Comparison of medical and surgical treatment for acute cervical compressive hydrated nucleus pulposus extrusion in dogs

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Abstract

Although successful outcomes have been reported after medical and surgical treatment for dogs with cervical hydrated nucleus pulposus extrusion (HNPE), it is unknown which treatment option is preferred. Thirty-four dogs treated medically (n=18) or surgically (n=16) for cervical HNPE were retrospectively identified. Signalment, clinical presentation and imaging findings were compared between medically and surgically treated dogs. Medical management consisted of restricted exercise in combination with physiotherapy. Surgical treatment consisted of a ventral slot procedure. Short-term follow up information was retrieved from re-examination visits. Long-term outcome was obtained via telephone interviews. More dogs in the surgical group demonstrated cervical hyperaesthesia on initial clinical presentation ($P = 0.045$), otherwise there was no significant difference in signalment, clinical presentation, or imaging findings between both groups. Two dogs in the medically managed group underwent surgical decompression due to an unsatisfactory response to medical management. All cases for which long-term information was available (n=30) were neurologically normal at the time of data collection. There were no significant differences for any of the short or long-term outcome variables between both treatment groups. This study demonstrated successful outcomes after medical or surgical treatment and suggests that both treatment modalities can be considered for dogs with cervical HNPE.

Introduction

Acute intervertebral disc herniation is the most common spinal emergency in dogs and encompasses several pathological processes (Cardy and others 2015). It can be defined as a localised displacement of intervertebral disc material beyond its normal anatomical boundaries (Fardon and Milette 2001). Although acute intervertebral disc herniation or extrusion is most often preceded by advanced degenerative changes, including dehydration and calcification of the nucleus pulposus (Smolders and others 2013), sudden extrusion of well-hydrated and non-degenerate nucleus pulposus material can also occur (De Risio 2015). Although there is some controversy about the most appropriate terminology (Lowrie and others 2014, Falzone 2017), two separate types of herniation of non-degenerate to minimally degenerate nucleus pulposus have been recognised; 'acute non-compressive nucleus pulposus extrusion' and 'hydrated nucleus pulposus extrusion' (De Risio and others 2009, Beltran and others 2012). Acute compressive hydrated nucleus pulposus extrusion (HNPE), formerly referred to as 'intraspinal cyst' (Konar and others 2008), is characterised by sudden extrusion of hydrated, non-degenerate to minimally degenerate nucleus pulposus material which in turn leads to contusion and varying degrees of spinal cord compression (Beltran and others 2012). This condition has a predilection for the cervical vertebral column and is therefore most typically associated with clinical signs of severe cervical spinal cord dysfunction, such as non-ambulatory tetraparesis and even tetraplegia (Konar and others 2008, Beltran and others 2012, Dolera and others 2015, Royaux and others 2016). Dogs with cervical HNPE have more severe neurological deficits and less severe signs of cervical hyperaesthesia compared to dogs with other compressive cervical myelopathies (Hamilton and others 2014). Magnetic resonance imaging (MRI) is considered the diagnostic modality of choice (Beltran and others 2012, Dolera and others 2015, Falzone 2017). Characteristic MRI findings in dogs with cervical HNPE include extradural compressive material, isointense to hydrated nucleus pulpous on all sequences located immediately dorsal to the affected intervertebral disc space. The affected intervertebral disc space is narrowed and contains a reduced volume of normally hydrated nucleus pulposus (Beltran and others 2012) (Figure 1A and B). Cytologic and histologic evaluation of the extruded material reveals findings consistent with nucleus pulposus with early signs of degeneration (Dolera and others 2015, Manunta and others 2015, Royaux and others 2016, Falzone 2017). Successful outcomes have been reported after both medical and surgical treatment (Beltran and others 2012, Dolera and others 2015, Manunta and others 2015, Royaux and others 2016) and the most appropriate type of treatment is currently unknown (Lowrie and others 2014, Royaux and others 2016). Although it has been suggested that medical management is usually reserved for dogs with a less severe clinical signs and milder degree of spinal cord compression (Beltran and others 2012, Dolera and others 2015, Falzone 2017), the exact role of medical management is currently unclear. The aims of this study were therefore to compare the clinical presentation and outcome after medical and surgical treatment for dogs diagnosed with cervical compressive HNPE. It was hypothesized that no differences would exist in the clinical presentation and imaging findings of dogs treated medically or surgically for cervical compressive HNPE and that although short-term outcomes would be more favourable for surgically treated dogs, no differences would exist for long-term outcomes.

