Thoracolumbar Intervertebral Disk Extrusion in Dogs: Do Onset of Clinical Signs, Time of Surgery, and Neurological Grade Matter?

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Abstract

Objective The aim of this study was to determine the influence of time between the beginning of clinical signs, presentation and decompression, and combinations of several factors on the outcome and recovery of dogs undergoing surgery for thoracolumbar intervertebral disk extrusion (IVDE).

Study Design In all, 433 client-owned dogs treated for IVDE between 2016 and 2020 were reviewed for signalment, neurological grade, rate of onset, duration of clinical signs, and surgical variables. Time from presentation to surgery was divided into three categories: S1 (0–12 hours), S2 (12–24 hours), and S3 (>24 hours). These variables were investigated to determine their influence on the return of pain sensation, urinary continence, ambulation and overall outcome.

Results A significant association was found between an acute onset of clinical signs, worse neurological grade at presentation and poorer outcomes. There was a significant difference between S1, S2, and S3 in neurological grade at presentation ($p < 0.001$) and at discharge ($p < 0.001$); however, the latter was no longer significant when adjusted for the grade at presentation ($p = 1{,}000$). Disk fenestration was associated with a faster return to ambulation ($p = 0.033$). Duration of clinical signs and time of surgery did not correlate with the time to recovery and return of pain sensation, urinary continence, or ambulation.

Conclusions Dogs presented with severe neurological status and/or rapid onset of clinical signs were operated on more promptly, but their outcomes were also poorer. There was no significant evidence for a better outcome when surgery was not delayed.

Keywords
- neurosurgery
- spinal disk disease
- spine surgery
- IVDE
- intervertebral disk disease

Introduction

Intervertebral disk extrusion (IVDE) is a common neurological disorder in dogs. Clinical signs can vary and range from pain to paralysis depending on the location, the degree of spinal cord injury, and duration of the compression of the spinal cord by extruded disk material.[1–6]

There are several reports of successful conservative management in dogs affected or presumptively affected by IVDE with minimal neurological deficits with a success rate ranging from 55.6 to 100%.[6–8] In dogs with marked neurological deficits, non-ambulatory paresis or paralysis, surgical decompression has been the recommended treatment option, and it has been associated with a

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more favorable outcome compared to conservative management.[2,9–11]

Many studies have looked at prognostic variables that influence the quality of recovery, including weight,[4,12] age,[2,4] breed,[12] imaging findings,[13,14] and severity of preoperative neurological deficits.[2,3,5,6,15–17] Presence of deep pain sensation correlates definitively with improved recovery.[3,4,6,18,19]

Although many veterinary surgeons consider IVDE a surgical emergency, the ideal timing for surgical intervention in dogs has not been determined, as it has not been established whether the duration of clinical signs and the outcome of dogs surgically treated for IVDE are correlated.[1,4,6,9,18,20–22] The rate of onset of neurological signs has also been investigated in relation to the time of recovery and some studies have found no difference on the overall outcome for cases with an acute onset,[4,21] while others have found these cases having a slower and worse recovery.[3,6,9] It is speculated that the rate of onset could influence the recovery time[6] because a high-speed extrusion translates in a greater impact on the spinal cord, leading to a more severe contusion and injury.[2] Experimental evidence seems to suggest that most of the damage would be caused by the primary impact and shock on the spinal cord, rather than the compression over time.[23,24] Should this be true in the clinical setting, the recovery of function and time to recovery could be more dependent on the severity of the primary injury rather than the delay of surgical intervention.[1,25,26] The ideal timing of surgery remains controversial.[11]

