MYELOGRAPHY VS. COMPUTED TOMOGRAPHY IN THE EVALUATION OF ACUTE THORACOLUMBAR INTERVERTEBRAL DISK EXTRUSION IN CHONDRODYSTROPHIC DOGS

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Myelography and/or computed tomography (CT) are commonly used to evaluate acute intervertebral disk extrusion in chondrodystrophic dogs. The purpose of this study was to evaluate the sensitivity of myelography and two different CT protocols in determining level and lateralization of acute thoracolumbar intervertebral disk extrusion in comparison with surgical findings, investigate interobserver variability, and determine examination duration times. Results of conventional CT, helical CT, and myelography were compared with surgical findings in 19 chondrodystrophic dogs with acute thoracolumbar intervertebral disk extrusion. Agreement among investigators was determined for different imaging modalities, and examination times were recorded. In the diagnosis of level of disk extrusion there was agreement of myelography, conventional CT, and helical CT with surgical findings in 94.7%, 100%, and 94.7% of dogs, respectively ($P = 0.144$). In the diagnosis of level and lateralization of disk extrusion there was agreement of myelography, conventional CT, and helical CT with surgical findings in 78.9%, 87.4%, and 85.3% of dogs, respectively ($P = 0.328$). Interobserver agreement was very good for all imaging modalities (myelography $\kappa = 0.87$; conventional CT $\kappa = 0.86$; helical CT $\kappa = 0.95$). There were significant differences in median examination duration times between helical CT (4 min), conventional CT (8 min), and myelography (32 min) ($P < 0.001$). Both helical and conventional CT appear to be accurate for evaluation of acute thoracolumbar intervertebral disk extrusion in chondrodystrophic dogs and are faster to perform than myelography. *Veterinary Radiology & Ultrasound, Vol. 50, No. 4, 2009, pp 353–359.*

Key words: canine, computed tomography, intervertebral disk extrusion, myelography.

Introduction

INTERVERTEBRAL DISK HERNIATION is common in dogs.[1] Two subtypes with differing pathophysiologic mechanisms have been described.[2] In Hansen Type I intervertebral disk herniation, the nucleus pulposus undergoes chondroid degeneration and subsequent mineralization. The annulus fibrosus weakens, and disk material can extrude into the vertebral canal causing an acute neuropathy. Chondrodystrophic breeds are most commonly affected. In Hansen Type II intervertebral disk herniation, the annulus fibrosus undergoes progressive thickening due to fibroid degeneration. This can result in progressive protrusion of the affected disk into the vertebral canal with subsequent spinal cord compression. The resulting neuropathy is insidious and progressive. Large breed dogs are most commonly affected.[2]

Clinical signs of Hansen type I disk extrusion range from pain to paralysis, with varying degrees of loss of pain perception.[3] While mildly affected dogs may improve with conservative treatment, animals exhibiting acute, severe pain and acute paraparesis or paralysis, animals with recurrent pain and ataxia unresponsive to conservative treatment, and animals with progressive deterioration of neurologic status require diagnostic imaging to determine site of disk extrusion followed by surgery.[3,4]

Myelography and computed tomography (CT) are commonly used to localize disk herniation. Myelography allows assessment of the entire spine if needed but it is invasive, there may be technical difficulties, the radiologist and support staff are subject to radiation exposure, and adverse reactions to the contrast medium are possible.[5,6] Although newer contrast media such as iohexol and iopamidol carry less risk of adverse reactions, seizures are still a risk.[7–9] More severe complications of myelography in dogs include asystole and intracranial subarachnoid hemorrhage.[10,11] Agreement of myelography with surgical

findings in localizing intervertebral disk extrusion in dogs ranges between 37% and 100%.[12–20] Uncertainty in determination of the exact site of extrusion might necessitate additional imaging procedures or result in surgical exploration at the wrong site. In humans, CT is more accurate than myelography in the diagnosis and localization of intervertebral disk protrusion and is considered superior by most examiners, with agreement between CT and surgical findings ranging from 71.0% to 92.3%.[21–28] In dogs, CT is 90% accurate in the identification of the site of disk herniation.[12] Helical (spiral) CT allows a significant reduction in examination time compared with conventional (sequential) CT.[29] Because of short acquisition times and high accuracy in the detection of vertebral fractures, helical CT is recommended by many as the method of choice when assessing humans for spinal trauma.[30–32] However, the advantage of fast acquisition times has been partially offset by a reduction in image quality.

