EVALUATION OF DIFFERENT COMPUTED TOMOGRAPHY TECHNIQUES AND MYELOGRAPHY FOR THE DIAGNOSIS OF ACUTE CANINE MYELOPATHY

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Forty-six dogs with either cervical (C1–C5 or C6–T2) or thoracolumbar (T3–L3) acute myelopathy underwent prospective conventional computed tomography (CT), angiographic CT, myelography, and CT myelography. Findings were confirmed at either surgery or necropsy. Seventy-eight percent of lesions were extradural, 11% were extradural with an intramedullary abnormality, 7% were intramedullary, 2% were intradural–extramedullary, and 2% had nerve root compression without spinal cord compression. Intervertebral disc herniation was the most frequent abnormality regardless of signalment or neurolocalization. Twenty-one of 23 Hansen type I disc extrusions but none of the Hansen type II disc protrusions were mineralized. Two chondrodystrophic dogs had acute myelopathy attributable to extradural hemorrhage and subarachnoid cyst. CT myelography had the highest interobserver agreement, was the most sensitive technique for identification of compression, demonstrating lesions in 8% of dogs interpreted as normal from myelography and enabling localization and lateralization in 8% of lesions incompletely localized on myelography due to concurrent spinal cord swelling. None of the imaging techniques evaluated permitted definitive diagnosis of spinal cord infarction or meningomyelitis but myelography and CT myelography did rule out a surgical lesion in those cases. While conventional CT was adequate for the diagnosis and localization of mineralized Hansen type I disc extrusions in chondrodystrophic breeds, if no lesion was identified, plegia was present due to concurrent extradural compression and spinal cord swelling, or the dog was nonchondrodystrophic, CT myelography was often necessary for correct diagnosis. © 2010 *Veterinary Radiology & Ultrasound*

Key words: angiography, diagnostic imaging, dog, intervertebral disc herniation, spinal neoplasia.

Introduction

The potentially permanent neurologic consequences of acute spinal cord compression demand expedited localization, characterization, and surgical decompression if appropriate.[1] Myelography is a sensitive method of diagnosing spinal cord compression but its limitations and technical difficulties are well known and computed tomography (CT) myelography may be necessary for diagnosis, especially if magnetic resonance (MR) imaging is not available.[2–7] Conventional CT has been used for diagnosis of spinal cord compression due to mineralized intervertebral disc herniation or neoplasia involving vertebrae.[8–10] Nonselective angiographic CT studies have been used to describe cervical venous sinus anatomy and proposed as a rapid method for the diagnosis of spinal cord compression by identification of altered vertebral venous sinuses.[11–13]

While there are retrospective studies,[9,10,14,15] there are no prospective studies comparing multiple signalments, etiologies, and imaging modalities of acute canine myelopathies. The purposes of this study were: (1) to determine prospectively the sensitivity for conventional CT, angiographic CT, CT myelography, and conventional myelography for the diagnosis of acute spinal cord disease, (2) to identify the limitations of each imaging technique for diagnosis of acute myelopathies, and (3) to make recommendations for the selection of imaging modality when investigating acute myelopathies, without compromising sensitivity.

Materials and Methods

Client consent was mandatory for patient inclusion. Forty-six dogs with acute myelopathy that had one area of

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neurolocalization corresponding to the clinical signs were recruited. Lesion localization was either cervical (C1–C5 or C6–T2; 25 dogs) or thoracolumbar spinal cord segments (T3–L3; 21 dogs) and confirmed by surgery or necropsy. Of the cervical dogs, 10 had pain as the predominant feature while 15 were paretic (motor function present but weak). No cervical dogs were plegic (complete loss of motor function). Of the thoracolumbar dogs, 14 dogs had paresis as the predominant feature and seven were plegic. No thoracolumbar dogs presented with only pain and none of the plegic dogs had loss of deep pain.

Dachshunds and beagles were the most frequently represented breeds, but in total 25 chondrodystrophic and 21 nonchondrodystrophic dogs were recruited. The median age was 8 years (range 1–14 years) for the cervical group, 5 years (range 1–11 years) for the thoracolumbar group and 6.5 years overall. The median weight was 12.6 kg (range 6.0–31.4 kg) for the cervical group, 8.4 kg (range 2.8–28.8 kg) for the thoracolumbar group and 11.75 kg overall.

