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Basic Science

MRI-based relationships between spine pathology, intervertebral disc degeneration, and muscle fatty infiltration in chondrodystrophic and non-chondrodystrophic dogs

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Abstract

BACKGROUND CONTEXT: Human studies have revealed a link between muscle degeneration and low back pain, although the cause and effect of this relationship is not clear. Dogs provide a naturally developing model of intervertebral disc (IVD)-related low back pain that may provide insight into relationships between IVD and muscle degeneration.

PURPOSE: This study aimed to quantify, via magnetic resonance imaging (MRI), the magnitude and location of fatty infiltration in spine muscles of chondrodystrophic (CD) and non-chondrodystrophic (NCD) dogs suffering from both intervertebral disc herniation (IVDH) and non-disc-related spinal disorders, and relate this to intervertebral disc degeneration (IVDD).

STUDY DESIGN: This study used retrospective MRI-based analysis of IVDD and muscle fatty infiltration in CD and NCD dogs.

METHODS: A portion of this study was funded ($1,000) by the Pet Trust Fund, Ontario Veterinary College. Magnetic resonance imaging from 180 dogs were separated into four groups: (1) CD with IVDH; (2) CD with non-IVDH spinal pathology; (3) NCD with IVDH; (4) NCD with non-IVDH spinal pathology. For each dog at intervertebral levels T12–T13 to L6–L7, IVDD was subjectively graded and muscle-fat indices (MFIndices) were quantified for multifidus, erector spinae, and psoas muscle groups.

RESULTS: Intervertebral disc degeneration grade was higher ($p<.0001$) for CD compared with NCD dogs, and for dogs diagnosed with IVDH compared with dogs with non-IVDH pathology. Muscle-fat indices of multifidus and psoas were higher ($p<.01$), indicating greater fatty infiltration, for NCD compared with CD dogs, and for dogs with non-IVDH pathology compared with dogs with IVDH. Erector spinae demonstrated higher ($p<.0001$) MFIndices compared with multifidus and psoas; however, this level of fatty infiltration was not dependent upon breed or pathology.

CONCLUSIONS: Dog groups with higher average IVDD grades demonstrated less fatty infiltration within their multifidus and psoas muscles, compared with groups with lower IVDD grades. This finding was consistent across both CD and NCD breeds as well as across dogs presenting with IVDH and those presenting with a non-IVDH spinal pathology. Thus, the presence or severity of IVDD is not uniquely related to fatty infiltration in these muscles, but rather the presence, or possibly severity or chronicity, of general spine pathology is likely a better predictor of fatty infiltration.

Keywords: Canine; Erector spinae; Fat; Herniation; Imaging; Multifidus

FDA device/drug status: Not applicable.

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Introduction

A cause of chronic low back pain (LBP) can be related to intervertebral disc degeneration (IVDD) and herniation [1–4], although the underlying etiology and pathogenesis of this process is still being investigated. Studies in human patients have suggested a link between muscle degeneration and LBP [5–9], although the cause and effect of this relationship is not clear. Muscle degeneration can be characterized by atrophy and increased fatty occupation between muscle fibers and bundles of fibers [10,11]. Continued work is needed to understand the processes by which this muscle degeneration develops and how it relates to low back injury and pain.

Animal models of LBP have the potential to provide insight to the link between spinal pathology and muscle degeneration. In a study conducted by Hodges et al. [12], induction of intervertebral disc (IVD) injury in a porcine model led to acute degenerative changes in the multifidus muscle after 3 days, including an increase in intramuscular fat. However, another study designed to assess the more chronic effect of experimentally induced IVD degeneration found no histologic sign of multifidus fatty infiltration after 12 weeks, but did observe significant muscle stiffening brought on by proliferation of the muscle extracellular matrix [13]. These changes were suggested to be an adaptation mechanism of the body secondary to an IVD injury. Although these studies provide excellent insight to possible cause-effect relationships between spine pathology and muscle degeneration, the experimental induction of IVD injury or degeneration cannot mimic exactly the naturally occurring process in humans. Models of naturally occurring IVD degeneration have been studied in the sand rat [14], pin tail mouse [15], Chinese hamster [16], baboon [17], and dog [18].

