The computed tomographic appearance of acute thoracolumbar intervertebral disc herniations in dogs

Natasha J. Olby, Vet MB, PhD, Karen R. Muñana, DVM, MS, Nicholas J.H. Sharp, BVM, PhD, Donald E. Thrall, DVM, PhD

The appearance of herniated intervertebral disc material in the thoracolumbar vertebral canal was evaluated in 23 dogs using computed tomography (CT). The images were then compared with the myelographic and surgical findings. The normal spinal cord, outlined by epidural fat over intervertebral disc spaces, was of intermediate attenuation on transverse CT images. Herniated disc material was identified in all animals as a heterogeneous hyperattenuating extradural mass. The attenuation of the disc material increased with the degree of mineralization. In seven dogs, the herniated material was only slightly more attenuating than the spinal cord. In these dogs, small fragments of mineralized disc material and significant hemorrhage were found in the epidural space at surgery. In dogs with a long standing history of disc herniations, disc material identified in the vertebral canal had a more hyperattenuating and homogeneous appearance than recently herniated disc material. We conclude that mineralized, herniated disc material and hemorrhage can be identified quickly and safely in dogs using CT.

Key words: intervertebral disc herniation, computed tomography, myelography, epidural hemorrhage, dog.

Introduction

Since the development of non-ionic, water soluble, iodinated contrast media, myelography has been the standard means of diagnosing intervertebral disc herniations. However, this diagnostic test is invasive, with the potential to cause side effects such as seizures and exacerbation of neurological signs. Access to computed tomography (CT) is now fairly standard in academic institutions and specialty neurology practices. Using up to date equipment (third and fourth generation scanners), imaging of the vertebral column using CT is quick and produces transverse images of the vertebral canal that can be reconstructed in other planes. Computed tomography has been used successfully to image the brain and the lumbosacral junction, and to evaluate spinal neoplasia and the cervical spine of dogs with caudal cervical spondylomyelopathy. However, when CT is used in the assessment of the spinal cord, subarachnoid injection of iodinated contrast medium is often performed concurrently because the spinal cord may not be clearly visible in CT images. Obviously the use of CT with subarachnoid contrast medium invalidates the potential advantage of diagnosing disc herniation without the side effects associated with myelography. However, intervertebral disc herniation, especially in chondrodystrophoid breeds, usually occurs after the nucleus pulposus has become mineralized. We therefore hypothesized that the presence of mineralized intervertebral disc material in the vertebral canal can be detected clearly using CT without the subarachnoid injection of contrast medium. This paper describes the computed tomographic appearance of intervertebral disc material in the vertebral canal within days and up to several years after disc herniation. The relative accuracy of CT versus myelography for identifying the site of disc herniation has been examined in a separate study.

Materials and Methods

Twenty three animals with a presumptive diagnosis of intervertebral disc herniation were imaged. Nineteen dogs were evaluated immediately prior to decompressive surgery and four additional dogs were evaluated from 3 months to 9 years after decompressive surgery. A neurological examination was performed on all animals at the time of admission to the hospital, and routine biochemistry panels, complete blood cell counts, urine and CSF analysis were completed. All animals were imaged while they were under general anesthesia using a third generation CT scanner (GE Sytec SRi). Lateral and ventrodorsal pilot images were acquired prior to acquisition of the transverse images. Based on results of the neurological examination, contiguous, transverse images were acquired at 3 mm intervals from the tenth thoracic to the third lumbar vertebrae (if the neuro-
logical examination localized the lesion between the third thoracic and third lumbar spinal segments) or from the third lumbar to the first sacral vertebrae (if the neurological examination localized the lesion between the fourth lumbar and third sacral spinal segments). The gantry was angled so that the image plane was parallel to the intervertebral discs. In some cases, the gantry angles had to be changed half way through the scan to follow the curvature of the vertebral column. CT settings were 120 kVp, 80 mA, with a scan time of 5 seconds per slice. To correlate the computed tomographic appearance and myelographic characteristics of disc herniation, myelography was performed after the CT scan in all dogs by injection of 0.4 ml/kg iohexol (240 mg iodine/ml) (Omnipaque, Nycomed) into the subarachnoid space of L4-5 or L5-6. Plain radiographs were performed after the CT scans and prior to myelography. Decompressive surgery was performed based on the myelogram and CT images, and the surgical and myelographic findings compared with the computed tomographic appearance. When evaluating the transverse CT images, the degree of attenuation of the spinal cord was measured in Hounsfield units (HU) in each image. In order to do this a region of interest (ROI) was chosen that was slightly smaller than the cross sectional area of the spinal cord and the same ROI used in each image for that dog. On images in which there was disc material in the canal, the mean attenuation of the disc material and spinal cord that fell within the ROI were measured. This was done to ensure that the ROI was as large as possible as it was noted that artifacts such as those produced by beam hardening could alter the attenuation of small focal areas of the spinal cord on individual slices. The values that were used to determine the mean attenuation of the normal spinal cord were taken from at least 5 images in each dog that were at least 2 images (6 mm) distant from the site of disc herniation. The attenuation of the normal spinal cord was expressed as a mean ± standard deviation. The mean combined attenuation of the spinal cord and disc material in the image with the maximum amount of disc material within the vertebral canal (i.e. the site of maximum spinal cord compression) was also calculated. For comparison, the attenuation of the cranial pole of the right kidney was measured in each dog.

