Original article

Clinical reasoning in canine spinal disease: what combination of clinical information is useful?

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Abstract

Spinal disease in dogs is commonly encountered in veterinary practice. Numerous diseases may cause similar clinical signs and presenting histories. The study objective was to use statistical models to identify combinations of discrete parameters from the patient signalment, history and neurological examination that could suggest the most likely diagnoses with statistical significance.

A retrospective study of 500 dogs referred to the Queen Mother Hospital for Animals prior to June 2012 for the investigation of spinal disease was performed. Details regarding signalment, history, physical and neurological examinations, neuroanatomical localisation and imaging data were obtained. Univariate analyses of variables (breed, age, weight, onset, deterioration, pain, asymmetry, neuroanatomical localisation) were performed and variables retained in a multivariate logistic regression model if $P<0.05$. Leading diagnoses were intervertebral disc extrusion (IVDE, n=149), intervertebral disc protrusion (IVDP, n=149), ischaemic myelopathy (IM, n=48) and neoplasms (n=44).

Multivariate logistic regression characterised IM and Acute Non-compressive Nucleus Pulposus Extrusions (ANNPE) as the only per-acute onset, non-progressive, non-painful and asymmetrical T3-L3 myelopathies. IVDE was most commonly characterised as acute onset, often deteriorating, painful and largely symmetrical T3-L3 myelopathy. This study suggests that most spinal diseases cause distinctive combinations of presenting clinical parameters (Signalment, Onset, Deterioration, Pain, Asymmetry, Neuroanatomical localisation). Taking particular account of these parameters may aid decision making in a clinical setting.

Keywords: Neuroanatomical Localisation, Differential Diagnoses, Dogs, Spinal Disease, Statistical Analysis.

Abbreviations

ANNPE: Acute non-compressive nucleus pulposus extrusion

CKCS: Cavalier King Charles spaniels

CM/SM: Chiari-like malformation/syringomyelia

CSM: Cervical spondylomyelopathy

DM: Degenerative myelopathy

ECS: English Cocker Spaniels

IM: Ischaemic myelopathy

IVDD: Intervertebral disc disease

IVDE: Intervertebral disc extrusion

IVDP: Intervertebral disc protrusion

DLSS: Degenerative lumbosacral stenosis

MUA: Meningoencephalomyelitis of unknown aetiology

SCS: Spinal cord segments

SRMA: Steroid responsive meningitis and arteritis

SBT: Staffordshire bull terriers

XB: Cross breed

Introduction

Spinal disease in dogs is commonly encountered in veterinary practice and encompasses over 40 diseases, many of which can produce similar histories and clinical signs (da Costa 2010b, Parent 2010). Determining which cases need rapid treatment for a favourable outcome usually requires diagnostic testing such as spinal imaging to be performed, however not all owners will be in a financial position to allow such investigations. Constructing an accurate as possible list of differential diagnoses, ranked in order of likelihood, allows rational decisions to be made not only in the formulation of an ideal diagnostic plan, but also in choosing reasonable empiric or symptomatic treatments.

Using the neurological examination to determine where the lesion is along the neuraxis (neuroanatomical localisation) is a key step in investigating spinal disease (Parent 2010). Many diseases may however occur at any point along the length of the spinal cord, or if they have a predilection site, there may be sufficient overlap with possible locations of other diseases that further discrimination between differential diagnoses based on the neuroanatomical localisation alone is not possible. Individual spinal diseases may also be consistently associated with particular signalment, onset, deterioration and asymmetry of clinical signs, and evidence of apparent pain. For example ischaemic myelopathy (IM) and acute non-compressive nucleus pulposus extrusion (ANNPE) will cause per-acute onset, and often highly asymmetric clinical signs (De Risio and others 2009, De Risio and Platt 2010, Gandini and others 2003, McKee and others 2010). In contrast, intervertebral disc extrusion (IVDE) can often cause acute onset myelopathy with spinal hyperaesthesia, and is more prevalent in chondrodystrophic breeds (Brisson 2010). Taking consideration of these multiple, pertinent variables should allow a more refined list of differential diagnoses to be made. While experienced clinicians may intuitively use such a system in their clinical approach, it has yet to be subject to statistical evaluation.

Adopting a more systematic and evidence-based approach may make it possible to generate information and algorithms that are accessible to less-experienced clinicians and can be incorporated into clinical decision making on a daily basis (Schmidt 2007). The objective of this retrospective study was to use statistical analysis to identify factors from the history and neurological examination findings that were significantly associated with common spinal diseases in dogs presented for investigation at a referral hospital. An overall goal of this study was to provide clinicians with validated information with which to develop improved clinical reasoning when investigating spinal disease in dogs.

Materials and Methods

All records of dogs referred to the Royal Veterinary College Referral Hospital prior to June 2012 and investigated for a presumptive diagnosis of spinal disease were considered. Records were sequentially reviewed in a reverse chronological order until the required sample size of 500 dogs (derived from a modified sample size calculation) was achieved. Dogs included in this retrospective study required a complete neurological examination, full clinical records and MRI imaging. All included dogs had a full neurological examination and the neuroanatomical localisation determined by one of three board certified neurologists or four neurology residents under the supervision of board certified colleagues. MRI (1.5-Tesla Gyroscan NT, Philips Medical Systems) reviewed by a board certified radiologist was used to confirm lesion localisation and radiological diagnosis. MRI imaging was performed between three and forty seven hours after admission depending on the nature of the presenting condition. Guidelines on MRI characterisation of IM (Abramson and others 2005, De Risio and others 2007), ANNPE (De Risio and others 2009, McKee and others 2010), neoplasms (Bagley 2010, Jull and others 2011, Palus and others 2012), degenerative lumbosacral stenosis (DLSS) (Meij and Bergknut 2010), Chiari-like malformation and syringomyelia (CM/SM) (Lu and others

2003, Rushbridge and others 2007) and intervertebral disc disease (IVDD) (Besalti and others 2006, da Costa 2010a, Levine and others 2009) were used in making radiological diagnoses. Intervertebral disc disease was further classified as IVDE or intervertebral disc protrusion (IVDP) according to previously described methods (Besalti and others 2006). Surgery was subsequently performed in 95% of IVDE cases and 53% of IVDP cases at which time diagnosis was confirmed. Cases of osseous-associated cervical spondylomyelopathy and disc-associated cervical spondylomyelopathy were included under the single diagnosis Cervical Spondylomyelopathy (CSM) (De decker and others 2012, Delamaide Gasper and others 2014). Where required ancillary diagnostic tests including: CSF analysis, surgical biopsies, tests for infectious disease (bacterial culture/sensitivity, antibody titres and/or PCR for *Toxoplamsa gondii, Neospora caninum* or canine distemper virus) and genetic testing were used to confirm a diagnosis. Degenerative myelopathy (DM) is recognised as a post-mortem diagnosis. In this study all dogs with DM were presumptively diagnosed on the basis of a consistent clinical presentation and an A/A homozygous SOD-1 mutation (Awano and others 2009, Holder and others 2014, Zeng and others 2014). Of eight presumed DM cases three were subsequently available for post-mortem and all three dogs were diagnosed with DM at that time.

