vertebra.
Reference:

7. Thrall Donald E. Physical principles of computed tomography and magnetic resonance imaging. *The textbook of veterinary diagnostic radiology* W.B. Saunders company. 4th Ed. 2002;29-34.
20. Tilley LP, Smith FWK. Wobbler syndrome. *The 5-Minute Veterinary Consult Canine and Feline* Lippincott Williams and Wilkins. 2nd Ed. 2000;1320-1321
Reference:

7. Thrall Donald E. Physical principles of computed tomography and magnetic resonance imaging. *The textbook of veterinary diagnostic radiology* W.B. Saunders company. 4th Ed. 2002;29-34.
20. Tilley LP, Smith FWK. Wobbler syndrome. *The 5-Minute Veterinary Consult Canine and Feline* Lippincott Williams and Wilkins. 2nd Ed. 2000;1320-1321