Materials and Methods

This study was approved by the clinical research ethical review board of the Royal Veterinary College, University of London (Ref: 2016/U16).

The digital medical databases of the Small Animal Referral Hospital, Royal Veterinary College, University of London and the Small Animal Hospital, School of Veterinary

Medicine, University of Glasgow were searched for dogs diagnosed with cervical compressive HNPE between January 2012 and January 2017. Search terms included hydrated nucleus pulposus extrusion and HNPE. To be included in this study, animals had to have clinical signs and imaging findings consistent with a diagnosis of cervical HNPE (Beltran and others 2012) and the medical files and imaging studies had to be available for review. The medical records and imaging studies of each potential case were evaluated by a board certified neurologist to determine study eligibility. Dogs were excluded if clinical signs could not solely be attributed to cervical compressive HNPE or if the medical records or imaging studies were not available for review.

Information retrieved from the medical records included signalment, bodyweight, duration, onset, type and severity of clinical signs, general physical and neurological examination findings, results of diagnostic investigations and type of treatment. For the specific purpose of this study, onset of clinical signs was determined as acute if clinical signs occurred in a period less than 24 hours, subacute if clinical signs occurred over a period between 24 and 48 hours or chronic when clinical signs occurred over a period longer than 48hrs (Beltran and others). The severity of neurological deficits was graded from 0 to 6 and was defined as tetraplegia with reduced/absent nociception with respiratory difficulties/death (grade 0), tetraplegia with intact nociception (grade 1), non-ambulatory tetraparesis (grade 2), ambulatory tetraparesis (grade 3), strongly ambulatory with mild deficits (grade 4), no observational gait abnormalities with cervical hyperaesthesia (grade 5) or neurologically normal (grade 6). This grading system was adapted from a previous study (Fenn and others 2016).

Diagnosis of cervical compressive HNPE was made by high-field MRI (1.5T, Intera, Philips Medical Systems, Eindhoven, The Netherlands or Magnetom, Siemens, Camberley, United Kingdom) under general anaesthesia in all dogs. All animals underwent MRI within 24 hours after presentation for clinical assessment. Dogs were placed in dorsal recumbency, and protocols included a minimum of T2-weighted (repetition time, 3,000 milliseconds; echo time, 120 milliseconds) and T1-weighted (repetition time, 400 milliseconds; echo time, 8 milliseconds) sagittal and transverse images. Slice thickness for sagittal and transverse images were 1.75 mm and 2.5 mm, respectively, with an interslice gap of 0.3 mm in both planes. For each animal the affected intervertebral disc space, the degree of spinal cord compression, and the presence of intraparenchymal spinal intensity (ISI) changes were noted. The degree of spinal cord compression was determined by calculating the remaining spinal cord area, which was defined as the cross sectional area of the compressed spinal cord segment divided by the cross sectional area at the adjacent, non-compressed segment, typically overlying the cranial or caudal vertebral body adjacent to the affected disc space (De Decker and others 2012). Measurements were made on T2-weighted images in the transverse plane. A remaining spinal cord area of 1 represents no spinal cord compression, while a value of 0 would represent complete spinal cord compression. Intraparenchymal spinal intensity (ISI) changes were defined as focal intraparenchymal areas that had a different intensity (hyper or hypointense) compared to the surrounding normal spinal cord parenchyma (da Costa and others 2006). All imaging studies were evaluated and all measurements performed by a board-certified neurologist blinded for the clinical presentation, type of treatment and outcome of the individual dog. Standard image archiving and communication system software (Osirix Foundation, V.5.5.2 Geneva, Switzerland) was used to view and assess the imaging studies.

