# Comparison between non-contrast computed tomography and magnetic resonance imaging for detection and characterization of thoracolumbar myelopathy caused by intervertebral disk herniation in dogs

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Running head: MRI and CT for diagnosing thoracolumbar disk disease in dogs

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Abstract

Magnetic resonance (MR) imaging and computed tomography (CT) are commonly used to image the vertebral column in dogs with thoracolumbar myelopathy. The purpose of this prospective study was to compare diagnostic sensitivity and observer agreement for these two tests in a group of dogs with surgically confirmed thoracolumbar myelopathy due to intervertebral disk herniation (IVDH). All included dogs had MR imaging followed by non-contrast CT using standardized protocols. Two board-certified radiologists and one board-certified neurologist interpreted each imaging study independently without knowledge of clinical or surgical findings. The operating surgeon was aware of MR findings but not CT findings at the time surgical findings were recorded. Forty-four dogs met the inclusion criteria. The sensitivity of CT was 88.6% (79.5%-94.2%) and of MR was 98.5% (95% confidence interval, 94.1%-99.7%) for diagnosis of intervertebral disk herniation. Specificity was not calculated, as all dogs had IVDH at surgery. Magnetic resonance imaging was more accurate than CT for correctly identifying the site of intervertebral disk herniation-associated spinal cord compression and differentiating disk extrusion versus protrusion. Computed tomography was less accurate for diagnosis of lesion location for peracute cases of IVDH, as well as for chondrodystrophic, female, older and smaller (<7kg) dogs. Inter-rater agreement was good for determining lesion lateralization for both MR and CT ($\kappa$=0.687, 95% CI=0.552, 0.822, P=0.002, and $\kappa$=0.692, 95% CI=0.542, 0.842, P=0.003). Findings from the current study indicated that MR imaging was more sensitive

and accurate than non-contrast CT for diagnosis and characterization of thoracolumbar myelopathy due to IVDH in dogs.

## Introduction

Thoracolumbar myelopathy is a common indication for vertebral column imaging in dogs. Clinical signs may include vertebral column pain, paraparesis or paraplegia, and pelvic limb ataxia. Common causes of thoracolumbar myelopathy in dogs include both compressive and non-compressive intervertebral disk herniation, diskospondylitis (as a result of fibrous tissue proliferation, inflammation, or secondary disk extrusion), fibrocartilagenous embolism, meningomyelitis, trauma, congenital malformations, degenerative disease, and neoplasia.[1,2]

Myelography, computed tomography (CT) and magnetic resonance (MR) imaging are standard techniques currently utilized for vertebral column imaging in dogs.[3] Many canine studies have compared the sensitivities of various CT techniques with myelography for detecting intervertebral disk herniation.[4-8] Computed tomography has been found to have a similar sensitivity compared to myelography for the identification of canine intervertebral disk herniation (82% versus 84%).[6] Additionally, CT was shown to have increased sensitivity for identification of herniated disk material in larger dogs with more chronic lesions, while myelography was found to be better than CT for diagnosing intervertebral disk herniation in dogs that weighed <5 kg.[6] Non-contrast CT has been shown to be adequate for identification of intervertebral disk herniation in chondrodystrophic dogs,[4,9] but CT-myelography is often necessary to indicate lateralization of intervertebral disk herniation lesions in cases where spinal cord swelling is present, as

well as in non-chondrodystrophic dogs.[4] One crucial limitation of CT and myelography is that spinal cord parenchymal changes are poorly depicted and this limitation may hamper the diagnosis of diseases such as non-compressive intervertebral disk herniation, fibrocartilagenous embolism, and meningomyelitis.[4] Additionally, the inability to detect spinal cord parenchymal changes via CT and myelography restricts the use of these modalities to generate prognostic data in thoracolumbar intervertebral disk herniation; these data can be readily obtained via T2 weighted MR sequences of the spinal cord.[13,14]

Magnetic resonance imaging is now available in most veterinary teaching hospitals and private referral centers. While the accuracy of MR imaging versus myelography has been studied for the detection of intervertebral disk herniation in dogs,[15] direct comparisons between CT and MR imaging have not yet been made to the authors' knowledge. The goals of this prospective study were to compare MR imaging and CT studies in dogs with thoracolumbar spinal cord disease due to intervertebral disc herniation and to assess the following: 1) the relative diagnostic sensitivity of both modalities for detection of intervertebral disk herniation and determination of location, side (right, left, ventral), and type of herniation (extrusion versus protrusion); 2) estimate rater agreement for diagnosing and identifying the location, side, and type of intervertebral disk herniation; and 3) estimate rater agreement in assessing the spinal cord and in performing morphometric measurements (e.g., T2-weighted hyperintensity and compressive length ratio). Our hypotheses were 1) that CT would be less sensitive than MR for diagnosis of thoracolumbar intervertebral disk herniation; and 2) that rater agreement would be stronger when MR was utilized to assess lesion location, side, and type of intervertebral disk herniation compared to CT.