All dogs were imaged under general anesthesia using inhaled agents. The specific protocol was determined by individual patient requirements and anesthetist preference. Imaging was performed by one author (S.D.) in the same order for all dogs: conventional CT, angiographic CT, myelography, CT myelography. CT image acquisition was performed throughout the region of neurolocalization (for C1–T2, foramen magnum to T3 vertebral body; for T3–L3, T2–L4 vertebral body). Dogs were in dorsal recumbency to reduce respiration-induced motion artifact. A single slice helical CT scanner* was used, utilizing described techniques.[16] Briefly, axial scan mode image acquisition, 1 mm slice width, 120 KVp and 100 mA were used for conventional and myelographic CT scans. For the nonselective angiographic study, helical scan mode image acquisition, 2 mm slice width, pitch of 1.4, 120 KVp, and 100 mA were used. For cervical spine CT image acquisition, the gantry was tilted to align with the intervertebral disc at C3/4 and the neck was extended. For thoracolumbar image acquisition, the gantry was tilted to align with the intervertebral disc at L2/3. Limbs were positioned to minimize their inclusion in the scan field. For the nonselective angiographic CT, 2 ml/kg of an ionic iodinated contrast medium containing a mixture of diatrizoate meglumine and diatrizoate sodium† was administered intravenously as a bolus via either the cephalic or saphenous vein and image acquisition begun 45 s after the injection. Following completion of the conventional and angiographic CT studies, a myelogram of the entire spine was performed in all dogs via fluoroscopy-guided lumbar puncture using the minimum intrathecal volume necessary of 300 mgI/ml iohexol‡ for adequate opacification of the subarachnoid space to the level of C1 vertebral body. This varied between individuals from 0.23 to 0.41 ml/kg of 300 mgI/ml iohexol. Pre- and post-intrathecal injection radiographs were acquired using direct digital radiography.§ Following myelography, CT myelography of the region (C1–T2 or T3–L3) was performed as for the conventional CT.

To prevent bias, CT studies from an additional eight dogs with a grossly normal spinal cord (four conventional CT, two myelography, two CT myelography) were included for interpretation but not statistical analysis. Two board-certified radiologists (R.D., T.S.) interpreted each individual study without information regarding signalment or presenting signs, and were given freedom of window and level adjustment and the use of multiplanar reconstruction software. Interpreters were asked to identify spinal cord compression (yes/no), characterize (extradural/intradural extramedullary/intramedullary), localize (by vertebral body or intervertebral disc space), and lateralize the lesion, and record any other significant findings. Vertebral venous sinus height and diameter were evaluated and, where possible, measured by one author (S.D.) from angiographic CT transverse images at the level of mid vertebral bodies and at the intervertebral foramina.

Because of uncertainty in some dogs of the exact region of cervical neurolocalization, C1–C5 and C6–T2 lesions were grouped together for statistical analysis. Fisher's exact test was used to identify an association between mineralized or lytic and nonmineralized lesions with correct lesion characterization, localization, and lateralization. Interobserver agreement was calculated using kappa statistic. Chi-squared test was used to evaluate correlation between interobserver agreement and imaging modality and mineralized or lytic lesions.

Results

Correctly identified lesions from dogs with acute myelopathy are summarized in Table 1. 78% of lesions were extradural, 11% were extradural with an intramedullary abnormality, 7% were intramedullary, 2% were intradural–extramedullary, and 2% had nerve root compression but no evidence of spinal cord compression. Forty lesions, one subarachnoid cyst and 39 intervertebral disc herniations, were confirmed by surgery. Twenty-three of the disc herniations were Hansen type I disc extrusions and 16 were Hansen type II disc protrusions, making intervertebral disc herniations the most frequent etiology regardless of signalment. One of these Hansen type I disc extrusions resulted in disc material within the intervertebral foramen causing only nerve root compression and five of the Hansen type I extrusions had concurrent spinal cord swelling.

*GE HighSpeed LXi, General Electric Healthcare, Milwaukee, WI.
†370 mg iodine/ml, MD-76®, Mallinckrodt Inc., St. Louis, MO.
‡Omnipaque®, GE Healthcare Inc., Princeton, NJ.
§Eklin Medical Systems Inc., Santa Clara, CA.

TABLE 1. Number of Lesions Diagnosed Correctly (Characterization, Localization, and Lateralization) for Each Imaging Technique

Myelopathy Characterization	Neuro-Localization	CT*	Angiographic CT	Myelography	CT-Myelography
Extradural	C1–T2 ($n=24$)	12	11	20	24
	T3–L3 ($n=12$)	5	4	8	11†
Concurrent extradural and intramedullary	T3–L3 ($n=5$)	0	0	0	5
Intradural–extramedullary	T3–L3 ($n=1$)	0	0	1	1
Intramedullary	T3–L3 ($n=3$)	0	0	0	0
Disc extrusion without myelopathy‡	C1–T2 ($n=1$)	1	1	0	1

*CT here refers to conventional computed tomography (CT). †The 12th intervertebral disc extrusion lesion in this group was correctly diagnosed and lateralized but the location was reported incorrectly by one intervertebral disc space.‡Hansen type I disc extrusion into an intervertebral foramen causing nerve root compression but not spinal cord compression.

