THE RELATIVE SENSITIVITY OF COMPUTED TOMOGRAPHY AND MYELOGRAPHY FOR IDENTIFICATION OF THORACOLUMBAR INTERVERTEBRAL DISK HERNIATIONS IN DOGS

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We compared the relative sensitivity of computed tomography (CT) and myelography for identification of disk herniation in dogs. Criteria for patient selection included presurgical CT, myelography, or both and surgical or necropsy confirmation of disk herniation between the T3 and L6 vertebral articulations. Imaging findings were described as positive or inconclusive. Adverse events such as hypotension, cardiac arrhythmias, seizures, death, and lower urinary tract infection were compared between imaging groups. One hundred and eighty-two dogs met the inclusion criteria, with 116 dogs having myelography performed as the initial diagnostic imaging modality and 66 dogs having CT performed as the initial modality. The relative sensitivity for locating the site of disk herniation was 83.6% when myelography was the first test performed and 81.8% when CT was the first test performed. CT was more sensitive than myelography at detecting lesions in chronically affected dogs ($P = 0.025$). Myelography was more sensitive than CT at detecting lesions in smaller dogs (< 5 kg; $P = 0.004$). Dogs that received both imaging modalities were significantly more likely to die or be euthanized compared with myelography alone ($P < 0.001$). Both myelography and CT are reasonable diagnostic imaging modalities for locating the site of disk herniation. CT should be considered especially in heavier, more chronically affected dogs. The major limitations of this study include lack of randomization to imaging modality and the use of surgical exploration or necropsy as the gold standard. *Veterinary Radiology & Ultrasound, Vol. 50, No. 3, 2009, pp 247–252.*

Key words: computed, disk, dogs, herniation, myelography, tomography.

Introduction

ACCURATE LOCALIZATION OF the site of intervertebral disk herniation is important for surgical planning. Survey radiography may allow detection of degenerative disk disease but it lacks the ability to assess spinal cord compression or the precise location of herniated disk material. Radiographs have a reported accuracy of 51–61% for identifying the site at which thoracolumbar disk herniation is located.[1–3]

Myelography has been the standard for diagnosing intervertebral disk herniation in the dog. Complications of myelography include seizures,[4,5] myelopathy, apnea, cardiac arrhythmias,[6] meningitis, death, and intracranial subarachnoid hemorrhage.[7]

The accuracy of lesion localization using myelography ranges between 40% and 97% while the accuracy of lateralization of herniated disk material ranges from 78% to 100%.[3,8–10] The ventrodorsal myelographic view can also be useful in predicting lateralization of herniated disk material (89% accurate) and in 83% of dogs with unequal gaps in the contrast medium column, disk material was found on the side with the shorter gap; this phenomenon was termed paradoxical contrast obstruction.[11]

Imaging the vertebral column using computed tomography (CT) is noninvasive and can generally be performed more quickly than myelography.[12] It is possible to identify mineralized disk material and hemorrhage in the vertebral canal using non-contrast-enhanced CT.[13] Myelography and CT can be also be used in combination to determine the site and lateralization of disk herniation, as well as the extent of spinal cord compression.[14] However, the relative value of these two imaging modalities for assessment of intervertebral disk herniation is not known. Thus, aim of the present study was to estimate the relative sensitivity of myelography and CT for identifying the location of disk herniation in dogs and to examine adverse effects associated with these procedures. It was hypothesized that both imaging modalities would be reasonably sensitive and that CT would allow identification of disk herniation more consistently in chondrodystrophic breeds, as the herniated disk material in these dogs

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is frequently mineralized. It was also hypothesized that the number of adverse events would be higher in dogs undergoing myelography.

Materials and Methods

Medical records of dogs evaluated between April 2005 and October 2007 with the diagnosis of thoracic or lumbar disk herniation were identified. Criteria for selection included presurgical imaging with CT, myelography, or both and surgical or necropsy confirmation of disk herniation between the T3 and L6 vertebral articulations.

