Hydrated Nucleus Pulposus Extrusion in Dogs: Thoracolumbar Compared to Cervical Cases

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Abstract

Objective The aim of this study was to review and describe cases of thoracolumbar (TL) hydrated nucleus pulposus extrusion (HNPE) diagnosed with magnetic resonance imaging and surgery, and compare them to cases of cervical (C) HNPE.

Study Design Retrospective, single-center study.

Results Thirty-six dogs met the inclusion criteria. Fifteen cases were C and 21 TL. Thirteen dogs were chondrodystrophic breeds, mean body weight was 13 kg, median age was 7.5 years, and 30/36 were male. Fewer dogs were chondrodystrophic in the C group compared with the TL group ($p = 0.022$). More than 90% had an acute onset, and strong activity was more often reported in the TL group. TL HNPE was more often painful, and extruded disc material more often lateralized ($p = 0.017$). Median Modified Frankel Score at presentation was 3 and 72.2% were non-ambulatory. More TL HNPE (11/21) were treated surgically compared with C HNPE (4/15). Treatment choice was correlated with spinal cord compression ($p = 0.0075$). Median Modified Frankel Score improved during hospitalization ($p = 0.002$) and there was no difference in outcome between C and TL HNPE or conservative and surgical treatment. Mean follow-up time was 33 days. All patients were ambulatory at follow-up.

Conclusion This study suggests that the HNPE is not limited to the C vertebral column of dogs and can occur in the TL vertebral column as well. Dogs with TL HNPE show spinal hyperesthesia more often and extruded nucleus material is more often lateralized. Outcome is similar to what has previously been described for C HNPE.

Keywords

- hydrated nucleus pulposus extrusion
- intervertebral disc extrusion
- paresis
- paralysis
- dog

Introduction

In 1952, Hansen described the difference between a degenerative intervertebral disc disease with a nucleus pulposus extrusion (Hansen type I) and an intervertebral disc disease with an annulus protrusion (Hansen type II).[1] Modern imaging technology has made it possible to sub-classify the nucleus pulposus extrusion based on the degree of the nucleus pulposus degeneration. Five different sub-types of Hansen type I extrusion within the spinal canal are described today, and they do not only have differences in pathological appearances, but also on clinical presentation, treatment and prognosis.[2,3]

In 2008, Konar and colleagues published a case series of dogs suffering from cervical (C) compression caused by a ventral intra-spinal cyst.[4] Several following publications of similar cases showed that a cystic wall was missing, and that the compressing material consisted of mildly degenerated nucleus pulposus material.[5,6] The term 'hydrated nucleus pulposus extrusion' (HNPE) has since been established for this condition.[3,5,7] Clinically, most of these patients present with an acute onset of often severe ambulatory paresis or paraplegia, and a lack of intense pain, which is otherwise normally detected in other types of disc extrusion with more degenerated and calcified nucleus pulposus.[2,3,8] Cervical

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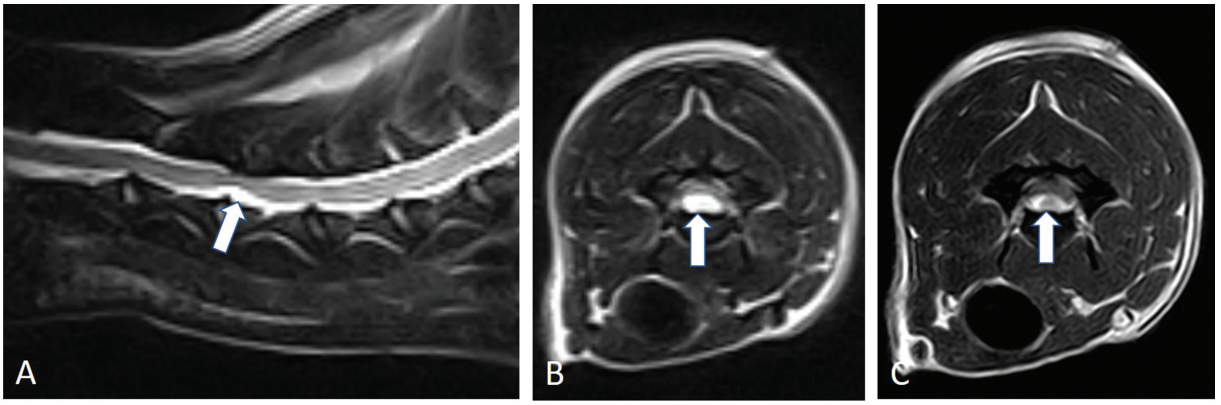

Fig. 1 MRI findings in dog 6 diagnosed with cervical hydrated nucleus pulposus extrusion at C3-4. A) and B) T2 sequences, C) HYCE sequence. Notice the ventral and centrally located compressive, hyper intense material (white arrows).