Owners were informed about the clinical diagnosis and treatment options for cervical compressive HNPE by a board-certified neurologist or a veterinary surgeon enrolled in a neurology residency program. The choice of treatment (medical or surgical) was made by the owners. Surgical management consisted of a decompressive ventral slot procedure.

Perioperative anesthetic and analgesic treatments were at the discretion of the anaesthetist and clinician responsible for the case. Postoperative care consisted of restricted exercise for 4 weeks in combination with physiotherapy and appropriate anti-inflammatory and analgesic medication. Medical management was identical to post-operative care for surgical cases. Restricted exercise was advised in dogs treated medically for cervical HNPE to avoid the potential extrusion of additional nucleus pulposus material. Restricted exercise typically consisted of allowing the dog to make two or three leashed walks a day for toileting purposes and avoiding jumping, running, excessive playing or any other high-impact movements. Owners of both surgically and medically treated dogs were advised to use a body harness instead of a neck collar. For the purpose of this study, dogs that underwent surgical management because of an unsatisfactory response to medical management were included in both groups of dogs. During hospitalisation, all dogs underwent a daily neurological assessment by a board certified neurologist or neurology resident and details of the neurological examination findings were noted in the medical records.

For all dogs, the following information was retrieved from the medical records; complications related to treatment or hospitalisation, duration of hospitalisation, time until neurological improvement was seen, and for those dogs that were non-ambulatory, time until dogs were able to ambulate without support after treatment was initiated. For the purpose of this study, neurological improvement was defined as improvement from a lower to at least one higher neurological grade. Occurrence of improvement and neurological grade were determined at the time of discharge from hospitalisation and at re-examination visits 4 to 8 weeks after diagnosis.

Long-term follow-up was defined as a follow-up period of at least 3 months (Olby and others 2004) and was initially obtained via telephone interview with the referring veterinary surgeons. Conforming to local ethics and welfare committee guidelines, only owners of dogs that were believed to be alive at the time of data collection were subsequently contacted. Owners were mailed a letter with study details and a questionnaire that had been reviewed and approved by the Royal Veterinary College Ethics and Welfare committee. This questionnaire covered specific aspects of the disease, such as signs of pain; amount of activity; gait abnormalities, and incontinence; type of medical and surgical treatment received; and response to treatment. Telephone interviews were conducted by one of the authors (TB) for patients from the Royal Veterinary College and by another author for patients from Glasgow University (RGQ). A successful outcome was defined as resolution or improvement of clinical signs with the dog being able to ambulate independently, able to voluntarily control urination and defecation, and considered by the owner to have no signs of pain.

Data analysis was performed with the assistance of a standard statistical software package (SPSS, V.21.01, SPSS, Chicago, Illinois, USA). Data were assessed for normal distribution using the Shapiro-Wilk test for normality. Median values were reported for variables that were not normally distributed. Continuous variables were compared using a Mann-Whitney U test. Categorical variables were compared using either a Fisher's Exact or Chi Square test. Values of $P<0.05$ were considered statistically significant.

Results

Thirty-three dogs were initially diagnosed with cervical compressive HNPE during the study period. Eighteen dogs were initially treated medically, 14 surgically and one dog was euthanised without treatment attempted. This dog presented with non-ambulatory tetraparesis and had a remaining spinal cord area of 0.71. The owners requested euthanasia due to concerns about long-term recovery and quality of life. Two dogs that underwent initial medical management, underwent eventual surgical decompression due to an unsatisfactory response to medical management. This resulted in a total of 16 surgically treated dogs, 18 medically treated dogs and a total of 34 dogs in which some for of treatment was attempted (Table 1).