One hundred and eighty-two dogs were identified. Breeds represented were Dachshund (miniature and standard; $n = 115$), mixed breed dog ($n = 14$), Pekingese ($n = 7$), Poodle (miniature; $n = 5$), Cocker Spaniel ($n = 5$), Shih Tzu ($n = 4$), German Shepherd dog ($n = 3$), and 21 breeds with ≤ 2 dogs each ($n = 29$). The following breeds were considered chondrodystrophic: Dachshund (miniature and standard), Pekingese, West Highland White Terrier, Corgi, Japanese Chin, Bassett Hound, Shih Tzu, Cocker Spaniel, Lhasa Apso, Bichon Frise, and Beagle.[15–18] Thus, there were 146 chondrodystrophic dogs and 36 nonchondrodystrophic dogs. The gender distribution was 82 neutered female dogs, six intact female dogs, 71 neutered male dogs, and 23 intact male dogs. Mean weight was 9.2 kg (range 1.8–41.7, standard deviation 7.7). Median age was 6.2 years (range 1–13, standard deviation 2.8).

The mean duration of clinical signs was 5 days (range 0.5–90, standard deviation 9.7). One hundred and fifty-three dogs had acute signs (≤ 7 days [mean 2.3 days]) and 28 had chronic signs (> 7 days [mean 20 days]); duration of clinical signs was not known for one dog. The following modified Frankel spinal cord injury scale was used: paraplegia with no deep nociception (grade 0), paraplegia with no superficial nociception (grade 1), paraplegia with intact nociception (grade 2), nonambulatory paraparesis (grade 3), ambulatory paraparesis and ataxia (grade 4), or spinal hyperesthesia only (grade 5).[19,20] The average modified Frankel score at presentation was 2.4 (standard deviation 1.3). Forty-four dogs were ambulatory at presentation with a modified Frankel score ≥ 4. One hundred and thirty-eight dogs were nonambulatory at presentation with modified Frankel score ≤ 3.

Follow-up neurologic status was recorded for 113 dogs at a 4–6-week recheck appointment as normal, improved (increase of ≥ 1 Frankel grade), no change (same Frankel grade), worse (decrease of at least 1 Frankel grade), died, or euthanized. Seven dogs were normal at recheck with no paresis or ataxia. Sixty-eight dogs had an improved Frankel score. Twenty-six dogs had no change in the Frankel score, 20 of which remained with a static grade 4 with residual ambulatory paraparesis, two dogs deteriorated with a decreased Frankel score, 10 dogs died or were euthanized and did not survive to discharge, and 69 dogs were lost to follow-up. For comparative purposes, evaluable patients were classified as ambulatory (modified Frankel score ≥ 4) or nonambulatory (modified Frankel score <4) at presentation and at the 4–6-week follow period when available.

Diagnostic imaging was performed under general anesthesia for all dogs. Adverse anesthesia-related events were retrieved retrospectively from the anesthetic record. Hypotension was defined as mean arterial pressure <60 mmHg for >5 min. Cardiac arrhythmias were classified as ventricular arrhythmia, atrioventricular block, bradyarrhythmia with heart rate <60 beats/min, or tachyarrhythmia with a heart rate >180 beats/min; deaths resulting from cardiac arrhythmia were noted. Other adverse events recorded included seizures within the first 24 h postoperatively and development of a lower urinary tract infection (UTI) before discharge from the hospital. Urine was collected by cystocentesis for culture in patients with a voiding disability or clinical signs of a UTI.

Myelography was performed using iohexol (Omnipaque, GE Health Care, Princeton, NJ) injected into the subarachnoid space at L5–L6 or L4–L5, and occasionally at the atlanto-occipital cistern if adequate subarachnoid filling could not be achieved via lumbar injection. Lateral, ventrodorsal, and oblique images were obtained using fluoroscopy. CT was accomplished using a GE light speed quadslice multidetector helical scanner (GE Medical Systems, Milwaukee, WI). The area to be imaged was selected based on neurologic examination or a previous inconclusive myelogram. Transverse images were acquired in 1.25, 2.5, or 5 mm slices based on patient size with coronal or sagittal reformats when necessary. Imaging studies that were obtained in the immediate postoperative period to determine whether disk material was appropriately removed or reherniation had occurred were excluded from analysis. Dogs with imaging that was performed during two separate hospitalizations for unrelated disk-associated myelopathy were retained as separate entries.