Materials and Methods

**Animals-** All dogs included in the study were evaluated at Texas A&M University Veterinary Medical Teaching Hospital between October 2009 and August 2011 for neurological clinical signs that were localized to the T3-S1 spinal cord segments. Dogs that were diagnosed with, and had surgical confirmation of thoracic or lumbar intervertebral disk herniation were included in the study. Dogs that had previous surgery for intervertebral disk herniation or had known systemic diseases that would pose an increased risk for anesthetic-related complications were excluded from the study. Owner consent was obtained prior to study enrollment using standard documents approved by the Texas A&M University College of Veterinary Medicine and Biomedical Sciences Clinical Research Review Committee.

**Procedures** - Complete physical and neurologic examinations were performed in all dogs at admission. Neurologic signs were evaluated and localized by a board-certified neurologist, neurology or surgery resident and were graded using the following modified Frankel scale: paraplegia with absent deep nociception (grade 0), paraplegia with intact deep but not superficial nociception (grade 1), paraplegia with intact superficial nociception (grade 2), non-ambulatory paraparesis (grade 3), ambulatory paraparesis and ataxia (grade 4), and paraspinal hyperesthesia only (grade 5).[16] Dogs were anesthetized following the neurologic examination using an individual protocol based on patient requirements as determined by the Texas A&M anesthesia service.

Diagnostic imaging of the thoracolumbar vertebral column was performed using a 1 Tesla MR imaging system (Siemens Magnetom Expert, New York, NY) incorporating sagittal and transverse T2-weighted images and dorsal short-tau inversion recovery (STIR) imaging sequences. These three sequences comprise an abbreviated study utilized for Dachshunds with clinical signs of thoracolumbar myelopathy at our hospital. For non-Dachshund breeds additional sequences may have been performed but only the transverse and sagittal T2-weighted and dorsal STIR images were distributed to observers for the purposes of this study. MR parameters (TE, TR and slice thickness) were varied according to the specific needs of the patients (T2W: TR 3500-4500ms, TE 90-99ms, NEX 2-3, slice thickness 2.0 (sagittal) and 3.0mm (transverse), interslice gap 0.16-0.19mm (sagittal) and 0.24-0.30mm (transverse), field of view 19.9cm$^2$-22.4cm$^2$ (sagittal) and 13.2cm$^2$-14.9cm$^2$ (transverse), matrix 256x420-256-440) (STIR: TR 4000ms, TE 30ms, NEX 2-3, slice thickness 2.0, interslice gap 0.18mm, field of view 24.9cm$^2$, matrix 256x420-256x504). Transverse CT images of the thoracolumbar spine were obtained using a GE light speed quadslice multidetector helical scanner (GE Medical Systems, Milwaukee, WI) immediately after MR imaging. Dogs were placed in dorsal recumbency and the standard protocol used was contiguous 2.5mm slice acquisition (120kV, 235.0 mA), then reconstruction in a low spatial resolution ("soft tissue") algorithm at 2.5 mm slice thickness and high spatial resolution ("bone") algorithm at 1.3 mm slice thickness. Viewers were allowed to alter window width and level according to preference. MR images were used for clinical decision making as per institutional standards and CT images were not interpreted at the time of acquisition.

**Clinical Data Collected-** Age, gender, breed, body weight, duration of clinical signs prior to imaging, and the duration of imaging studies were recorded from the anesthesia record. Dogs were classified as chondrodystrophoid or non-chondrodystrophoid based on previously published criteria.[17-21] The following additional data were obtained from the operating surgeon: 1) the vertebral articulation over which compression was most severe (lesion location) at the time of hemilaminectomy; 2) the side over which the hemilaminectomy was performed; and 3) the type of disk herniation that was present (extrusion versus protrusion) based on visual inspection.

**Image Analysis-** One transverse thoracolumbar (T3-L7 vertebral bodies) CT sequence and 1 thoracolumbar (T8-L7 vertebral bodies) MR study were evaluated for each patient. For the CT images, window width and level adjustment was allowed, as was use of multi-planar reformatting software. Scout, transverse and sagittal T2-weighted, and dorsal STIR sequences were included in each individual MR study. Image readers were unaware of patient signalment and case history, other than that all patients were imaged for signs of thoracolumbar myelopathy. Two board-certified radiologists (B.Y. and J.G.) and one board-certified neurologist (J.L.) interpreted each study individually.