**Results**

There were sixteen Dachshunds, four mixed breeds, one cocker spaniel and two miniature poodles in the study. In these animals, the normal spinal cord was characterized by intermediate attenuation on transverse images (mean attenuation: 31.3 ± 8.6 HU; range: 4 – 55 HU). This was similar to the attenuation of the right kidney (mean attenuation: 35.2 ± 4.4 HU; range: 25 – 41 HU). The attenuation of the normal spinal cord varied a mean of 24 HU in individual dogs. Epidural fat was visible lateral to the spinal cord over the disc spaces (Figure 1A). Dorsal to the vertebral bodies the epidural space was smaller, particularly in the caudal thoracic region and consequently fat was not visible (Figure 1B). In sequential images, there was a small mid-sagittal ridge on the dorsal aspect of the vertebral body (Figure 1B). The prominence of the ridge varied between individual animals and vertebrae; it was largest in the lumbar vertebrae, and in some animals was absent from the tenth and eleventh thoracic vertebrae. In images just caudal to the center of the vertebral body there was a small focus of increased attenuation in the position of the bony ridge on the ventral midline of the vertebral canal that was separate from the vertebral body (Figure 1C). This frequently lay over the basivertebral vascular channel in the underlying bone (Figure 1C). In two other animals a similar structure with soft tissue attenuation characteristics was identified at this location (Figure 1D). Thoracic vertebrae could be identified by the presence of the ribs bilaterally (Figures 1 and 2A). The transverse processes of lumbar vertebrae were also clearly evident lateral to the vertebral bodies, sloping ventrally (Figures 3A and 4A).

Dogs with thoracolumbar intervertebral disc herniations could be divided into 3 groups on the basis of the CT findings. The first group contained twelve dogs; eleven dachshunds and one mixed breed. These dogs had large quantities of mineralized material in the vertebral canal. The herniated disc material was clearly visible as a heterogeneous, hyperattenuating mass (mean attenuation: 219 ± 95 HU; range: 104–407 HU) within the vertebral canal causing severe spinal cord compression (Figure 2A). In all 12 dogs, the presence of extradural compression was confirmed with myelography (Figure 2B). It was confirmed at surgery that the compression was caused by herniated, mineralized disc material.

The second group included seven dogs. The dog breeds represented included three dachshunds, three mixed breeds and one miniature poodle. These animals had disc herniations that caused less obvious compression of the spinal cord. The herniated material was distinguishable from the spinal cord but was only slightly more attenuating than the spinal cord (mean attenuation: 59 ± 17 HU; range: 38–98 HU) (Figure 3A), and extended over distances of up to 5 vertebrae. In all animals in this group, small fragments of mineralized disc material associated with epidural hemorrhage were found at surgery. The site of disc herniation could be identified on CT images in these animals by the heterogeneous appearance of the spinal cord and the presence of material with increased attenuation characteristics in the epidural space (Figure 3A). The site was confirmed both with myelography (Figure 3B) and at surgery.

