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Imaging the cauda equina

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INTRODUCTION
Cauda equine syndrome can be the result of a variety of diseases including neoplasia, trauma, discospondylitis, and degenerative or inflammatory disorders. Current imaging modalities allow assessment of gross structural abnormalities but do not provide functional information about the neural tissues and give limited information on inflammatory changes. The main goal of diagnostic imaging is to show accurately the morphological changes present. Although imaging techniques are becoming more sensitive for detecting pathology, there are still problems with specificity and determination of clinical significance of imaging abnormalities. Interpretation of the significance of changes on magnetic resonance imaging (MRI) requires careful integration with the clinical examination due to the poor correlation between MRI changes and clinical signs.

RADIOGRAPHY
Survey radiology can identify neoplasia involving the osseous structures, discospondylitis, fractures and degenerative changes affecting the spine and diseases which may mimic cauda equine syndrome e.g. hip dysplasia. However the poor soft tissue contrast and problems with superimposition means that accuracy is often low. The use of contrast radiographic techniques (myelography, epidurography and discography) can improve diagnostic yield but are invasive and may be difficult to interpret or may not show pathology affecting the foramina or nerve roots. In many larger dogs the dural sac terminates cranial to the lumbosacral disc space, making myelography unhelpful for the diagnosis of lumbosacral disc disease. Due to these limitations cauda equine syndrome is now usually imaged using computed tomography or MRI.

COMPUTED TOMOGRAPHY (CT)
CT permits accurate assessment of the osseous parts of the spine and enables differentiation of bone from soft tissue structures and gas which may not be possible on MRI. With multi-slice CT scanners reformatting of images into different planes is possible without the step artefacts seen in older single slice scanners and the multi-planar capabilities are similar to those that can be obtained with magnetic resonance imaging (MRI). CT has the advantage over MRI in that studies can be performed under sedation and are considerably quicker to perform than MRI. Despite advances in technology the soft tissue contrast with CT is still poorer than MRI which remains the modality of choice to assess the soft tissues. Accurate assessment of disc protrusion and nerve root pathology is possible with CT and there is good agreement between CT and MRI findings in dogs with degenerative lumbosacral stenosis (Suwankong and others, 2006). Contrast enhanced CT shows that increased enhancement is seen with compressive soft tissues but there is no correlation with the type of tissue involved and activity of the pathology (Jones and others, 2002).

MAGNETIC RESONANCE IMAGING (MRI)
MRI is the imaging modality of choice for the cauda equine due to multiplanar capabilities and excellent soft tissue contrast. Despite artefacts from implants (e.g. total hip replacement (THR)) images of the lumbosacral (LS) disc space can be obtained in almost all patients. However disease affecting the lumbosacral plexus cannot be evaluated with MRI following THR due to the large susceptibility artefacts that occur due to the implants. There has been little work done on the technique of MRI in terms of minimum required sequences, imaging planes and image resolution for the investigation of canine cauda equine syndrome. Variations in image quality and differences in MRI protocols are likely to have an impact on accuracy for detection of subtle lesions but has not been investigated to date. In the author’s experience an MRI protocol should include images obtained in 3 orthogonal planes and both T1-weighted and T2-weighted sequences. The use of fat suppressed sequences (e.g. STIR) should be obtained in cases of non-specific back pain and where evaluation of bone marrow and the paraspinal soft tissues is important. The use of intravenous contrast is mandatory for cases of suspected neoplasia and infectious disease. Newer pulse sequences (e.g. CISS, FIESTA) allow thin slice images with high contrast and are useful for evaluating the nerve roots. T2* gradient echo sequences often give the best visualisation of small bone spurs and areas of bone destruction.
Whilst assessment of disc changes can easily be made from sagittal and transverse plane images accurate assessment of the intervertebral foramina should be made from assessment of transverse, parasagittal and dorsal plane images. Transitional LS vertebrae have been associated with LS disease in several studies. The morphology of transitional LS vertebrae is difficult to assess on sagittal and transverse plane images and is best done on dorsal plane images. One of the limitations of MRI is that cortical bone, ligamentous structures and gas may all appear as signal void. It is therefore difficult to differentiate osseous compression from soft tissue hypertrophy.

**MRI ABNORMALITIES**

The appearance of the normal canine intervertebral disk has been described (Sether and others, 1990) and appears similar to that in man. On T2-weighted images the nucleus pulposus is hypointense with a variably present nuclear cleft and is surrounded by the annulus which is hypointense on all sequences. The endplates appear as thin, uniform thickness signal void, with the cartilage layer not usually visible. With normal ageing there is loss of water from the disc resulting in nuclear dehydration which is seen as reduction in signal on T2-weighted images, however this is not enough to explain the signal loss seen on MRI (Czervionke and Haughton, 2002). In *in vitro* studies show that the reduction in signal of the disc nucleus on T2-weighted images more closely reflects glycosaminoglycan concentration than absolute water content. It has been suggested that the reduced signal is due to altered state of the water within the disc nucleus rather than solely due to dehydration (Modic and others, 2007). Degenerative changes of the LS disc can occur in non-chondrodystrophic dogs less than 1 year old and are best assessed on MRI. Several classification schemes of disc degeneration exist for people (Fardon and others, 2001). These correlate discal pathological changes with the MRI changes, however do not address other components of degenerative lumbar sacral stenosis e.g. facet joint involvement. More recently a classification scheme involving MRI, discography and plain radiography has been proposed in an attempt to describe the pathological changes more fully (Thalgott and others, 2004). Whilst there is pathological-imaging correlation reported for canine degenerative disc changes (Sether and others, 1990) there is no universally accepted MRI based classification scheme available for canine disc disease. Degenerative endplate changes are commonly recognised in man, and were first classified by Modic in 1988. Modic type 1 changes occur due to disruption and fissuring of endplates and vascularised fibrous tissue within adjacent endplates. On MRI Modic type 1 endplates appear as decreased signal intensity on T1-weighted images and increased signal on T2-weighted images. Modic type 2 changes are due to endplate disruption and yellow (lipid) marrow replacement and appear as increased signal on T1-weighted images and isointense or slightly hyperintense signal on T2-weighted images. Modic type 3 changes reflect bony sclerosis, and appear as low signal on both T1-weighted and T2-weighted sequences. In man there is some correlation between Modic type 1 changes and low back pain. Whilst bone marrow changes seen with osteoarthrosis have been described in dogs the prevalence and significance of vertebral marrow changes is unknown.