Upchurch and colleagues showed some evidence that a delay from the onset of clinical signs associated with IVDE to surgery is unlikely to affect the ultimate outcome or the length of time for a dog to regain pain sensation, urinary continence, or ambulation. Equally, the rapidity with which the onset of clinical signs develops was not shown to influence the quality of the outcome.[21] A recent large study analyzed a cohort of 1,501 dogs with thoracolumbar IVDE[27] and the results might support the recommendation that an early surgical intervention is warranted to improve overall outcome. In this study, a significant association between the time from the onset of the clinical signs until surgery and the overall outcome was identified, suggesting that a shorter delay to decompression might improve the overall outcome. However, this correlation was not confirmed on a bivariate analysis. Similarly, a significant association was found between the time from onset of the clinical signs until surgery and the time of recovery, which was not confirmed on a multivariate regression model. Moreover, they found no significant association between neurological grade at presentation and outcome. In another recent prospective study, the delay between onset of clinical signs and presentation and time between presentation and spinal surgery was not associated with the rapidity of recovery of ambulation in 151 dogs surgically treated for thoracolumbar IVDE.[22] In the same study, only duration of surgery and neurological grade at presentation were significantly associated with rapidity of recovery of ambulation.

Our study investigated the outcome and the time of recovery of a large population of dogs surgically treated for thoracolumbar IVDE. The purpose of this retrospective study was to evaluate whether the overall outcome and/or time to recovery is influenced by the delay from presentation to surgical decompression, the rate of onset of clinical signs, and other variables of interest.

Materials and Methods

The medical records of Northwest Veterinary Specialists (United Kingdom) and of Kansas State University (United States) were searched to identify dogs diagnosed and surgically treated for IVDE localized from the third thoracic (T3) to third lumbar (L3) vertebrae between January 2016 and December 2020. The diagnosis was confirmed via magnetic resonance (MR) and/or computed tomography (CT). Criteria for inclusion in the study comprised availability of complete medical records, including timing of onset of clinical signs, presentation and surgery, neurological grade at examination, and neurological grade at discharge. Dogs with incomplete medical records, history of previous IVDE surgery, or diagnosed with concurrent pathologies that could influence their neurological status, were excluded from the study.

Data Collection

Each dog's medical record was examined, and details of signalment, medical and surgical treatment, and duration of hospitalization were collected. The time between the initial onset of clinical signs and presentation at the hospital (D1) and the duration from the presentation to the time of surgical decompression (D2)[21] were recorded. D2 was subsequently divided into three categories based on the time between presentation and surgical decompression: 0 to 12 hours (S1), 12 to 24 hours (S2), and over 24 hours (S3). Each dog's neurological status was graded using a modified Frankel score as shown in ►**Table 1**.[28,29] The rate of onset was defined as the time from when the dog was last clinically normal until neurological signs developed, and it was graded as described previously[3] and shown in ►**Table 2**.

Diagnostic Imaging

All dogs included were confirmed as having a thoracolumbar IVDE (Hansen type I) via computed tomography (CT), MR, or both. The length of extruded disk material was measured by multiplying the number of transverse image slices in which the extruded disk material was present, by the slice thickness. A ratio was then calculated between the length of the

Table 1 Modified Frankel score

Neurologic grade	Clinical presentation
Grade 0	Paraplegia with no deep nociception
Grade 1	Paraplegia with no superficial nociception
Grade 2	Paraplegia with intact nociception
Grade 3	Nonambulatory paraparesis
Grade 4	Ambulatory paraparesis
Grade 5	Spinal hyperesthesia

Table 2 The criteria for the rate of onset is illustrated in the table

Rate of onset	Definition of the time period
Sudden	<2 h
Rapid	From 2 to 48 h
Intermediate	>48–120 h
Progressive	>120 h
Mixed	Progression of disease (over >120 h) followed by a rapid deterioration in <48 h

extruded disk material associated with the surgically operated site and the length of the L2 vertebral body (DM/L2) as previously reported.[21]

Surgical Procedure

All dogs underwent a dorsolateral hemilaminectomy or mini-hemilaminectomy with the aid of surgical microscope (Zeiss OPMI CS-NC-2). If the IVDE was spreading to more than one intervertebral space, these were all approached surgically to relieve the spinal cord compression. At the surgeon's discretion, prophylactic fenestration was performed at the affected disk site(s). Anesthetic and surgery time were recorded for all dogs.

