

TITLE: Comparison between Hemilaminectomy with either Anulectomy or Partial Discectomy for Treatment of Thoracolumbar Intervertebral Disc Protrusion in Dogs

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Running head: Surgical treatment of thoracolumbar IVDP

Comparison between hemilaminectomy with either anulectomy or partial discectomy
for treatment of thoracolumbar intervertebral disc protrusion in dogs

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Summary

Objectives: To compare the clinical outcome of dogs undergoing a hemilaminectomy with anulectomy (HA) or a hemilaminectomy with partial discectomy (HPD) for treatment of thoracolumbar intervertebral disc protrusion.

Methods: Medical records from 2006 to 2015 were retrospectively reviewed. Dogs were included if they had clinical signs and imaging findings consistent with thoracolumbar intervertebral disc protrusion and had undergone surgical treatment with a HA or HPD. Outcome data were obtained via veterinary records and owner questionnaires. Recorded variables included age, sex, body weight, neurological deficits, surgical time, perioperative complications, postoperative neurological deterioration and recurrence of clinical signs.

Results: The two treatment groups showed no significant difference in signalment, clinical presentation and imaging findings. However, significant differences were detected in outcome. Early postoperative neurological deterioration was recorded in 16/29 dogs in the HA group and 7/24 dogs in the HPD group ($p=0.037$). Sustained clinical improvement for a minimum of 18 months postoperatively was reported in 9/22 dogs in the HA group compared with 17/23 dogs in the HPD group ($p=0.019$).

Clinical significance: Hemilaminectomy with partial discectomy for decompression of thoracolumbar intervertebral disc protrusion was associated with decreased postoperative neurological deterioration and increased sustained clinical improvement compared to hemilaminectomy with anulectomy.

Introduction

Degenerative intervertebral disc disease is the most common pathological condition affecting the canine thoracolumbar vertebral column (1). Two types of degenerative intervertebral disc disease have historically been recognized. Type I intervertebral disc disease, or intervertebral disc extrusion, is seen most commonly in chondrodystrophic dog breeds and involves the acute herniation of degenerate and calcified nucleus pulposus material through all layers of the ruptured anulus fibrosus into the vertebral canal (1-3). Type II intervertebral disc disease, or intervertebral disc protrusion, typically affects non-chondrodystrophic large breed dogs and the pathological abnormalities are predominantly seen in the anulus fibrosus. The weakened, hypertrophied anulus fibrosus protrudes into the vertebral canal, leading to chronic progressive spinal cord compression (2-4). Various surgical techniques have been reported in the management of thoracolumbar intervertebral disc protrusion, including hemilaminectomy with anulectomy, dorsal laminectomy and partial lateral corpectomy (5-10). These techniques are often technically demanding and complicated by the fact that affected dogs may present with multiple sites of spinal cord compression (1, 9).

Historically, the surgeons at our institution have performed a hemilaminectomy with anulectomy (HA) to treat thoracolumbar intervertebral disc protrusion, in which the dorsal, protruding anulus fibrosus is excised. However, this technique provides limited access to the ventral part of the vertebral canal and often necessitates manipulation of the spinal cord to enable excision of the protruding portion of the anulus fibrosus. To overcome these limitations the standard anulectomy technique has been modified in more recent years by combining a hemilaminectomy with a partial discectomy (HPD). This modification allows inspection of the vertebral canal before making a lateral approach to the affected intervertebral disc space and subsequent removal of the dorsolateral anulus fibrosus and

associated vertebral endplates using a pneumatic drill or surgical aspirator. However, it is currently unknown if this modified surgical approach is associated with improved postoperative outcome. Therefore the aims of the current study were to compare the clinical outcome of dogs undergoing a HA or a HPD for treatment of thoracolumbar intervertebral disc protrusion. It was hypothesized that HPD would be associated with improved postoperative outcomes compared to HA.