HNPE have a typical magnetic resonance imaging (MRI) appearance: reduced volume of the affected nucleus pulposus, compressive material often with a bilobed 'seagull' shape and isointense to nucleus pulposus lying directly over the affected intervertebral disc.[5,9] Surgical or conservative treatment has often resulted in a good outcome.[10,11] The vast majority of reported cases of canine HNPE in the veterinary literature have occurred in the C vertebral column.[5,6,8,9,11–13] A review of HNPE cases in our hospital revealed that the majority of HNPE occurred in the thoracolumbar (TL) vertebral column. It is therefore the purpose of this study to present these cases and compare them to the C HNPE treated in our hospital as well as cases found in the literature.

Materials and Methods

Data Collection

The hospital's case log of spinal patients was reviewed for cases with suspected HNPE presenting between January 2015 and November 2020. Diagnostic images were reassessed in OsiriX DICOM Viewer (v.8.0.2) and medical records reviewed. Inclusion criteria were complete medical records as well as the diagnosis of HNPE on MRI, defined as extradural compressive material concentrated above an intervertebral disc space and being isointense to hydrated nucleus, as previously described.[5,9]

The following data were collected for all cases: Age, breed, gender, bodyweight, type of onset, activity at onset, presenting clinical signs including Modified Frankel Score (MFS 6: normal; MFS 5: paraspinal hyperesthesia only; MFS 4: ambulatory tetra-/paraparesis, the animal can take ten consecutive unassisted weight-bearing steps; MFS 3: non-ambulatory tetra-/paraparesis, not able to walk ten steps unassisted; MFS 2: tetra-/paraplegia with intact superficial and deep pain sensation; MFS 1: tetra-/paraplegia with absent superficial but intact deep pain sensation; MFS 0: tetra-/paraplegia with absent superficial and deep pain sensation), diagnostic imaging findings, choice of treatment (conservative *vs.* surgical *vs.* euthanasia), macroscopic description of disc material in surgical cases, anaesthetic protocols and all medication administered, time spent in hospital and clinical status including MFS at discharge. Time to regain ambulation and MFS at follow-up visits were also included if available. Spinal hyperesthesia was defined as either absent, mild or strong. Type of onset was defined as acute ($<$ 24 hours), subacute (24–48 hour) or chronic ($>$ 48 hours) in accordance with previous studies.[5,9]

Diagnostic images were obtained with a low field 0.25 Tesla MRI (esaote Vet-MR Grande) and consisted of at least sagittal and transverse T2-weighted images, and 3D HYCE transverse sequences (►**Figs. 1** and **2**). Other sequences included GE STIR (transverse and or dorsal) as well as Turbo 3D T1 (transverse and dorsal) in cases administered contrast. The slice thickness and the slice gap varied between 1.6 and 5mm and 1.6 and 5.5mm, respectively, depending on the chosen MRI sequence (3D HYCE: TR 10, TE 5, slice thickness 1.6–2mm, slice gap 1.6–2mm, T2 sag: TR 3000–5830, TE 90–120, slice thickness 3–5, slice gap 3.3–5.5mm, STIR: TR 1780–2400, TE 25, slice thickness 3–4, slice gap 3.3–4.4mm, Turbo 3D T1: TR 38, TE 16, slice thickness 1.9–2.8mm, slice gap 1.9–2.8mm).