In groups one and two, epidural fat was not visible at the level of the herniated disc material. In addition, both groups had mineralized material that could be identified within the nucleus pulposus of some of the intervertebral discs when the CT image plane was through the center of the disc.
FIG. 1. Transverse images of the spinal cord and vertebra at various levels from three different dogs. The dogs' right side is on the side labeled by the figure letter in each case. (A) A transverse image of the caudal thoracic spinal cord dorsal to an intervertebral disc. Note the presence of epidural fat lateral to the spinal cord (long arrow), the spleen on the left side of the abdomen (arrow heads), the appearance of the intervertebral disc and the presence of ribs bilaterally (short arrow). (B) A transverse image of the caudal thoracic spinal cord dorsal to the vertebral body of the same dog as in Figure 1A. The spinal cord appears to fill the entire vertebral canal. (C) A transverse image of the caudal thoracic spinal cord of a different dog dorsal to the vertebral body showing a small, round focus of hyperattenuating material in the midline of the floor of the vertebral body (arrow) overlying the basivertebral vascular channel (arrowhead). (D) A transverse image of the caudal thoracic spinal cord dorsal to the vertebral body of another dog showing a small, round focus of intermediate attenuation in the midline of the floor of the vertebral body (arrow) in the same position as the hyperattenuating focus noted in Figure 1C.

(Figure 3A). In these animals, mineralized material was also identified within the disc on survey radiographs. In both groups there were animals in which the spinal cord was outlined by a rim of increased attenuation cranial and caudal to the acutely herniated disc material (Figure 4A). This was believed to represent blood in the epidural space because at surgery these animals had extensive epidural hemorrhage around the herniated disc material. This was more pronounced in the animals in the second group: two of these dogs had hemorrhage that extended over the length of 6 vertebrae. In the myelograms of these dogs, the subarachnoid space tended to be thin over a long distance both cranial and caudal to the site of the disc herniation (Figure 3B).

The full extent of the disc material was clearly visible on CT images in both groups 1 and 2, and in some animals the material extended over 5 vertebrae and up to 75% of the cross sectional area of the vertebral canal. In both groups additional disc herniations, presumed to be incidental and of no current clinical significance due to the lack of spinal cord compression, were identified. At these sites, small amounts of hyperattenuating herniated disc material were seen ventral or lateral to the spinal cord (Figure 4B) and in the myelograms there was no evidence of spinal cord compression. These sites were not explored surgically.

The final group of four dogs were those that were examined for recurrent back pain and/or progressive hind limb weakness at periods of 3 months, 9 months, 4 years, and 9 years following a previous acute intervertebral disc herniation. The breeds represented included two dachshunds, one miniature poodle and one cocker spaniel. Three of the dogs had been treated with decompressive surgery and the fourth had been managed conservatively with cage rest alone. In two dogs a large amount of disc material was present in the vertebral canal causing severe compression of the spinal cord. In one of these two dogs a dorsal laminectomy had been performed at the time of disc herniation and there was a large amount of residual disc material at the surgical site ventral to the spinal cord (Figure 5). The other dog had been managed conservatively. The herniated disc material in these two dogs was extremely hyperattenuating (mean at-
Fig. 2. (A) A transverse image of the caudal thoracic spinal cord and vertebra from a dog in group 1. There is a large hyperattenuating mass within the ventral aspect of the vertebral canal causing severe compression of the spinal cord. The dog’s right side is on the side labeled with the letter A. (B) The myelogram from the same animal as Figure 2A showing extradural compression at T12-13.

