Does choice of imaging modality affect outcome in dogs with thoracolumbar spinal conditions?

OBJECTIVES: A retrospective cross-sectional study was done to look for differences in outcome in canine spinal patients that had myelography compared to those that had magnetic resonance imaging.

METHODS: Medical records of dogs with spinal conditions in the period January 2004 to December 2007 were reviewed. Data on patient age, gender, breed, size, neurolocalisation, rate of onset, imaging modality, time taken to image, type of treatment, neurological grade at admission and discharge, length and cost of hospitalisation and status at discharge were collected. Only dogs with neurological grade 3 to 6 with signs referable to the thoracolumbar spine were included.

RESULTS: Of 107 dogs that met the inclusion criteria, 66 (62%) had myelography and 41 (38%) had magnetic resonance imaging. Using multivariable analyses, non-chondrodystrophoid breed, increasing age and higher neurological grade at admission were found to be associated negatively with survival. Neurological grade 5 at admission was found to be associated positively with likelihood of neurological improvement. Male gender, higher neurological grade at admission and medical treatment were associated negatively with length of hospitalisation. Magnetic resonance imaging, surgical treatment and period of hospitalisation were associated positively with total cost of hospitalisation.

CLINICAL SIGNIFICANCE: No significant association was found between type of imaging and any patient outcome variables except cost of hospitalisation, which was higher for dogs having magnetic resonance imaging. Although magnetic resonance imaging may be considered advantageous compared to myelography because it is non-invasive and provides superior anatomical detail for surgical guidance, no beneficial effect on outcome of dogs with non-ambulatory thoracolumbar spinal disease was found.

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INTRODUCTION

For many years, myelography has been the principal imaging modality used for investigation of dogs with signs of spinal cord disease, particularly those considered potential candidates for surgery (Roberts and Selcer 1993, McCartney 1997). Magnetic resonance (MR) imaging has become more widely available in recent years, and is used increasingly frequently for investigation of dogs with signs of spinal cord disease. MR imaging may be considered advantageous compared to myelography because it provides a more complete depiction of spinal anatomy and pathology (Sether and others 1990, Sande 1992, Ito and others 2005, Penning and others 2006, Naude and others 2008) and because it avoids the need to inject contrast material into the subarachnoid space, which eliminates the risk of adverse reactions to contrast medium (Roberts and Selcer 1993, Carroll and others 1997). MR imaging has replaced myelography in some institutions.

Myelography is a moderately accurate method for localising spinal lesions in small animals. Estimates of accuracy of myelography vary from 72 to 99% (McCartney 1997, Tanaka and others 2004, Gibbons and others 2006). There have been no similar studies of accuracy of MR imaging, but a comparison of myelography and MR imaging in a series of dogs with cervical spondylomyelopathy concluded that MR imaging was more accurate for predicting the site, severity and the cause of spinal cord compression (da Costa and others 2006). Another recent study of dogs with cervical disc disease investigated use of transverse MR images to measure the reduction in cross-sectional area of the spinal cord caused by extruded disc material as a possible prognostic sign (Ryan and others 2008). Although no prognostic result was found, this study demonstrated how MR imaging enables a more detailed assessment of certain spinal lesions than would be
possible with myelography. Another study of dogs with thoracolumbar disc extrusion found that those with a more extensive hyperintensity affecting the spinal cord in T2-weighted sequences were less likely to have a successful outcome (Ito and others 2005), hence prognostic potential may be another advantage of MR imaging.

If superiority of MR imaging compared to myelography is to be considered meaningful for patients, it should produce additional benefits, such as optimal treatment selection, reduced surgery time, reduced hospitalisation time, lower morbidity, lower cost, better neurological function or increased survival. However, it is unclear whether the use of MR imaging leads to improved outcome of dogs with spinal conditions because there are no published veterinary studies on this subject.