Materials and methods

Digital medical records from 1st January 2006 to 30th April 2015 were searched. Inclusion criteria included complete medical records, compatible clinical signs and a diagnosis of thoracolumbar intervertebral disc protrusion confirmed by diagnostic imaging, using published myelographic (1) or MRI criteria (11) and surgical findings. Dogs were excluded if clinical records or imaging studies were incomplete or unavailable for review, or if concurrent spinal cord disease (such as degenerative myelopathy) was present. The study was approved by the institution's Ethics and Welfare Committee (Protocol number URN 20151344).

Information retrieved from medical records included signalment, neurologic examination findings, concurrent medical conditions, diagnostic imaging findings, duration of the surgery and perioperative complications. Neurologic status was graded by the modified Frankel score, which was defined as paraplegia with no deep nociception (grade 0), paraplegia with no superficial nociception (grade 1), paraplegia with nociception (grade 2), non-ambulatory paraparesis (grade 3), ambulatory paraparesis and ataxia (grade 4), spinal hyperesthesia only (grade 5), or no dysfunction nor pain (neurologically normal) (12).

Anaesthetic protocols varied between dogs but typically included premedication with acepromazine maleate (0.01 mg/kg IV) and methadone (0.1 to 0.2 mg/kg IV), induction with propofol (4 to 6 mg/kg IV) and maintenance of anaesthesia with isoflurane in oxygen. Myelography was performed in dogs following intrathecal injection of iohexol^a contrast medium (0.2 mL/kg with a maximal dose of 10 mL) through the L5-6 intervertebral space. For MRI, a 1.5 Tesla unit^b was used. Dogs were placed in dorsal recumbency, and protocols included a minimum of T2-weighted (repetition time 3000 ms; echo time 120 ms) and T1-weighted (repetition time 400 ms; echo time 8 ms) 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 0.3-0.9 mm. Imaging studies were assessed for location and number of compressive intervertebral disc protrusions. MRI studies were additionally assessed for degree of spinal cord compression and the presence of intraparenchymal signal intensity changes, defined as focal intraparenchymal areas that had a different intensity (hyper- or hypointense) compared to the surrounding normal spinal cord parenchyma. A board-certified neurologist (SDD) unaware of the clinical presentation, treatment and outcome of the individual dogs evaluated all imaging studies.

All surgeries were performed by a board-certified neurologist (8 surgeons in total). The HA surgery entailed performing a hemilaminectomy using a standard dorsolateral approach (13, 14) after which the protruding part of the dorsal annulus fibrosus was excised with a beaver blade or number 11 scalpel blade (Figure 1A-B). The HPD surgery (Figure 1C-D, 2) entailed performing a routine hemilaminectomy followed by a lateral approach to the intervertebral disc space. A window was created in the dorsolateral part of the affected intervertebral disc and adjacent vertebral endplates using a pneumatic drill or ultrasonic bone curette^c. Care was taken to leave the most dorsal part of the annulus fibrosus intact and thus the vertebral canal was not entered during this stage of the surgery. Finally, the most dorsal part of the annulus

fibrosus was pulled ventrally and removed via the lateral window, so decompressing the overlying spinal cord. The dorsal 25 to 33% of the intervertebral disc and endplates were removed, with the depth extending approximately to the midline of the vertebral canal.

Intraoperative analgesia consisted of methadone (0.1-0.2mg/kg IV every 4 hours), with constant rate IV infusions of ketamine (5-10µg/kg/min) and fentanyl (0.1-0.2µg/kg/min).

Postoperative analgesia consisted of 48-96 hours of opioids IV, in combination with a 7-14 day course of oral NSAIDs and/or gabapentin (10mg/kg every 8 to 12 hours). Early postoperative neurological deterioration was defined as a decrease in neurological grade within 48 hours of surgery (15).