Table 1. Signalment, clinical presentation, imaging findings and outcome of 34 dogs treated medically (n=18) or surgically (n=16) for cervical compressive hydrated nucleus pulposus extrusion

VARIABLE	MEDICALLY TREATED DOGS (N=18)	SURGICALLY TREATED DOGS (N=16)	P-VALUE
Median age in months	96	101.5	0.48
Median weight in kg	10.8	18.8	0.16
Male dogs (%)	14 (78)	12 (75)	1.0
Median duration clinical signs in hours	12	12	0.22
Median neurological grade at presentation	2	2	0.06
Ambulatory at presentation (%)	5 (28)	3 (19)	0.69
Cervical hyperaesthesia at presentation (%)	7 (39)	12 (75)	0.045
ISI change present (%)	7 (39)	7 (44)	1.0
Median remaining spinal cord area	0.79	0,79	0.90
Median days to neurological improvement	2	2	0.32
Median days of hospitalisation	4	5	0.061
Ambulatory on discharge from hospitalisation (%)	15 (83)	12 (75)	0.33
Median days to regain ambulation	2	5	0.052
Neurologically improved on reexamination visit (%)*	9 (100)	7 (100)	0.47
Neurologically normal on reexamination visit (%)*	5 (56)	3 (43)	0.64

Neurologically improved on long-term follow-up (%)**	16 (100)	14 (100)	1.0
Neurologically normal on long-term follow-up (%)**	16 (100)	14 (100)	1.0
Successful outcome (%) ***	16 (89)	14 (100)	1.0

ISI = Intraparenchymal spinal intensity. * information available for 9 medically and 7 surgically treated dogs. ** information available for 16 medically treated and 14 surgically treated dogs. *** information available for 18 medically and 14 surgically treated dogs. Cervical hyperaesthesia on presentation was the only significantly different variable between dogs treated medically or surgically for cervical compressive hydrated nucleus pulposus extrusion.

Medically treated dogs

Eighteen dogs were treated medically for cervical compressive HNPE. This group consisted of 14 males (5 neutered) and four females (2 neutered) aged between two and 12.5 years old (median 8 years) and weighing between five and 37 kg (median 10.75kg). Affected breeds included Yorkshire terrier (n=4), Border collie, Labrador retriever and Shih Tzu (n=2 for each) and eight breeds were represented by one dog. Duration of clinical signs ranged from 12 hours to seven days (median 12 hours) and onset of clinical signs was considered acute in 17 dogs and chronic in one dog. Thirteen dogs presented with non-ambulatory tetraparesis (grade 2) and five dogs with ambulatory tetraparesis (grade 3). During neurological examination seven dogs displayed cervical hyperaesthesia. All 18 dogs could urinate voluntarily. The most frequently affected intervertebral disc space was C4-C5 (n=8 dogs), followed by C5-C6, C3-C4 (n=4 for both), C2-C3 and C6-C7 (n=1 for both). In seven dogs

T2-weighted hyperintense ISI changes were present at the site of compression and the remaining spinal cord area ranged from 0.55 to 0.92 (median 0.79).

Two medically treated dogs, which both presented with non-ambulatory tetraparesis (grade 2), did not demonstrate any improvement and therefore underwent surgical treatment two and five days respectively after medical treatment was started. Surgery was uneventful in both cases, with both dogs demonstrating gradual neurological improvement. They were discharged six and five days respectively after surgery both being strongly ambulatory with mild neurological deficits (grade 4). Duration of hospitalisation for the remaining 16 dogs ranged from one to six days (median 4 days). Fifteen dogs were ambulatory at the time of discharge. For the one dog that was non-ambulatory at the time of discharge, time to regain ambulation was 28 days (median time to regain ambulation was 2 days). Time to neurological improvement ranged from one to 28 days (median 2 days).

