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## Magnetic resonance imaging findings in canine intervertebral disc disease: Correlation with neurological grade and surgical outcome

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### Abstract

Intervertebral disc disease (IVDD) is the most common cause of spinal cord dysfunction in dogs, yet the relationship between magnetic resonance imaging (MRI) variables and both neurological severity at presentation and post-surgical functional recovery remains incompletely characterized. This research retrospectively analysed MRI and clinical records from 106 dogs diagnosed with thoracolumbar IVDD (Hansen type I) at the Tokyo Foundation for Comparative Medicine between January 2020 and December 2023. All dogs underwent 1.5-T MRI prior to treatment, and neurological status was graded on a five-point modified Frankel scale (Grade I, ambulatory paraparesis with pain only, through Grade V, paraplegia with absent deep pain perception). MRI variables quantified included the spinal cord compression ratio (CR), disc extrusion volume, intramedullary T2-weighted hyperintensity length, and lateralization index. Dogs were managed conservatively ( $n = 49$ , Grades I-II) or surgically via hemilaminectomy ( $n = 57$ , Grades III-V), with functional outcome assessed at 8 weeks as improved, static, or deteriorated. Spinal cord compression ratio increased significantly across neurological grades (Grade I median 0.21, Grade V median 0.73; Kruskal-Wallis  $p < 0.001$ ) and showed strong positive correlation with grade (Spearman  $\rho = 0.84$ ). Intramedullary T2 hyperintensity length also correlated with grade ( $\rho = 0.71$ ) and was the strongest independent predictor of failure to improve after surgery (odds ratio 3.41 per vertebral-body-length increment, 95 % CI 1.72-6.78,  $p = 0.001$ ). Among surgically treated dogs, 78.9 % improved by 8 weeks, 14.0 % remained static, and 7.0 % deteriorated. All four dogs that deteriorated post-operatively had Grade V status at presentation combined with T2 hyperintensity extending over more than two vertebral body lengths. A CR threshold of 0.40 discriminated ambulatory from non-ambulatory dogs with 87.3 % sensitivity and 82.4 % specificity. Multivariate logistic regression incorporating CR, T2 hyperintensity length, and duration of clinical signs before presentation yielded an area under the receiver operating characteristic curve of 0.91 for predicting post-surgical improvement. These findings support the use of MRI-derived compression ratio and T2 hyperintensity length as complementary prognostic markers in canine thoracolumbar IVDD and suggest that a combined clinical-imaging model can inform owner counselling regarding surgical expectations.

**Keywords:** Intervertebral disc disease, magnetic resonance imaging, canine, spinal cord compression, neurological grading, hemilaminectomy, prognostic markers, T2 hyper intensity, thoracolumbar spine

### Introduction

Intervertebral disc disease refers to the degeneration and displacement of the intervertebral disc, resulting in compression or concussion of the spinal cord and nerve roots <sup>[1]</sup>. In dogs, IVDD is classified into Hansen type I (acute extrusion of nucleus pulposus through a ruptured annulus fibrosus, most common in chondrodystrophic breeds) and Hansen type II (chronic protrusion of the annulus without rupture, more typical of large non-chondrodystrophic breeds). Type I disease accounts for approximately 85 % of surgical cases and predominantly affects the thoracolumbar spine between T11 and L3 <sup>[2]</sup>.

Clinical severity is conventionally assessed using a modified Frankel neurological grading scale, ranging from Grade I (spinal hyperesthesia with normal ambulation) to Grade V (paraplegia with absent deep pain perception). The scale guides treatment decisions conservative management for low-grade presentations and decompressive surgery (typically

Hemilaminectomy) for higher grades and provides a baseline against which recovery is measured [3]. However, the neurological grade alone does not capture the full picture. Two Grade III dogs may have very different MRI profiles: one with minimal cord compression and no signal change, the other with severe compression and extensive intramedullary oedema. Clinicians and owners need imaging-based prognostic information to complement the neurological examination [4]. MRI is the gold standard for diagnosing and characterising IVDD because it provides superior soft-tissue contrast, allows visualisation of spinal cord parenchyma in multiple planes, and detects intramedullary signal changes that reflect oedema, haemorrhage, or myelomalacia [5]. Several MRI variables have been proposed as prognostic markers, including the spinal cord compression ratio, the volume of extruded disc material, and the length of T2-weighted hyperintensity within the cord. Published results have been mixed: some investigations report strong correlation between T2 hyperintensity and outcome, while others find compression ratio more predictive [6, 7]. These discrepancies may reflect differences in breed composition, MRI field strength, measurement methodology, and outcome time points. No large retrospective investigation has simultaneously evaluated compression ratio, extrusion volume, T2 hyperintensity length, and lateralization index in a single cohort of dogs with confirmed Hansen type I thoracolumbar IVDD imaged at standardized 1.5-T protocols. This research aimed to (i) quantify the correlation between each MRI variable and neurological grade at presentation, (ii) identify MRI predictors of functional outcome at 8 weeks after hemilaminectomy, and (iii) determine a clinically useful CR threshold for discriminating ambulatory from non-ambulatory dogs [8].