Details regarding signalment, disease onset and deterioration, mentation, abnormalities in gait and posture, cranial nerve deficits, postural reaction deficits, spinal reflexes, spinal hyperaesthesia, nociception, asymmetry of neurological examination findings, neurologic grade (Modified Frankel Score (Van Wie and others 2013)) and treatment were obtained from clinical records. Clinical records were in the form of information provided by the referring veterinary practice, handwritten daily kennel sheets during hospitalisation at the Royal Veterinary College, and database records of diagnostic tests and imaging findings. Clinical deterioration was determined at the point of admission by an overall assessment of owner

perspectives, patient records provided by the referring veterinarian and information gained on initial neurological assessment following admission to the Royal Veterinary College. Determination of whether a condition was painful was primarily based on direct palpation and manipulation at the time of admission to the Royal Veterinary College but also took into account owners perspectives, patient records and in a small proportion cases analgesia administered prior to referral. Neurological signs were considered asymmetrical when there was an unequivocal difference in the neurological examination findings between the left and right side of the dog. Diagnoses with two or fewer cases, such as congenital abnormalities, vertebral malformations or trauma, were grouped into the category 'Other'.

All variables were treated as categorical. Onset (days to presentation) was classified as Peracute (<2 days), Acute (2-7 days) or Chronic (>7 days). Age was classified as Younger (<3years), Middle aged (3-9 years), Older (>9 years). Size was classified as Smaller (<10kg), Medium size (10-30kg) or Larger (>30kg). A total of 39 animals without neurological deficits or with spinal pain only were excluded from the statistical analysis. Univariate analyses of potential explanatory variables for each condition were performed. Variables were considered for inclusion in multivariate logistic regression if $P<0.30$ and retained in the final model if $P<0.05$, based on the likelihood ratio test. Multivariate logistic regression was carried out using a Forced Entry Method (where all variables are entered into the equation in a single step) to examine associations between included variables with a significance level of $P<0.05$ (Tabachnick & Fidell 2006). Results are presented with Odds Ratios (OR) and 95% confidence intervals (CI) for each condition versus the overall spinal disease population (Tabachnick & Fidell 2006). Following multivariate logistic regression for each disease variables retained in the final model ($P<0.05$) included: age/weight (Signalment), median time to presentation (Onset), deterioration of condition, pain on palpation or manipulation (Pain), asymmetry in

neurological deficits and neuroanatomical localisation. Non-normally distributed data was presented as median value with the range. Normally distributed data was presented as means and standard deviation (means ± SD). Computations were performed using SPSS (Statistical Package for the Social Sciences v. 21.0.1; SPSS Inc.). Information detailing the full output from multivariate logistic regression is included in Supplementary Table 1.

Results

Signalment

Medical records and MR images of dogs with a presumptive diagnosis of spinal disease between January 2011 and June 2012 were included. Five hundred and seventy three dogs were initially considered with 51 excluded due to lack of MRI imaging and 22 excluded due to incomplete clinical records to leave a final sample population of 500 dogs. Mean age was 7.3 ± 3.2 years (Range: 21 days to 18 years) with mean body weight of 19.4 ± 13.2 kg (Range: 1.6 kg-72.3 kg). One hundred and ninety one dogs were female (162 neutered, 29 entire) and 309 were male (227 neutered, 82 entire). Twenty-six spinal diseases were included with IVDE (149 cases), IVDP (95 cases), IM (48 cases) and neoplasms (44 cases) the leading diagnoses (Table 1). Over 92% of cases were represented by the top ten spinal disease diagnoses (Table 1).

There were 73 breeds with: cross-breeds (XB: 66), Cavalier King Charles spaniels (CKCS: 44), dachshunds (37), Staffordshire bull terriers (SBT: 25) and English cocker spaniels (ECS: 25) the leading breeds. Chondrodystrophic breeds accounted for 75.2% of IVDE. Cavalier King Charles spaniels accounted for 93.0% of CM/SM cases ($P<0.0001$) and 10.5% of IVDP cases.

Cervical spondylomyelopathy, neoplasms and DLSS were more often seen in larger breed dogs while IVDE was more often associated with smaller breeds (Tables 1, 2). Neoplasms and IVDP

were associated with older dogs, whilst CSM was associated with younger dogs although this did not take into account specific diagnoses of Osseous-Associated CSM versus Disc-Associated CSM (Tables 1, 2). Intrinsic myelopathies such as IM and ANNPE were associated with medium size or larger breeds (Tables 1, 2).

Presentation

Ischaemic myelopathy and ANNPE were per-acute conditions with median time to presentation (TTP) of one day (Figure 1, Table 1). Intervertebral disc extrusion presented acutely with a median TTP of two days. Inflammatory conditions such as Steroid Responsive Meningitis & Arteritis (SRMA) and Meningoencephalomyelitis of unknown aetiology (MUA) had a median TTP of approximately one week (Figure 1, Table 1). Neoplasms and IVDP both had a typically chronic but extremely varied time to deterioration with some cases presenting acutely whilst others had displayed clinical signs for many months (Figure 1, Table 1). Ischaemic myelopathy and ANNPE patients were clinically stable or improving in 92% of cases (Tables 1, 2). In contrast, the majority of dogs with DM, CM/SM, neoplasms, DLSS or inflammatory conditions had deteriorating clinical signs (Tables 1, 2).

Neurological examination findings

Over 92% of patients with spinal disease had overt neurological deficits on neurological examination. Exceptions included SRMA where no cases had neurological deficits and CM/SM where only 28% of cases had mild neurological deficits. All SRMA and CM/SM cases were noted to have spinal pain on palpation or manipulation. Meningoencephalomyelitis of unknown aetiology was the only spinal disease significantly associated with altered mentation (52% cases) and cranial nerve deficits (56%) (OR: 7.22, CI: 2.62-19.90. P=0.001) due to brain

involvement (Table 1). Cranial nerve abnormalities were also reported in 10 cases of neoplasia, due to the multifocal nature of the type of neoplasm involved (Table 1).