Outcomes

Every dog was assessed at least once daily by a veterinary surgeon and the number of days between surgery and recovery of certain functions was recorded. For dogs presented with neurological grade of 0 to 3, time to urinary continence (defined as the ability of the dog to urinate voluntarily without active or passive abdominal pressure) and ambulation (defined for some dogs as the point at which the dog was first able to walk 10 or more steps unassisted) were assessed by the clinician or resident and recorded. For some dogs that had been discharged prior to return to ambulation, owners were instructed on counting the steps the dog was able to make unassisted and report when this was 10 or more. For dogs presented with neurological grade of 0, time between surgery and the first signs of deep pain perception was assessed by the clinician or resident and recorded. The degree of recovery was determined through the medical records, and it was classified as previously described[21] (►**Table 3**).

Statistical Analysis

The sample size exceeded the numbers required to detect a medium effect size at 80% power across a range of test types according to Cohen.[30] Data are summarized as medians with ranges. Numbers of individuals of each breed were insufficient to assess if breed influenced outcome variables. Variables of interest were age, weight, extrusion's ratio (DM/L2), an aesthetic and surgery length, D1, D2, onset rate, fenestration, sex, and neurological grade at presentation. Specific bivariate comparisons between continuous and/or ordinal variables were undertaken with Spearman's rank correlation. Neurological grade at discharge was compared to D2 (categorized as <12, 12–24, >24 hours) using rank regression (using Rfit in R) both without and with inclusion of neurological grade at presentation as a covariate. For dogs graded 0 at presentation, the influence of the 12 variables of interest listed above on time to pain sensation and on whether pain sensation returned was investigated in a backward elimination selection in a rank regression model and in a binary logistic regression model, respectively. Similarly for dogs graded 0 to 2, time to continence and whether continence returned were investigated. Finally for dogs graded 0 to 3, a similar approach was used for time to ambulation and whether ambulation returned. The threshold for statistical significance was taken as $p < 0.05$. All analyses were performed using R 4.2.2 or Minitab 19 statistical software.

Results

Four hundred and thirty-three dogs met the inclusion criteria. The median age was 6.25 years (range: 1–16 years) and median weight was 7.8 kg (range: 2.2–42 kg). There were 203 (46.9%) Dachshunds, 31 (7.2%) Shih Tzus, 24 (5.5%) Cocker Spaniels, 23 (5.4%) mixed breed dogs, 18 (4.2%) French Bulldogs, 12 (2.8%) Jack Russell Terriers, 10 (2.3%) Lhasa Apso, and 8 or less of 43 additional breeds. There were 183 females (37 intact) and 250 males (50 intact).

The surgical procedure involved one intervertebral space in 334 (77.1%) dogs and two or more in 99 dogs. Fenestration of the affected disk(s) was performed in 98 (22.6%) dogs.

Table 3 The criteria for the degree of recovery is illustrated in the table

Degree of recovery	Clinical outcome
Full recovery	Return to normal ambulation (grade 0–4) or a resolution of pain (grade 5)
Partial recovery	Mild motor and proprioceptive deficits not interfering with function (grade 0–4) or a decrease without resolution of pain (grade 5)
Incomplete Recovery	An improvement in signs with residual paraparesis that does interfere with function (grade 0–4) or an insignificant decrease in pain (grade 5)
Poor recovery	Maintenance of the preoperative neurological status
Progressive	Deterioration of neurological status or development of myelomalacia

Table 4 A summary of median D1 and D2 for each presenting neurological grade

Neurologic grade at presentation	D1 (h)	D2 (h)	Number
5	168 (12–1,008)	24 (4–240)	9
4	144 (2–5,040)	22 (2–984)	127
3	63 (3–10,800)	5 (2–360)	110
2	48 (1–1,440)	6 (3–86)	23
1	36 (2–336)	4 (2–46)	91
0	48 (5–1,440)	4 (2–41)	73

Abbreviation: D1, time from the initial onset of clinical signs to presentation; D2, time from presentation to decompressive surgery.

Table 5 A summary of median D1 and D2 for each presenting rate of onset

Rate of onset	D1 (h)	D2 (h)	Number
Sudden (<2 h)	13 (1-816)	4 (2-73)	56
Rapid (2–48 h)	26 (2-960)	4 (2-165)	183
Intermediate (48–120 h)	96 (54-576)	6 (2-73)	64
Progressive (>120 h)	336 (48-5040)	21 (2-984)	68
Mixed (>120 h followed by acute worsening <48 h)	168 (6-10800)	4 (2-168)	61

D1 = Time from the initial onset of clinical signs to presentation.
D2 = Time from presentation to decompressive surgery.