The purpose of this study was to determine the sensitivity of myelography, conventional CT and helical CT compared with surgical findings in the diagnosis of acute intervertebral disk extrusion in chondrodystrophic dogs, to evaluate interobserver agreement in interpretation of the images acquired using these three modalities and to compare duration of examination times of the three modalities.

Materials and Methods

Between July and December 2006, 19 chondrodystrophic dogs with spontaneous acute paraparesis or paraplegia and a subsequent imaging diagnosis of intervertebral disk extrusion were assessed in this study. Informed written consent was obtained from all owners, and the project was approved by the Institutional Animal Care and Use Committee of the University of Tennessee. Only dogs with clinical signs severe enough to warrant diagnostic imaging and surgery were included in the study. Patients with a history of spinal trauma, clinical signs of cervical or multifocal involvement, severe concurrent diseases and dogs unable to undergo prolonged anesthesia were not included. Dogs with extensive spinal cord compression due to more than one extruded disk or if the site of origin of herniated disk material could not be determined at surgery were also not included.

Breeds represented were Dachshunds ($n = 14$), Miniature Dachshunds ($n = 3$), Beagle ($n = 1$), and mixed breed dog ($n = 1$). The mean age was 4.9 ± 1.7 years ($n = 18$); the age of one dog was unknown. Mean weight was 7.1 ± 2.8 kg. All dogs had paraparesis or paraplegia of 1–14 days duration.

Dogs were anesthetized for imaging. CT was performed using a single slice fourth generation helical scanner.* Dogs

were in dorsal recumbency. For the helical examination a lateral scout view was obtained, and the gantry was tilted to generate transverse slices approximately perpendicular to the vertebral canal at the thoracolumbar junction. CT examination was performed from the ninth thoracic vertebra (T9) to the fifth lumbar vertebra (L5) with the following settings: 130 kVp, 175 mA, slice thickness 3 mm, pitch 1. Images were reconstructed using a standard algorithm (Fig. 1A). For the conventional CT examination, a lateral scout view was obtained, and the gantry was tilted to generate transverse slices parallel to each individual intervertebral disk space. CT examination of the individual intervertebral disk spaces T9–T10 to L4–L5 was performed with the following settings: 130 kVp, 175 mA, slice thickness 2 mm. Three to four images were obtained at each individual disk space; no images were obtained between disk spaces. Images were reconstructed using a standard algorithm (Fig. 1B).

Following CT examination, lateral and ventrodorsal radiographs of the spine were obtained.†,‡ Dogs were then positioned in lateral recumbency with the hind legs slightly flexed cranially, and an area dorsal to the lumbar spine was clipped and aseptically prepared. Myelography was performed by inserting a 1.5–2.5 in. 22-G needle into the ventral aspect of the subarachnoid space at L5–L6 or L4–L5 and injecting iohexol§ (240 mgI/ml; 0.30–0.45 ml/kg) under fluoroscopic control until adequate contrast medium filling of the subarachnoid space was observed throughout the thoracolumbar spine. Lateral, ventrodorsal, and oblique fluoroscopic spot film images of the thoracolumbar spine were obtained.¶

The duration of each imaging procedure was recorded. CT examination time was the time from initiation of the scout view to acquisition of the final image, whereas myelographic examination time was the time from acquisition of the first survey radiograph to acquisition of the final image after injection of contrast medium.

At the conclusion of the imaging procedures, a hemilaminectomy was performed. Presence, site, and lateralization of extruded disk material were recorded. After surgery, routine postoperative care was provided.

