Magnetic resonance imaging findings in dogs with thoracolumbar intervertebral disk disease: 69 cases (1997–2005)

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**Objective**—To determine magnetic resonance imaging (MRI) abnormalities in dogs with intervertebral disk disease (IVDD) and develop a classification scheme for IVDD in dogs based on MRI findings.

**Design**—Retrospective case series.

**Animals**—69 dogs.

**Procedure**—Medical records of dogs admitted because of thoracolumbar IVDD in which MRI of T9 through L7 had been performed were reviewed.

**Results**—A total of 759 intervertebral disk spaces were examined. Of these, 342 (45.1%) were classified as having a normal MRI appearance; the remaining 417 (54.9%) had various types of IVDD. Disk degeneration was identified in 276 disk spaces in 56 dogs, bulging of the intervertebral disk was identified in 37 disk spaces in 24 dogs, disk protrusion was identified in 54 disk spaces in 32 dogs, and disk extrusion was identified in 50 disk spaces in 48 dogs. Cartilage endplate changes were identified in 35 vertebrae in 17 dogs, and increased signal intensity of the spinal cord was identified in 21 dogs.

**Conclusions and Clinical Relevance**—Four types of IVDD (disk degeneration, bulging of the intervertebral disk, disk protrusion, and disk extrusion) were identified on the basis of MRI findings in dogs with thoracolumbar IVDD. We recommend that a standardized nomenclature be adopted for the various types of thoracolumbar IVDD in dogs. (J Am Vet Med Assoc 2006;228:902–908)

Intervertebral disk disease in dogs has been classified on the basis of clinical, radiographic, and histologic findings. Recently, however, MRI has come into wider use as a diagnostic tool in veterinary medicine, and MRI has been reported to be the best method for early recognition of disk degeneration in dogs. Magnetic resonance imaging provides clear images of the soft tissues of the spine and enables precise distinction of pathologic changes.

In human medicine, classification schemes for IVDD based on MRI findings have been developed. In contrast, although the MRI appearance of the spinal cord and intervertebral disks in dogs has been reported, to our knowledge, no classification system for thoracolumbar IVDD or cartilage endplate degeneration in dogs has been published. Because of the increasing availability of MRI for the diagnosis of CNS disorders in dogs, a description of MRI findings in dogs with IVDD and a classification scheme for the various types of intervertebral disk abnormalities evident on magnetic resonance images would be helpful. The purposes of the study reported here, therefore, were to determine MRI abnormalities in dogs with IVDD and develop a classification scheme for IVDD in dogs based on MRI findings.

**Criteria for Selection of Cases**

Medical records of all dogs admitted to the Department of Surgery, Faculty of Veterinary Medicine, Ankara University between March 1997 and May 2005 were reviewed. Cases were included in the study if thoracolumbar IVDD had been diagnosed by means of MRI, the medical record was complete, MRI of the T9 through L7 vertebrae had been performed, and the diagnosis of IVDD corresponded with the neurologic status.

**Procedure**

Information obtained from the medical records of cases included in the study consisted of age, breed, sex, and neurologic status. Neurologic status was graded from 0 to 5 (0 = no neurologic dysfunction or signs of pain, 1 = signs of thoracolumbar pain with or without bladder control, 2 = paraparesis, 3 = nonambulatory paraparesis, 4 = paraplegia with or without bladder control, and 5 = paraplegia with loss of bladder control and deep pain perception). Deep pain perception was assumed to be present if the dog reacted by vocalizing or attempting to bite when the toes of the hind limbs were clamped with a surgical forceps.