Conservative management consisted of minimum 4 weeks of rest, pain management and rehabilitation. Surgical management consisted of decompressive surgery with either ventral slot or a hemilaminectomy. Postoperative care was identical to the conservatively managed group. A urinary catheter was placed when deemed necessary by the veterinarian in charge, both in conservatively and surgically treated cases. Dogs were discharged from hospital when

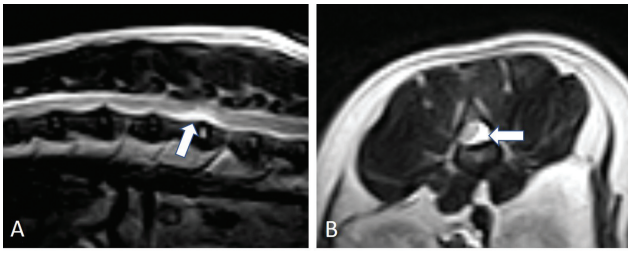

Fig. 2 MRI findings in dog 22 diagnosed with thoracolumbar hydrated nucleus pulposus extrusion at L2-3. A) and B) T2 sequences. Notice the lateralisation of the extruded disc material (white arrow) on the transverse image.

their pain was sufficiently managed, and they had regained urinary function.

Anaesthetic Protocols

The anaesthetic protocol consisted of premedication with methadone (Semfortan vet, 10mg/ml, Dechra, Upplands Väsby, Sweden) and acepromazine (Plegicil vet, 10mg/ml, Pharmaxim, Helsingborg, Sweden) subcutaneously, followed by intravenous induction with propofol (Rapinovet, 10mg/ml, Intervet, Stockholm, Sweden or Propovet Multidose, 10mg/ml, Orion Pharma Animal Health, Helsinki, Finland) and maintenance on inhalation with isofluran.

The patients were treated with at least one of the following opioids whilst hospitalised: methadone (Semfortan vet, 10mg/ml, Dechra, Upplands Väsby, Sweden), buprenorphine (Temgesic, 0.3mg/ml, Indivior Europe, Dublin, Ireland), or fentanyl (Fentanyl, 50ug/ml, B. Braun, Danderyd, Sweden). All received a non-steroidal anti-inflammatory drug (NSAID). NSAID treatment was recommended for at least four weeks for both treatment groups. Twenty-two dogs received gabapentin (Teva-Gabapentin, Teva Helsingborg, Sweden) alongside NSAID treatment. Case dependant treatment with bladder stimulants, gastro-protectives, appetite stimulants, and antibiotics was necessary in some cases.

Statistical Analysis

Data were collected in Microsoft© Excel (2017). For statistical analysis, RStudio (Version 0.99.893 ©2009–2016 for Macintosh) was used. Comparison between groups (C *vs.* TL or conservative *vs.* surgical) was performed with Fisher's exact test for binary variables, and the Mann–Whitney U test for continuous or scaled variables. Paired samples (changes in MFS over time) were analysed with the Wilcoxon Rank sum test. A significance level of 0.05 was used.

Results

Thirty-six dogs met the inclusion criteria (►**Appendix Table 1**). Of these, 15 cases were C and 21 TL. Thirty dogs (30/36) were male. Mean bodyweight was 13 kg overall (range: 3.3–44.0 kg) and not statistically different between the C and TL groups ($p > 0.05$). There were 10 mixed breed dogs, two of each of Short-haired Dachshunds, Cocker Spaniels, Miniature Poodles, Border Terriers, Labrador Retrievers and Pugs, and further one of each of 14 other breeds (Welsh Springer Spaniel, German Hunting Terrier, Basenji, Fox Terrier, Västgötaspits, Lagotto Romagnolo, Whippet, Japanese Spits, Basset Blue de Gascogne, Dandie Dinmont Terrier, Long-haired Dachshund, French Bulldog, Portuguese Water Dog and Welsh Corgi Cardigan). There was a significant difference in breed composition between C HNPE and TL HNPE ($p = 0.022$). Overall, 13/36 dogs were chondrodystrophic, 3/15 C HNPE and 10/21 TL HNPE. Median age at presentation was 7.5 years (range: 2.4–12 years) with no statistical difference between the C and TL groups. All but two dogs had a history of acute onset. Half of all dogs had known strong activity or trauma at onset (5/15 of C HNPE *vs.* 13/21 of TL HNPE, $p > 0.05$). The described activities were mostly the dog playing in or out of sight, either alone, with another dog, or with a ball. Nineteen of 33 dogs presented with spinal hyperesthesia, and 14/33 without (8/13 pain-free C HNPE *vs.* 6/20 pain-free TL HNPE, $p > 0.05$). Of cases with spinal hyperesthesia, the majority was experiencing only mild pain (15/19). Median MFS at presentation was 3 (range: 1–5) and there was no significant difference in presenting MFS between the C and TL groups ($p > 0.05$).