Dogs underwent a 4-6 week period of restricted exercise post-operatively, followed by a gradual return to exercise. Follow up data were obtained from medical records of re-examination visits 4 to 6 weeks postoperatively. Long term follow up data was obtained by review of medical records of referring veterinarians. Data collection included date and cause of death, as well as the last documented clinical and neurological status. Standardized questionnaires were sent to owners of dogs that were alive at the time of follow up, which included questions regarding the time and extent of neurological recovery postoperatively, complications encountered and recurrence of neurological deficits.

Statistical analysis - Data analysis was performed using a standard statistical software package^d. Data were assessed for normal distribution using the Shapiro-Wilk test for normality. Differences between normally distributed continuous variables were explored with an independent samples *t* test with a Levine test for equality of variances. Differences between non-normally distributed continuous data were assessed with a Mann-Whitney U test. A Fisher exact test was used to compare categorical variables, with a Yates correction for continuity. Values of $p < 0.05$ were considered significant. Variables were considered for inclusion in binary logistic regression if $P <$

0.30. Normally distributed data are presented as mean \pm SD, and non-normally distributed data as median and interquartile range (IQR).

Results

Dogs treated for thoracolumbar intervertebral disc protrusion by HA (n = 29) or HPD (n = 24) were included. Signalment, body weight and clinical data are summarized (Table 1). The most frequently represented breeds were the German shepherd (n = 21) and Staffordshire bull terriers (n = 10).

Hemilaminectomy with anulectomy: Presenting complaints included paraparesis (n = 26), pelvic limb ataxia (n = 14) and spinal hyperaesthesia (n = 6). Seven dogs had a concurrent disease at the time of presentation (including anal furunculosis, laryngeal paralysis, osteoarthritis and partial cruciate ligament rupture). Neurological examination revealed 19 dogs with grade 4 status, 8 dogs with grade 3, 1 dog with grade 2 and 1 dog with grade 0. Four dogs underwent myelography, while the remaining 25 underwent MRI. Nineteen dogs had multiple thoracolumbar intervertebral disc protrusions (10 dogs had 2 intervertebral disc protrusions, 8 dogs had 3, and 1 dog had 4). MRI revealed intraparenchymal signal changes in 8 dogs. The mean remaining spinal cord area was $57.8 \pm 4.7\%$.

The mean surgical time was 238 ± 20 minutes. One intervertebral disc space was operated on in 13 dogs, 2 spaces in 9 dogs, 3 spaces in 6 dogs and 4 spaces in 1 dog. Perioperative complications were encountered in 8 dogs, including urinary tract infection (n = 4), hematoma development at the surgical site requiring revision surgery (n = 2) and aspiration pneumonia (n = 1). Early postoperative neurological deterioration was recorded in 16/29 dogs. The mean duration of hospitalization was 9.8 ± 1 days. Neurological improvement was noted in a median of 5 days (IQR

3). Twenty-six of 29 dogs survived to hospital discharge of which 4 were ambulatory without support (grade 4), 16 were ambulatory if supported (grade 3) and 6 were non-ambulatory (5 were grade 3, 1 was grade 2). Of the 3 dogs that did not survive to hospital discharge, one developed aspiration pneumonia, one developed peracute onset tetraparesis 24 hours post surgery and one failed to show neurological improvement (this dog presented as a neurological grade 0), leading to euthanasia in each case.

Long-term follow up information was available for 22 dogs. Four dogs showed a clinical improvement but remained within the same neurological grade, 4 improved by 1 grade, 9 improved by 2 grades, and 5 showed a complete recovery with full resolution of all neurological deficits and spinal pain. Recurrence of clinical signs consistent with thoracolumbar intervertebral disc protrusion within 18 months of surgery occurred in 13/22 dogs, of which 12 were euthanized as a result. Neurological deterioration was seen at a median of 270 days postoperatively (range 35-320 days). Further diagnostic investigations were not undertaken prior to euthanasia in any of the dogs. The mean survival time for all dogs was 726 ± 543 days (444 ± 427 for dogs in which the cause of death was perceived neurological deterioration, 865 ± 189 for dogs in which the cause of death was unrelated).