Images were interpreted either by a surgeon, neurologist, radiologist, or resident, depending on whether the images were obtained during the normal workday or on an after hour emergency basis. For this project, an imaging study was positive if the primary interpreter determined that it was possible to identify an appropriate site for decompressive surgery. Imaging studies were inconclusive if the interpreter could not discern a lesion or if the location of herniated disk material was unclear. For dogs receiving both CT and myelography the order of procedures was noted. The imaging reports were recorded either immediately or at a later date if the imaging study was performed on an emergency basis. These reports were retrieved from the medical record and the suspected site of disk herniation was recorded.

Available digital CT images without intrathecal contrast medium were evaluated retrospectively by a single

TABLE 1. Clinical Data in Dogs where Myelography was Selected as the Initial Imaging Modality

	Total Number Dogs	Myelography Initially Positive	Relative Sensitivity (95% CI)
All dogs	116	97	84% (76, 90)
Chondrodystrophic	89	80	90% (82, 95)
Nonchondrodystrophic	27	17	63% (44, 79)
Acutely affected	103	92	89% (82, 94)
Chronically affected	13	5	38% (16, 66)
Body weight <5 kg	26	26	100% (89, 100)
Body weight >5 kg	90	71	79% (70, 86)
Modified Frankel score $\geqslant 4$ (walking) at presentation	29	22	76% (58, 89)
Modified Frankel score <4 (not walking) at presentation	87	75	86% (78, 92)
Modified Frankel score $\geqslant 4$ at follow-up	57	52	91% (82, 97)
Modified Frankel score <4 at follow-up	12	12	100% (78, 100)
Modified Frankel follow-up not available	47	33	70% (56, 82)

CI, confidence interval.

TABLE 2. Clinical Data in Dogs where Computed Tomography (CT) was Selected as the Initial Imaging Modality

	Total Number Dogs	CT Initially Positive	Relative Sensitivity (95% CI)
All dogs	66	54	82% (71, 90)
Chondrodystrophic	55	47	86% (74, 93)
Nonchondrodystrophic	11	7	64% (34, 87)
Acutely affected	50	42	84% (72, 92)
Chronically affected	15	12	80% (55, 95)
Body weight <5 kg	6	3	50% (15, 85)
Body weight >5 kg	58	49	85% (73, 92)
Modified Frankel score $\geqslant 4$ (walking) at presentation	15	11	73% (48, 91)
Modified Frankel score <4 (not walking) at presentation	51	43	84% (72, 92)
Modified Frankel score $\geqslant 4$ at follow-up	30	23	77% (59, 89)
Modified Frankel score <4 at follow-up	4	4	100% (47, 100)
Modified Frankel follow-up not available	32	27	84% (69, 94)

investigator (S.I.) for the presence of mineralized material within the vertebral canal. If compressive material was identified within the vertebral canal, a small region of interest marker was placed over the most visibly hyperattenuating material and a measurement of attenuation in Hounsfeld units (HU) was obtained.

Relative sensitivity was defined as the proportion of dogs where the first used imaging modality correctly identified the site of spinal cord compression. Relative sensitivity between CT and myelography was compared using χ^2 or Fisher exact tests. Analyses were performed overall and within population subsets based on signalment and other dog-related factors. Adverse events were compared among the three imaging groups (myelogram, CT, and both) using χ^2 tests and pairwise by Fisher's exact tests. Categorical analyses including the calculation of mid-*P* exact confidence intervals were performed in a single statistical package* and results were interpreted at the 5% level of significance.