Imaging Findings

All 36 dogs had MRI performed. Twenty-four dogs (24/36) had an initial non-diagnostic computed tomography (CT) performed. Three of 21 TL cases and 9/15 C cases had only an MRI without an initial non-diagnostic CT. In all cases, the extruded material had a T2 intensity similar to normal nucleus pulposus, independent from their location (C or TL). The intervertebral disc space was decreased in 14/15 C cases, which is different from the TL herniations where only 6/21 cases revealed a decreased intervertebral disc space. A seagull-like appearance of the extruded material was noticed in 9/15 C cases and only in 2/21 TL cases (►**Appendix Table 2**).

Of the 15 C cases, C5–6 was the most affected site ($n = 5$), followed by C3–4 and C4–5 ($n = 4$ respectively) and C6–7 ($n = 2$). Of the 21 TL cases, T13-L1 was most affected ($n = 8$) followed by L1–2 ($n = 5$), T12–13 ($n = 3$), L2–3 ($n = 2$) and T11–12 ($n = 1$). It was inconclusive which disc was affected in two TL cases. Disc extrusions were lateralized in 21/36 cases (5/15 C HNPE *vs.* 16/21 TL HNPE, $p = 0.017$) (►**Fig. 2**). The degree of spinal cord compression was statistically not different between the C and TL groups ($p > 0.05$). Eighteen of 36 cases had only a mild spinal cord compression (8/15 C and 10/21 TL). No intramedullary change (increased T2 intensity on MRI) was seen in 9/15 C HNPE and 10/21 TL HNPE (►**Appendix Table 2**).

Treatment and Outcome

Overall, 19/36 dogs had conservative treatment, 15/36 dogs had surgery and 2/36 were euthanatized at the discretion of the owners. Eleven of 21 TL HNPE were treated surgically *versus* 4/15 C HNPE ($p > 0.05$). The decision for surgery was statistically correlated to the degree of spinal cord compression ($p = 0.0075$) but not to the presenting MFS, the presence of spinal hyperesthesia, or presence of intramedullary changes on MRI. All surgically treated cases had macroscopic evidence of HNPE on decompressive surgery. Disc material was described as 'gelatinous' in 12/15 cases and 'lumpy fluid' in 3/15 as described in earlier publications.[5] One TL case had histopathology performed, confirming the material as nucleus pulposus with mild chondrocyte metaplasia and degeneration. In no case, a capsule surrounding the compressing material was found.

The overall mean number of hospitalization days was 5.3 days (range: 0–16 days). This was not statistically different between the C and TL groups or the treatment groups ($p > 0.05$ for both). At discharge, median MFS had improved from 3 (range: 1–5) at presentation to 4 (range: 3–5) ($p = 0.002$). There was no significant difference in MFS at

discharge between C and TL HNPE or treatment groups ($p > 0.05$ for both). Fifteen of 34 had an improved MFS at discharge (7/13 C HNPE *vs.* 8/21 TL HNPE), 17/34 had the same score and 2/34 had a worse score. No dogs had an MFS lower than 3 at discharge.

Follow-up information was available for 23 dogs. Mean number of days from discharge to follow-up was 33 (range: 3–51 days). Information was retrieved from veterinary re-examination in 19 cases, and rehabilitation visits at our facilities in four cases. The patients improved significantly, with 5/23 dogs being back to normal and pain-free at follow-up, and the remaining 18/23 dogs being ambulatory with some degree of residual ataxia (MFS 4). Overall, 18/23 presented with an improved score at follow-up compared with initial presentation (7/9 C HNPE and 11/14 TL HNPE), 5/23 presented with the same score and no dog presented with a worse score. There was no significant difference in neurological status at follow-up between either C and TL groups or treatment groups ($p > 0.05$ for both).