MR imaging has been used for small animal patients at our institution since 1998, using a mobile scanner that was initially available only 1 day per week. From 2004, MR imaging was available on Wednesday and Friday every week, and non-ambulatory spinal patients requiring prompt investigation and treatment had either myelography or MR imaging depending on the day they were admitted to the hospital: non-ambulatory spinal patients admitted on Wednesday or Friday had MR imaging whereas those admitted on other days had myelography. During this period, selection of imaging modality for individual non-ambulatory patients was determined primarily by the day of the week on which they were admitted, rather than by the attending clinicians. Since 2008, MR imaging has been available throughout the week. The aim of this study was to utilise case material collected during the period 2004 to 2007 to identify differences in outcome in patients that had myelography compared to patients that had MR imaging for investigation of suspected thoracolumbar spinal disease.

**MATERIALS AND METHODS**

Medical records of dogs with spinal conditions in the period January 2004 to December 2007 were reviewed. Patient age (years), gender (male, female, neutered, entire), breed (chondrodystrophoid or non-chondrodystrophoid), size (<10 kg, 10 to 25 kg, >25 kg), neurolocalisation, rate of onset (acute; < 24 hours, subacute; 24 to 72 hours, chronic; > 72 hours), neurological grade on admission and discharge, imaging modality (myelography or MR), time taken for imaging (minutes), type of treatment (medical only or surgical), length of hospitalisation (days), total cost of hospitalisation (GBP) and status at discharge (alive or dead) were recorded.

Neurological grade was assessed using an ordinal scale: grade 1, thoracolumbar pain with no neurological deficits; grade 2, pain and ambulatory paraparesis; grade 3, non-ambulatory paraparesis; grade 4, paraplegia; grade 5, paraplegia and no bladder tone; and grade 6, paraplegia, no bladder tone and absence of deep pain perception (Scott and McKee 1999). This scale was used because the descriptors are simple and unambiguous and were readily identified in the patient records. It identifies the stages of recovery proposed by Olby and others (2001). Only dogs with signs of thoracolumbar spinal disease and neurological grade in the range 3 to 6 were included in the study. Dogs with signs referable to spinal lesions caudal to L6 were excluded.

All dogs had either myelography or MR imaging. Dogs that had both imaging studies were excluded. Myelography was performed using conventional techniques, primarily via lumbar puncture. The site of contrast medium injection and the number of injections varied between patients. In each instance, the contrast medium used was iohexol (Omnipaque 300, Nycomed Amersham Imaging) at a concentration of 300 mg iodine/ml and dose in the range 0.3 to 0.5 ml/kg bodyweight. MR imaging was performed using a 1.5 Tesla scanner (Gyroscan NT, Philips Medical Systems) with the dogs in dorsal recumbency. Sagittal MR images of the spine were acquired using T1- and T2-weighted sequences. Additional images in transverse and/or dorsal planes were made in the areas of suspected abnormality; and additional sequences, including T1-weighting after intravenous administra- tion of gadoteric meglumine (Dotarem, Guerbet) and T2* gradient echo and short tau inversion recovery, were used based on the interpretation of initial findings.

For both myelography and MR imaging, the time for imaging was calculated as the difference between the time of the first survey image and the time of last image as recorded in the DICOM files. On the basis of the radiological report in file, results of spinal imaging studies were classified as normal, probable disc disease, probable fibrocartilaginous embolism and other.

Calculation of minimum sample size (Eng 2003) was based on $\alpha = 0.05$ and $\beta = 0.2$. By assuming that the smallest difference of interest for the outcome period of hospitalisation would be equal to half the standard deviation, the calculated minimum sample size was 125.

Univariable associations between each outcome variable (length of hospitalisation, total cost of hospitalisation, status at discharge (alive or dead) and change in neurological grade) and each patient level independent variable (age, sex, breed category, bodyweight, onset of signs, treatment, neurological grade change between admission and discharge, days hospitalised, imaging diagnosis, whether discharged alive or dead, imaging modality) were assessed using Cox regression, linear regression, logistic regression and ordinal logistic regression. For age, recorded as a quantitative variable, a test for linear trend and a test for departure from linear trend were conducted to determine whether age could be modelled in linear association with the outcome. Exposure variables with a P value of <0.20 in univariable analysis and considered potentially causal were eligible for inclusion in a multivariable model for each outcome variable (Katz 2003). For length of hospitalisation, status at discharge and change in neurological grade, a forward stepwise addition approach using likelihood ratio tests was employed to assess each independent variable's inclusion in the multivariable model. Variables were retained if P values for both the likelihood ratio test and the Wald test were <0.05. For total cost of hospitalisation, the value of the F-test and R-squared coefficient were used to assess the effect of the inclusion of each variable. All analyses were undertaken using Stata v8.0 (StataCorp LP, College Station, USA). Differences of P<0.05 were considered significant.
RESULTS