Results

One hundred and sixteen dogs underwent myelography as the first imaging modality and 66 dogs underwent CT as the first modality. There was no significant association between body type (chondrodystrophic vs. nonchondrodystrophic) and first imaging modality. Of the 116 dogs where myelography was chosen initially, the lesion was correctly identified in 97 dogs (83.6% sensitivity; 95% confidence interval [CI], 76.0–89.5%) with 19 dogs requiring CT imaging to determine the location of disk herniation (Table 1). Of the 66 where CT was chosen initially, the lesion was correctly identified in 54 (81.8% sensitivity; 95% CI, 71.1–89.8%), with 12 dogs requiring myelography to determine the location of disk herniation (Table 2). CT was more sensitive ($P = 0.025$) than myelography for detecting lesions in chronically affected dogs (80%; 95% CI, 55–95% vs. 38%; 95% CI, 16–66%). Myelography was more sensitive ($P = 0.004$) than CT at detecting lesions in dogs with a body weight <5 kg (100%; 95% CI, 89–100% vs. 50%; 95% CI, 15–85%). No differences between modalities were noted with reference to signalment, body type (chondrodystrophic vs. nonchondrodystrophic), degree of dysfunction at presentation, or improvement at follow-up.

Seizures occurred in 5/182 dogs, all of which received myelography as the sole imaging modality or in combination with CT (Table 3). Dogs that received both imaging modalities were significantly more likely to have a seizure than those that had CT alone. Similarly, patients who

*EpiInfo version 6.04d for Windows, CDC, Atlanta, GA

TABLE 3. Comparison of Adverse Effects among Dogs with Confirmed Intervertebral Disk Disease Receiving Myelogram ($n = 97$), CT ($n = 54$) and Both Imaging Modalities ($n = 31$)

Adverse Event	Myelogram Only (95% CI)	CT Only (95% CI)	Both Imaging (95% CI)	*P*-Value*
Died/ euthanized	4%† (1, 12) 4/97	7% (1, 21) 4/54	29%† (12, 54) 9/31	0.005
Hypotension	40% (30, 50) 39/97	37% (24, 50) 20/54	30% (16, 48) 9/31	0.635
Arrhythmia	30% (22, 40) 29/97	29% (18, 42) 16/54	26% (13, 43) 8/31	0.895
UTI	36%† (27, 46) 35/97	43% (30, 56) 23/54	58%† (40, 74) 18/31	0.096
Seizures	2% (0, 7) 2/97	0%† 0/54	10%† (25, 24) 3/31	0.028

*Based on χ^2 test.†Pairwise proportions significantly different ($P < 0.05$) based on χ^2 or Fisher's exact test. CI, confidence interval; UTI, urinary tract infection; CT, computed tomography.

received both imaging modalities were significantly more likely to develop a lower UTI than patients who received a myelogram alone. Seventy-six dogs had positive urine culture results, six had negative results, and 100 were not tested as they were free of clinical signs or did not have voiding disability during hospitalization. There was a significant association between the likelihood of a patient to die or be euthanized if both imaging modalities were performed compared with myelography alone. There were no significant differences between imaging modalities for the development of intraoperative cardiac arrhythmias or prolonged hypotension.

Digital CT images were available for 50/54 dogs having the site of disk herniation correctly identified with the initial CT study. All 50 dogs had mineralized material (HU > 100) within the canal. The mean HU value of the herniated material was 297 HU (range, 106–858; standard deviation, 186). Of the 50 dogs with mineralized material within the vertebral canal, 39 had acute disk herniation ($\leq$ 7 days) and 11 had chronic disk herniation (> 7 days). CT was unable to identify the site of disk herniation in 12 dogs where CT was selected as the primary imaging modality. Digital CT images were available for 10/12 of these dogs (eight acute, three chronic, one unknown duration), none of which had visible compressive mineralized material present in the vertebral canal.

Discussion

The increasing emphasis on evidence-based decision making in veterinary medicine necessitates a more complete understanding of the accuracy of diagnostic imaging studies.[21,22] Despite the fact that CT is widely used for evaluating the vertebral column in veterinary medicine, limited data are available on the ability of CT to successfully identify disk herniation in comparison to more traditional imaging modalities. In this report the relative sensitivity of CT and myelography for locating the site of disk herniation in a large population of dogs was comparable, at 81.8% and 83.6%, respectively. In a previous study of 20 dogs where CT was followed by myelography, CT was 90% sensitive and myelography was 88% sensitive at identifying the major site of disk herniation.[23] The slightly lower accuracy and sensitivity for both modalities in our study may be due to differences in the number of dogs, experimental design, and observers. It is likely that the larger sample size in our study led to a more reliable estimate sensitivity. Differences in study design may have also affected the estimates of sensitivity. In our study, images were interpreted by a large number of observers with various levels of postgraduate training. Additionally, both CT and myelography were not performed sequentially in all dogs. Rather, the primary imaging modality was selected by clinicians and the need for additional imaging was determined by these individuals and the availability of the modality.