Discussion

To the knowledge of the authors, this study is the largest compilation of TL HNPE diagnosed with MRI in dogs. Only a few studies have documented sporadic cases of TL HNPE[4,10] or mentioned anecdotal evidence hereof.[14] Most studies include C cases only.[5,6,8,9,11–13] MRI findings for HNPE have focused on C cases.[5,9] We found similar lesions in the TL spine (►**Figs. 2** and **3**), as did another recent study.[10] In dogs presented with acute paresis/paralysis of the hindlimbs, especially after strenuous activity, an acute non-compressive nucleus pulposus extrusion or a vascular embolism is on the list of differential diagnosis after a non-diagnostic CT. Acute non-compressive nucleus pulposus extrusion and fibrocartilaginous embolism are usually treated conservatively. The findings in our study suggest that a TL HNPE, possibly profiting from surgical decompression, should be expected in some of these cases. Magnetic resonance imaging is therefore indicated after a non-diagnostic CT. If MRI is not available, a CT-myelogram or CT with contrast can identify a spinal compression.[12]

In our study, overall median age was 7.5 years (range: 2.4–12), which is only slightly lower than previous studies, ranging from 8 to 10 years.[4,5,10,11,13] We found a higher proportion of male dogs, also similar to previous studies, ranging from 58 to 82%.[4,5,8–13] All but two cases presented with an acute onset, also like previous studies.[4–6,9,11,12] Interestingly, though not significant, we identified more TL cases being highly active at clinical onset. We saw a trend that more TL HNPE were chondrodystrophic compared with C HNPE. Thoracolumbar intervertebral disc extrusion is common in chondrodystrophic dogs, and therefore a TL HNPE could be an early intervertebral disc extrusion caused by a strong force acting on the mildly degenerated intervertebral disc. On clinical presentation, 72.2% of our patients were non-ambulatory (MFS 3 or below). Similarly, most studies identify 70 to 80% non-ambulatory cases[8,10–12] but it differs greatly, ranging from as little as 28[9] to 100%.[5] Most studies identify over 65% pain-free C cases,[4,5,9,10,12,13] but two studies found only close to or less than 50% to be pain-free.[8,11] In our study, 61.5% of C HNPE were pain-free on presentation. Our C HNPE study population therefore does not differ from the established literature. However, our TL HNPE study population seems to differ to some degree from C HNPE. We saw a trend that TL cases were more often painful on spinal palpation, and we found more lateralization of the extruded nucleus material, affecting the nerve root exiting the foramen. This could explain the higher incident of TL HNPE with spinal hyperesthesia.

It is assumed that the hydrated disc material in HNPE is absorbed or dispersed over time.[10,13,15] Perhaps therefore conservative treatment is often mentioned as a favourable alternative to surgical treatment.[5,10,11,13] Our study also showed that conservative treatment had an equally good outcome to surgical treatment, both in C and TL cases. Overall short-term outcome was good, with all patients being ambulatory at follow-up, 78.3% having some degree of ataxia and 21.7% having regained normal gait. This is compatible with previous studies.[4,6,9,11,13]

The limitations of this study include its retrospective design. The small sample sizes, when divided into anatomical localization (C *vs.* TL) and treatment groups (surgical *vs.* conservative), can have led to biases and to results not being significant. A multi-center study could allow for even larger sample sizes in future studies. There is some controversy regarding the terminology of HNPE in the TL spine. The terminology for HNPE has previously been discussed, with early records of 'intraspinal cysts'[4,15] later being suspected HNPE.[6,7] Nevertheless, a recent study describes the findings of eight TL pseudocysts.[16] These had similar appearance on MRI to HNPE, but were more oval shaped. Most dogs had concurrent disc protrusion or extrusion at the level of the lesions, but all were surgically identified as cysts, with cystic walls consisting of fibrous tissue and chondroid cells on histology. Clinical presentation was similar to HNPE with predominantly acute onsets, though in contrast to cyst formation in general, as the authors themselves point out. None of the 36 cases in our study raised suspicion of cyst formation, and none of our 15 surgically treated cases showed evidence to be a cystic lesion. Thoracolumbar pseudocysts could be a different entity with a different