The remaining two dogs with chronic histories presented with recurrent back pain, but no site of compression could be identified using CT or myelography. However, both had interesting features identified on CT. In one dog a CT scan of the thoracolumbar spine was performed to evaluate the previous surgical site, as it had undergone hemilaminectomy of T11-12, T12-13 and T13-L1 nine months previously. There was severe atrophy of the epaxial muscles at the level of the hemilaminectomy site but no other abnormal findings (Figure 6). The other dog was evaluated for episodic hind limb weakness and back pain. This dog had also undergone hemilaminectomies of T11-12–T13-L1 four years previously. On CT there was a prominent area of material with the attenuation characteristics of fat along the hemilaminectomy site. The fat did not appear to be compressing the spinal cord on CT images (Figure 7), and myelographically there was no significant compression of the spinal cord. Fluoroscopic-guided aspiration of this region confirmed that it was fat. At the initial surgery, a fat pad had been placed over the hemilaminectomy site. Further surgical exploration was not performed and the dog has been stable since it was last evaluated.

Discussion

The normal spinal cord, surrounded by epidural fat, is clearly visible dorsal to the intervertebral discs in the thoracolumbar region on transverse CT images. The outline of the spinal cord is less distinct dorsal to the vertebral bodies because of the relative absence of epidural fat, but the spinal cord is homogeneous in its attenuation characteristics. The intervertebral disc can be evaluated on the transverse CT images and mineralization of the nucleus pulposus is easily identified. Normally, there is a mid-sagittal ridge of bone on
FIG. 4. (A) A transverse image of the lumbar spinal cord and vertebra. The spinal cord is outlined by a narrow rim of hyperattenuation (arrow) believed to be epidural hemorrhage. (B) A transverse image of the caudal thoracic spinal cord and vertebra. There is a small amount of hyperattenuating disc material ventral to the spinal cord. Based on the myelogram, this disc herniation was of no current clinical significance. There is also a large amount of hyperattenuating mineralized material in the center of the intervertebral disc. In both of the above images, the dog’s right side is on the side labeled by the figure letter.

FIG. 5. A transverse image of the caudal thoracic spinal cord and vertebra from a dog in group 3 revealing a defect in the dorsal lamina of the vertebra due to previous surgery. Two masses of homogeneous, hyperattenuating, mineralized material extend into the vertebral canal, occupying about half of its cross sectional area.

FIG. 6. A transverse image of the caudal thoracic spinal cord and vertebra. The left lateral pedicle has been removed surgically. The paraspinal musculature is severely atrophied over the surgical site. There is no evidence of spinal cord compression.

FIG. 7. A transverse image of the caudal thoracic spinal cord and vertebra. The right lateral pedicle has been removed surgically. There is mild atrophy of the paraspinal muscles over the surgical site, but there is also a large area of material with low attenuation characteristics (identified as fat) lying lateral to the spinal cord at the level of the spinal defect.

the dorsal aspect of the vertebral body. However, in some dogs there is also a small focus of mineralized material on the floor of the canal that is separate from the bone of the vertebra. In trying to identify this structure, it was noted that two dogs had a focus with soft tissue attenuation characteristics in the same position as the mineralized focus in the other dogs. The only soft tissue structure in this position is the dorsal longitudinal ligament. We therefore speculate that this focus could represent mineralization of the dorsal longitudinal ligament. This can potentially be mistaken for disc material, but can be identified as mineralized ligament by its position, its homo-
Vertebrae can be identified as thoracic or lumbar without difficulty based on the presence of ribs or transverse processes. The location of any particular image can therefore be identified by counting sequential vertebrae or by using pilot images depicting slice location. Acquiring lateral and ventrodorsal pilot images may reduce the risk of missing a vertebral malformation that could affect the accurate localization of individual disc spaces at surgery. This is important as ten per cent of dachshunds have unusual numbers of vertebrae. If the pilot images are not of sufficient quality to identify skeletal abnormalities, it may be useful to make a routine survey radiograph in all animals prior to performing the CT scan.

The presence of herniated mineralized disc material in the vertebral canal was apparent without the injection of subarachnoid or intravenous contrast medium in this study, even in animals where little disc material was herniated. We were able to divide the dogs with recent, acute intervertebral disc herniations for descriptive purposes into a group in which herniation of a large amount of mineralized material occurred, and a group with much smaller, hemorrhagic disc herniations, although there was some overlap between the groups. It is interesting to note that although the breeds represented in this study were the same as in other studies, dachshunds were more likely to belong to the first group, whereas the other chondrodystrophoid breeds represented were more likely to belong in the second group. It was difficult to assess the degree of spinal cord compression from myelograms of dogs in group 2 as the subarachnoid contrast medium was frequently thin at and around the level of the disc herniation. The demonstration of mild spinal cord compression in such dogs using CT may indicate that decompression of these dogs is not necessary.