Pain on palpation

Spinal disease patients were frequently painful on palpation and manipulation with only IM (75% of cases) DM (88% of cases) and ANNPE (60% of cases) being generally non-painful (Tables 1, 2). Intervertebral disc extrusion, IM, ANNPE and neoplasms resulted in loss of deep pain perception in 5-6% of cases.

Asymmetry

Ischaemic myelopathy (81%), CSM (80%), ANNPE (79%) and neoplasms (70%) showed clear asymmetry of neurological deficit (Table 1). In contrast IVDE and IVDP only showed asymmetrical neurological examination findings in approximately 50% of cases (Table 1).

Neuroanatomical localisation

There was 94% agreement between lesion localisation determined by neurological examination and location of the lesion identified on MRI. Neuroanatomical localisation varied significantly by spinal disease (Table 1). Between 67%-71% of IVDE, IM and ANNPE lesions occurred in T3-L3 spinal cord segments (SCS) (Table 1). There were an increased number of lesions at the T12-L2 intervertebral disc spaces with 58%, 41% and 52% of all IVDE, ANNPE and IM lesions occurring in this area respectively. Neoplasms had the most diverse localisation with lesions identified in all spinal cord segments and the brain (Table 1). MUA had multifocal lesions identified on MRI in 86% of cases, which invariably included at least one lesion detected in the brain.

Statistical modeling

Statistically significant output of multivariate logistic regression for leading spinal diseases compared to the overall spinal disease population is shown in Table 2. Variables associated with particular spinal diseases are displayed as Odds Ratios (OR) with 95% confidence intervals to a significance level of $P<0.05$.

Discussion

The initial assessment and formulation of a diagnostic or empiric treatment plan for dogs presenting with signs of spinal disease can be challenging for clinicians. An accurate neuroanatomical localisation, as determined by a thorough neurological examination, is essential to establishing a list of likely or plausible differential diagnoses. However using other clinical information gained from the history and examination, in addition to the neuroanatomical localisation, to help define the problem more precisely will produce a more truncated and manageable list of differential diagnoses to work from. Using such a problem-oriented approach has long been advocated in veterinary medicine as it provides a logical framework for clinical decision making (Lane 2008; May 2013). Although such an approach has recently been shown to be useful in dogs with brain disease it has never been investigated or validated in a large patient population of dogs with spinal disease (Armasu and others 2014). The objective of this preliminary study was to use statistical analysis to identify factors from the history, presentation and neurological examination that were associated with common spinal diseases, in order to improve clinical decision making with these cases.

The spinal disease population in this study included a wide range of breeds (73), ages (21 days–18 years), sizes (1.6-72.3kg) and presenting clinical signs. 26 separate diagnoses were

reached, with the one of the ten most commonly occurring diseases being diagnosed in 92% of the dogs (Table 1). Although 92% of spinal disease cases presented with overt signs of neurological dysfunction a small group of dogs presented with spinal pain only. These included all dogs with SRMA and a large proportion of dogs (72%) with CM/SM. This absence of overt neurological dysfunction provides a useful initial point of classification in order to establish differential diagnoses in these dogs. By further considering factors from the history and presentation the confidence in a particular differential diagnosis can be further increased: 93% of CM/SM cases were CKCS (OR: 23.4, CI: 12.3-34.6, P=0.001) and 90% of SRMA cases were dogs under the age of two (OR: 13.1, CI: 7.3-20.3, P=0.001) (Driver and others 2013, Rusbridge and others 2006, Tipold and Schatzberg 2010). Due to the large number of diverse breeds included in the study, many with small sample sizes, it was not possible to effectively include breed as an independent variable in multivariate logistic regression analysis although this can be considered to be a focus of future work.

A systematic consideration of signalment, onset, deterioration, pain, asymmetry and neuroanatomical localisation can be used to begin to effectively differentiate between those spinal diseases causing neurological dysfunction. IM and ANNPE were unique in being characterised as per-acute onset, non-progressive, largely non-painful and often highly asymmetric T3-L3 myelopathies that affected medium and larger breed dogs (Tables 1, 2, Figure 1) (De Risio and others 2009, De Risio and Platt 2010, Gandini and others 2003). This likely reflects the aetiology of the respective lesions, with fibrocartilaginous emboli obstructing the lumen of the lateralised spinal cord vasculature in IM and extruded nucleus pulposus causing spinal cord injury with little or no residual compression in ANNPE (De Risio and others 2009, De Risio and Platt, 2010, Gandini and others 2003). It is of note that 40% of dogs with ANNPE were considered to be painful. These dogs were typically referred within three to

six hours of onset and it possible they were still experiencing acute pain following the trauma of initial nucleus pulposus extrusion (De Risio and others 2009, McKee and others 2010). Seventy one percent of IM lesions and 67% of ANNPE lesions occurred in the T3-L3 spinal cord segments (Table 1). IM lesions were over 6-fold more likely to be associated with a T3-L3 myelopathy (Tables 1, 2). There were no occurrences of IM in the C1-C5 spinal cord segments contrary to what has previously been reported (Tables 1, 2) (Abramson and others 2005, De Risio and Platt 2010). IM and ANNPE were also more often associated with medium and larger sized dogs as previously described (Tables 1, 2) (De Risio and others 2009, De Risio and Platt 2010). Although the clinical presentation of IM and ANNPE has been described previously, the results of this study emphasise the value of recognising this characteristic set of clinical signs by demonstrating that it does not occur frequently in any other spinal disorder. Being able to include or exclude IM and ANNPE from a list of differential diagnoses is critical as both are non-surgical conditions. However advanced imaging may still be advisable as IM should be managed with early physiotherapy whilst ANNPE patients should ideally undergo an initial period of rest prior to active rehabilitation to prevent further disc extrusion (Abramson and others 2005, De Risio and others 2009, De Risio and Platt 2010, Gandini and others 2003, McKee and others 2010).