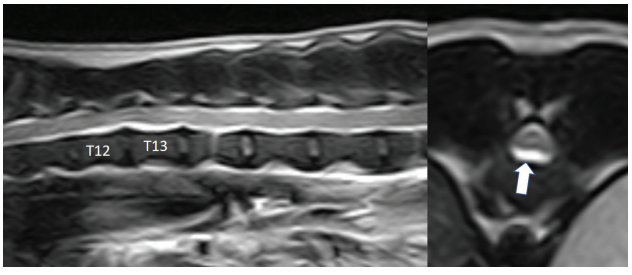

Fig. 3 MRI findings in dog 32 diagnosed with thoracolumbar hydrated nucleus pulposus extrusion at T12-T13. A) and B) T2 sequences. Notice the ventral mild-moderate compression by the extruded disc material (white arrow) on the transverse image.

etiopathology to HNPE. Twenty-two cases out of 178 published C HNPE have been confirmed histologically, and one case out of four TL HNPE. The remaining HNPE were diagnosed by MRI only. Future prospective studies should aim at confirming more suspected cases of TL HNPE with histopathology.

In conclusion, our study suggests that HNPE may not be affecting mainly the C vertebral column of dogs but can often occur in the TL vertebral column as well. Clinical examination of TL HNPE shows more often spinal hyperesthesia, and on MRI more extruded nucleus material is lateralized compared with C HNPE. The outcome of TL HNPE is similar to what has previously been described for C HNPE.

Conflicts of Interest

None.

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Appendix Table 1 Affected intervertebral site, presence of spinal hyperesthesia, neurological status at presentation, outcome, number of hospitalization days, neurological status at discharge and neurological status at follow-up for all 36 dogs included in the study

Dog	Disc herniation site	Spinal hyperesthesia	MFS at presentation	Outcome	Hospitalization days	MFS at discharge	MFS at follow-up
1	C5–6	Yes	5	Conservative	2	5	–
2	C6–7	Yes	4	Conservative	6	5	4
3	C3–4	No	3	Surgery	5	4	4
4	C3–4	No	3	Euthanasia	NA	NA	NA
5	C5–6	–	5	Conservative	0	5	–
6	C3–4	Yes	4	Surgery	3	4	Normal gait
7	C6–7	No	2	Conservative	6	4	–
8	C4–5	Yes	3	Surgery	16	4	4
9	C3–4	No	4	Conservative	4	4	Normal gait
10	C4–5	No	3	Conservative	6	4	4
11	C5–6	No	3	Euthanasia	NA	NA	NA
12	C4–5	–	3	Conservative	13	3	4
13	C4–5	No	2	Conservative	9	4	–
14	C5–6	Yes	4	Conservative	3	3	4
15	C5–6	No	2	Surgery	12	3	4
16	T12–13	No	3	Surgery	7	3	–
17	T12–13	Yes	3	Surgery	8	3	4
18	L2–3	Yes	3	Conservative	3	3	–
19	T13-L1	Yes	2	Surgery	4	4	Normal gait
20	L1–2	No	1	Surgery	7	3	4
21	L1–2	Yes	3	Surgery	3	3	Normal gait
22	L2–3	Yes	4	Surgery	4	3	4
23	T13-L1	Yes	3	Surgery	2	3	4
24	T13-L1	No	4	Conservative	2	4	4
25	T11–12	–	3	Conservative	6	3	4
26	T12–13, T13-L1, and L1–2	No	4	Conservative	4	4	4
27	L1–2	Yes	5	Conservative	4	5	Normal gait
28	L1–2	Yes	3	Surgery	4	4	4
29	T13-L1	Yes	3	Conservative	6	4	4
30	T13-L1	Yes	3	Surgery	4	4	–
31	T12–13	No	3	Conservative	2	4	–
32	L1–2 or L2–3	Yes	3	Surgery	6	4	–
33	L1–2	Yes	3	Surgery	7	3	4
34	T13-L1	Yes	3	Conservative	3	3	–
35	T13-L1	Yes	3	Conservative	6	3	–
36	T13-L1	No	3	Conservative	2	4	4

Abbreviations: MFS, Modified Frankel Score (0–5); NA, not applicable; –, no data.