For MRI, dogs were anesthetized with diazepam (0.2 mg/kg [0.09 mg/lb], IV) and propofol (5 mg/kg [2.3 mg/lb], IV); anesthesia was maintained with a constant infusion of propofol (0.3 to 0.4 mg/kg/min [0.14 to 0.18 mg/lb/min], IV). Magnetic resonance images were obtained with a 1.5-Tesla surface coil. Sagittal T1-weighted images were obtained with a repetition time of 400 to 700 milliseconds and an echo time of 10 to 14 milliseconds; sagittal T2-weighted images were obtained with a repetition time of 3,000 to 4,000 milliseconds and an echo time of 90 to 99 milliseconds. Transverse T1-weighted images were obtained with a repetition time of 370 to 700 milliseconds and an echo time of 12 to 20 milliseconds; transverse T2-weighted images were obtained with a repetition time of 2,000 to 4,000 milliseconds and an echo time of 10 to 14 milliseconds.
time of 90 to 98 milliseconds. Slice thickness was 2 mm with an interslice gap of 0 mm for transverse images. From 2 and 4 slices were obtained for each disk, depending on the size of the dog.

For the present study, T1- and T2-weighted images of T9 through L7 were evaluated by individuals unaware of the historical and clinical findings with regard to appearance of the spinal cord, intervertebral disks, cartilage endplates, and any extruded disk material. A classification scheme adapted from a scheme developed for use in people was used to classify IVDD findings. Specifically, dogs were classified as having disk degeneration, bulging of the intervertebral disk, disk protrusion, or disk extrusion.

Criteria for disk degeneration were modified from criteria used in humans. The MRI appearance of the intervertebral disk was considered to be normal if the nucleus pulposus was homogeneous and bright white with a clear distinction between the anulus fibrosus and nucleus pulposus and hyperintense to isointense signal intensity, compared with signal intensity of the CSF. Dogs were subclassified as having type I disk degeneration if the intervertebral disk space was inhomogeneous and gray; the distinction between the anulus fibrosus and nucleus pulposus and hyperintense to isointense signal intensity, compared with signal intensity of the CSF. Dogs were subclassified as having type II disk degeneration if the intervertebral disk space was structurally inhomogeneous and gray to black, the distinction between the anulus fibrosus and nucleus pulposus was lost, signal intensity was intermediate to hypointense, and width of the disk space was decreased.

Dogs were classified as having bulging of the intervertebral disk if there was symmetric uniform extension of the outer disk margin circumferentially. Dogs were classified as having disk protrusion if the disk protruded in a central direction or to the right or left with focal disruption of the anulus. Dogs were classified as having disk protrusion if the disk had herniated through all layers of the anulus and appeared as a focal epidural mass. Dogs with disk protrusion were subclassified as having dispersed disk disease if extruded disk material was no longer in contact with the affected disk space but, rather, spread out along the epidural space and as having nondispersed disk disease if extruded disk material was not dispersed through the vertebral canal but located near the affected disk space as a buttonlike extrusion.

Cartilage endplate changes were classified on the basis of criteria developed for use in human medicine. Dogs were considered to have type I cartilage endplate changes if areas of low signal intensity were seen on T1-weighted images and areas of high signal intensity were seen on T2-weighted images, type II cartilage endplate changes if areas of high signal intensity were seen on T1-weighted images and areas of isointense or slightly hyperintense signal intensity were seen on T2-weighted images, and type III cartilage endplate changes if areas of hypointense signal intensity were seen on T1- and T2-weighted images. The degree of attenuation of the vertebral canal was determined by calculating the ratio of the height of any extruded disk material to the height of the vertebral canal in the direction of disk extrusion on sagittal images.

Statistical analysis—Pearson χ² tests were used to determine whether age was associated with the presence of disk degeneration, bulging of the intervertebral disk, disk protrusion, disk extrusion, dispersed disk extrusion, nondispersed disk extrusion, or cartilage endplate changes and whether degree of attenuation of the vertebral canal was associated with neurologic status score.