In the majority of cases aggressive LS disease (discospondylitis and neoplasia) is readily diagnosed on MRI and CT. Discospondylitis typically causes destruction of the vertebral endplates, discal enhancement and disruption and contrast enhancement of the paraspinal soft tissues. There are commonly pockets of fluid in the disc space and paraspinal soft tissues and extension into the vertebral canal is common. In some cases it may be difficult to differentiate chronic degenerative disc disease from low-grade infection. Both may show irregular endplates and contrast enhancement of the endplates and subchondral bone is seen with degenerative endplate changes. The presence of apparent fluid pockets within the disk is also not specific for discospondylitis and may also be seen with chronic disc disease (Sether and others, 1990) and is seen with vacuum phenomenon due to diffusion of fluid into the disc space (Wang and others, 2007). Neoplasia affecting the vertebrae and soft tissues of the cauda equina is easily diagnosed on MRI typically with destruction of adjacent structures and the presence of a soft tissue mass. Occasionally chronic inflammatory lesions may result in widening of the foramina and remodelling of the vertebral canal which should not be mistaken for the destruction seen with neoplasia. Swelling of the nerve roots is commonly seen with chronic compressive lesions and may reflect oedema, increased vascularity, inflammation or degenerative changes. Both contrast-enhanced CT and MRI may show enhancement of the nerves (Kobayashi and others, 2006) and is thus a non-specific finding which cannot be used to differentiate nerve root neoplasia from inflammatory or compressive changes.Neuritis affecting the lumbosacral plexus is increasingly being recognised and may be indistinguishable from neoplasia in the early stages. Follow up MRI or biopsy may be required to confirm the diagnosis. Peripheral nerve tumours often affect the lumbosacral plexus and may mimic cauda equina syndrome. Lesions affecting the lumbosacral plexus may not be visible on standard sagittal plane or transverse images of the LS disk. In cases where pathology affecting the lumbosacral plexus is a possibility it is important to image as far caudally as the tuber ischi of either a transverse or dorsal plane.
Subclinical abnormalities of the lumbosacral spine are commonly recognised on CT (Jones and others, 2000) and MRI. Whilst severe changes on MRI may be expected to cause clinical signs and a completely normal study will not there is a large grey zone with dogs with mild-moderate changes on MRI that may or may not show clinical features of cauda equine syndrome. Mayhew and other showed that there is a poor correlation between MRI findings and clinical signs in dogs with degenerative lumbosacral stenosis (Mayhew and others, 2002). Despite these problems most studies show reasonably good correlation between MRI and surgical findings confirming the usefulness of MRI for surgical planning.

ASSESSMENT OF MOTION
The role of motion in the pathogenesis and treatment of cauda equine syndrome is unclear. There are marked species differences in the range of motion of the lumbosacral joint, with dogs having approximately three times the range of flexion/extension compared to man (Benninger and others, 2004) making direct comparisons difficult. Multiple studies have shown that there is a large range of motion in the lumbosacral spine of dogs and that both dorsal and ventral translational motion of S1 relative to L7 can occur. There is increased ventral translational motion of L7 in symptomatic dogs but this may also be seen in asymptomatic dogs and is a non-specific finding. There is also breed variation in geometry of the facet joints which may be expected to have some influence on LS motion. Motion of the spine is complex and occurs in multiple planes however assessment of motion of the vertebrae in the sagittal plane is easily performed on lateral radiographs. The effect of motion on neural structures and soft tissues cannot be determined from plain radiographs. Flexed and extension studies can be performed with both CT and MRI but are often un rewarding. In man dynamic examinations may increase specific and sensitivity but in the majority of cases does not give useful information and the usefulness of MRI obtained with axial loading of the spine is not proven (Leone and others, 2007). When performing MRI of the lumbosacral junction in dogs the spine is often in a slightly hyperextended position which, in most dogs, is likely to exaggerate any dynamic instability. There is no objective data showing that dynamic MRI studies of the lumbosacral junction in dogs result in improved diagnostic accuracy, although may be helpful for surgical planning.

CONCLUSION
MRI is the imaging modality of choice for imaging of cauda equina disease and is sensitive for detecting pathology. In the majority of cases a probable aetiological diagnosis can be made but determination of significance of changes should be based on clinical and neurological examination. If MRI is not available then CT in the majority of cases will give similar information and is preferred for evaluation of purely osseous abnormalities. Radiography in the majority of cases is unhelpful or non-specific but is useful to screen for aggressive disease and fractures and to evaluate dynamic changes.

REFERENCES