Hemilaminectomy with partial discectomy: Presenting complaints included paraparesis (n = 8), pelvic limb ataxia (n = 12) and spinal hyperaesthesia (n = 6). Five dogs had a concurrent disease at the time of presentation (including urinary tract infection, chronic diarrhoea osteoarthritis and partial cruciate ligament rupture). Neurological examination revealed 17 dogs with grade 4 neurological status, 5 with grade 3 and 2 with grade 2. One dog underwent myelography, while the remaining 23 underwent MRI. Fifteen dogs had multiple

thoracolumbar intervertebral disc protrusions (9 dogs had 2 intervertebral disc protrusions and 6 dogs had 3). MRI revealed intraparenchymal signal intensity changes in 9 dogs. The mean remaining spinal cord area was $52.3 \pm 4.6\%$.

The mean surgical time was 206 ± 13 minutes. An ultrasonic bone curette was used in 7 of the dogs to remove the dorsolateral aspect of the intervertebral disc and vertebral endplates, while a pneumatic surgical drill was used in the remaining 17 dogs. A single intervertebral disc space was operated on in 10 dogs, 2 spaces in 8 dogs, and 3 spaces in 6 dogs. Perioperative complications were encountered in 5 dogs, including urinary tract infection ($n = 2$), surgical wound infection ($n = 2$) and seroma formation at the surgical site ($n = 1$). Early postoperative neurological deterioration was recorded in 7/24 dogs. The mean duration of hospitalization was 7.6 ± 0.7 days. Neurological improvement was noted in a median of 3 days (IQR 3). All dogs survived to hospital discharge, of which 5 were ambulatory without support (grade 4), 14 were ambulatory if supported (grade 3) and 5 were non-ambulatory (grade 3).

Long term follow up information was available for 23 dogs. The median time to maximum recovery was 28 days (IQR 13). Three dogs showed a clinical improvement but remained within the same neurological grade, three dogs improved by 1 grade, 6 by 2 grades, 4 by 3 neurological grades and 7 showed a complete recovery with full resolution of neurological deficits and spinal pain. Recurrence of clinical signs within 18 months of surgery occurred in 6/23 dogs, all of which were euthanized as a result. Neurological deterioration was seen at a median of 190 days post-operatively (range 120-210 days). Further diagnostic investigations were not undertaken prior to euthanasia. The mean survival time for all dogs was 574 ± 484 days (670 ± 672 for dogs in which the cause of death was perceived neurological deterioration, 455 ± 205 for dogs in which the cause of death was unrelated).

Comparison of presentation and outcome

The two treatment groups showed no significant difference in age, body weight, sex, duration of clinical signs prior to referral, presence of concurrent disease, outcome of treatment prior to referral, severity of neurological deficits, presence of thoracolumbar hyperesthesia, remaining spinal cord area, number of compressive intervertebral disc protrusions and presence of ISI changes (Table 1).

Univariate analysis revealed that significantly fewer dogs undergoing HPD showed early postoperative neurological deterioration ($p=0.001$), with a significantly decreased time to neurological improvement ($p=0.027$), and significantly decreased time to ambulation ($p=0.046$) compared to dogs undergoing HA. Significantly more of the dogs undergoing HPD showed a sustained clinical improvement without neurological deterioration for a minimum of 18 months postoperatively compared with dogs undergoing HA ($p=0.016$).

Following multivariate analysis, two variables maintained statistical significance: early postoperative neurological deterioration ($p=0.037$) and sustained clinical improvement for a minimum of 18 months postoperatively ($p=0.019$).