Fisher exact tests were used to determine whether sex was associated with the presence of bulging of the intervertebral disk, disk protrusion, dispersed disk extrusion, or nondispersed disk extrusion; whether the presence of bulging of the intervertebral disk was associated with disk protrusion, dispersed disk extrusion, or nondispersed disk extrusion; whether the presence of disk degeneration was associated with disk protrusion, dispersed disk extrusion, or nondispersed disk extrusion; whether the presence of dispersed disk extrusion was associated with dispersed disk extrusion or nondispersed disk extrusion; whether the presence of dispersed disk extrusion was associated with nondispersed disk extrusion; whether the presence of increased signal intensity was associated with neurologic status score; whether the presence of cartilage endplate changes was associated with disk degeneration, dispersed disk extrusion, or nondispersed disk extrusion; whether the location of extruded disk material (ie, left, right, or center) was associated with neurologic status score or the presence of increased signal intensity; and whether the presence of disk protrusion or bulging was associated with the presence of disk extrusion.

Odds ratios were calculated, and Mann-Whitney U tests were used to compare the ages of male and female dogs and the ages of dogs with and without increased signal intensity of the spinal cord. The Kruskal-Wallis test was used to compare ages of dogs grouped according to neurologic status score. All analyses were performed with standard software; values of P < 0.05 were considered significant.

Results

Sixty-nine dogs met the criteria for inclusion in the study. Dogs ranged from 1 to 14 years old (mean, 6.6 years); there were 49 male and 20 female dogs. There were 22 Pekingese, 18 Miniature Poodles, 12 Dachshunds, 5 Cocker Spaniels, 3 German Shepherd Dogs, 2 Bassett Hounds, 2 Collies, 2 Samoyeds, 1 French Bulldog, 1 Pug, and 1 Rottweiler. Sixty-one of the dogs were chondrodystrophic. Eight (12%) dogs weighed > 20 kg (44 lb), whereas the remaining 61 weighed less than this. At the time of examination, 13 (19%) dogs were classified as having grade 2 neurologic deficits, 34 (49%) were classified as having grade 3 deficits, 20 (29%) were classified as having grade 4 deficits, and 2 (3%) were classified as having grade 5 deficits. A total of 759 intervertebral disk spaces were examined. Of these, 342 (45.1%) were classified as...
having a normal MRI appearance (ie, homogeneous, bright white nucleus pulposus with a clear distinction between the annulus fibrosus and nucleus pulposus and hyperintense to isointense signal intensity, compared with signal intensity of the CSF). The remaining 417 (54.9%) disk spaces had various types of IVDD. The T12-13 and L3-4 disk spaces were affected more often (71.3% of the time) than were other spaces.

Disk degeneration was identified in 276 disk spaces in 56 dogs (Table 1). Thirty-two dogs had type I disk degeneration (181 disk spaces), 6 dogs had type II disk degeneration (23 disk spaces), 2 dogs had type III disk degeneration (3 disk spaces), and 16 dogs had multiple types of disk degeneration (69 disk spaces; Figure 1). In 53 of the 56 dogs with disk degeneration, > 1 disk space was affected. In the remaining 3 dogs, disk degeneration involving a single space was identified along with other types of IVDD. In 5 of the dogs with disk degeneration, degenerative disks appeared unrelated to or distant from the disk space associated with clinical signs. In the remaining 51 dogs with disk degeneration, however, a degenerative disk was adjacent to (ie, cranial or caudal) a disk space with bulging of the intervertebral disk, disk protrusion, or disk extrusion.

The 13 dogs without evidence of disk degeneration all had other types of IVDD. Of the 56 cases in which disk degeneration was identified, dispersed disk extrusion was seen in 28 (50%) and nondispersed disk extrusion was seen in 14 (25%). The presence of disk degeneration was not significantly associated with age or with the presence of other types of IVDD.

Bulging of the intervertebral disk was identified in 37 disk spaces in 24 dogs, and disk protrusion was identified in 54 disk spaces in 32 dogs (Figures 2 and 3). Fourteen dogs had both bulging of an intervertebral disk and disk protrusion. Twenty-four dogs with bulging of the intervertebral disk, disk protrusion, or both also had disk extrusion. For cases in which protrusion or bulging was identified, the proportions with dispersed disk extrusion versus nondispersed disk extrusion were not significantly different. Mean ± SD age of dogs with disk protrusion was 7.5 ± 2.5 years; mean age of dogs with bulging of an intervertebral disk was 8.1 ± 3.0 years. In the 32 dogs with disk protrusion, direction of the protrusion was to the right in 5, central in 13, to the left in 5, and in multiple directions in 9.