Images from all studies were sent to a picture archive and communication system (PACS)‖ for further evaluation. Studies were copied into neutral folders, the three imaging modalities were separated, randomized, and independently evaluated by two board-certified neurologists (W.B.T., K.M.H.) and three board-certified radiologists
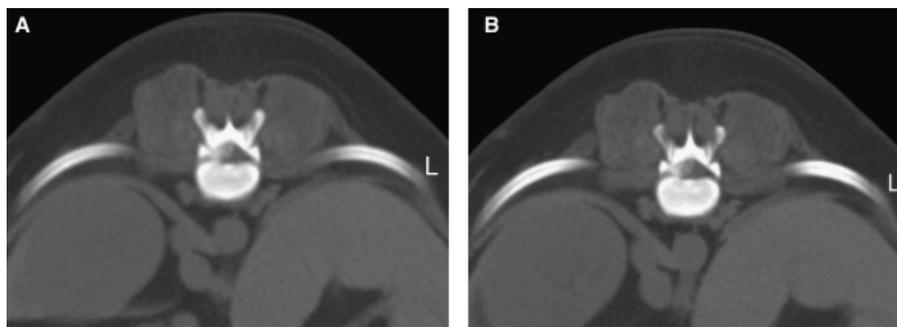

FIG. 1. Transverse helical (A) and conventional (B) computed tomography images obtained at the same table position in a dog. There is a large amount of hyperattenuating material associated with the right aspect of the vertebral canal and subsequent spinal cord compression at the level of the intervertebral disk space T13–L1.

(R.L.E., A.RM., W.H.A.) who were unaware of the clinical and surgical findings. Investigators had the option of manipulating images on PACS during evaluation, including but not limited to magnifying and windowing. For each imaging study investigators were asked to determine number of thoracic and lumbar vertebrae and record anatomical variations (hypoplastic ribs, transitional vertebrae, etc.). The results were compared with results of survey radiographic evaluation performed by the primary investigator. Investigators were also asked to determine level and lateralization of compressive lesion(s), and the results were compared with surgical findings. Investigators were asked to indicate their confidence in their diagnosis of a compressive lesion on a visual analog scale ranging from 0 to 100 (0, not confident at all; 100, most confident). Investigators were also asked to determine the level of intervertebral disk extrusion based solely on survey radiographs.

Statistical analysis was performed using commercially available software.[**],[††],[‡‡] Means and standard deviations were calculated for normally distributed continuous data, and medians and ranges were determined for nonnormally distributed data. Proportions were calculated for categorical data. Analysis of variance (ANOVA) and Kruskal–Wallis ANOVA on ranks were used to compare imaging findings of individual investigators to surgical findings and to compare examination times of different imaging procedures. κ statistics were used to determine interobserver agreement. A P-value of <0.05 was considered significant.

Results

Sixteen dogs had normal spinal anatomy, with 13 thoracic and seven lumbar vertebrae. Two dogs had transitional thoracolumbar vertebrae, and one dog had 13

thoracic and eight lumbar vertebrae. Radiography/myelography, conventional CT, and helical CT were 97.9%, 87.4%, and 88.4% accurate in determination of vertebral number and anatomic variations, respectively. Failure to include the entire length of spine into the scout view during CT examination with resultant inability to determine vertebral number, and inability to identify a transitional thoracolumbar vertebra on lateral CT scout view were problems when evaluating spinal anatomy.