Discussion

This study evaluated the clinical presentation and outcome of dogs undergoing surgical management of thoracolumbar intervertebral disc protrusion with either a hemilaminectomy and anulectomy (HA) or a hemilaminectomy and partial discectomy (HPD). The HPD technique was designed as a simple modification of the standard HA, with the aim of improving access to and excision of the dorsal annulus fibrosus with minimal spinal cord

manipulation. Compared with a partial lateral corpectomy, the vertebral body is left intact and only the vertebral endplates are removed, thus potentially reducing intraoperative haemorrhage and nerve root injury (16). This less invasive approach was found to provide sufficient access for effective removal of the protruding annulus fibrosus, assessed via the hemilaminectomy (Figure 1).

The biomechanical consequences of the HA and HPD surgery on thoracolumbar vertebral column stability have not been evaluated. A previous study showed a significant increase in the range of motion of the thoracolumbar vertebral column following a partial lateral corpectomy, which was further exacerbated when combined with a hemilaminectomy (17). In contrast to the partial corpectomy technique, the HA and HPD surgeries both endeavor to leave the vertebral body intact and hence less instability may be anticipated with these techniques. However, the dorsolateral endplates and a larger portion of the intervertebral disc are excised with a HPD compared with a HA, potentially leading to greater instability. *Ex vivo* cadaveric studies to further evaluate the biomechanical consequences of HA and HPD would be worthwhile, alongside longer term follow up of clinical cases with repeat MRI to evaluate the *in vivo* effects of both surgical techniques.

Theoretically a partial discectomy could be performed in combination with a mini-hemilaminectomy, in which the articular processes are left intact and the intervertebral foramina is enlarged (10). Alternatively a partial discectomy could be performed in isolation, without a prior hemilaminectomy, as has been reported for partial lateral corpectomy (6, 7). Potential benefits to these options may include increased biomechanical stability of the affected region of the vertebral column following surgery, however intraoperative assessment of the degree of spinal cord decompression achieved would be limited. Studies to evaluate these surgical options are required.

In agreement with previous studies evaluating surgical management of chronic spinal cord compression, early postoperative neurological deterioration was considered the most important perioperative complication. However, it was a transient phenomenon associated with subsequent neurological improvement (14, 15, 18). Of the dogs undergoing HA, 16/29 showed a postoperative neurological deterioration, compared with 7/24 of dogs in the HPD group. The cause of early postoperative neurological deterioration has not been definitively determined but possible factors include reperfusion injury, altered hemodynamics, intraoperative spinal cord manipulation, intraoperative hypotension and exacerbation of pre-existing spinal cord pathology (1, 14, 15, 19). In the current study there was no significant difference in the duration of clinical signs prior to referral, severity of neurological deficits on presentation, intraparenchymal signal intensity changes or remaining spinal cord area between treatment groups, suggesting that pre-existing spinal cord pathology may not be the major determinant of early postoperative neurological deterioration. Given the differences between the 2 surgical techniques, removal of a compressive intervertebral disc protrusion by HPD is likely to require less spinal cord manipulation, compared to HA. Hence, it is possible that the observed differences in early postoperative neurological deterioration result from different degrees of intraoperative spinal cord manipulation required to obtain adequate decompression. Spinal cord manipulation may, therefore, be an important factor in early postoperative neurological deterioration

Prolonged anaesthesia, as typically necessitated by these challenging surgeries, may exacerbate the pathology of the chronically compressed spinal cord secondary to hypotension and reduced spinal cord perfusion. In a recent study of dogs undergoing surgical management of an acute intervertebral disc extrusion, intraoperative hypotension was not found to be significantly associated with a poorer outcome (20). However, this may differ in a population of dogs with intervertebral disc protrusion and chronic spinal cord compression.

Further studies are needed to evaluate the role of intraoperative hypotension and spinal cord perfusion in postoperative outcome.