Eight of these 16 dogs were re-examined four to eight weeks after a diagnosis of cervical compressive HNPE was made. At this time, all eight dogs had an improved neurological status and were ambulatory, and four were considered to be neurologically normal. Long-term follow-up information was available for all 16 dogs and was obtained from the referring veterinary surgeon (n=4) or both the referring veterinary surgeon and the owner (n=12). Duration of follow-up ranged from three to 32 months (median 8 months). All dogs had demonstrated a neurological improvement with all dogs ambulatory and considered to be neurologically normal.

In summary, medical treatment resulted in a successful outcome in 16 of 18 dogs (88.9%). The remaining two dogs did not demonstrate improvement after medical management and experienced a complete neurological recovery after undergoing subsequent surgical management.

Surgically treated dogs

Sixteen dogs underwent surgery for cervical compressive HNPE. Fourteen dogs underwent surgery immediately after diagnosis, while two dogs underwent surgery after an unsuccessful response to medical management. This group consisted of 12 males (6 neutered) and four females (2 neutered) aged between three and 14 years old (median 8.5 years) and weighing between 9.5 and 40 kg (median 18.73kg). Affected breeds included English Cocker Spaniel (n=3), Whippet (n=2), nine breeds were represented by one dog each and two dogs were crossbreeds. Duration of clinical signs ranged from 12 hours to two days (median 12 hours) and onset of clinical signs was considered acute in 13 dogs and subacute in three dogs. Six dogs presented with tetraplegia with intact nociception (grade 1), seven with non-ambulatory tetraparesis (grade 2), two with ambulatory tetraparesis (grade 3) and one with cervical hyperaesthesia without a gait abnormality (grade 5). Cervical hyperaesthesia could be elicited in 12 dogs during neurological examination and four dogs were considered unable to urinate voluntarily. The most often affected intervertebral disc space was C3-C4 (n=9), followed by C4-C5, C5-C6 (n=3 for each), and C2-C3 (n=1). In seven dogs T2-weighted hyperintense ISI changes were present at the site of compression and the remaining spinal cord area ranged from 0.55 to 0.999 (median 0.79). Surgery was uneventful in all cases and surgery revealed white or transparent water-like or gelatinous extradural compressive material in all cases.

Duration of hospitalisation ranged from two to 16 days (median 5 days). Twelve dogs were ambulatory at discharge and for dogs that were non-ambulatory at the time of diagnosis, time to regain ambulation ranged from seven to 28 days (median time to regain ambulation was 5 days). Time to neurological improvement ranged from one to 28 days (median 2 days). For dogs that were unable to urinate voluntarily at the time of diagnosis (n=4), time to regain voluntary control of urination ranged from two to five days (mean 3.5 days).

Seven of 16 dogs returned for re-examination visits four to eight weeks after diagnosis. At that time six dogs had an improved neurological status, all seven were ambulatory and two were neurologically normal. One of these seven dogs presented seven weeks after surgery for sudden onset of cervical hyperaesthesia. Repeat MRI was suggestive for a collapsed ventral slot **(Figure 1)** with compression of the left nerve root. Medical treatment was initiated with Gabapentin (10mg/kg, PO, every 8 hours for 2weeks) and a recommendation of four weeks restricted exercise. This dog demonstrated gradual neurological improvement and was considered neurologically normal three months after surgery. Long-term follow-up information was available for 14 dogs and was obtained from the referring veterinary surgeon (n=5) or both the referring veterinary surgeon and the owner (n=9). Duration of follow-up ranged from three to 33 months (median 18.5 months). One dog had died of an unrelated cause 26 months after surgery and was, at this time, considered to be neurologically normal. Of the remaining 13 dogs, all had demonstrated a neurological improvement, with all dogs ambulatory and neurologically normal at the time of data collection.

In summary, surgical management resulted in a successful long-term outcome in all dogs with available long-term information. One of 16 dogs (6.25%) experienced a surgical complication, which was responsive to medical management.