The median D1 was 2 days (range: 1 hour to 450 days). D2 was available in 432 dogs. The median D2 was 5 hours (range: 2–984 hours). The median length of anesthesia was 165 minutes (range: 75–380 minutes) and the median surgery length was 70 minutes (range: 20–285 minutes). Postoperative treatments varied and included some combination of opioids, nonsteroidal anti-inflammatory drugs, tramadol, glucocorticoids, gabapentin, α antagonists, diazepam, and postoperative physical therapy.

The neurological grade at presentation was 5 for 9 dogs (2.1%), 4 for 127 dogs (29.3%), 3 for 110 dogs (25.4%), 2 for 23 dogs (5.3%), 1 for 91 dogs (21%), and 0 for 73 dogs (16.9%). Rate of onset was available in 432 dogs, and it was considered sudden for 56 dogs (13%), rapid for 183 dogs (42.4%), intermediate for 64 dogs (14.8%), progressive for 68 dogs (15.7%), and mixed for 61 dogs (14.1%). ►**Tables 4** and **5** show the median D1 and D2 for each presenting neurological grade and rate of onset. D1 and D2 changed consistently with neurological presentation grades ($r_s = 0.321$ and $r_s = 0.471$, respectively, both $p < 0.001$), being shorter for dogs with a worse grade at presentation. There were significant differences between S1, S2, and S3 in neurological grade at presentation and in neurological grade at discharge (both $p < 0.001$ from rank regression); median grades were significantly lower for S1 in both cases. However, if the neurological grade at presentation is included in the rank regression, no significant difference is found between the three subcategories of D2 in neurological grade at discharge ($p = 1.000$). D1, D2, and rate of onset were not significantly correlated with any outcome variables.

None of the dogs presented with a neurological grade 5 underwent surgery on or within 12 hours (S1) but were equally distributed between S2 and S3. Dogs presented with a neurological grade 4 were equally distributed between S1, S2, and S3, and there was no significant difference between the degree of recovery of these dogs (Kruskal–Wallis test; $p = 0.744$). Dogs presented with neurological grade 3 underwent surgery mostly within 12 or 24 hours (65% in S1 and 25% in S2). Finally, 89% of dogs that presented with neurological grades 2 to 0 underwent surgery within 12 hours (S1).

The degree of recovery was available for 356 dogs. Among all neurologic grades, 72.7% of the population regained acceptable locomotor function (full or partial recovery) after surgical treatment. In detail, 114 (32%) had a full recovery, 145 (40.7%) had a partial recovery, 49 (13.8%) had an incomplete recovery, 28 (7.9%) had a poor recovery, and 20 (5.6%) had progression of disease or development of myelomalacia. The degree of recovery related to presenting neurological grade is reported in ►**Table 6** and ►**Fig. 1**.

A significant association was found between more acute onset of clinical signs, lower neurological grade at discharge ($r_s = 0.199$; $p < 0.001$) and worse degree of recovery ($r_s = -0.161$; $p = 0.002$). Similarly, there was a significant

Table 6 A summary of the degree of recovery for each presenting neurological grade category

Neurologic grade at time of surgery	Full recovery	Partial recovery	Incomplete recovery	Poor recovery	Progressive disease	Total	% of dogs that had full or partial recovery
5	6	1	0	0	0	7	100%
4	44	46	9	1	2	102	88%
3	29	41	11	5	0	86	81%
2	4	10	3	1	2	20	70%
1	23	34	12	2	5	76	75%
0	8	13	14	19	11	65	32%

Degree of recovery for each neurological grade at the time of surgery.