Instructions for interpretation were identical for CT and MR studies. Interpreters were asked to identify whether or not there was a lesion present (yes/no), characterize the type of lesion (intramedullary, intradural-extramedullary, extradural or lesion present/cannot characterize). Interpreters were asked to further characterize the lesion as compressive intervertebral disk herniation, ischemic myelopathy, myelitis, neoplasia, diskospondylitis, syringohydromyelia, hemorrhage, trauma, or malformation whenever

possible. For the purposes of this study, ischemic myelopathy encompassed both non-compressive disk extrusion (NCDE) and fibrocartilagenous embolism (FCE), and was defined as a sharply marginated T2-weighted hyperintensity of the spinal cord.[22,23] No analogous CT characteristic was used. Imaging diagnoses of presumptive myelitis,[24,25] diskospondylitis,[1,26-29] spinal neoplasia,[30] or trauma[31] were based on previously published characteristic CT or MR imaging findings.

If intervertebral disk herniation was identified, reviewers were instructed to locate the site of greatest cord compression. This was based on 1 or more of the following criteria: displacement of epidural fat or cerebrospinal fluid at the lesion site, presence of presumed disk material within the vertebral canal, deformation of the spinal cord dorsal to an intervertebral disk space, or signal changes/changes in density in the local epidural region of a disk consistent with hemorrhage or disk material. The primary location of compressive material was recorded to be right, left or ventral to the spinal cord, with lateralization reflecting the recommended surgical approach that would allow the most complete access to the herniated material. Interpreters noted if the herniation was an extrusion, protrusion, or if they were uncertain. An extrusion was defined as a complete tear of the dorsal annulus with material consistent with nucleus pulposus within the vertebral canal or intervertebral foramen compressing neural and/or vascular structures.[32] A protrusion was defined as a lesion compressing neural and/or vascular structures which had an attachment with the annulus fibrosis that was greater in length than the distance of displacement into the vertebral canal in any imaging plane.[32]

Sagittal T2-weighted sequences were used to determine whether or not hyperintensity was present in the spinal cord at the level of the compressive lesion. The

compression ratio and compression length ratio were calculated by all three observers for each intervertebral disk herniation case on sagittal reformatted CT images. The compression ratio was not calculated for cases where disk herniation was not detected on CT. The compression ratio was calculated by dividing the height of the maximally compressed spinal cord by the total height of the vertebral canal at the level of compression (Figure 1A,B). The compression length ratio was calculated by adding the width of the number of transverse slices over which compression was seen and dividing by the length of the second lumbar vertebral body.

**Statistical Analysis**

Statistical analysis was designed and performed by one author (GF) by manually entering formulae into a spreadsheet program (design effect, kappa), free software (confidence intervals; Epi Info, version 6.04, CDC, Atlanta, GA) and commercially available software (Intra-class correlation, logistic regression, Wilcoxon signed-rank tests; IBM SPSS Statistics, version 21.0; IBM Corporation, Armonk, NY). Clinical data were summarized using frequencies for categorical variables and medians and inter-quartile ranges for quantitative variables. Quantitative data were dichotomized based on the median to estimate the effect of the variable on accuracy estimates. Accuracy of CT and MRI was estimated by calculating the proportion of surgery confirmed intervertebral disk herniation cases in which the location of the lesion, predominant lesion side, and protrusion versus extrusion was correctly identified by the evaluator. The design effect was estimated to account for the dependency among repeated observations and used to adjust confidence intervals (CI).[33] Accuracy measures were compared between CT and MRI

using binary logistic regression including dog as a random effect and a fixed effect for imaging modality. Inter-rater agreement was estimated by calculating the kappa statistic for categorical and the intra-class correlation for quantitative variables.[34] Strength of agreement was determined based on the following values: ≤ 0.20 poor agreement, 0.21-0.40 fair agreement, 0.41-0.60 moderate agreement, 0.61-0.80 good agreement, and 0.81-1.00 very good agreement.[35] Procedure time was compared using Wilcoxon signed-rank tests. Statistical results were interpreted at the 5% level of significance.