IVDE was associated with middle-aged dogs of small or medium size (Tables 1, 2) that were often chondrodystrophic (OR: 16.1, CI: 9.1-28.3, P=0.002). IVDE cases were 2.2-fold more often associated with an acute presentation than other conditions and often had mildly deteriorating neurological signs (Figure 1, Tables 1, 2). The percentage of patients assessed as deteriorating may have been underestimated as the Modified Frankel Score is not suited to precise classification of neurological dysfunction in non-ambulatory dogs and many owners were unable to assess the deterioration of their dogs once they became non-ambulatory (Van

Wie and others 2013). In addition the rapid presentation and early surgical intervention in these dogs meant that the possibility of further deterioration was often avoided. IVDE cases were almost 7-fold more often associated with pain on neurological examination and over 40-fold more often associated with a T3-L3 myelopathy (Tables 1, 2) reflecting previous findings (Brisson 2010, Jeffery and others 2013, Kranenburg and others 2013). There was no statistically significant asymmetry in the neurological examination findings of IVDE cases (Table 2). In cases where asymmetry was noted, MRI findings agreed with lesion lateralization on clinical examination in only 57% of instances. This poor correlation likely reflects the bilateral nature of the spinal cord injury: the direct compression of the spinal cord by the extruded disc material, and the compression against the opposing vertebral lamina or pedicle (Besalti and others 2006, Brisson 2010, Jeffery and others 2013, Levine and others 2009). IVDE presents most predictably as an acute onset, deteriorating and painful T3-L3 myelopathy that is unlikely to show markedly asymmetric clinical signs (Tables 1, 2). In contrast, the common presenting characteristics of IVDP were suggestive of a more chronic onset, often stable but still painful myelopathy that affected medium sized middle aged or older dogs (Tables 1, 2). Whilst often localising to T3-L3 spinal cord segments, IVDP was 10-fold more often associated with C1-C5 SCS than other spinal diseases (Tables 1, 2). These findings correlate well with the previously described waxing and waning clinical signs and diverse localisation of chronic IVDP (Brisson 2010, Jeffery and others 2013).

MUA presented as an acute onset condition, with the majority of patients showing signs of pain (Tables 1, 2). MUA was 38-fold more often associated with a multifocal neuroanatomical localisation with multiple SCS and the brain often affected (Tables 1, 2) (Tipold and Stein 2010). Neoplasms were more often associated with older and larger breed dogs and had a median TTP of 23 days with a maximum TTP of 187 days (Tables 1, 2). This

variation in TTP may reflect a diverse range of effects of individual neoplasms, with tumour type, location, histological grade/invasiveness, metastatic potential and the autoregulatory mechanisms allowing an individual to cope with a space occupying or progressively invasive neoplasm affecting the nervous system, which may vary widely (Bagley 2010, Park and others 2012). Neoplasms were also associated with asymmetric neurological deficits (Table 2). DLSS and CSM were more often associated with larger breed dogs (Table 2) whilst CSM was 16-fold more likely to be associated with younger dogs and have a chronic onset which was consistent with previous findings (da Costa 2010c, De Decker and others 2012, Gasper and others 2014). This study did not differentiate between osseous-associated CSM and disc-associated CSM which are known to have characteristic age and breed predictions (da Costa 2010c, De Decker and others 2012, Gasper and others 2014). It is of note that six out of 10 cases were confirmed as osseous-associated CSM which may have contributed to the association of CSM with younger dogs.

The goal of this study was to establish statistically significant parameters that could be used to improve clinical decision making in evaluating dogs with spinal disease. These preliminary data confirm that spinal diseases had statistically significant combinations of clinical parameters. The data also show that using as few as six variables (Signalment, Onset, Deterioration, Pain, Asymmetry, Neuroanatomical Localisation) systematically evaluated from the history and neurological examination can aid in generating a focused list of differential diagnoses (Figure 2). Used appropriately a shorter and more realistic list of differential diagnoses permits the clinician to institute more cost-effective, appropriate and timely diagnostic and treatment plans. In many cases this may involve the decision on if and when to refer a case for specialist investigation and treatment, or whether empiric therapy based on clinical suspicion is likely to succeed in cases where further investigations are not possible or

permitted. Narrowing the diagnostic possibilities using rigorously applied clinical reasoning may also improve the accuracy of prognostications where a definitive diagnosis cannot be made.

The clinical presentations of some conditions are highly consistent, such as ANNPE, IM, IVDE, whilst others are less precisely characterised. As with all statistical approaches the methods employed in this analysis have some limitations. The 500 cases were selected sequentially as they presented to our clinic meaning that some conditions were represented in greater numbers than others. By default this means that the number of cases (dogs with the spinal disease of interest) and the associated number of controls (dogs without that disease) varies by diagnosis. Although this variance is automatically accounted for in the logistic regression model it inherently means that conditions with fewer cases lack the statistical power of other diseases. The statistical significance of presenting characteristics for some diseases could be improved with increased sample sizes, and although it would have been possible to artificially select patients for each diagnosis we felt the current analytical approach more accurately reflected our presenting population, and therefore the conclusions and statistical inferences were more relevant. It is also evident that the analysis is somewhat dependent on the owner's recollection of their pet's condition and that the presentation of the cases may have been influenced by previous treatment. Future work will involve increasing the case numbers for each spinal disease to further refine and improve the statistical associations for each disease. It is recognised that this analysis was carried out on a referral population, which will inherently bias cases towards the more severe end of the spectrum where advanced imaging or surgical intervention are thought necessary. There are no data or publications currently available with which to compare the presentation of spinal diseases in first opinion practice in the UK although work is ongoing using the RVC VetCompass database to address this issue. It is clear

that the management of complex spinal disease cases cannot be reduced to a simple algorithm, nor is that the intention of this study. However, attempts to develop a statistically supported evidence base from which to determine clinical decisions and diagnostic approach should be considered both valid and necessary. Use of such knowledge could improve the timeliness and accuracy of diagnosis in dogs presenting with signs of spinal disease.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

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Table 1: Summary of presentation and neurological examination findings by spinal disease