Computed tomography can identify acute hemorrhage in the vertebral canal. The appearance of CT images in this study suggests that epidural hemorrhage can extend over a number of vertebrae to each side of the disc herniation. This is not an unexpected finding as paired spinal venous sinuses lie dorsal to the intervertebral discs and are likely to be damaged when disc material is herniated. The results of this study suggest that thinning of the contrast medium over a long distance cranial and caudal to the site of disc herniation may not solely represent spinal cord swelling. It may, in part, be a result of the presence of blood in the epidural space, causing compression of the subarachnoid space over several vertebrae.

There are several advantages to using non-contrast CT images to identify disc herniations. It is a non-invasive diagnostic technique that is not associated with the side effects seen following myelography. The speed with which a diagnostic CT scan can be done (approximately 10 minutes on the CT scanner used in this study) is also beneficial to animals under general anesthesia for diagnostic testing and decompressive surgery. The risk of systemic hypotension is higher under general anesthesia and as hypotension can reduce blood flow to the injured spinal cord and worsen the outcome, minimizing the time under anesthesia is desirable. The full extent and lateralization of the disc material was clearly visible and the CT images were found to be more useful than myelography for surgical planning.

The disadvantages of the use of CT include cost and availability of on-site CT scanners. At our institution, CT scans cost more than myelograms, but this was balanced in part by the reduced time spent under anesthesia and so the final cost was not significantly different. To effectively use CT to diagnose acute disc herniations that require immediate surgery, it is necessary to have an on-site CT scanner and this is clearly a limiting factor for many veterinarians at present. Mineralized disc material was clearly visible on the CT images; however, we postulate that herniated material with soft tissue attenuation characteristics may not be visible on non-contrast CT images. Therefore this study evaluated the use of CT in dogs that were likely to have herniated mineralized disc material based on their breed and clinical presentation. The sensitivity of CT for detecting disc herniations may be enhanced by the use of intravenous contrast medium, and it is also possible to perform a myelogram after CT if a site of compression is not identified. The use of less concentrated contrast media intrathecally may also improve the sensitivity of the CT scan while minimizing the side effects. We were concerned that it would be difficult to differentiate chronic disc herniations of no clinical significance from acute disc herniations using CT. Although this remains a concern, it was noted that chronically herniated disc material, as seen in 2 of the dogs in group 3, was markedly more hyperattenuating than acutely herniated disc material, presumably because it continues to mineralize over time. Moreover, the accuracy of CT at diagnosing and localizing herniated disc material compares favorably with myelography. The concern that a site of disc herniation may be missed by imaging only a limited region of the vertebral column appears unfounded, as 75% of disc herniations occur between T11 and L2. However, the importance of a thorough neurological examination is emphasized to allow localization of the neurological signs to spinal segments T3-L3 or L4-S3.

We conclude that it is possible to identify mineralized disc material and hemorrhage in the vertebral canal using non-contrast CT. Moreover, recent disc herniations can be distinguished from old herniations by the appearance of the disc material. The diagnosis of intervertebral disc herniations using non-contrast CT scans is beneficial to the dog because it avoids the injection of contrast medium into the subarachnoid space, potentially damaging the injured spinal cord and the epidural space, causing compression of the subarachnoid space over several vertebrae.
Another advantage is that it is quick to perform and so reduces anesthesia time. Non-contrast CT scans of the spine can therefore be useful in the diagnosis of acute intervertebral disc herniations in chondrodystrophoid breeds of dog.

ACKNOWLEDGMENT

The authors would like to acknowledge the expert technical assistance given by Paul Fisher, Paul Mickel and Heather Thomas. This study was funded by a College of Veterinary Medicine, North Carolina State Research Grant and by the American Kennel Club.

REFERENCES