**Results**

Fifty-three dogs were enrolled in the study, with 44 meeting inclusion criteria. Dogs were excluded either because intervertebral disk herniation was not treated surgically (n=3) or because thoracolumbar myelopathy was due to a different disease process (n=6). Represented breeds included miniature Dachshund (n=26), Cocker Spaniel (n=2), Beagle (n=2), Bichon Frise (n=2), miniature Poodle (n=2), and 1 each of the following: Bassett Hound, Jack Russell Terrier, Yorkshire Terrier, Pug, Chihuahua, Lhasa Apso, English Bulldog, Papillon, Pekingese, and mixed breed dog. In total there were 33 chondrodystrophic and 11 non-chondrodystrophic dogs enrolled in the study. The study population included 1 intact female dog, 23 spayed female dogs, 7 intact male dogs, and 13 neutered male dogs. Study dogs had a median weight of 6.9 kg (range, 3-16 kg) and the median duration of clinical signs prior to presentation was 2 days (range <1-60 days). The median modified Frankel score at presentation was 3 (range 0-5). Median scan times were 55 min (range, 25–145 minutes) for MR imaging and 20 min (range, 4-45 minutes) for CT ($P<0.001$).

The primary sites of surgically confirmed intervertebral disk herniation were as follows: T13-L1 (n=12), T12-T13 (n=8), L1-L2 (n=6), T11-T12 (n=6), L3-L4 (n=5), L2-L3 (n=4) and L4-L5 (n=3). Hyperintensity of the spinal cord locally in the area of disk herniation was noted on T2 weighted sagittal images in 18/44 dogs.

The relative sensitivity of MR for detecting intervertebral disk herniation lesions in dogs with surgically confirmed disease was 98.5% (95% confidence interval [CI] 94.1-99.7%) vs. 88.6% for CT (CI 79.5-94.2% P=<0.001). Computed tomography correctly identified the vertebral articulation over which intervertebral disk herniation was located 84.1% of the time (Table 1). MR was more accurate than CT for locating intervertebral disk herniation lesions in peracute intervertebral disk herniation (≤1day duration; P=0.014). Computed tomography correctly diagnosed a lower proportion of chondrodystrophic dogs (P=0.036). Computed tomography was less accurate for identifying the location and lateralization of intervertebral disk herniation in dogs that were >5 years old (P=0.003), those <7kg (P=0.027), and female dogs (P=0.005) (Table 2). The determination of lateralization in non-chondrodystrophic dogs was more accurate using MR (P=0.044). Magnetic resonance was more accurate compared to CT in differentiating disk extrusion versus protrusion (Table 3).

Inter-rater agreement was good for determining lesion lateralization for both MR and CT ($\kappa$=0.687, 95% CI=0.552, 0.822, P=0.002, and $\kappa$=0.692, 95% CI=0.542, 0.842, P=0.003) (Table 4). Inter-rater agreement for MR detection of intervertebral disk protrusion versus extrusion was poor but nearly all evaluators noted an extrusion (96.2%). Inter-rater agreement for MR detection of T2-weighted hyperintensity was fair. Inter-rater agreement for the detection of protrusion versus extrusion using CT was also fair ($\kappa$=0.377,

95% CI=0.099, 0.656, P=0.008). Intra-class correlation was moderate for measurement of the compression ratio, but was considered good for measurement of compression length (Table 4).

**Discussion**

Despite the fact that both CT and MR are widely used, there has been a lack of published evidence to support the preferential use of either modality for dogs with thoracolumbar myelopathy. We prospectively performed both MR and CT studies in a group of dogs with clinical signs of thoracolumbar myelopathy and surgically confirmed intervertebral disc herniation. We found that non-contrast CT had a high relative sensitivity (88.6%) when compared with MR, but MR sensitivity was greater (98.5%). A limitation of our study was that these measures were not adjusted for prevalence and since the included population was comprised solely of dogs with intervertebral disk herniation, specificity could not be evaluated. Another important observation was that CT was less accurate than MR for correctly identifying the site of intervertebral disk herniation - associated spinal cord compression and differentiating disk extrusion versus protrusion. There was high inter-rater agreement for both CT and MR for detecting intervertebral disk herniation. Inter-rater agreement was lower for the identification of the side of the lesion and differentiation of protrusion versus extrusion in both imaging modalities.

Our results indicated that MR may be more useful than CT for diagnosis of lesion location for peracute cases of intervertebral disk herniation, as well as for chondrodystrophic, female, older and smaller (<7kg) dogs. The latter was an unexpected finding since one would expect chondrodystrophic and older dogs both to have increased

mineralization of the nucleus pulposus, which would increase conspicuity of disk herniation by increasing the attenuation of the extruded material on CT. In this study our population of non-chondrodystrophic dogs was significantly smaller than the chondrodystrophic population. A more balanced population with higher numbers of non-chondrodystrophic dogs might have revealed significance for both variables. Small dogs (<5 kg) with intervertebral disk herniation have previously been shown to be more likely to have a diagnostic myelogram compared to CT,[6] and it was therefore not unexpected that MR was better than CT at detecting intervertebral disk herniation in small patients.