Records of 107 dogs met the inclusion criteria. There were 15 entire male dogs, 40 male-neutered dogs, 15 entire female dogs and 37 female-neutered dogs. Median age was six years (range 2 to 13 years). There were 76 chondrodystrophoid dogs and 28 dogs of non-chondrodystrophoid breeds (with three dogs not classified). Fifty-four dogs were less than 10 kg, 21 were 10 to 25 kg and 26 were greater than 25 kg (bodyweight data were missing for six dogs). Fifty-eight (54%) dogs had myelography and 41 (38%) dogs had MR imaging (Table 1). Sixty-four (97%) myelograms and 41 (38%) dogs had MR imaging obtained for this subgroup and the total sample studied. Results of spinal imaging studies were normal in 4 (4%) instances, probable disc disease in 87 (81%), probable fibrocartilaginous embolism in 5 (5%) and other in 11 (10%). Twenty-one (21%) dogs were treated medically and 81 (79%) were treated surgically, with five dogs being euthanased after imaging and before any treatment. The median neurological grade at both admission and discharge was three, although 51 (48%) dogs were discharged with a lower neurological grade (median difference in grade= -1).

Ninety-one (85%) dogs left the hospital alive and 16 (15%) dogs died or were euthanased while hospitalised. Increased imaging time (for both myelography and MR imaging) was associated with the largest patient size category (pWald=0.02). There was a trend towards increased imaging time for MR imaging compared to myelography (pWald =0.064) that was independent of patient type.

Type of dog, age and neurological grade at admission were found to be associated with status at discharge. Chondrodystrophoid dogs had an improved odds of leaving the hospital alive compared to other breeds [adjusted odds ratio (ORadj) 27.0, 95% confidence interval (CI) 1.7 to 407, pWald=0.02]. For each additional year of patient age, the odds of leaving the hospital alive was reduced to 59% of the odds associated with the younger age (pWald=0.02). Dogs that had a neurological grade of 6 at admission had a 1% chance of leaving the hospital alive compared to dogs with neurological grade 3 (pWald=0.02).

Male dogs (ORadj 0.16, 95% CI 0.02 to 0.30, pWald=0.0262), dogs with a higher neurological grade at admission (ORadj 0.17, 95% CI 0.11 to 0.24, pWald<0.0001) and dogs receiving medical treatment (ORadj 0.37, 95% CI 0.16 to 0.85, pWald=0.003), all had reduced odds of a longer stay in hospital.

Of the predictor variables tested, only neurological grade 5 at admission was found to be associated positively with neurological improvement (pWald=0.02). No significant association between the rate of onset of thoracolumbar spinal disease and any of the patient outcomes was identified.

MR imaging, surgical treatment and period of hospitalisation were associated positively with total cost of hospitalisation. Dogs that had MR imaging had a higher average bill than those that had myelography (average difference £670, 95% CI £434 to £906, P=0.001). Dogs treated surgically had a higher average bill than those treated by medical management (average difference was £484, 95% CI £186 to £781, P=0.002). Each additional day in hospital increased the final bill by an average of £78 (95% CI £60 to £95, P=0.001). No significant association was found between type of imaging and outcome variables of any patient except cost of hospitalisation. Other results were not significant (P>0.5).

In order to assess the effect of heterogeneity of the sample, the analysis was repeated for the subgroup of 87 dogs with surgically confirmed thoracolumbar intervertebral disc disease (70 of which were chondrodystrophoid dogs). There were no significant differences in the results obtained for this subgroup and the total sample studied.