			Signalment		*Presentation*		*Neurological deficits*		*Neuroanatomical localisation*				
	n	%	*Age (years, median and range)*	*Weight (kg, median and range)*	*Median time to presentation (days, range)*	*Deteriorating*	*Pain on palpation or manipulation*	*Asymmetric deficits*	*Multifocal*	*C1-C5*	*C6-T2*	*T3-L3*	*L4-S3*
Intervertebral Disc Extrusion (IVDE)	149	29.8	7.0 (2.6-16.4)	11.1 (3.6-52.0)	2.0 (1.0-39.0)	55%	87%	48%	1%	15%	6%	**71%**	6%
Intervertebral Disc Protrusion (IVDP)	95	19.0	8.5 (1.4-16.3)	15.3 (4.4-49.0)	22.0 (3.0-190.0)	44%	84%	52%	6%	29%	21%	**37%**	6%
Ischaemic Myelopathy (IM)	48	9.6	6.3 (1.8-18.1)	22.0 (3.7-72.3)	1.0 (1.0-10.0)	8%	25%	81%	0%	0%	17%	**71%**	12%
Neoplasm	44	8.8	9.1 (3.1-15.1)	23.3 (7.0-63.0)	22.5 (2.0-181.0)	59%	75%	70%	20%	7%	25%	30%	18%
Chiari-Like malformation / Syringomyelia (CM/SM)	29	5.8	5.1 (1.0-10.1)	10.1 (6.5-15.4)	44.0 (1.0-186.0)	76%	97%	14%	**59%***	38%	0%	3%	0%
Meningoencephalomyelitis Unknown Aetiology (MUA)	29	5.8	5.7 (0.9-15.2)	9.8 (1.6-36.7)	7.0 (2.0-62.0)	59%	86%	45%	**86%**	3%	3%	3%	3%
Acute Non-Compressive Nucleus Pulposus Extrusion (ANNPE)	24	4.8	8.5 (1.4-13.2)	23.4 (2.6-52.0)	1.0 (1.0-8.0)	8%	40%	79%	0%	12%	21%	**67%**	0%
Degenerative Lumbosacral Stenosis (DLSS)	14	2.8	8.2 (2.9-14.3)	31.5 (12.1-51.0)	14.5 (4.0-169.0)	64%	100%	64%	N/A	N/A	N/A	7%	**93%**
Cervical Spondylomyelopathy (CSM)	10	2.0	6.8 (2.4-10.5)	41.2 (12.1-72.0)	16.0 (4.0-131.0)	50%	80%	80%	0%	**50%**	**50%**	N/A	N/A
Steroid Responsive Meningitis & Arteritis (SRMA)	9	1.8	1.7 (1.2-4.9)	11.1 (2.0-14.7)	6.0 (3.0-21.0)	56%	100%	0%	**56%[a]**	44%[a]	0%	0%	0%
Subarachnoid Diverticulum	9	1.8	6.1 (1.8-9.4)	31.4 (5.8-57.0)	30.0 (10.0-123.0)	44%	67%	22%	11%	22%	**44%**	22%	0%
Bacterial / Protozoal	8	1.6	6.7 (2.2-11.1)	24.8 (11.5-45.0)	19.0 (2.0-99.0)	62%	100%	62%	0%	0%	0%	**50%**	**50%**
Degenerative Myelopathy (DM)	8	1.6	9.6 (8.1-13.3)	34.6 (21.6-42.7)	90.5 (24.0-181.0)	100%	12%	50%	12%	0%	0%	**62%**	25%
Other	24	4.8%											

*72% of dogs with CM/SM presented with only pain and no neurological deficits. 28% of dogs with CM/SM had both pain and neurological deficits

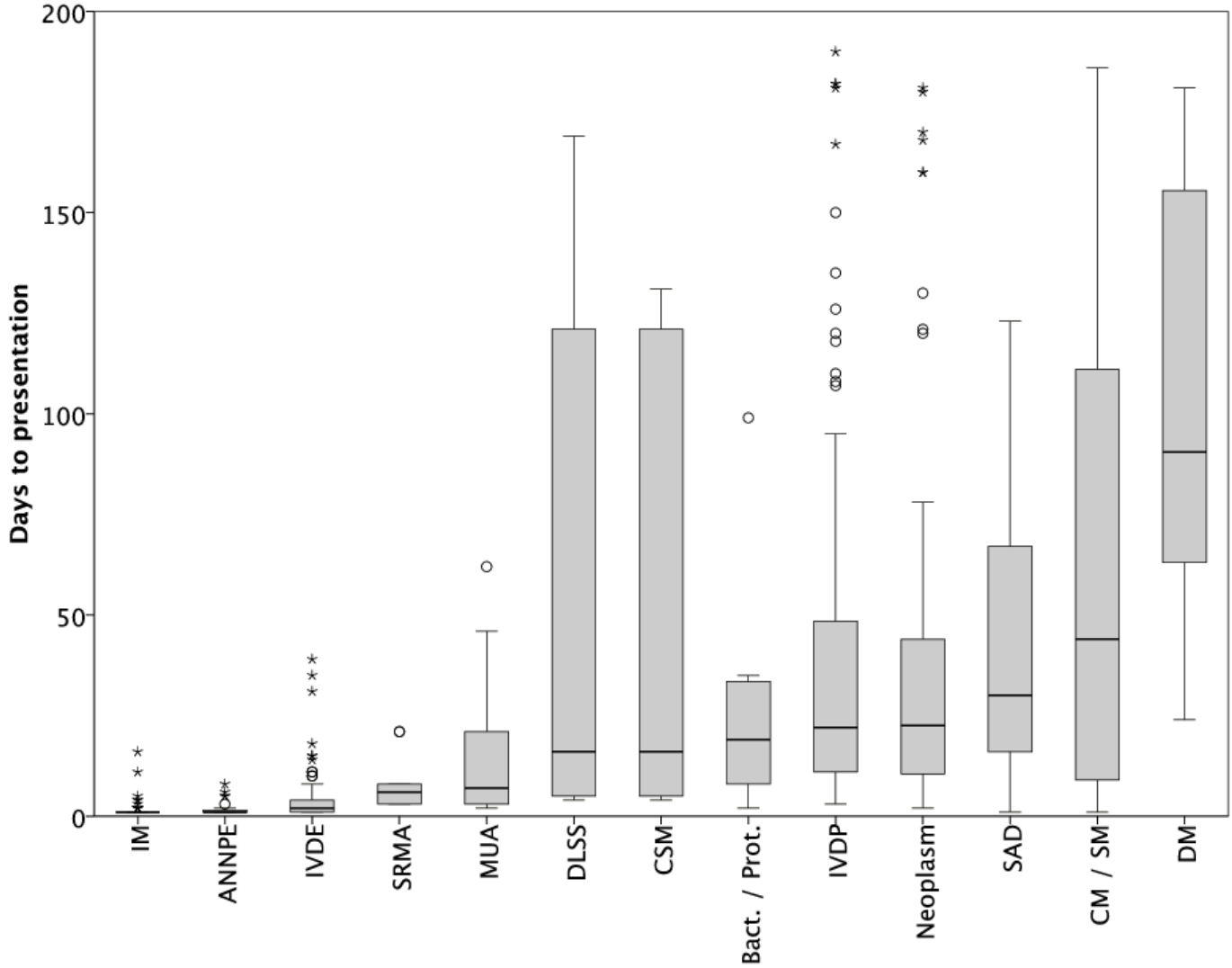
Table 2: Multivariate logistical regression analysis of presentation and neurological examination characteristics of leading spinal diseases with 10 or more cases