The strong association between MR accuracy and female dogs in every category evaluated (location, lateralization, extrusion versus protrusion) also was not expected. It is possible that there could be a difference in the degenerative process of disk disease between sexes that affects conspicuity of extruded material using CT. In people, differences in prevalence of different types of vertebral column disease have been noted between sexes and are thought to be due to hormonal differences.[36] Additional investigation would be needed in order to determine whether there is truly a disparity or if this was an anomalous finding.

The MR portion of this study only included T2-weighted transverse and sagittal and dorsal STIR sequences. A previous manuscript reported that sensitivity and specificity of MR for site and side identification were both 100% when T2-weighted sequences were evaluated alongside T1-weighted pre- and post-contrast sequences.[15] Since decision-making about the selection of additional sequences can be made in real time during an MR study the clinician could theoretically request additional sequences as necessary to increase sensitivity.

Magnetic resonance imaging out-performed CT in differentiating disk extrusion versus disk protrusion (94.4% versus 85.7% proportion correct). While this distinction may have only minor clinical importance in some dogs, it may be critical to surgical decision-making in dogs with multiple intervertebral disk herniation lesions and acute progression of neurologic signs.

While studies in humans and a previous veterinary study comparing myelography to MR support the claim that MR is the most sensitive modality to detect intervertebral disk herniation, some authors have questioned whether MR enhances outcome in dogs with vertebral column disease. A recent large-scale retrospective study found that dogs that had myelography versus MR for the diagnosis of thoracolumbar spinal cord diseases did not have differences in clinical outcome. Additionally, MR was associated with increased client financial cost and increased imaging time.[37] The authors of the current study postulate that the enhanced relative sensitivity of MR compared to other modalities for the identification and characterization of thoracolumbar intervertebral disk herniation could have important clinical effects despite the lack of improved outcome. For example, performing a hemilaminectomy at the incorrect location or side of the vertebral column could negatively impact the degree of surgical decompression. Likewise, the poor depiction of the spinal cord parenchyma with myelography or conventional CT limits the ability to diagnose diseases such as fibrocartilagenous embolism, non-compressive intervertebral disk herniation, myelitis, and intramedullary neoplasia[38] which may result in a non-diagnostic imaging study, diagnostic delay, and/or unnecessary surgical decompression. Additionally, for some non- intervertebral disk herniation diseases such as fibrocartilagenous embolism and for both non-compressive and compressive

thoracolumbar intervertebral disk herniation, MR findings may provide important prognostic data regarding motor outcomes.[13,14,22,23] Although the degree of spinal cord compression by extruded disk material seen on MR has not been shown to be associated with postsurgical outcome regardless of chondrodystrophoid status,[39] important prognostic information has been identified using the sagittal T2-weighted MR sequence.[13,14] Dogs with intervertebral disk herniation and associated T2-weighted hyperintensity have been shown to have a lower neurologic score prior to imaging and are less likely to be ambulatory at >3 month follow-up.[14] Magnetic resonance imaging may also offer ante-mortem evidence of myelomalacia, with extensive T2-weighted hyperintensity being a possible characteristic of development of this devastating complication.[40]

Because of the prognostic value of T2-weighted hyperintensity in intervertebral disk herniation cases, we evaluated the inter-rater agreement for the 3 observers in this study. Surprisingly, the inter-rater agreement was only fair, which was much lower than anticipated. Likewise, the morphometric measures assessed on CT also had only fair inter-rater agreement. As all three observers were experienced with MR and CT for the identification of spinal disease, the rater variability in assessed measures is difficult to attribute to differences between raters in experience level. Of the two previous studies that investigated the prognostic value of T2-weighted hyperintensity, one was performed on a low-field MR system[13] and in the other the data were interpreted by a single experienced observer.[14] Our study showed that detection of T2-weighted hyperintensity was not very reliable. Additional investigation into the inter-rater agreement of T2-weighted hyperintensity and reliability as a prognostic indicator should be considered.