Twenty-one of 23 Hansen type I disc extrusions but 0/16 Hansen type II disc protrusions were hyperattenuating, indicating mineralization, on conventional CT. Three extradural compressive lesions were confirmed by necropsy as hemorrhage, osteosarcoma, and fibrosarcoma. Three intramedullary lesions that were not identified on imaging were confirmed at necropsy as spinal cord infarction in one dog and meningomyelitis in two others. None of the normal studies included to prevent bias were misdiagnosed as compressive myelopathies, but these data were not included in statistical analysis.

The sensitivity for each imaging modality is summarized in Table 2. When mineralized extradural lesions were excluded, the overall sensitivity of conventional CT decreased from 66% to 40% and angiographic CT decreased from 53% to 20%. Conversely, all mineralized disc herniations were correctly identified on conventional CT, however in five thoracolumbar patients the associated spinal cord swelling was not identified using conventional CT.

There was a significant difference between the correct lesion diagnosis (characterization, localization and lateralization) of mineralized/lytic lesions compared with nonmineralized/nonlytic lesions from conventional and angiographic CT ($P<0.001$). This suggested reliance on mineralization/lysis for correct diagnosis in these modalities. No significant difference was identified for correct diagnosis of mineralized/lytic lesions and nonmineralized/nonlytic lesions from myelography ($P=0.18$) or CT myelography ($P=1.00$).

TABLE 2. Sensitivity of Each Imaging Technique for All Lesions by Region of Neurolocalization

	Neurolocalization	Sensitivity (%)
Conventional CT	Cervical	71
	Thoracolumbar	57
	Overall	66
Angiographic CT	Cervical	71
	Thoracolumbar	23
	Overall	53
Myelography	Cervical	80
	Thoracolumbar	78
	Overall	79
CT myelography	Cervical	100
	Thoracolumbar	95
	Overall	97

CT, computed tomography.

Agreement among all CT imaging techniques was absolute for large volume mineralized intervertebral disc herniations and neoplasia with bony lysis, however there was poor agreement among CT studies for nonmineralized/nonlytic lesions. Myelography and CT myelography findings agreed with the exception of five dogs with extradural compression with concurrent intramedullary spinal cord swelling, and four dogs with a low volume disc herniation (including one dog with disc extrusion into the intervertebral foramen) that were not correctly diagnosed from myelography. While the spinal cord swelling was apparent on myelogram in those five dogs, the extradural lesion causing the swelling could not be localized or lateralized. The four dogs with a low volume disc herniation that were not identified using myelography were cervical in location.

Agreement between observers for survey CT was 0.2, for angiographic CT it was 0.23, for myelography it was 0.74, and for CT myelography it was 0.88 (<0 = no agreement, 0–0.20 is slight agreement, 0.21–0.40 = moderate agreement, 0.61–0.80 = substantial agreement and 0.81–1.00 = almost perfect agreement). Disagreement between observers was significantly associated with conventional and angiographic CT studies ($P<0.02$). In fact, the only conventional CT and angiographic CT studies that observers were in complete agreement for were large volume mineralized intervertebral disc herniations and lysis associated with neoplasia. Interobserver agreement was significantly associated with myelography and CT myelography ($P<0.04$) and mineralized or lytic lesions ($P<0.02$).

Vacuum phenomenon was recorded in 1/25 C1–T2 and 4/21 T3–L3 locations from survey and angiographic CT images but was only associated with the site of compression in 1/5 dogs. Identification of vacuum phenomenon from these studies was associated with incorrect diagnosis of extradural compression at that location in 3/5 dogs on survey and angiographic CT.

There was no correlation between vertebral venous sinus diameter, height or diameter and height and site of extradural compression ($P>0.430$) in dogs with C1–T2

neuropathy. Venous sinuses could not be identified from any T3–L3 angiographic CT study.

Discussion

As expected, CT myelography was the most sensitive imaging technique for lesion characterization, localization and lateralization when all etiologies were considered, outperforming myelography, conventional CT and angiographic CT. Perhaps most importantly, CT myelography permitted correct identification of concurrent extradural compression and spinal cord swelling and differentiated these dogs from dogs having intramedullary disease. The high frequency of spinal cord compression due to mineralized intervertebral disc herniation, the low frequency of other spinal diseases and absence of trauma-induced spinal disease are limitations, but reflect our patient population during the study period.