**Figure 1**—Sagittal T2-weighted magnetic resonance images of 2 dogs with IVDD. **A**—Type I disk degeneration can be seen at L2-3, and type II disk degeneration can be seen at L3-4 (arrows). Notice also the area of extruded disk material dorsal to L4-5 (arrowheads). **B**—Type III disk degeneration can be seen at T11-12 and type III cartilage endplate changes involving the caudal aspect of T11 (arrows). Notice the area of intervertebral disk protrusion at T13-L1 (arrowhead).

Disk extrusion was identified in 50 disk spaces in 48 dogs. Of these, 33 disk spaces (31 dogs) were classified as having dispersed disk extrusion and 17 disk spaces (17 dogs) were classified as having nondispersed disk extrusion. Extruded disk material was characterized by low signal intensity within the epidural space in T1- and T2-weighted images (Figure 4). Forty-six of the 48 dogs with disk extrusion had a single affected disk space, and 2 had 2 affected disk spaces.

Of the 31 dogs with dispersed disk extrusion, 28 (90%) also had disk degeneration and 9 (29%) also had disk protrusion. Of the 17 dogs with nondispersed disk extrusion, 14 (82%) also had disk degeneration, 8 (47%) also had disk protrusion, and 6 (35%) also had bulging of an intervertebral disk. The risk of occurrence of dispersed disk extrusion, nondispersed disk extrusion, and disk degeneration were compared by logistic regression analysis, and there were no significant differences in risk of occurrence.
extrusion, or both was lower for cases in which protrusion, bulging, or both were present, compared with the risk in cases in which protrusion, bulging, or both were absent. Of the 31 dogs with dispersed disk extrusion, 10 had extruded disk material located in the right side of the vertebral canal, 18 had material located in the left side of the vertebral canal, and 3 had material located centrally. Of the 17 dogs with nondispersed disk extrusion, 8 had extruded disk material located in the right side of the vertebral canal, 6 had material located in the left side of the vertebral canal, and 3 had material located centrally. Lateralization of extruded disk material to the right or left side of the vertebral canal was not significantly associated with neurologic status score.

There was a negative association between the presence of bulging of an intervertebral disk and the presence of dispersed disk disease. Similarly, there were negative associations between the presence of disk protrusion and the presence of dispersed disk extrusion and between the presence of dispersed disk extrusion.

Figure 2—Transverse T2-weighted magnetic resonance image of a dog with IVDD. Notice the diffuse extension of the intervertebral disk in all directions (arrows), representing bulging of the disk.

Figure 3—Sagittal T1-weighted magnetic resonance image of a dog with IVDD. Notice the protrusion of the intervertebral disk at T13-L1 (arrowhead). Also notice the type III cartilage endplate changes involving the caudal aspect of T11 (arrow).

Figure 4—Sagittal T1-weighted magnetic resonance images of 2 dogs with IVDD. A—There is evidence of dispersed disk extrusion affecting L4-5. Notice the area of extruded disk material (arrowheads). B—There is evidence of nondispersed disk extrusion affecting T12-13. Notice the buttonlike area of extruded disk material (arrowhead).

Figure 5—Transverse T2-weighted magnetic resonance image of a dog with IVDD. Extruded disk material (EDM) has compressed the spinal cord (SC), causing attenuation of the vertebral canal. There is increased signal intensity in the spinal cord.
Mean ± SD age of dogs with dispersed disk extrusion was 5.7 ± 2.2 years, and age was significantly associated with presence of dispersed disk extrusion. There was no significant association between age and the presence of nondispersed disk extrusion. Mean age of dogs with disk extrusion was 6.0 ± 2.4 years.