Comparison between medically and surgically treated dogs

Cervical hyperaesthesia on initial clinical presentation was significantly more often reported in dogs that underwent surgical management compared to medical management (P=0.045). There were no significant differences between both treatment groups for age, bodyweight, gender, neutering status, duration of clinical signs, ambulatory status at presentation, neurological grade, affected intervertebral disc space, ISI changes, and remaining spinal cord area (P>0.05). There were also no significant differences between both treatment groups for time until neurological improvement, duration of hospitalisation, ambulatory status on discharge, degree of neurological improvement on discharge, time to regain ambulatory status, neurological improvement, neurological grade and likelihood of regaining a 'neurologically normal' status at short-term or long-term follow-up (P>0.05) (Table 1).

Discussion

This study evaluated and compared the clinical presentation, imaging findings and outcome of dogs treated medically or surgically for cervical compressive HNPE. The signalment and clinical presentation of dogs included in this study were similar to those reported previously (Beltran and others 2012, Hamilton and others 2014, Dolera and others 2015). A variation of small and large, predominantly non-chondrodystrophic dog breeds with an acute onset of severe neurological deficits were included. Non-ambulatory tetraparesis was the most common clinical presentation and that the majority of dogs presented within 24 hours of onset of clinical signs. Despite the severity of clinical signs, all dogs with available long-term follow-up information experienced a successful outcome and were considered to be neurologically normal at the time of data collection. This finding is in agreement with previous studies suggesting a good to excellent prognosis for full neurological recovery in dogs with cervical compressive HNPE (Kamishina and others 2009, Beltran and others 2012, Dolera and others 2015, Royaux and others 2016, Falzone 2017). Although successful outcomes have been reported after both medical and surgical management of cervical compressive HNPE, it is currently unclear which type of treatment is associated with more favourable outcomes (Lowrie and others 2014, Manunta and others 2015, Royaux and others

2016). Previous studies have suggested that medical management in dogs with spinal disease is usually reserved for dogs with less severe clinical signs and less severe spinal cord compression (Hillman and others 2009, Beltran and others 2012, De Decker and others 2014, Crawford and others 2017). More severe spinal cord compression observed on MRI has indeed been considered the most important indicator to elect surgery over medical treatment in dogs with cervical compressive HNPE (Beltran and others 2012). In contrast, the study presented here failed to demonstrate any important differences in signalment, clinical presentation and imaging findings, including degree of spinal cord compression, between dogs treated medically or surgically for cervical HNPE. The only significant difference between the two treatment groups was that cervical hyperaesthesia was significantly more often noted in dogs treated surgically compared to dogs treated medically. Furthermore, no significant differences were observed for any of the short and long-term outcome measures between both treatment groups. Although these results should be interpreted with caution, our findings suggest that medical treatment can result in rapid and complete neurological recovery in dogs with even severe clinical signs. This finding is of major clinical importance because not every animal is a suitable surgical candidate and not every owner will be able or prepared to pursue surgical intervention for their dog. The clinical importance of this finding is illustrated by the fact that one of the dogs in this study was euthanised after a diagnosis of cervical HNPE was made without any form of treatment attempted due to uncertainties about the long-term prognosis and quality of life after non-surgical treatment. Two dogs underwent surgery because of a perceived unsatisfactory response to medical management. The decision to perform surgery was taken after respectively two and five days and both dogs eventually experienced a complete neurological recovery. Although it cannot be excluded that both dogs would have experienced eventual good recoveries if given more time, these results also suggest that results of surgical treatment are not necessarily negatively influenced by giving considerations to initial medical management.