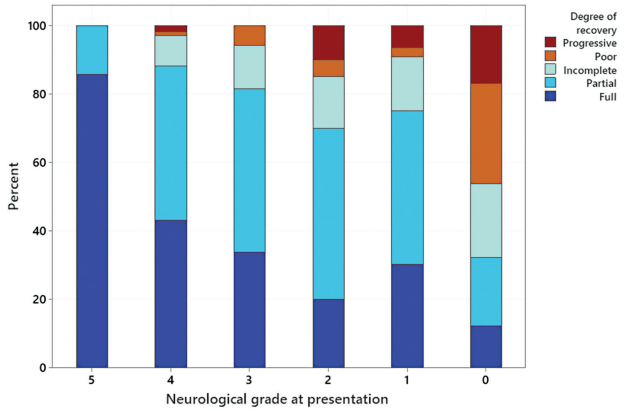

Fig. 1 A representation of the degree of recovery for each presenting neurological grade category.

correlation between higher grades at discharge and better degree of recovery ($r_s = -0.498$; $p < 0.001$).

The ratio of the length of the extruded disk material to the length of L2 vertebral body was available for 409 dogs. The median ratio was 1.08 (range: 0.29–6.07) and it was significantly correlated with more acute onset grades ($r_s = -0.150$; $p = 0.002$), a shorter D2 ($r_s = -0.191$; $p < 0.001$) and a lower grade at presentation ($r_s = -0.265$; $p < 0.001$) and discharge ($r_s = -0.108$; $p = 0.032$).

For the 73 dogs that presented with neurological grade 0, there was no significant relationship between return to pain sensation or time to return of pain sensation and any other variable.

For the 187 dogs presented with a neurological grade 0 to 2, there was a significant relationship between a return to urinary continence and weight (odds ratio: 0.909; 95% confidence interval [CI]: 0.847–0.975; $p = 0.008$) and neurological grade at presentation (odds ratio: 5.3; 95% CI: 2.4–12.1; $p < 0.001$); heavier dogs and more severe cases were associated with longer time to regain urinary continence. Rank regression suggested a longer time to return to continence for older dogs ($p = 0.034$) and for cases with lower neurological grade at presentation ($p < 0.001$).

For the 297 dogs with a preoperative grade 0 to 3, the variables significantly associated with return to ambulation were age (odds ratio: 0.984; 95% CI: 0.973–0.995; $p = 0.004$) and the neurological grade at presentation (odds ratio: 3.2; 95% CI: 2.1–4.8; $p < 0.001$); lower success was associated with older and heavier dogs and more severe cases. Rank regression identified fenestration during surgery ($p = 0.033$), anesthetic length ($p = 0.012$), and neurological grade at presentation ($p < 0.001$) as significantly associated with time to return to ambulation. Dogs presented with grades 1 to 3 were more likely and quicker to regain ambulation compared with grade 0, with, respectively, 92 and 46% of dogs that regained ambulation in these two groups and return to ambulation was faster when anesthetic length was longer and when fenestration was performed during surgery (median: 2 days; nonfenestration median: 14 days).

Discussion

In our population, the main factors influencing the clinical outcome were neurological grade 0 at presentation and an acute onset of clinical signs. In previous studies, functional recovery for dogs presenting with a neurological grade 0 varied between 38 and 86%,[3,4,6,31,32] which is higher than our population (32%) and it was not associated with immediacy of surgery.[25] In the present study, 13.5% of dogs had an unsuccessful outcome, either maintaining their preoperative status or experiencing a disease progression or myelomalacia, which is marginally lower compared to a previous study.[33]

In our study, the rate of onset was significantly associated with lower-grade discharge and degree of recovery, suggesting that cases presented with peracute/acute onset have a slower recovery and a worse overall outcome. This is in agreement with previous studies,[2,3,6,9] and based on our findings, we believe that the rate of onset should be considered a reliable prognostic factor in the clinical setting, along with the neurological grade at presentation.

Within the dogs included in this study, 13 dogs that presented with a grade 4 deteriorated immediately following decompressive surgery and were discharged with grade 0 to 2. Deterioration of the neurological status following surgery is a well-known complication of IVDE.[32] Of these dogs, 12 were operated on by residents and there were not any records of intraoperative complications. It could be speculated that this relatively high postoperative morbidity rate could have been caused by an excessive manipulation of the spinal cord during surgery, lack of surgical expertise, or a combination of both. The experience of the primary surgeon has been previously identified as a significant risk factor for development of postoperative adverse events.[34]