At surgery, the site of disk extrusion was T12–T13 in 9 dogs, T13–L1 in nine dogs and L1–L2 in one dog. In 12 dogs, disk extrusion was lateralized to the right, and in seven dogs disk extrusion was lateralized to the left. Based on survey radiographs alone, the correct level of disk extrusion was accurately identified in 94.7% of dogs (range 68.4–94.7% for individual investigators). In the diagnosis of level of disk extrusion there was agreement of myelography, conventional CT, and helical CT with surgical findings in 94.7% (79.0–94.7%), 100% (89.5–100%), and 94.7% of patients (84.2–94.7%), respectively ($P = 0.144$). In the diagnosis of level and lateralization of disk extrusion there was agreement of myelography, conventional CT, and helical CT with surgical findings in $78.9 \pm 13.4\%$, $87.4 \pm 7.1\%$, and $85.3 \pm 2.4\%$, respectively ($P = 0.328$). Interobserver agreement was very good for all imaging modalities (Myelography $\kappa = 0.87$; conventional CT $\kappa = 0.86$; helical CT $\kappa = 0.95$). On a scale from 0 to 100 investigators were 96% (0–100%), 100% (13–100%), and 100% (3–100%) confident in their diagnosis based on myelography, conventional and helical CT, respectively. In four dogs disk material and/or epidural hemorrhage extended cranially or caudally from site of disk extrusion, necessitating hemilaminectomy at adjacent disk spaces. In these dogs, spinal cord compression at these additional spots was depicted in 40.0%, 50.0%, and 50.0% of myelographic, conventional CT, and helical CT studies, respectively. In two dogs, additional chronic disk extrusions were diagnosed, and surgical decompression for these le-

sions was performed at the same time as for acute extrusion. These lesions were depicted in 50.0%, 70.0%, and 80.0% of myelographic, conventional CT, and helical CT studies, respectively.

Median examination duration times for myelography, conventional, and helical CT were 32 (range 18–48), 8 (7–11), and 4 (3–10) min, respectively ($P < 0.001$).

Discussion

Objectives of this study were to evaluate the sensitivity of myelography and two different CT protocols for diagnosis of intervertebral disk extrusion in chondrodystrophic dogs, evaluate interobserver variability, and compare duration of examination times. The majority of dogs were middle-aged Dachshunds or Miniature Dachshunds, typical for acute intervertebral disk extrusion.[33,34] All disk extrusions occurred between T12–T13 and L1–L2 intervertebral disk spaces, which is also typical.[35]

On survey radiographs, narrowing, or wedging of the affected intervertebral disk space, narrowing of the space between neighboring articular processes, altered shape of the intervertebral foramen and presence of mineralized disk material within the vertebral canal may be present as a result of intervertebral disk extrusion.[36] High sensitivity of survey radiographs for diagnosis of acute disk extrusion determined in this study (median 94.7%) is better than the 51%–61% sensitivity described in previous reports.[37,38] The cause of this improved sensitivity is uncertain. In contrast to previous studies, digital radiographs were used, which might have contributed to improved sensitivity due to ability to zoom and window the images and improved image contrast. We are not aware of comparisons of accuracy of conventional and digital radiography in the evaluation of disk herniation. Additionally, all dogs in this study only had one major site of acute disk herniation. Presence of additional sites would have complicated the diagnosis and would likely have resulted in a lower sensitivity for radiography. Despite the high sensitivity found in this study, survey radiographs cannot be used alone for diagnosis of disk herniation because they do not provide information about lateralization of disk extrusion, extent and degree of compression and/or presence of additional lesions.

In the diagnosis of level of disk extrusion there was agreement between myelography and surgery in 94.7%, which is comparable to the 90–98% correct longitudinal localization of intervertebral disk extrusion as reported previously.[13,14,19,20] In the diagnosis of level and lateralization of disk extrusion, there was agreement between myelography and surgical findings in 78.9%, which compares with the 37–100% also reported previously.[13,14,18–20,39] Differences in myelographic technique and inability to accurately determine location of extruded disk material at surgery have been proposed as potential factors contributing to poor sensitivity in circumferential localization of extruded disk material on myelography.[14] Concurrent hemorrhage, spinal cord swelling, and inadvertent filling of the epidural and/or subdural space with contrast medium are other factors that may have contributed to difficulty in achieving a myelographic diagnosis.[40,41] Although investigators in this study had variable degree of experience, interobserver agreement in myelographic interpretation was very good ($\kappa = 0.87$). Lack of experience did not appear to play a role in the relatively low sensitivity found for lateralization of extruded disk material by means of myelography.