	n	*Signalment (age, size)*		*Onset (days to presentation)*	*Deteriorating*	*Pain on palpation or manipulation*	*Asymmetric deficits*	*Neuroanatomical localisation*
Intervertebral Disc Extrusion (IVDE)	147	Middle aged 3.4 (1.7-6.9) *P* = 0.001	Smaller 4.7 (1.9-10.1) *P* = 0.002 Medium size 2.4 (1.1-5.4) *P* = 0.03	Acute 2.2 (1.4-4.1) *P* = 0.04	Deteriorating 2.4 (1.3-4.5) *P* = 0.005	Painful 6.9 (3.4-14.1) *P* = 0.001	Rarely asymmetric 0.5 (0.3-0.9) *P* = 0.01	T3-L3 42.6 (8.7-207.7) *P* = 0.0001 C1-C5 17.2 (3.3-90.3) *P* = 0.001
Intervertebral Disc Protrusion (IVDP)	92	Middle aged 4.2 (0.9-19.4) *P* = 0.04 Older 8.8 (1.8-43.2) *P* = 0.007	Medium size 4.4 (2.1-10.4) P = 0.004	Chronic 74.6 (17.1-125.3) *P* = 0.001	Often stable 0.5 (0.3-0.9) *P* = 0.016	Painful 1.7 (0.9-3.4) *P* = 0.05	-	C1-C5 10.1 (3.5-29.5) *P* = 0.001 T3-L3 9.4 (3.1-28.5) *P* = 0.002
Ischaemic Myelopathy (IM)	48	-	Medium size 2.5 (1.1-5.6) *P* = 0.02 Larger 2.3 (1.1-5.3) *P* = 0.03	Peracute 2.6 (1.9-8.5) *P* = 0.04	Stable or improving 0.18 (0.06-0.6) *P* = 0.005	Non-painful 0.12 (0.1-0.3) *P* = 0.001	Asymmetric 2.9 (2.0-7.1) *P* = 0.02	T3-L3 6.3 (3.9-9.1) *P* = 0.005
Neoplasm	44	Older 2.2 (1.8-5.6) *P* = 0.017	Larger 3.9 (1.7-8.7) *P* = 0.001	Chronic 8.3 (2.4-19.4) *P* = 0.001	Deteriorating 1.4 (1.0-3.9) *P* = 0.04	-	Asymmetric 2.7 (1.3-5.6) *P* = 0.006	-
Meningoencephalomyelitis Unknown Aetiology (MUA)	29	-	-	Acute 7.1 (1.2-21.8) *P* = 0.03	-	-	-	Multifocal 38.7 (4.6-126.8) *P* = 0.01
Acute Non-Compressive Nucleus Pulposus Extrusion (ANNPE)	24	-	Medium size 3.8 (1.0-14.7) *P* = 0.01 Larger 2.0 (0.9-6.5) *P* = 0.03	Peracute 2.0 (1.1-3.6) *P* = 0.04	Stable or improving 0.4 (0.3-1.1) *P* = 0.04	-	Asymmetric 2.2 (1.1-4.7) *P* = 0.04	-
Degenerative Lumbosacral Stenosis (DLSS)	14	-	Larger 12.3 (1.6-96.1) *P* = 0.02	-	-	-	-	-
Cervical Spondylomyelopathy (CSM)	10	Younger 16.3 (3.6-36.1) *P* = 0.02	Larger 6.7 (1.0-55.2) *P* = 0.04	Chronic 10.4 (1.1-100.8) *P* = 0.04	-	-	-	-

Where statistically significant ($P \leq 0.05$) data presented include Odds Ratios with 95% confidence intervals (CI) indicated in parentheses. Characteristics with no statistically significant bias are indicated with '-'