The execution of fenestration of the affected disk during decompressive surgery has been recommended in dogs to prevent further extrusion of the nucleus pulposus in the early postoperative period, which may result in recurrence of the compression.[11,20,35–37] However, its benefits remain controversial.[20,38–40] In our population of dogs presented with a neurological grade between 0 and 3, performance of fenestration during surgery seemed to be associated with a faster return to ambulation ($p = 0.033$). Fenestration would not be expected to directly influence time of recovery, but rather provide a prophylactic measure against possible recurrence. We could speculate that a portion of the disk material left behind could herniate in the early postoperative period in those dogs in which fenestration was not performed, and therefore negatively affect the return to ambulation. This could not be confirmed in this study as dogs were not routinely re-imaged following surgery.

In the present study, there was a correlation between the DM/L2 ratio measured on CT images, MRI, or both, and the rate of onset ($p = 0.002$) and neurological grade at presentation ($p < 0.001$) and at discharge ($p = 0.032$). This means that dogs with more extruded disk material were also more likely to have an acute rate of onset and a worse neurological grade both at presentation and at discharge. This ratio does not specifically characterize the degree of spinal cord

compression, but instead gives the clinician a basic perception of the amount of herniated intervertebral disk material. Our findings suggest that during a peracute/acute onset of IVDE a larger volume of disk material is extruded, and, consequentially, a more severe spinal cord impact and damage is sustained. This reflects clinically in a rapid rate of onset, a worse neurological grade at presentation, and a worse neurological grade at discharge.

Our study has several limitations. Being a retrospective study, a bias on when to perform decompressive surgery could not be excluded. Several surgeons were involved with the cases included in our study, and this poses inconsistency in the decision on when to operate dogs presented with IVDE, as well as a nonstandardized clinical approach, surgical technique, and experience, which could all have influenced the variables and outcome for some patients, and ultimately our results.

The choice to operate sooner could have been influenced by the rate of onset, severity of the neurological grade on presentation, or both combined, and it appears likely in our study given that the lower was the grade at presentation and/or the faster was the rate of onset, the shorter was the time between presentation and surgery in most dogs.

In conclusion, we did not find a significant correlation between duration of clinical signs, time between onset of neurological signs and spinal surgery, and overall outcome. However, the strong correlation found between the rate of onset and neurological grade at presentation, and the recovery time and overall outcome might constitute valuable prognostic information for surgeons dealing with IVDE. Furthermore, fenestration of the affected disks seems to result in a more positive outcome, which supports the recommendation of performing this procedure during IVDE surgery.

Due to the retrospective nature of this study and the numerous variables involved as previously stated, caution is required when interpreting these results. Further studies, preferably prospective, are required to better define the ideal surgical timing and prognostic factors associated with the outcome in dogs surgically treated for IVDE.

Authors' Contribution

K.C. contributed to conception and study design, acquisition of data, data analysis and interpretation, and writing of the draft. D.A.U. contributed to study design, acquisition of data, and data analysis and interpretation. E.P. contributed to acquisition of data and data analysis and interpretation. L.M. contributed to conception and study design, and data analysis and interpretation. All the authors reviewed, revised, and approved the submitted manuscript.

Conflict of Interest

None declared.