There are certainly disadvantages of MR with increased cost being the most obvious. Lack of availability of MR units or neurologists and/or surgeons comfortable with image interpretation may also be a limitation in some areas. There are also patient-related contraindications for MR imaging. Animals with artificial pacemakers are not candidates for MR imaging.[38] Surgical implants and identification microchips are typically not a direct contraindication from a safety standpoint, but if metal implants are near the region of interest then an artifact may obstruct visualization of the area.[41,42] Artifacts from nearby metal can also occur with CT,[43] and in some cases myelography may allow the best visualization of the region of interest. Another disadvantage of MR is the time it takes to complete the imaging study. In our study CT acquisition time was significantly shorter than for MR imaging studies. It is worth noting that in our study population there was fairly wide variation in MR study duration. One possible explanation for this is that duration was recorded as the entire study duration. Since the MR images were used for clinical decision-making, some dogs required additional imaging sequences although only T2-weighted transverse and sagittal and dorsal STIR images were reviewed for the purposes of this study. Perhaps these data could be improved upon by evaluating a narrowed enrollment population of small breed dogs with acute intervertebral disk herniation. This might allow a more accurate, and potentially briefer duration for MR in these cases.

The limitations of this study primarily lie with the use of surgical confirmation as the gold standard for diagnosis of intervertebral disk herniation and the use of MR to make diagnoses when dogs were initially evaluated. Surgeons used MR studies to guide clinical decision-making and therefore it is difficult to consider surgical findings as a stand-alone gold standard.[44] It is possible that surgeons were biased by MR findings when they

recorded their surgical findings. For our particular study design we found no alternative gold standard superior to surgery for confirmation and characterization of disk herniation. In dogs that had multiple sites of disk herniation, only the site of suspected clinical importance was operated. It would be considered routine procedure to operate a second site if the first of multiple was entered and a chronic disk herniation was found and was unexpected, but it would not be considered clinically appropriate to surgically investigate every site of disk herniation. That said, without surgical exploration of every site it is difficult to definitively prove that the site determined by imaging to be of highest clinical importance was truly correct or not. We attempted to minimize bias by requiring image observers to independently read the imaging studies while blinded to all clinical information aside from knowing the overall purpose of the study.[45,46] Patient sample selection bias was something that was difficult to minimize with our study design. At our institution MR is considered the standard of care for vertebral column imaging and we did not feel that it would have been ethical to use CT as the primary modality for clinical decision-making, especially if the scenario arose where the CT was negative and MR revealed surgical disk herniation in retrospect. Similarly, the time under anesthesia would have been prolonged if we went through the steps of CT, CT with intravenous contrast, MR then surgical decompression. Using our study design, it was not possible to have a surgically confirmed CT positive, MR negative disk herniation which diminished our ability to weight comparisons between MR and CT for lesion location and lateralization. However, variables like herniation characterization and inter-rater agreement could still be compared directly.

In conclusion, findings from the current study indicated that non-contrast CT studies are highly sensitive for the diagnosis of intervertebral disk herniation in dogs and scan times are shorter than MR scan times. The sensitivity of MR was greater than CT for the diagnosis of thoracolumbar intervertebral disk herniation and for the determination of lesion location, type of disk herniation, and lateralization in some dogs. The current study had limitations in that selection bias existed and therefore results should be interpreted with caution. While MR T2-weighted images may provide prognostic data in the setting of thoracolumbar intervertebral disk herniation, there was only fair inter-rater agreement regarding the presence of high T2 signal using sagittal images only.

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Figure Legend

Figure 1. Calculation of the compression ratio was achieved by dividing the height of the spinal cord (black line, panel A) at the site of maximal compression on transverse images by the total height of the vertebral canal (black line, panel B).

**Table 1.** Comparison of magnetic resonance imaging (MRI) and computed tomography (CT) for identification of lesion location in 44 dogs with surgically confirmed intervertebral disk herniation (IVDH) from a single veterinary referral center.

| | | | MRI | CT | |
|---|---|---|---|---|---|
| **Variable** | **Category** | **n** | **PE (95% CI)** | **PE (95% CI)** | **P value*** |
| Duration | ≤ 1 day | 18 | 0.963 (0.833, 0.996) | 0.815 (0.650, 0.916) | 0.014 |
| | > 1 day | 26 | 0.910 (0.794, 0.969) | 0.859 (0.721, 0.938) | 0.280 |
| Breed | Chondrodystrophic | 35 | 0.962 (0.870, 0.992) | 0.886 (0.780, 0.946) | 0.036 |
| | Other breeds | 9 | 0.815 (0.595, 0.935) | 0.667 (0.412, 0.856) | 0.178 |
| Age | ≤ 5 yrs | 23 | 0.942 (0.851, 0.981) | 0.957 (0.862, 0.990) | 0.675 |
| | > 5 yrs | 21 | 0.921 (0.766, 0.981) | 0.714 (0.548, 0.840) | 0.003 |
| Weight | < 7 kg | 23 | 0.913 (0.778, 0.973) | 0.783 (0.632, 0.885) | 0.027 |
| | ≥ 7 kg | 21 | 0.952 (0.850, 0.989) | 0.905 (0.760, 0.970) | 0.254 |
| Sex | Female | 24 | 0.958 (0.814, 0.995) | 0.806 (0.649, 0.906) | 0.005 |
| | Male | 20 | 0.900 (0.783, 0.960) | 0.883 (0.754, 0.952) | 0.745 |
| Overall | | 44 | 0.932 (0.856, 0.971) | 0.841 (0.744, 0.907) | 0.014 |