The fact that dogs with cervical compressive HNPE seem to respond favourably to medical management is possibly explained by several factors. Development of clinical signs in animals with acute extrusion of degenerate and calcified nucleus pulposus ('Hansen type I' intervertebral disc disease) is multifactorial with spinal cord contusion and ongoing spinal cord compression considered two important factors (Jeffery and others 2013). Ongoing spinal cord compression results in decreased spinal cord perfusion and damage to myelin and axons (Olby and others 2004). Although the optimal timing of decompressive surgery is somewhat controversial, early surgical decompression has been suggested to improve outcome in people with acute spinal cord injury and ongoing spinal cord compression (Yousefifard and others 2017). The acute onset of severe neurological deficits suggests also an important role for spinal cord contusion in the pathophysiology of cervical HNPE (Beltran and others 2012, Jeffery and others 2013). Median duration for neurological improvement and time to regain ambulation after initiation of medical management were however only two days. This rapid neurological improvement without surgical decompression could question the role of sustained spinal cord compression in the pathophysiology of cervical HNPE. In contrast to extruded nucleus pulposus in dogs with "Hansen type I" intervertebral disc disease, the extruded material in dogs with HNPE has been described as a gelatinous liquid, water-like or lumpy liquid (Dolera and others 2015, Falzone 2017). It is possible that the soft texture of extruded material in HNPE is therefore not necessarily associated with sustained spinal cord compression. It has also been suggested that the biochemical characteristics of the almost healthy extruded nucleus pulposus in cervical HNPE could allow spontaneous and rapid resorption (Manunta and others 2015). Previous reports have indeed demonstrated complete disappearance of extruded material when follow-up MRI was performed 1.5 to six months after medical treatment for cervical compressive HNPE was started (Kamishina and others 2010, Manunta and others 2015).

Surgery by a decompressive ventral slot procedure is an accepted treatment modality for cervical compressive HNPE in dogs and can be justified by the combination of severe clinical signs and the presence of extradural, moderately compressive material (Beltran and others 2012, Dolera and others 2015, Falzone 2017). In agreement with previous studies, surgical treatment resulted in rapid improvement and excellent outcomes. This study failed however to demonstrate a clear benefit from surgical intervention over medical management. Spinal surgery is furthermore associated with increased expenses and potential complications. Although a ventral slot procedure can be considered a standard surgical technique, potential complications include intraoperative haemorrhage of the internal vertebral venous plexus, vertebral subluxation, a collapsed ventral slot, respiratory compromise, and infection (Sharp and Wheeler 2005). One dog included in this study experienced a postoperative complication, consisting of a collapsed ventral slot. Although severe complications after ventral slot surgery are rare and this dog improved with subsequent medical management, these findings illustrate that the decision to perform decompressive spinal surgery should be carefully considered and should ideally be reserved for dogs unlikely to recover after medical management. Further studies are therefore needed to identify prognostic factors for medical management and identify reliable surgical indicators for dogs with cervical compressive HNPE.

This study is obviously limited by its retrospective study design. Allocation of included dogs to medical or surgical treatment was not randomised and direct comparisons between both treatment modalities should therefore be done with caution. Efforts were however made to compare the signalment, clinical presentation and imaging findings between both treatment groups. Although the final decision to perform surgery or pursue medical management was made by the owners of the individual dogs, it cannot be excluded that owners were influenced by preferences and previous experience of the responsible clinician. Furthermore, only a small number of dogs could be included in this study. A small sample size can be associated with a type II error or the failure to detect an effect that is actually present. It can therefore not be excluded that differences in clinical presentation and outcome would have become apparent with a larger population size. A sample size calculation based on the results of this study indicated that we should have included 174 dogs if we we would have wanted to demonstrate a significant difference in successful outcome between medical and surgical treatment for cervical compressive HNPE.

Despite these limitations, the results of this study provide important new information. Excellent outcomes, characterised by rapid and complete neurological recovery were observed after both medical and surgical treatment for cervical compressive HNPE. In agreement with previous suggestions (Munanta and others 2015), medical management should, despite the severity of clinical signs, be considered a viable treatment option in dogs with cervical compressive HNPE. Further studies are necessary to identify surgical indications and objectively compare outcome after medical and surgical treatment for cervical compressive HNPE.

Conflicts of interest

The authors declare that there were no conflicts of interest.