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References

1 Davis GJ, Brown DC. Prognostic indicators for time to ambulation after surgical decompression in nonambulatory dogs with acute thoracolumbar disk extrusions: 112 cases. Vet Surg 2002;31(06): 513–518
2 Macias C, Mckee WM, May C, Innes JF. Thoracolumbar disc disease in large dogs: a study of 99 cases. J Small Anim Pract 2002;43(10): 439–446
3 Ferreira AJ, Correia JH, Jaggy A. Thoracolumbar disc disease in 71 paraplegic dogs: influence of rate of onset and duration of clinical signs on treatment results. J Small Anim Pract 2002;43(04): 158–163
4 Olby N, Levine J, Harris T, Muñana K, Skeen T, Sharp N. Long-term functional outcome of dogs with severe injuries of the thoracolumbar spinal cord: 87 cases (1996-2001). J Am Vet Med Assoc 2003;222(06):762–769
5 Ruddle TL, Allen DA, Schertel ER, et al. Outcome and prognostic factors in non-ambulatory Hansen type I intervertebral disc extrusions: 308 cases. Vet Comp Orthop Traumatol 2006;19 (01):29–34
6 Scott HW, McKee WM. Laminectomy for 34 dogs with thoracolumbar intervertebral disc disease and loss of deep pain perception. J Small Anim Pract 1999;40(09):417–422
7 Levine JM, Levine GJ, Johnson SI, Kerwin SC, Hettlich BF, Fosgate GT. Evaluation of the success of medical management for presumptive thoracolumbar intervertebral disk herniation in dogs. Vet Surg 2007;36(05):482–491
8 Davies JV, Sharp NJH. A comparison of conservative treatment and fenestration for thoracolumbar intervertebral disc disease in the dog. J Small Anim Pract 1983;24:721–729
9 Brown NO, Helphrey M, Prata R. Thoracolumbar disk disease in the dog: a retrospective analysis of 187 cases. J Am Anim Hosp Assoc 1977;13:665–672
10 Langerhuus L, Miles J. Proportion recovery and times to ambulation for non-ambulatory dogs with thoracolumbar disc extrusions treated with hemilaminectomy or conservative treatment: a systematic review and meta-analysis of case-series studies. Vet J 2017;220:7–16
11 Olby NJ, Moore SA, Brisson B, et al. ACVIM consensus statement on diagnosis and management of acute canine thoracolumbar intervertebral disc extrusion. J Vet Intern Med 2022;36(05): 1570–1596
12 Shaw TA, De Risio L, Laws EJ, Rose JH, Harcourt-Brown TR, Granger N. Prognostic factors associated with recovery of ambulation and urinary continence in dogs with acute lumbosacral spinal cord injury. J Vet Intern Med 2017;31(03):825–831
13 Duval J, Dewey C, Roberts R, Aron D. Spinal cord swelling as a myelographic indicator of prognosis: a retrospective study in dogs with intervertebral disc disease and loss of deep pain perception. Vet Surg 1996;25(01):6–12
14 Ito D, Matsunaga S, Jeffery ND, et al. Prognostic value of magnetic resonance imaging in dogs with paraplegia caused by thoracolumbar intervertebral disk extrusion: 77 cases (2000-2003). J Am Vet Med Assoc 2005;227(09):1454–1460
15 Bergman R, Lanz O, Shell L. Acute spinal cord trauma: mechanisms and clinical syndromes. Vet Med 2000;95(11):846–849
16 Gambardella PC. Dorsal decompressive laminectomy for treatment of thoracolumbar disk disease in dogs: a retrospective study of 98 cases. Vet Surg 1980;9(01):24–26
17 Skytte D, Schmökel H. Relationship of preoperative neurologic score with intervals to regaining micturition and ambulation following surgical treatment of thoracolumbar disk herniation in dogs. J Am Vet Med Assoc 2018;253(02): 196–200
18 Kazakos G, Polizopoulou ZS, Patsikas MN, Tsimopoulos G, Roubies N, Dessiris A. Duration and severity of clinical signs as prognostic indicators in 30 dogs with thoracolumbar disk disease after