The decision to perform CT examination of the spine from T9 to L5 rather than from T3 to L3 was made based on the following considerations. Each individual CT image results in radiation dose to the patient and requires an increase in anesthesia time. Additionally, each CT image obtained reduces life expectancy of the X-ray tube. Therefore, minimizing the number of CT slices is beneficial to both radiologist and patient. Because the caudal thoracic and cranial lumbar spine is most commonly affected by intervertebral disk extrusion in small breed dogs,[42] and disk extrusion cranial to T10 is uncommon due to intercapital ligaments crossing the vertebral canal dorsal to intervertebral disks,[43] a decision was made to scan from the level of T9 caudally. The scan area was extended caudally to L5 based on consideration of surgical planning. Disk extrusions can be spread over several vertebral bodies or be associated with extensive epidural hemorrhage necessitating surgical decompression at intervertebral disk spaces cranial or caudal to the affected intervertebral disk space.[44]

On CT images, mineralized extruded disk material appears as heterogenous hyperattenuating material within the vertebral canal, resulting in compression and displacement of the spinal cord.[45] Typically, spinal CT is performed with slice orientation perpendicular to the vertebral canal or parallel to the intervertebral disk spaces, with slice thickness as thin as possible to minimize volume averaging.[46] Disadvantages of this approach include diminished image quality because of a decrease in signal to noise ratio[46] and increase in examination time due to adjustment of gantry tilt between examination of different disk spaces. Helical CT is often the method of choice when assessing humans for spinal trauma due to short acquisition times and high accuracy in the detection of vertebral fractures.[30–32] However, conventional CT has been found to be more accurate in the detection of spinal fractures than helical CT in some settings, which was attributed to a reduction in exposure dose and image quality.[47] Additionally, thicker slices as used in our helical CT protocol may result in decreased image quality due to volume averaging.[46] However, we found very good agreement between both conventional CT and helical CT with surgical findings, and no significant difference in sensitivity between the CT protocols. In the

diagnosis of level of disk extrusion there was agreement between conventional CT and helical CT with surgical findings in 100% (89.5–100%) and 94.7% (84.2–94.7%), respectively. In the diagnosis of level and lateralization of disk extrusion there was agreement between conventional CT and helical CT with surgical findings in 87.4 ± 7.1% and 85.3 ± 2.4%, respectively. In humans, agreement between CT and surgical findings has been reported to range from 71.0 to 92.3%.[21–28] Inability to differentiate bulging or protruding annulus fibrosus from extruded disk material, presence of additional lesions and small size of lesions are problems when evaluating intervertebral disk disease in humans by means of CT.[48–50] Reasons for discrepancies between CT findings and surgical findings in our study were difficult to elucidate. In some instances, disk material was found to the right and left of the spinal cord when evaluating entire longitudinal extent of disk extrusion. Because conventional CT slices were centered over intervertebral disk spaces and did not cover the entire length of adjacent vertebral bodies, disk material outside the scan area might have been missed (Fig. 2). Mistakes also occurred when counting vertebrae on the CT scout view, especially if there were transitional vertebrae or abnormal vertebral formulas. Finally, we used surgical localization of disk material as the gold standard, which has been questioned by other authors.[14]

Interobserver agreement was very good for all imaging modalities. For myelography, κ was 0.87, which is comparable to 0.81 reported in another study in dogs.[14] Interobserver agreement for both CT protocols (conventional CT κ = 0.86; helical CT κ = 0.95) was slightly better than results of studies in humans, where κ values for CT in the diagnosis of intervertebral disk herniation have been reported to range between 0.66 and 0.7.[50,51]

There were significant differences in examination duration times between myelography and both CT protocols. These data have to be interpreted with caution. To minimize the influence of anesthesia complications, positioning, patient preparation, and time needed for interpretation of imaging results after completion of study, only the time during which image acquisition took place was recorded. Additionally, all myelograms were performed by board certified radiologists. However, numerous factors contribute to time needed for the imaging procedure, and our results likely underestimate the examination times in many clinical settings.