Appendix Table 2 MRI findings for the 36 dogs included in the study

Dog	Disc herniation site	Location of extruded material in relation to spinal cord	Seagull-like appearance of the extruded material	T2 intensity extruded material in relation to normal nucleus pulposus	IVD space	Volume of the nucleus pulposus	Spinal cord compression	Intramedullary changes
1	C5–6	Ventral midline	Yes	Isointense	Severe decrease	Reduced	Mild	Suspected
2	C6–7	Left lateralised	No	Isointense	Mild decrease	Reduced	No (Nerve root compression only)	No
3	C3–4	Ventral midline	Yes	Isointense	Mild decrease	Reduced	Moderate-severe	Suspected
4	C3–4	Ventral midline	Yes	Isointense	Mild decrease	Reduced	Mild	Yes
5	C5–6	Ventral midline	No	Isointense	Moderate decrease	Reduced	Mild	No
6	C3–4	Ventral midline	Yes	Isointense	Mild decrease	Reduced	Moderate-severe	No
7	C6–7	Ventral midline	Yes	Isointense	Mild decrease	Reduced	Mild-moderate	No
8	C4–5	Ventral and right sided	yes	Isointense	Mild decrease	Reduced	Mild	No
9	C3–4	Ventral midline	Yes	Isointense	Mild decrease	Reduced	Mild	No
10	C4–5	Left lateralised	No	Isointense	Mild decrease	Reduced	Moderate	No
11	C5–6	Ventral midline	No	Isointense	Mild decrease	Reduced	Moderate	No
12	C4–5	Ventral and left sided	No	Isointense	Mild decrease	Reduced	Mild	Yes
13	C4–5	Ventral midline	Yes	Isointense	Mild decrease	Reduced	Mild	No
14	C5–6	Right lateralised	No	Isointense	Mild decrease	Reduced	Mild	Yes
15	C5–6	Ventral midline	Yes	Isointense	Normal	Reduced	Moderate-severe	Yes
16	T12–13	Left lateralised	No	Isointense	Normal	Reduced	Mild-moderate	No
17	T12–13	Left lateralised	No	Isointense	Normal	Reduced	Mild-moderate	Yes
18	L2–3	Right lateralised	No	Isointense	Mild decrease	Reduced	Moderate	No
19	T13-L1	Ventral midline	Yes	Isointense	Normal	Normal	Mild	No
20	L1–2	Left lateralised	No	Isointense	Normal	Reduced	Mild-moderate	No
21	L1–2	Left lateralised	No	Isointense	Normal	Reduced	Mild-moderate	No
22	L2–3	Left lateralised	No	Isointense	Normal	Reduced	Moderate	No
23	T13-L1	Right lateralised	No	Isointense	Normal	Normal	Moderate	Suspected
24	T13-L1	Left lateralised	No	Isointense	Mild decrease	Reduced	Mild-moderate	Suspected
25	T11–12	Left lateralised	No	Isointense	Normal	Normal	Mild	Yes
26	T12–13, T13-L1, and L1–2	Left lateralised	No	Isointense	Normal	Reduced	Mild	Yes

(*Continued*)

Appendix Table 2 (*Continued*)

Dog	Disc herniation site	Location of extruded material in relation to spinal cord	Seagull-like appearance of the extruded material	T2 intensity extruded material in relation to normal nucleus pulposus	IVD space	Volume of the nucleus pulposus	Spinal cord compression	Intramedullary changes
27	L1–2	Left lateralised	No	Isointense	Normal	Reduced	Mild	No
28	L1–2	Ventral and left lateralised	No	Isointense	Normal	Reduced	Moderate	Yes
29	T13-L1	Ventral midline	Yes	Isointense	Normal	Reduced	Mild	Yes
30	T13-L1	Right lateralised	No	Isointense	Mild decrease	Reduced	Mild-moderate	No
31	T12–13	Ventral midline	Yes	Isointense	Mild decrease	Reduced	Mild	Suspected
32	L1–2 or L2–3	Right lateralised, left lateralised and dorsal	No	Isointense	Normal	Reduced	Mild	Yes
33	L1–2	Ventral and right lateralised	No	Isointense	Mild decrease	Reduced	Mild	No
34	T13-L1	Right lateralised, left lateralised and ventral	No	Isointense	Mild decrease	Reduced	Mild	No
35	T13-L1	Ventral and left lateralised	No	Isointense	Normal	Reduced	Mild	Yes
36	T13-L1	Right lateralised	No	Isointense	Normal	Reduced	Mild-moderate	Yes

Abbreviations: IVD, intervertebral disc; MRI, magnetic resonance imaging.