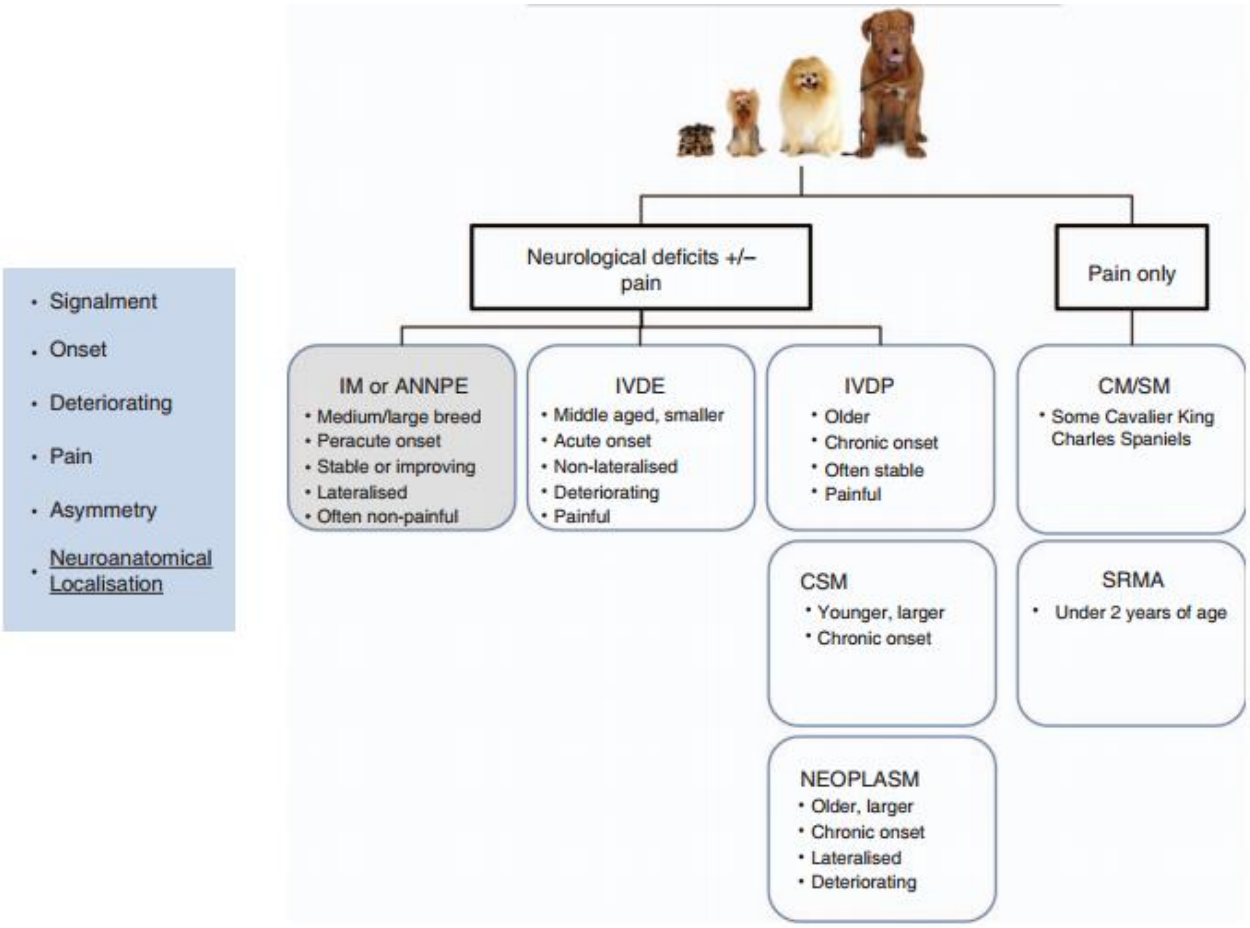
Figure legends

Figure 1: Boxplot of time to presentation (days) for leading spinal diseases



The bottom and top lines of the box represent the first and third quartiles, the line inside the box represents the median, error bars represent the 95% confidence intervals and circles outside the box represent outliers.
Bact/Prot: bacterial or protozoal infections e.g. diskospondylitis, CM/SM: Chiari-like malformation/syringomyelia, CSM: Cervical spondylomyelopathy, DM: Degenerative myelopathy, ANNPE: Acute non-compressive nucleus pulposus extrusion, IM: Ischaemic myelopathy, IVDD: Intervertebral disc disease, IVDE: Intervertebral disc extrusion, IVDP: Intervertebral disc protrusion, DLSS: Degenerative lumbosacral stenosis, MUA: Meningoencephalomyelitis of unknown aetiology, SRMA: Steroid responsive meningitis and arteritis

Figure 2: Schematic of statistically significant associations with common spinal diseases. ANNPE, acute non-compressive nucleus pulposus extrusion; CM/SM, Chiari-like malformation/syringomyelia; CSM, cervical spondylomyelopathy; IM, ischaemic myelopathy; IVDE, intervertebral disc extrusion; IVDP, intervertebral disc protrusion; SRMA, steroid-responsive meningitis and arteritis



Supplementary Table 1: Multivariate logistical regression analysis of presentation and neurological examination characteristics of leading spinal diseases with 10 or more cases.
Onset (days to presentation) was classified as Peracute (<2 days), Acute (2-7 days) or Chronic (>7 days). Age was classified as Younger (<3years), Middle aged (3-9 years), Older (>9 years). Size was classified as Smaller (<10kg), Medium size (10-30kg) or Larger (>30kg). Variables where no data are recorded are indicated by N/A (not applicable). Data with statistical significance of $P \leq 0.05$ are indicated in bold.

Spinal disease	***n***	***Characteristic***	***Variable***	***Odds ratio***	***95% Confidence interval***	***P Value***
Intervertebral Disc Extrusion (IVDE)	147	Signalment (age, size)	**Smaller**	**4.7**	**1.9-10.1**	**0.002**
			Medium size	**2.4**	**1.1-5.4**	**0.03**
			Larger	1.1	0.9-1.9	0.64
			Younger	0.8	0.2-1.1	0.11
			Middle aged	**3.4**	**1.7-6.9**	**0.001**
			Older	1.1	0.9-2.2	0.24
		Onset (days to presentation)	Peracute	1.6	1.1-2.3	0.14
			Acute	**2.2**	**1.4-4.1**	**0.04**
			Chronic	**0.02**	**0.01-0.05**	**0.001**
		Deteriorating	**Deteriorating**	**2.4**	**1.3-4.5**	**0.005**
		Pain	**Painful**	**6.9**	**3.4-14.1**	**0.001**
		Asymmetry	**Asymmetrical**	**0.5**	**0.3-0.9**	**0.01**
		Neuroanatomical localisation	Multifocal	0.9	0.4-2.0	0.53
			C1-C5	**17.2**	**3.3-90.3**	**0.001**
			C6-T2	6.3	1.2-32.6	0.11
			T3-L3	**42.6**	**8.7-207.7**	**0.0001**
			L4-S3	7.6	1.4-42.1	0.07
Intervertebral Disc Protrusion (IVDP)	92	Signalment (age, size)	Smaller	1.8	1.1-3.6	0.30
			Medium size	**4.4**	**2.1-10.4**	**0.004**
			Larger	0.6	0.3-1.3	0.16
			Younger	0.8	0.1-1.3	0.31
			Middle aged	**4.2**	**0.9-19.4**	**0.04**
			Older	**8.8**	**1.8-43.2**	**0.007**
		Onset (days to presentation)	Peracute	0.9	0.6-2.1	0.41
			Acute	6.9	2.2-45.1	0.10
			Chronic	**74.6**	**17.1-125.3**	**0.001**
		Deteriorating	**Deteriorating**	**0.5**	**0.3-0.9**	**0.016**
		Pain	**Painful**	**1.7**	**0.9-3.4**	**0.05**
		Asymmetry	Asymmetrical	0.8	0.4-1.4	0.41
		Neuroanatomical localisation	Multifocal	1.0	0.6-2.3	0.64
			C1-C5	**10.1**	**3.5-29.5**	**0.001**
			C6-T2	3.2	2.1-16.9	0.13
			T3-L3	9.4	**3.1-28.5**	**0.002**
			L4-S3	2.1	0.5-7.9	0.23