Investigators were aware that all dogs had clinical signs compatible with, and underwent surgical exploration for, treatment of intervertebral disk extrusion, which may have added bias. An attempt was made to minimize bias by implementing the following measures. The principal investigator did not participate in evaluation of imaging studies; all studies were randomized and distributed several months up to a year after acquisition; and two of the investigators were not involved in any of the imaging studies when dogs were originally imaged. However, it cannot be excluded that some investigators may have recognized individual patients when evaluating the imaging studies.

One problem when applying results of this study in a clinical setting is that the diagnosis of intervertebral disk extrusion is not known at the time the animal is imaged. Tumors and inflammatory disorders can cause similar clinical signs as intervertebral disk extrusion, and the decision whether to perform CT or myelography is made without knowledge of the actual diagnosis. In the dogs in this study, intervertebral disk extrusion was the most likely differential diagnosis based on signalment and clinical presentation, and no dogs had to be excluded due to a diagnosis other than disk extrusion. Useful follow-up studies might include a comparison of CT and myelography in the diagnosis of spinal disorders other than intervertebral disk extrusion, and a comparison of different imaging modalities in the diagnostic work-up of patients with spinal disease, regardless of the final diagnosis.

The patient population consisted of chondrodystrophic dogs, which are predisposed to chondroid degeneration
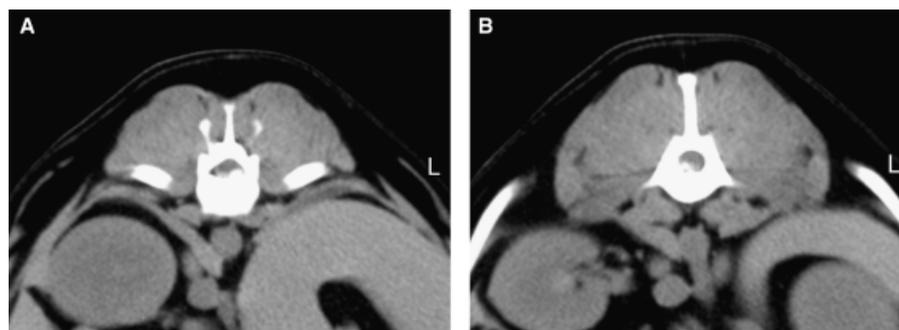

Fig. 2. Transverse images in a dog where a discrepancy between computed tomography (CT) findings was identified. (A) Transverse conventional image at the level of the intervertebral disk space at T13–L1. There is hyperattenuating material associated with the left ventral aspect of the vertebral canal. (B) Transverse helical image over the vertebral body L1. There is hyperattenuating material associated with the right ventral aspect of the vertebral canal. This area was not included in the conventional CT scan.

and mineralization of nucleus pulposus and subsequent intervertebral disk herniation.[2] Presence of mineralized disk material and presence of concurrent hemorrhage within the vertebral canal that is hyperattenuating to the spinal cord are findings expected in acute intervertebral disk extrusion in chondrodystrophic dogs and are easily recognized,[45] which explains high sensitivity and excellent interobserver agreement found in this study. The value of CT in comparison to myelography in the diagnosis of acute herniation of nonmineralized disk material and in the diagnosis of Hansen type II intervertebral disk disease will have to be determined in future studies.

A major limitation was that surgical exploration was only performed at sites of intervertebral disk extrusion found on imaging studies. To determine specificity and accuracy of CT and myelography, euthanasia and exploration of all intervertebral disk spaces would be necessary, which is impossible in a clinical setting.

Our results suggest that survey radiographs, myelography, conventional CT, and helical CT have good agreement with surgical findings when evaluating chondrodystrophic dogs with acute intervertebral disk extrusion and there is very good interobserver agreement when interpreted by specialists. Future studies are needed to investigate accuracy of CT in the evaluation of patients with herniation of nonmineralized disk material as well as Hansen type II intervertebral disk extrusion. Helical CT was significantly faster than myelography and conventional CT, and may be a valuable diagnostic tool for this indication despite recognized limitations.

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