A recurrence of clinical signs after an initial postoperative clinical improvement was reported in 13/22 of dogs in the HA group and 6/23 in the HPD group. However, a limitation of this study is that none of these dogs underwent repeat diagnostic imaging, and so the cause of their subsequent neurological deterioration is unknown. Possible aetiologies include development or progression of intervertebral disc protrusions at a different vertebral segment, further protrusion of the initially affected intervertebral disc, or development of an unrelated spinal cord condition, such as degenerative myelopathy, commonly seen in older German Shepherd Dogs (21, 22). The majority of dogs included in the current study had multiple compressive intervertebral disc protrusions and underwent simultaneous surgery at multiple sites. It is currently unknown if all affected intervertebral disc spaces should be surgically treated or only the sites associated with the most severe spinal cord compression. Incomplete excision of the protruding anulus fibrosus may lead to persistent compression with secondary ischemic and malacic changes in the spinal cord (6). Considering the technical differences between the 2 techniques in the current study, this may be more likely following a HA where only the protruding part of the anulus fibrosus is removed, compared to a HPD where a larger portion of the affected intervertebral disc is removed. Thus, while the HPD surgery may be associated with improved long-term outcomes, future larger scale prospective studies are needed to assess the cause and prevalence of recurrent clinical signs and to ascertain their relationship to the surgical procedure undertaken.

In seven of the dogs undergoing HPD, an ultrasonic bone curette was used to excise the dorsolateral aspect of the disc and vertebral endplates. Described advantages of the ultrasonic bone curette include safe and effective bone removal with minimal heat production

and mechanical injury, thus enhancing safety when working in narrow surgical corridors surrounded by important neurovascular structures (23, 24). In the human medical literature ultrasonic bone curettes have been used in skull base surgery for several years (25), and have been introduced into spinal surgery more recently (24-28). There are limited reports of the use of an ultrasonic bone curette in the veterinary literature; one study described its use in microfenestration in dogs with thoracolumbar intervertebral disc extrusion (29). Further studies are needed to evaluate the extent of spinal cord decompression achieved with an ultrasonic bone curette compared to a pneumatic drill, as well as the perioperative risks associated with its use.

The present study was limited by its retrospective nature, and the associated variability in clinical management, surgeon skills and preferences, and evaluation of objective clinical outcome measures. The small group sizes may have limited the power, and hence differences in studied parameters, such as the duration of clinical signs prior to referral, surgical time and survival time, may have reached statistical significance with a larger population size. An accepted neurological grading system was used to evaluate the severity of neurological deficits, however, the majority of dogs were ambulatory at presentation and so were assigned a similar neurological grade. This may have limited recognition of more subtle differences in the severity of the clinical signs.

Inherent in a retrospective study, dogs could not be randomized to treatment modality and the surgical technique used was based on the preference of the primary surgeon. Furthermore, in the earlier years of the reporting period all cases underwent HA, whereas in later years the HPD technique was introduced. Thus, technical improvements, changes in instrumentation (particularly the use of the ultrasonic bone curette) and the individual surgeon's learning curve may all have contributed to improved outcome in the HPD group.

Four dogs in the HA group underwent myelography, compared with only 1 in the HPD group. Myelography has been associated with clinical deterioration in cases of chronic spinal cord compression (30), however, only 1 dog in the current study showed a neurological deterioration following the myelogram and surgery, suggesting that this was not a significant complication.

Postoperative imaging was not performed in any of the cases, and hence we were unable to quantify the degree of spinal cord decompression achieved by each technique. Further studies to assess if greater spinal cord decompression is indeed achieved with the HPD would be worthwhile.

Despite the limitations of the study the data obtained revealed that, compared with dogs undergoing HA, fewer dogs undergoing HPD developed early postoperative neurological deterioration, while more showed a sustained clinical improvement postoperatively. Further prospective studies are needed to evaluate the extent of spinal cord decompression achieved in HPD and HA and the prognostic factors important in determining long-term outcome following each technique.

^a Omnipaque, GE Healthcare, Belgium

^b Intera 1.5T, Philips Medical Systems, The Netherlands

^c Sonopet Ultrasonic Aspirator, Neurotechnics Limited, England

^d SPSS, v. 21.0.1, SPSS Inc, Chicago, Ill

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