PE = point estimate of proportion correct. CI = confidence interval.
* Based on a binary logistic regression model including dog as a random effect and fixed effect for imaging modality

**Table 2.** Comparison of magnetic resonance imaging (MRI) and computed tomography (CT) for identification of lesion side in 44 dogs with surgically confirmed intervertebral disk herniation (IVDH) from a single veterinary referral center.

| Variable | Category | n | MRI PE (95% CI) | CT PE (95% CI) | P value* |
|---|---|---|---|---|---|
| Duration | ≤ 1 day | 18 | 0.854 (0.699, 0.940) | 0.813 (0.631, 0.921) | 0.636 |
| | > 1 day | 26 | 0.871 (0.756, 0.939) | 0.779 (0.621, 0.887) | 0.298 |
| Breed | Chondrodystrophic | 35 | 0.844 (0.748, 0.910) | 0.817 (0.694, 0.900) | 0.855 |
| | Other breed | 9 | 0.950 (0.731, 0.997) | 0.696 (0.393, 0.898) | 0.044 |
| Age | ≤ 5 yrs | 23 | 0.891 (0.782, 0.951) | 0.938 (0.799, 0.987) | 0.336 |
| | > 5 yrs | 21 | 0.826 (0.669, 0.921) | 0.608 (0.432, 0.761) | 0.047 |
| Weight | < 7 kg | 23 | 0.895 (0.778, 0.956) | 0.714 (0.547, 0.840) | 0.032 |
| | ≥ 7 kg | 21 | 0.830 (0.683, 0.920) | 0.887 (0.725, 0.963) | 0.302 |
| Sex | Female | 24 | 0.898 (0.785, 0.958) | 0.708 (0.539, 0.836) | 0.018 |
| | Male | 20 | 0.824 (0.676, 0.916) | 0.902 (0.763, 0.967) | 0.117 |
| Overall | | 44 | 0.864 (0.782, 0.919) | 0.793 (0.682, 0.874) | 0.263 |

PE = point estimate of proportion correct. CI = confidence interval.
* Based on a binary logistic regression model including dog as a random effect and fixed effect for imaging modality

**Table 3.** Comparison of magnetic resonance imaging (MRI) and computed tomography (CT) for recognition of protrusion versus extrusion of disk material in 44 dogs with surgically confirmed intervertebral disk herniation (IVDH) from a single veterinary referral center.

| Variable | Category | n | MRI PE (95% CI) | CT PE (95% CI) | P value* |
|---|---|---|---|---|---|
| Duration | ≤ 1 day | 18 | 0.962 (0.857, 0.993) | 0.843 (0.675, 0.937) | 0.049 |
| | > 1 day | 26 | 0.932 (0.841, 0.975) | 0.867 (0.712, 0.949) | 0.093 |
| Breed | Chondrodystrophic | 35 | 0.961 (0.897, 0.987) | 0.911 (0.815, 0.962) | 0.105 |
| | Other breed | 9 | 0.870 (0.639, 0.969) | 0.640 (0.329, 0.873) | 0.029 |
| Age | ≤ 5 yrs | 23 | 0.985 (0.907, 0.999) | 1.0 (0.931, 1.0) | 0.793 |
| | > 5 yrs | 21 | 0.898 (0.785, 0.958) | 0.700 (0.523, 0.835) | 0.003 |
| Weight | < 7 kg | 23 | 0.953 (0.860, 0.988) | 0.803 (0.635, 0.909) | 0.006 |
| | ≥ 7 kg | 21 | 0.934 (0.832, 0.979) | 0.917 (0.775, 0.976) | 0.688 |
| Sex | Female | 24 | 0.957 (0.870, 0.989) | 0.826 (0.679, 0.917) | 0.009 |
| | Male | 20 | 0.929 (0.819, 0.977) | 0.895 (0.708, 0.973) | 0.586 |
| Overall | | 44 | 0.944 (0.884, 0.975) | 0.857 (0.753, 0.924) | 0.010 |

PE = point estimate of proportion correct. CI = confidence interval.
* Based on a binary logistic regression model including dog as a random effect and fixed effect for imaging modality