Intervertebral disc herniation (IVDH), secondary to IVDD, is a disorder with commonly reported neurologic consequences in dogs [19,20], and as such, dogs have often served as a model for biomechanical-based surgical management studies of IVDD. Many aspects related to IVDD and IVDH in canine patients resemble that seen in human patients [18]. Dog breeds are typically divided into chondrodystrophic (CD) or non-chondrodystrophic (NCD) categories. Chondrodystrophic breeds are characterized by a genetic-based disruption of the endochondral ossification leading to abnormal long bone development. This abnormality has also been related to an increase in the prevalence of IVDD and IVDH in these breeds [18,21,22]. The three main clinical differences between the CD and NCD breeds are the age of appearance, location, and type of herniation [22]. Chondrodystrophic dogs begin the onset of IVDD earlier, often by 3 months of age, whereas NCD dogs typically develop IVDD later in life (after 5 years of age) [18,22]. The early changes in the IVD structure in CD breeds are generally observed in all IVD locations and can lead to acute, and often explosive IVD extrusion, called Hansen type 1 [22,23]. In NCD breeds, degeneration occurs at individual IVD levels, and herniation is characterized by a more gradual development resulting in protrusion rather than full extrusion, called Hansen type 2 [22,23]. Important similarities exist between the breed categories as well, such as the chondrification of the nucleus pulposus leading to IVDD, the location of herniations occurring dorsally or dorsolaterally (posteriorly or posterolaterally) within the disc, and the common presence of IVDD in asymptomatic dogs. It can be argued that each of these differences between CD and NCD breeds, as well as their similarities, are representative of certain aspects of the process in humans, and as such, the dog has been highlighted as a useful model for studying IVDD [18]. Thus, the purpose of our study was to quantify, via magnetic resonance imaging (MRI), the magnitude and location of fatty infiltration in spinal muscles of CD and NCD dogs suffering from both IVDH and non-IVDH spinal disorders, and relate this to IVDD grade.

Material and methods

Patients

Medical records, from the local veterinary college, of all cases diagnosed and categorized as thoracolumbar neuropathy conducted from January 2010 to September 2012, were retrospectively studied. All patients who met the inclusion criteria were included in the study. Inclusion criteria were (1) presence of a sagittal plane MRI of the thoracolumbar region (spanning at least the T12–T13 to L6–L7 intervertebral levels); (2) presence of axial plane MRIs through the disc space of each of these intervertebral levels that showed all surrounding musculature; (3) medical records including clinical assessment before the MRI and MRI report with a diagnosis of neuropathy originating in the thoracolumbar spinal region); (4) dogs could be characterized as either CD [24,25] or NCD (no mixed breeds were included) (Fig. 1).

Clinical diagnosis

All patients had a complete physical exam and neurologic exam performed by a board certified neurologist or a board certified surgeon before the MRI. All patients were diagnosed with thoracolumbar neuropathology based on orthopedic or neurologic assessment before the MRI. Specific diagnosis, based on prior exam and MRI findings, were recorded.

Patients were then categorized into one of four groups based on breed type and diagnosis (Fig. 1): (1) CD with IVDH; (2) CD with non-IVDH spinal pathology; (3) NCD with IVDH; (4) NCD with non-IVDH spinal pathology.

Magnetic resonance imaging

All MRIs were performed under anesthesia using the same 1.5-Tesla GE Sigma Excite magnet, GE 8 Channel cardiac array coil (General Electric, Schenectady, New York, USA). For each patient, eight DICOM images were analyzed from axial T2-weighted Fast Recovery Fast Spin Echo (frFSE) scans at the level of each IVD space from T12–T13 caudally to L6–L7, and also one sagittal T2-weighted image at the level of