Ischaemic Myelopathy (IM)	48	Signalment (age, size)	Smaller	1.2	0.5-3.2	0.71
			Medium size	**2.5**	**1.1-5.6**	**0.02**
			Larger	**2.3**	**1.1-5.3**	**0.03**
			Younger	0.5	0.1-2.1	0.43
			Middle aged	1.1	0.2-6.3	0.95
			Older	0.7	0.1-4.7	0.70
		Onset (days to presentation)	**Peracute**	**2.6**	**1.9-8.5**	**0.04**
			Acute	0.4	0.2-1.1	0.16
			Chronic	**0.1**	**0.0-0.32**	**0.05**
		Deteriorating	**Deteriorating**	**0.18**	**0.06-0.6**	**0.005**
		Pain	**Painful**	**0.12**	**0.1-0.3**	**0.001**
		Asymmetry	**Asymmetrical**	**2.9**	**2.0-7.1**	**0.02**
		Neuroanatomical localisation	Multifocal	N/A	N/A	N/A
			C1-C5	N/A	N/A	N/A
			C6-T2	0.7	0.1-3.2	0.61
			T3-L3	**6.3**	**3.9-9.1**	**0.005**
			L4-S3	0.8	0.2-2.8	0.78
Neoplasm	44	Signalment (age, size)	Smaller	0.9	0.6-1.8	0.33
			Medium size	4.1	1.6-12.7	0.013
			Larger	**3.9**	**1.7-8.7**	**0.001**
			Younger	0.1	0.0-0.9	0.17
			Middle aged	1.1	0.8-1.9	0.61
			Older	**2.2**	**1.8-5.6**	**0.017**
		Onset (days to presentation)	Peracute	0.2	0.01-0.9	0.12
			Acute	2.3	0.6-9.3	0.26
			Chronic	**8.3**	**2.4-19.4**	**0.001**
		Deteriorating	**Deteriorating**	**1.4**	**1.0-3.9**	**0.04**
		Pain	Painful	0.9	0.4-2.4	0.88
		Asymmetry	**Asymmetrical**	**2.7**	**1.3-5.6**	**0.006**
		Neuroanatomical localisation	Multifocal	1.2	0.8-2.3	0.10
			C1-C5	0.3	0.07-1.2	0.08
			C6-T2	0.5	0.2-1.4	0.18
			T3-L3	1.1	0.4-3.2	0.90
			L4-S3	0.9	0.2-2.5	0.67
Meningoencephalomyelitis Unknown Aetiology (MUA)	29	Signalment (age, size)	Smaller	1.4	1.1-6.3	0.11
			Medium size	0.56	0.2-1.8	0.33
			Larger	0.4	0.1-2.0	0.27
			Younger	0.7	0.5-1.3	0.41
			Middle aged	0.8	0.6-2.4	0.18
			Older	0.3	0.04-1.8	0.34
		Onset (days to presentation)	Peracute	0.6	0.3-1.8	0.41
			Acute	**7.1**	**1.2-21.8**	**0.03**
			Chronic	1.6	0.2-11.0	0.62
		Deteriorating	Deteriorating	1.3	0.4-3.7	0.67
		Pain	Painful	2.3	0.4-9.4	0.23
		Asymmetry	Asymmetrical	1.1	0.4-3.7	0.82
		Neuroanatomical localisation	**Multifocal**	**38.7**	**4.6-126.8**	**0.01**
			C1-C5	0.6	0.04-10.8	0.75
			C6-T2	0.2	0.01-3.8	0.32
			T3-L3	1.0	0.06-17.1	0.81
			L4-S3	0.9	0.2-14.3	0.83
Acute Non-Compressive Nucleus Pulposus Extrusion (ANNPE)	24	Signalment (age, size)	Smaller	0.6	0.3-1.1	0.19
			Medium size	**3.8**	**1.0-14.7**	**0.01**
			Larger	**2.0**	**0.9-6.5**	**0.03**
			Younger	0.9	0.2-2.8	0.59
			Middle aged	0.8	0.1-3.7	0.57
			Older	0.8	0.1-6.1	0.82

		Onset (days to presentation)	**Peracute**	**2.0**	**1.1-3.6**	**0.04**
			Acute	0.5	0.2-1.3	0.16
			Chronic	0.1	0.01-0.6	0.09
		Deteriorating	**Deteriorating**	**0.4**	**0.3-1.1**	**0.04**
		Pain	Painful	0.4	0.2-1.1	0.07
		Asymmetry	**Asymmetrical**	**2.2**	**1.1-4.7**	**0.04**
		Neuroanatomical localisation	Multifocal	N/A	N/A	N/A
			C1-C5	1.4	0.3-16.1	0.61
			C6-T2	1.1	0.3-23.1	0.71
			T3-L3	2.1	0.9-24.6	0.12
			L4-S3	N/A	N/A	N/A
Degenerative Lumbosacral Stenosis (DLSS)	14	Signalment (age, size)	Smaller	0.3	0.1-0.8	0.10
			Medium size	0.8	0.5-2.3	0.35
			Larger	**12.3**	**1.6-96.1**	**0.02**
			Younger	0.2	0.1-1.8	0.21
			Middle aged	1.1	0.3-37.7	0.87
			Older	2.8	0.06-128.3	0.61
		Onset (days to presentation)	Peracute	0.9	0.8-1.1	0.79
			Acute	2.4	0.6-11.4	0.25
			Chronic	4.6	0.9-15.1	0.10
		Deteriorating	Deteriorating	2.6	0.5-11.8	0.26
		Pain	Painful	1.8	1.1-8.6	0.44
		Asymmetry	Asymmetrical	3.3	0.6-18.2	0.17
		Neuroanatomical localisation	Multifocal	0.2	0.1-0.8	0.11
			C1-C5	N/A	N/A	N/A
			C6-T2	N/A	N/A	N/A
			T3-L3	0.3	0.03-0.28	0.14
			L4-S3	3.9	2.8-21.3	0.08
Cervical Spondylomyelopathy (CSM)	10	Signalment (age, size)	Smaller	0.1	0.0-1.2	0.34
			Medium size	1.8	1.0-16.3	0.31
			Larger	**6.7**	**1.1-55.2**	**0.04**
			Younger	**16.3**	**3.6-36.1**	**0.02**
			Middle aged	3.2	0.8-30.3	0.16
			Older	1.2	0.3-6.1	0.36
		Onset (days to presentation)	Peracute	0.4	0.1-1.3	0.31
			Acute	2.1	0.2-21.6	0.54
			Chronic	**10.4**	**1.1-100.8**	**0.04**
		Deteriorating	Deteriorating	0.9	0.3-3.4	0.91
		Pain	Painful	2.9	0.3-24.3	0.32
		Asymmetry	Asymmetrical	4.9	0.9-26.2	0.06
		Neuroanatomical localisation	Multifocal	N/A	N/A	N/A
			C1-C5	4.6	3.2-16.1	0.09
			C6-T2	5.1	1.8-26.1	0.13
			T3-L3	N/A	N/A	N/A
			L4-S3	N/A	N/A	N/A