Both duration of clinical signs and body weight were related to the sensitivity of the imaging studies. Dogs with chronic (> 7 days history) clinical signs were more likely to have their lesion successfully identified with CT compared with myelography. Potential reasons for this include a higher frequency of calcified disk herniation in chronically affected dogs or spinal cord atrophy associated with chronic lesions. CT is exquisitely sensitive for detecting calcified disk material in dogs and humans,[24] potentially making chronic herniations easier to identify than acute herniations. In our study, all disk herniations identified using CT as the initial modality were characterized by hyperattenuating material within the vertebral canal. This suggests that mineralization is an important factor in indentifying disk herniation using CT in both acute and chronic herniations. Additionally, long-standing disk material within the vertebral canal results in spinal cord atrophy due to loss of long tracts and relative preservation of the subarachnoid space.[25] In humans with lumbar disk herniation, myelographic studies are particularly difficult to evaluate for evidence of disk herniation in areas where the subarachnoid space is typically preserved.[24]

Dogs of lesser body weight (< 5 kg) were more likely to have a positive myelogram. Myelography is easier to perform in smaller dogs, likely because of the shorter distance between the skin surface and interarcuate space.[26] Additionally, the dural sac may extend more caudally in smaller animals allowing for easier penetration of the subarachnoid space.[27]

There are various reasons why myelography or CT may be nondiagnostic in some dogs with disk herniation. In humans with lumbar disk herniation, the presence of multiple disk protrusions, epidural leakage of contrast medium, small volumes of disk material, and lateralized disk herniation have been suspected to negatively impact the diagnostic utility of myelography.[24,28] In dogs with acute disk extrusion, spinal cord swelling may make interpretation of myelography challenging due to poor subarachnoid space filling over extensive regions of the vertebral column.[26] Additionally, disk herniation caudal to the termination of the dural sac may also make a myelogram difficult to interpret in dogs. CT may have been interpreted as inconclusive if there was lack of associated hemorrhage or mineralization associated with the herniated disk.

Adverse events associated with myelography have limited its use as a first line imaging technique in humans. Given the comparable relative sensitivity of myelography and CT in this report for dogs with thoracolumbar disk herniation, a careful examination of potential adverse events associated with both modalities was undertaken. Cardiac arrhythmias and hypotension were not significantly different between dogs that received either CT or myelography alone. This was unexpected, as hypotension and cardiac arrhythmia have been reported with myelography,[6] Proposed reasons for the lack of difference between study groups for arrythmias and hypotensive events may be due to the relative infrequency of events or inconsistent monitoring There was a significant association between myelography and postsurgical seizure activity. There was no evidence that myelopathy secondary to myelography impacted long-term outcome, although serial Frankel scores were not available in the immediate postoperative period to discern whether a transient effect of myelography existed. Dogs that required both myelography and CT, however, were significantly more likely to have postoperative UTI (vs. myelography alone) and die or be euthanized (vs. myelography alone). Patients who required both imaging modalities may have been affected with a more severe or complicated disease leading to a less favorable outcome. All modalities had some degree of adverse effects, including hypotension, arrhythmias, and UTI (Table 3). All patients were not tested for UTI, as those without clinical signs or voiding disability were assumed to be free of UTI. This may have led to bias in the results as some patients with UTI may have gone undetected, giving a falsely low frequency of UTI in this population. Additionally, patients at risk for a UTI may have been preferentially selected to have a urine culture performed if they had an indwelling or intermittent urinary catheter placed during the hospitalization period. Although many confounding variables may contribute to the likelihood of UTI, prolonged periods of hypothermia ($<35^{\circ}C$) while under anesthesia have been documented as a cause in dogs affected with intervertebral disk herniation, potentially due to decreasing host immune responses.[29] Patients that received both imaging modalities are likely to have longer anesthesia times, potentially placing them at risk for hypothermia and subsequent UTI. UTI is a manageable condition in most dogs and likely did not contribute to overall outcome in these patients.