DISCUSSION

Of the various possible predictor variables assessed in this study, neurological grade on admission was associated with the most outcomes. Dogs that had a neurological grade of 6 at admission had a much lower chance of survival than dogs with neurological grade 3. This result is consistent with another study comparing modified Frankel scores in dogs with meningomyeloelitis (Griffin and others 2008) in which dogs with a score of less than 3 (ambulatory dogs) tended to be discharged more frequently than more severely affected
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do (OR 5.6, 95% CI 0.9 to 35.3, P=0.07). This survival correlated negatively with neurological grade seems to be intuitive since the more severe the spinal cord injury is, the less likely it is that the prognosis will be favourable.

Patient age was also found to be negatively correlated with survival. It is plausible that older dogs may not tolerate spinal cord injuries as well as younger dogs; however, this result may be influenced by confounding factors, such as higher prevalence of comorbidities in older dogs or reluctance of owners to pursue treatment in older dogs.

Male dogs, dogs with higher neurological grade on presentation and dogs receiving medical treatment, had shorter periods of hospitalisation. The relevance of male gender is difficult to explain; hence, this may be a spurious result. That dogs with higher neurological grade on presentation if spent less time hospitalised initially appears counterintuitive because patients with more severe spinal cord injuries are likely to take longer time to recover voluntary motor function and bladder function sufficiently that they can be discharged from hospital than patients with less severe injuries. This result likely reflects the high mortality and correspondingly short period of hospitalisation of dogs with grade 6 neurological signs.

Dogs with a neurological grade of 5 at admission were most likely to be discharged with a lower neurological grade. This result reflects the fact that few dogs with a higher neurological grade (6) survived, whereas many of those with lower neurological grade (3 or 4) were discharged with the same grade.

No significant association was found between type of imaging (MR or myelography) and three important patient outcomes (length of period of hospitalisation, survival and change in neurological grade). Inability to satisfy the minimum a priori sample size for this study means that these results must be interpreted cautiously. The result of a priori sample size calculation for period of hospitalisation was 125 whereas 107 patients were found. Even if minimum sample size been achieved, it would still have allowed up to a 20% probability that the lack of a significant result was erroneous. Clearly, a larger group of patients would have been more useful statistically, but a suitable large group may be difficult to obtain because practices are increasingly equipped with full-time MR imaging facilities rather than relying on mobile MR units and, under these circumstances, it may be difficult ethically and practically to randomly assign patients to imaging modality without being influenced by variables such as type of patient, clinical signs or tentative diagnosis.

It is possible that this study failed to identify differences because of confounding factors. For example, the study would have been biased if imaging modality was selected according to criteria such as type of patient, clinical signs or tentative diagnosis. Although we cannot claim to have completely avoid such bias, we attempted to minimise its effect by studying patients admitted during a period when selection of MR imaging for individual patients was determined largely by a non-patient factor, namely day of the week. According to a previous study, a delay in performing decompressive spinal surgery adversely affects outcomes in paraplegic dogs with acute disc herniation (Penning and others 2006). This finding dictates that the neurologists at our institution aim to perform spinal imaging and surgery, if indicated, soon after admitting such patients. It is our usual practice for dogs with non-ambulatory paraparesis or worse (neurological grade 3 or above) to be imaged within a few hours of arrival in order to prevent unnecessary deterioration in their status. Hence, during the period of this study, if they arrived on a day when MR imaging was available, they had MR imaging and if they arrived on another day they had myelography. Although this method of assigning subjects to treatment group is not random, it has merit as a control of other patients was assessed by performing the analysis twice, with and without the dogs that had conditions other than disc disease. The lack of any significant difference in the results obtained by these analyses suggests that our conclusions are equally applicable across the spectrum of spinal conditions included in the study.

Diagnosis was not included in the predictor variables used in this study because definitive (surgical or histological) diagnosis was not obtained in all dogs, and the patient population in this study represents a subgroup of all canine spinal patients. For example, dogs with signs referable to lesions caudal to L6 were excluded because myelography is ineffective caudal to this point in many medium- and large-breed dogs in which the dural sac terminates at L6. The study population remains somewhat heterogeneous with respect to the patient age, breed (chondrodystrophoid or non-chondrodystrophoid), neurolocalisation, rate of onset of signs, neurological grade at admission and probable diagnosis. This degree of heterogeneity is considered realistic and appropriate for this study because imaging tests are chosen and performed before diagnosis in clinical settings with similarly heterogeneous populations. To perform the same study in a smaller group of dogs with the same diagnosis might enable specific conclusions, but it would be unclear if those conclusions were applicable to dogs with other spinal conditions. Wider applicability is a recognised advantage of observational studies compared to clinical trials with restrictive inclusion criteria (Krumholz 2008).