Attenuation of the vertebral canal was observed at the site of disk protrusion (n = 3), disk protrusion and bulging (1), disk protrusion and nondispersed disk extrusion (1), nondispersed disk extrusion (12), dispersed disk extrusion (28), and dispersed disk extrusion with nondispersed disk extrusion (1; Figure 5). Mean degree of attenuation of the vertebral canal was 49% (range, 29% to 79%). Degree of attenuation of the vertebral canal was not significantly associated with neurologic status score. The vertebral canal was attenuated in the transverse direction (n = 25), vertical direction (20), or both directions (2).

Cartilage endplate changes were identified in 35 vertebrae in 17 dogs, and in 27 of these vertebrae (15 dogs), cartilage endplate changes were located near a protruding, bulging, or extruded intervertebral disk. In the remaining 2 dogs, cartilage endplate changes were seen involving vertebrae near a disk space with degeneration. Two dogs had type I cartilage endplate changes (Figure 6), 11 had type II changes (Figure 7), and 5 had type III changes (Figure 1). Cartilage endplate changes were identified only in the cranial or caudal aspect of involved vertebrae in 10 dogs, in the cranial and caudal aspects of different vertebrae in 1 dog, and in the cranial or caudal aspect of a single vertebra in 6 dogs. No significant associations were found between the presence of cartilage endplate changes and any particular type of IVDD, but most dogs with such changes were > 5 years old.

Increased signal intensity of the spinal cord was identified in 21 dogs. Of these, 14 had dispersed disk extrusion and 4 had nondispersed disk extrusion. Mean duration of clinical signs for these 18 dogs was 4.6 days. The presence of increased signal intensity was significantly associated with neurologic status score.

Discussion

Thoracolumbar IVDD in dogs was first classified by Hansen, with Hansen type I IVDD defined as herniation of the nucleus pulposus through the annular fibers with subsequent extrusion of nuclear material into the vertebral canal and Hansen type II IVDD defined as annular protrusion caused by shifting of the central nuclear material and commonly associated with fibroid disk degeneration. Subsequently, the terms annular protrusion, protrusion, IVDD, and extrusion have been used by different authors with little agreement as to their explicit meaning. Radiography, myelography, and histology have been used in most previous studies of thoracolumbar IVDD in dogs, but there is no consensus concerning the nomenclature used to describe disk abnormalities, leading to confusion when results from various investigators are compared. For this reason, we believe that adoption of a standardized nomenclature for the assessment of various types of thoracolumbar IVDD in dogs is important. In the present study, we identified 4 types of IVDD (disk degeneration, bulging of the intervertebral disk, disk protrusion, and disk extrusion) on the basis of MRI findings.

Degenerative changes in intervertebral disks have been identified by means of histologic and biochemical...
analyses in chondrodystrophic and nonchondrodystrophic breeds. All intervertebral disks in dogs are susceptible to degeneration, and a postmortem examination of 100 dogs with suspected disk extrusion revealed a mean of 2.5 disk extrusions/dog. In the present study, only dogs with neurologic deficits related to the thoracolumbar area (ie, T9 through L7) were included. Of the 759 disks that were examined, 417 (54.9%) had evidence of some type of IVDD. Importantly, we did not detect any significant associations among the various types of IVDD with regard to certain types occurring together. Thus, the fate of degenerative disks observed in conjunction with disk protrusion or extrusion in some dogs seemed obscure, and there was no indication whether disk degeneration, which was thought to be clinically unimportant, could be a predisposing factor for extrusion. The same uncertainty applies with regard to whether bulging and protrusion could result in extrusion. Increasing the number of cases diagnosed by means of MRI would be helpful in clarifying the frequency of IVDD and the underlying pathophysiology.

The decreased signal intensity evident on T2-weighted images of degenerative disks is associated with progressive degenerative changes in the disk. The brightness of the nucleus pulposus correlates with proteoglycan concentration but not with water or collagen concentration. However, mineralization of the disk cannot be diagnosed definitely by means of MRI because changes associated with mineralization could be mistaken for changes associated with other lesions. The present study, disk degeneration was subclassified into 3 subtypes on the basis of criteria used for classifying disk degeneration in people.