Myelography has the advantage of imaging the entire spinal cord. A potential disadvantage of myelography is the development of postoperative seizures. In this study, seizures occurred in only 5/182 (3%) patients, all of which had a myelogram as part of the diagnostic imaging work up. There was no evidence that any of these patients had a long-term problem as a result of the postmyelographic seizures. Interestingly, two out of five patients were large breed dogs with larger volumes of iohexol being administered, a known risk factor for seizures.[5]

Several advantages of using CT to identify disk herniation includes the lack of negative side-effects associated with the procedure as compared with myelography, the ability to determine lateralization of disk material, and the time required for imaging.[13] We were unable to reliably estimate anesthesia times for CT vs. myelogarphy due to the lack of proximity of the CT scanner to anesthesia induction in our facility. Subjectively it is our impression that in our setting CT can be performed in a timely manner with estimated times of 15–20 min per spinal region, including time for patient positioning. Another distinct advantage of CT over myelography is the ability to obtain reformatted sagittal and dorsal images.[30]

The limitations of this study include its retrospective nature, selection bias for with choice of primary imaging modality, and use of surgical confirmation as a gold standard for the diagnosis of disk herniation. In particular the nonrandom assignment of dogs to CT vs. myelography is a concern as it may have biased the relative sensitivity estimates of either or both techniques. Animals that were judged to be less than ideal candidates for CT or myelography due to physical factors such as weight, for example, may have been preferentially imaged via one technique. The use of surgery as a gold standard for diagnosing disk herniation has been questioned. Because surgeons are aware of the results of imaging studies, they may incorrectly interpret surgical results to fit with imaging results, leading to inflated accuracy of myelography or CT.[31] Additionally, the hemilaminectomy may be extended cranial or caudally if disk material was present along the periphery of a suspected lesion, again resulting in the embellishment of the accuracy of imaging techniques. Circumferential distribution of the lesions was not evaluated in this study, although others have noted that lateralization of disk material was correctly predicted in 96% of dogs with CT compared with 92% of dogs with myelography.[23]

Our evaluation of myelography and CT used an imperfect method for determination of true intervertebral disk herniation status. Dogs unaffected with disk herniation were not evaluated so it was not possible to estimate the specificity of either of these two modalities. The sensitivity estimates should be considered relative sensitivities because they were calculated relative to the identification of disk herniation by one of the methods and subsequently confirmed by either surgery or necropsy. There is the possibility that some dogs presented because of disk herniation that was not recognized by either modality and those dogs would not have been included in our study population. Therefore, the presented sensitivity estimates may be higher than the true values. A prospective, randomized design could have allowed both modalities to be performed on all study dogs and would likely have reduced bias. Even with a prospective design, limitations with regard to the gold standard (surgery or necropsy) would have still persisted. Other limitations include the fact that the P-values were not adjusted for multiple comparisons. Whether or not P-values should be adjusted is controversial[32] but because all tests were performed based on a priori biological hypotheses, adjustment was considered to be unnecessary. Had adjustment been performed, some of the P-values would not have been significant, especially for the adverse events. With a larger sample size we may have found significant differences between imaging modalities for relative sensitivity, signalment, body type, degree of dysfunction, improvement, arrhythmias, or hypotension.

In summary, both myelography and CT are reasonable diagnostic imaging modalities for locating the site of disk herniation with a relative sensitivity of slightly $>80\%$. If one suspects a dog to have spinal cord compression secondary to intervertebral disk herniation and has access to either CT or myelography, then either modality may be used initially. Because we were unable to detect a difference in relative sensitivity, selection of the initial modality might therefore be based on such things as cost, time of anesthesia, availability of support personnel, personal preference, and avoidance of potential adverse effects. CT might be preferable in dogs with suspected chronic disease and myelography might be preferable in dogs weighing <5 kg. Because, however, the dogs in this study were not randomized as to which modality was used initially, bias may have been introduced and our results should be interpreted with caution.

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