Chondrodystrophoid dogs with intervertebral disc disease requiring surgical treatment were the predominant type of patient in this study, comprising 65% of the total. Chondrodystrophoid dogs had a higher survival rate than non-chondrodystrophoid breeds. This finding probably reflects the fact that 92% chondrodystrophoid dogs had thoracolumbar disc disease, a condition with a relatively good prognosis compared to other spinal cord conditions that are more prevalent in non-chondrodystrophoid dogs (e.g. neoplasia). The possibility that outcomes in the group of chondrodystrophoid dogs would be significantly different from those of other patients was assessed by performing the analysis twice, with and without the dogs that had conditions other than disc disease. The lack of any significant difference in the results obtained by these analyses suggests that our conclusions are equally applicable across the spectrum of spinal conditions included in the study.

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because the diagnosis based on imaging studies was not considered suitable as a basis for comparing these modalities. For example, most dogs with fibrocartilaginous embolism have a negative myelogram (Gandini and others 2003) but positive MR scan (De Risio and others 2007), but this difference may be academic when both results are indications for similar medical treatment and will be associated with comparable outcomes. It is the impact of imaging on subsequent case management that affects outcome, not the imaging diagnosis per se.

It must be emphasised that determination of diagnostic accuracy was not an aim of this study (and would have required different methodology). Although few studies to compare accuracy of myelography and MR imaging have been published in dogs (da Costa and others 2006), anecdotal evidence suggests a consensus in favour of MR imaging. In human beings MR imaging has been found to be either superior as a diagnostic test or equivalent to myelography for patients in which myelography is indicated. For example, in a series of human beings with cervical disc disease, myelography, CT myelography and MR imaging provided comparable information about narrowing of the subarachnoid space and compression of the spinal cord (Larsson and others 1989). For human beings with acute spinal injuries, MR imaging is the most sensitive method for detecting abnormalities in the intervertebral discs and spinal cord (Flanders and others 1990). For human beings with suspected developmental abnormalities, demyelinating conditions or spinal neoplasia, MR imaging is considered superior to myelography (du Boulay and others 1990). Interestingly, studies of human beings also indicate that the costs of spinal MR tend to be less than those of myelography, principally because MR avoids the need for overnight hospitalisation to monitor for side effects of myelography and may allow earlier return to work (du Boulay and others 1990, Jordan and others 1995, Annerzt and others 1996).

“The ultimate standard of the usefulness of a diagnostic test is not its accuracy but whether it improves patient-important outcomes” (Guyatt and others 2006). On the basis of our results, MR imaging appears to be as useful as myelography for dogs with non-ambulatory thoracolumbar disease. If there are advantages for MR imaging that affect patient outcomes, these are likely to be evident only for dogs whose treatment is improved because the information provided by the MR images differs significantly from the information that would have been obtained myelographically. This scenario is likely to apply only in the small proportion of canine spinal patients with conditions that require definitive surgical treatment, such as those with a benign neoplasm invading the vertebral canal in which the completeness of resection depends on use of a surgical approach suggested only by the MR images. Hence improved outcomes associated with use of MR imaging may not be evident for the majority of canine spinal patients. Clinicians may prefer to recommend MR imaging because it is non-invasive and provides superior anatomical detail for surgical guidance; however, if MR imaging does not appear to improve patient outcome in most dogs with acute thoracolumbar signs, myelography is still a reasonable option for these patients.

Although there are deficiencies in the methodology of this study that limit confidence in this result, it is possible that, despite the supposed advantages and higher cost of MR imaging compared to myelography, it confers no additional benefit for most dogs with non-ambulatory thoracolumbar spinal disease. This possibility may be of interest to those concerned about the cost of veterinary care, including dog owners and veterinarians (Coe and others 2007).

Conlicts of interest statement

None of the authors of this paper have financial or personal relationships with other people or organisations that could inappropriately influence or bias the content of the paper.

References

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