Results of the present study clearly demonstrate that IVDD can occur at multiple sites in individual dogs. Thus, in a dog with neurologic deficits, a combination of MRI and clinical findings should be used to determine the disk space causing clinical signs. Importantly, our findings suggest that disk degeneration, bulging of the intervertebral disk, and disk protrusion might not be associated with any clinical signs.

Bulging of the intervertebral disk is anatomically different from disk protrusion or degeneration. With bulging, the disk extends diffusely to the vertebral canal. In contrast, protrusion represents a shift in the location of the nucleus pulposus secondary to rupture of the innermost annular fibers at a single point in 1 direction. Thus, in the present study, extension of the disk in a single direction was regarded as protrusion. The presence of both bulging and protrusion in elderly dogs was interpreted to be a result of alterations in the disks that occur with aging. Because the presence of bulging was negatively associated with the presence of dispersed disk extrusion and the presence of protrusion was negatively associated with the presence of nondispersed disk extrusion, it can be speculated that bulging does not progress to dispersed disk extrusion and protrusion does not progress to nondispersed disk extrusion.

Hansen type I IVDD is commonly referred to as disk extrusion, but there is controversy about the nomenclature of IVDD and the use of the term extrusion in the veterinary literature. In the present study, 2 types of extrusion—dispersed and nondispersed—were identified. Such a subclassification was possible because the borders of any extruded disk material, along with the spinal cord and other soft tissue related to the spine, could be clearly identified on magnetic resonance images. Interestingly, most dogs with dispersed disk extrusion were < 7 years old, and age was significantly associated with presence of dispersed disk extrusion. In contrast, age was not significantly associated with the presence of nondispersed disk extrusion. Thus, whether extruded disk material becomes dispersed may be related to differences in chemical composition associated with aging.

The cartilage endplate is the anatomic boundary of the intervertebral disk. Because intervertebral disks are avascular, they receive nutrition by diffusion. The capillary network that nourishes the central region of the disk is adjacent to the cartilage endplate, and nutrients must first diffuse through this cartilage before reaching the nucleus pulposus. The cartilage endplates also play a role in the biomechanics of the spine through enhancement of the spine’s ability to absorb axial loads. Age-related changes in the cartilage endplate have been reported by many authors, but what relationship, if any, such changes have with disk degeneration remains doubtful in human medicine. Cartilage endplate changes evident on magnetic resonance images have been classified into 3 general types in people with and without clinical signs. In the present study, cartilage endplate changes were seen in vertebrae adjacent to disks with various types of IVDD, and all 3 types defined in people were identified in these dogs. Interestingly, in 10 of the 17 dogs with cartilage endplate changes, these changes involved only the cranial or caudal aspect of the affected vertebrae.

Taken together, our findings suggest that cartilage endplate changes may be related to or play a role in the development of IVDD. Cartilage endplate changes were also observed in dogs > 5 years old. No clear conclusions can be drawn from our data to suggest that cartilage endplate changes were present adjacent to intervertebral disks that were not causing any clinical signs because it could not be determined with certainty which disk was causing clinical signs in all dogs. Dogs in the present study had various grades of paraparesis or paresis, and it may also be seen in dogs.

Increased spinal cord signal intensity evident on magnetic resonance images represents edema, hemorrhage, or myelomalacia during the acute phase of spinal cord injuries, whereas it represents gliosis in the chronic phase. Cases included in the present study were gen...
erally examined during the chronic stage of spinal cord injury, and alterations in spinal cord signal intensity that were seen generally corresponded with clinical findings. In contrast, the degree of vertebral canal attenuation was not significantly associated with neurologic status.

Breed, age, and sex distributions and distribution of affected intervertebral disks in the present study were broadly similar to distributions reported in previous studies.14,15 In this population, Pekingese was the predominant breed, and the T12-L3 and L3-L4 disk spaces were the most commonly affected.

Multiple disks were found to be affected in some dogs in the present study. The benefits of prophylactic disk fenestration in dogs with IVDD remain controversial.16,17 It is possible that MRI of additional dogs with IVDD will help clarify in which dogs prophylactic fenestration is likely to be of benefit.

References