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Figure Legends

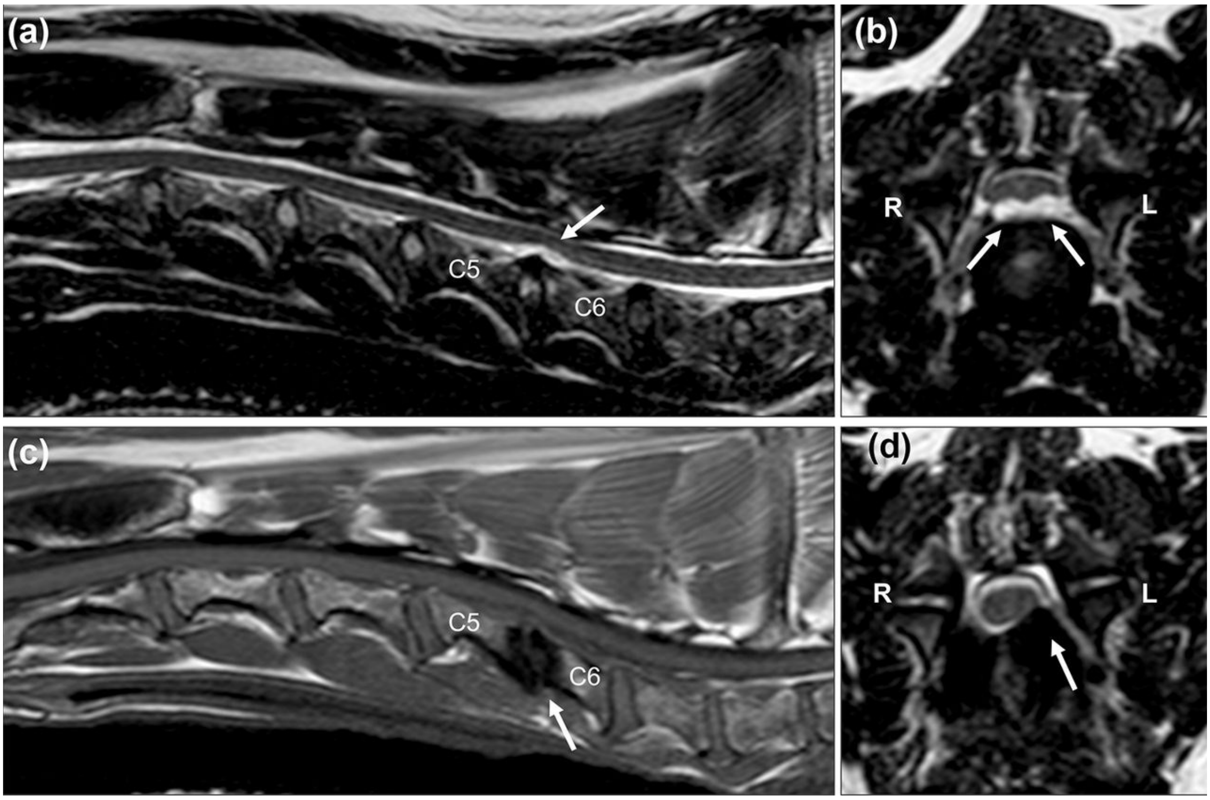

Figure 1. T2-weighted sagittal (A) and transverse (B) magnetic resonance (MR) images of an 8-year-old, male, Doberman Pinscher with cervical hyperaesthesia and no other neurological deficits. (A) A ventral extradural compression overlying the C5-C6 intervertebral disc is visible (arrow). The compressive material has the same intensity as normally hydrated nucleus pulposus. The intervertebral disc space is mildly narrowed and contains a reduced volume of normally hydrated nucleus pulposus. (B) The material has the typical bilobed or 'seagull' appearance (arrows) and causes moderate spinal cord compression. T1-weigted sagittal (C) and T2-weighted transverse (D) MR images of the same dog 7 weeks after a ventral slot procedure was performed. (C) The C5-C6 intervertebral disc space is collapsed (arrow). (D) A left sided extradural compression of the spinal cord and C6 nerve root (arrow)