surgical decompression. J Vet Med A Physiol Pathol Clin Med 2005;52(03):147–152
19 Bull C, Fehr M, Tipold A. Canine intervertebral disk disease: a retrospective study of clinical outcome in 238 dogs (2003-2004). Berl Munch Tierarztl Wochenschr 2008;121(3–4):159–170
20 Scott HW. Hemilaminectomy for the treatment of thoracolumbar disc disease in the dog: a follow-up study of 40 cases. J Small Anim Pract 1997;38(11):488–494
21 Upchurch DA, Renberg WC, Turner HS, McLellan JG. Effect of duration and onset of clinical signs on short-term outcome of dogs with Hansen type I thoracolumbar intervertebral disc extrusion. Vet Comp Orthop Traumatol 2020;33(03):161–166
22 Vincens Zanoguera L, Pauciulo C, et al. Does surgical timing affect the rapidity of recovery in deep pain-entire non-ambulatory dogs with thoracolumbar intervertebral disk extrusion? J Small Anim Pract 2022
23 Osterholm JL. The pathophysiological response to spinal cord injury. The current status of related research. J Neurosurg 1974; 40(01):5–33
24 Ducker TB, Kindt GW, Kempf LG. Pathological findings in acute experimental spinal cord trauma. J Neurosurg 1971;35(06):700–708
25 Jeffery ND, Barker AK, Hu HZ, et al. Factors associated with recovery from paraplegia in dogs with loss of pain perception in the pelvic limbs following intervertebral disk herniation. J Am Vet Med Assoc 2016;248(04):386–394
26 Ingram EA, Kale DC, Balfour RJ. Hemilaminectomy for thoracolumbar Hansen Type I intervertebral disk disease in ambulatory dogs with or without neurologic deficits: 39 cases (2008-2010). Vet Surg 2013;42(08):924–931
27 Immekeppel A, Rupp S, Demierre S, et al. Investigation of timing of surgery and other factors possibly influencing outcome in dogs with acute thoracolumbar disc extrusion: a retrospective study of 1501 cases. Acta Vet Scand 2021;63(01):30
28 Levine JM, Levine GJ, Kerwin SC, Hettlich BF, Fosgate GT. Association between various physical factors and acute thoracolumbar intervertebral disk extrusion or protrusion in Dachshunds. J Am Vet Med Assoc 2006;229(03):370–375
29 Levine JM, Ruaux CG, Bergman RL, Coates JR, Steiner JM, Williams DA. Matrix metalloproteinase-9 activity in the cerebrospinal fluid and serum of dogs with acute spinal cord trauma from intervertebral disk disease. Am J Vet Res 2006;67(02):283–287
30 Cohen J. A power primer. Psychol Bull 1992;112(01):155–159
31 Martin S, Liebel FX, Fadda A, Lazzerini K, Harcourt-Brown T. Same-day surgery may reduce the risk of losing pain perception in dogs with thoracolumbar disc extrusion. J Small Anim Pract 2020;61 (07):442–448
32 De Risio L, Muñana K, Murray M, Olby N, Sharp NJ, Cuddon P. Dorsal laminectomy for caudal cervical spondylomyelopathy: postoperative recovery and long-term follow-up in 20 dogs. Vet Surg 2002;31(05):418–427
33 Amsellem PN, Toombs JP, Laverty PH, Breur GJ. Loss of deep pain sensation following thoracolumbar intervertebral disc herniation in dogs: treatment and prognosis. Compend Contin Educ Pract Vet 2003;25:266–274
34 Rossmeisl JH Jr, White C, Pancotto TE, Bays A, Henao-Guerrero PN. Acute adverse events associated with ventral slot decompression in 546 dogs with cervical intervertebral disc disease. Vet Surg 2013;42(07):795–806
35 Stigen Ø, Ottesen N, Jäderlund KH. Early recurrence of thoracolumbar intervertebral disc extrusion after surgical decompression: a report of three cases. Acta Vet Scand 2010;52(01):10
36 Forterre F, Konar M, Spreng D, Jaggy A, Lang J. Influence of intervertebral disc fenestration at the herniation site in association with hemilaminectomy on recurrence in chondrodystrophic dogs with thoracolumbar disc disease: a prospective MRI study. Vet Surg 2008;37(04):399–405
37 Brisson BA, Moffatt SL, Swayne SL, Parent JM. Recurrence of thoracolumbar intervertebral disk extrusion in chondrodystrophic dogs after surgical decompression with or without prophylactic fenestration: 265 cases (1995-1999). J Am Vet Med Assoc 2004;224(11):1808–1814
38 Dhupa S, Glickman N, Waters DJ. Reoperative neurosurgery in dogs with thoracolumbar disc disease. Vet Surg 1999;28(06): 421–428
39 Fenn J, Olby NJCanine Spinal Cord Injury Consortium (CANSORT-SCI) Classification of intervertebral disc disease. Front Vet Sci 2020;7:579025
40 Pontikaki AE, Pavlidou K, Polizopoulou Z, Savvas I, Kazakos G. Prophylactic effect of fenestration on the recurrence of thoracolumbar intervertebral disc disease in dogs. Animals (Basel) 2022; 12(19):2601