**Table 4.** Agreement and evaluator confidence for magnetic resonance imaging (MRI) and computed tomography (CT) in 44 dogs with surgically confirmed intervertebral disk herniation (IVDH) from a single veterinary referral center.

| Imaging modality | Measure | Variable | n | Agreement PE (95% CI) | P value |
|---|---|---|---|---|---|
| MRI | Kappa | Lesion side | 44 | 0.687 (0.552, 0.822) | 0.002 |
| | | Protrusion/extrusion | 44 | 0.004 (0.000, 0.182) | 0.962 |
| | | T2WH presence | 44 | 0.386 (0.212, 0.560) | <0.001 |
| CT | Kappa | Lesion side | 42 | 0.692 (0.542, 0.842) | 0.003 |
| | | Protrusion/extrusion | 42 | 0.377 (0.099, 0.656) | 0.008 |
| | Intra-class correlation | Compression ratio | 37 | 0.402 (0.204, 0.598) | <0.001 |
| | | Compression length | 36 | 0.675 (0.515, 0.804) | <0.001 |

PE = point estimate of kappa or intra-class correlation. CI = confidence interval. T2WH = T2-weighted hyperintensity.

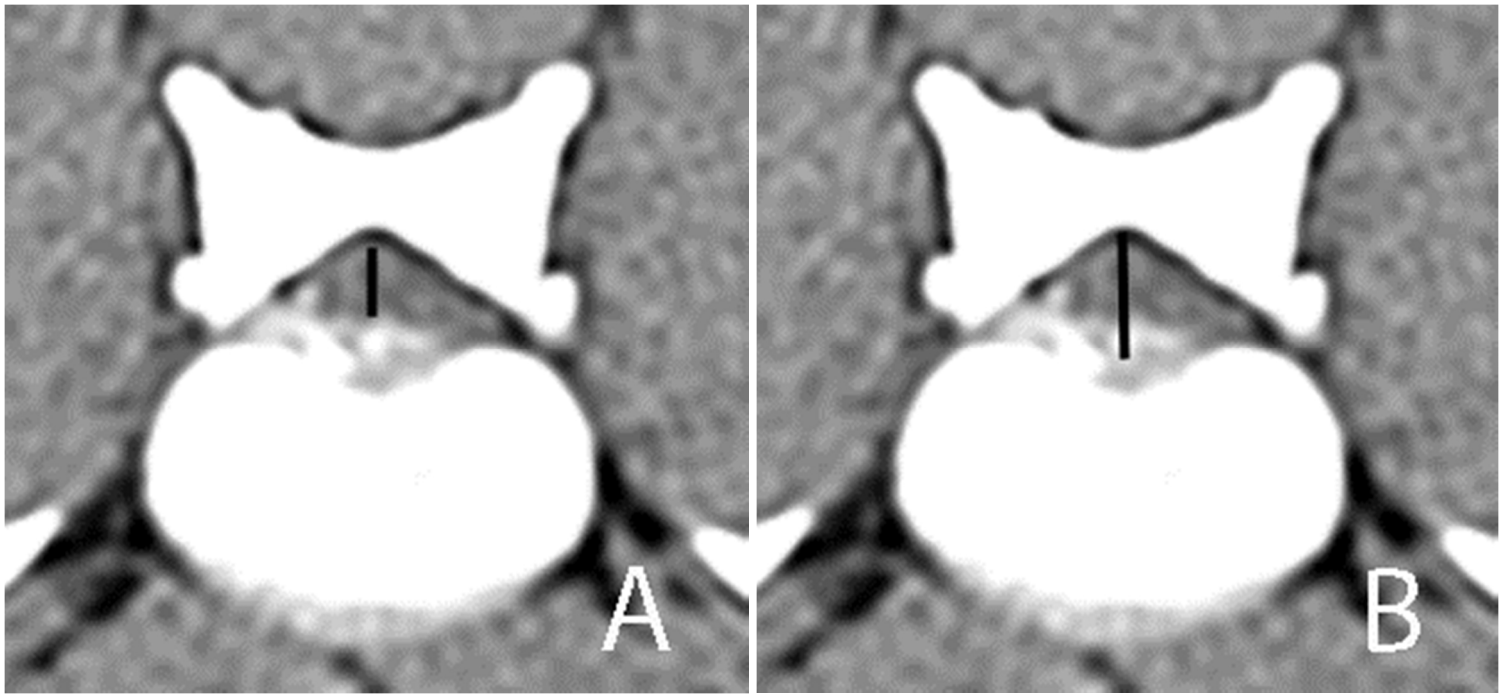


Figure 1