There are multiple retrospective studies and a single prospective study of CT vs. myelography for evaluation of chondrodystrophic breeds with acute thoracolumbar Hansen type I disc extrusion.[10,14,15] These studies often did not include nonchondrodystrophic dogs or spinal cord disease due to causes other than disc extrusions in chondrodystrophic dogs. In one study,[10] only a small proportion of patients included were imaged using conventional CT or CT myelography and myelography, making absolute comparison of these imaging modalities impossible. In another study[14] where conventional CT and myelography were compared, CT was limited to intervertebral disc spaces from T9/10 to L4/5 and mid vertebral bodies were not imaged. This technique would not allow diagnosis of vertebral neoplasia, or other abnormalities, cranial to T9. Furthermore, these previous studies were retrospective, meaning that dogs were included based on final diagnosis that, while informative, may be misleading for the population at large where etiology is unknown at the time of presentation. A study evaluating a small group of dachshunds with thoracolumbar disc extrusions concluded that conventional CT was inadequate for poorly mineralized disc extrusion in a small percentage of cases.[15] In that study window width and level optimization for the individual patient was not permitted which is unrealistic for the modern clinic setting. In our prospective study, intervertebral disc disease was the most common cause of acute myelopathy, and in chondrodystrophic dogs with Hansen type I extrusions, our conclusions were almost identical to those recent studies where conventional CT was determined to be a fast and accurate method for determining the site of mineralized disc extrusion.

The prospective nature of our study adds further information. In five dogs with mineralized disc extrusion, spinal cord swelling was identified only via myelography and CT myelography and this resulted in expansion of the surgical site. The extent of spinal cord swelling associated with extradural compression of the spinal cord is important because it is related to the prognosis.[1] All dogs with spinal cord swelling evident on myelographic imaging were plegic, suggesting that this category should preferably undergo CT myelography to permit correct lesion characterization, localization and lateralization, while simultaneously evaluating for spinal cord swelling. Importantly, we demonstrated nondisc disease as a cause of acute myelopathy in a low number of chondrodystrophic cases: extradural hemorrhage of unknown origin, correctly diagnosed from survey CT[9] and confirmed at necropsy, and subarachnoid cyst diagnosed from myelographic imaging, confirmed at surgery. Furthermore, the inclusion of all etiologies permitted our study to reaffirm that conventional CT had low sensitivity for clinically significant but poorly mineralized Hansen Type I disc extrusions and nonmineralized Hansen type II disc protrusions and that intramedullary lesions such as meningomyelitis and spinal cord infarction may not be conspicuous on myelography, CT, or CT myelography.[17–19]

Myelography is invasive and associated with complications,[4,5,7,20,21] thus nonmyelographic techniques are appealing. Nonselective angiographic CT was investigated following its description in Doberman pinschers with cervical spondylomyelopathy.[11] The CT angiography findings in this study were disappointing and did not add any additional information compared with conventional CT. Venous asymmetry[11] was not detected despite proven spinal cord compression and good opacification of the C1–T2 venous sinuses. This disappointing result may be attributed to the nonselective nature of the angiographic study or to changes in direction of flow within the valve-less, frequently anastomosing vertebral venous sinuses.[12,13,22] Furthermore, dimension changes may have been outside of the limits of software, obscured by reconstruction algorithm smoothing, or statistically insignificant considering the normal ampulla formation along the cervical spine.[22,23] The lack of conspicuity of the T3–L3 venous sinuses may have been due to inadequate opacification in combination with smaller sinus size[22–24] especially in dachshunds with a high spinal cord-to-spinal canal ratio.[24,25]

Ancillary imaging findings, such as vacuum phenomenon, have been associated with intervertebral disc extrusion, intervertebral disc degeneration, articular process degenerative joint disease, synovial cyst formation, and spondylosis deformans.[26–28] In our study, vacuum phenomenon was only associated with one site of extradural spinal cord compression and was interpreted incorrectly as the site of compression on survey and angiographic CT studies in three dogs. We discourage the use of the vacuum phenomenon to localize sites of compression.

In conclusion, most painful and paretic chondrodystrophic dogs in our study had mineralized Hansen type I disc

extrusions and were adequately imaged using conventional CT. However in a small number of chondrodystrophic dogs myelographic techniques were necessary to diagnose both disc related and nondisc related diseases. Plegic chondrodystrophic dogs suggestive of concurrent spinal cord swelling, dogs with low volume cervical disc extrusions and all nonchondrodystrophic dogs, were assessed best using CT myelography.

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