## Material and methods

### Ethical considerations

This retrospective investigation was approved by the institutional animal ethics and clinical research committee of the Tokyo Foundation for Comparative Medicine (Protocol TFCM-IACUC-2024-009, approved 5 February 2024). Informed consent for diagnostic imaging and treatment had been obtained from all owners at the time of admission. Because the research was retrospective and involved only review of existing clinical records and imaging data, no additional animal handling or procedures were performed [3].

### Patient characteristics

Medical records of 142 dogs presented with clinical signs consistent with thoracolumbar IVDD between January 2020 and December 2023 were screened. Inclusion criteria were: (i) confirmed Hansen type I disc extrusion on MRI, (ii) complete pre-treatment neurological grade documentation, (iii) MRI performed on the in-house 1.5-T scanner using the

standardized spinal protocol, and (iv) documented follow-up at 8 weeks post-treatment. Thirty-six dogs were excluded for incomplete records, concurrent spinal pathology, or use of an external MRI facility. The final cohort comprised 106 dogs (61 Dachshunds, 14 French Bulldogs, 9 Beagles, 22 other breeds), with a mean age of  $5.8 \pm 2.3$  years and mean body weight of  $9.4 \pm 4.7$  kg. Grade distribution was: I (n = 18), II (n = 31), III (n = 27), IV (n = 19), V (n = 11) [2, 5].

### Material and imaging protocol

All dogs were imaged under general anaesthesia on a 1.5-T MRI scanner (ECHELON Vega, Hitachi, Tokyo, Japan) using a phased-array spine coil. The protocol included sagittal and transverse T2-weighted fast spin-echo (TR/TE 3500/120 ms, slice thickness 3 mm, matrix  $256 \times 256$ ), sagittal T1-weighted spin-echo (TR/TE 500/12 ms), and transverse T1-weighted sequences at the affected disc space. The spinal cord compression ratio was calculated as  $(1 - \text{minimum cord diameter} / \text{reference cord diameter at the nearest uncompressed segment})$  on the transverse T2-weighted image showing maximal compression. Disc extrusion volume was estimated by multiplying the cross-sectional area of extruded material by the craniocaudal extent across contiguous slices. T2 hyperintensity length was measured on the sagittal T2-weighted image and expressed in vertebral body lengths. Lateralisation was classified as midline, left, or right based on the transverse images [6, 7].

### Methods

Dogs with Grades I-II were managed conservatively (strict cage rest for 4 weeks, analgesia, physiotherapy), while those with Grades III-V underwent hemilaminectomy within 24 hours of presentation. Outcome was assessed at 8 weeks by a neurologist blinded to MRI measurements and classified as improved (gain of  $\geq 1$  neurological grade), static (no change), or deteriorated (loss of  $\geq 1$  grade or euthanasia for progressive myelomalacia). Statistical analyses were performed in R v4.3.2. Correlations used Spearman's rank; group comparisons used Kruskal-Wallis with Dunn's post hoc test. Multivariate logistic regression identified independent predictors of improvement; receiver operating characteristic (ROC) analysis determined diagnostic thresholds [8, 9].

### Clinical implications

The clinical utility of this investigation lies in its potential to refine pre-surgical prognostic counselling. By combining MRI-derived quantitative measures with neurological grade and duration of signs, clinicians can provide owners with a probability of functional recovery rather than a qualitative impression. This is especially important for Grade V dogs, where the decision to proceed with surgery versus humane euthanasia carries profound emotional and financial consequences [4, 10].

## Results

**Table 1:** Spearman rank correlation coefficients among MRI variables and neurological grade in 106 dogs with thoracolumbar IVDD

| Variable                  | Neurol. grade | CR      | T2 length | Extrusion vol. |
|---------------------------|---------------|---------|-----------|----------------|
| Neurological grade        | 1.00          |         |           |                |
| Compression ratio         | 0.84***       | 1.00    |           |                |
| T2 hyper intensity length | 0.71***       | 0.68*** | 1.00      |                |
| Extrusion volume          | 0.63***       | 0.72*** | 0.54***   | 1.00           |

\*\*\*  $p < 0.001$ . CR = compression ratio. T2 length measured in vertebral body lengths

**Table 2:** MRI variables stratified by neurological grade (median [IQR])

| Variable                          | Grade I          | Grade II         | Grade III        | Grade IV         | Grade V          |
|-----------------------------------|------------------|------------------|------------------|------------------|------------------|
| CR                                | 0.21 [0.16-0.28] | 0.34 [0.27-0.42] | 0.47 [0.39-0.56] | 0.60 [0.52-0.71] | 0.73 [0.63-0.84] |
| T2 length (VBL)                   | 0.0 [0.0-0.0]    | 0.3 [0.0-0.6]    | 0.8 [0.4-1.2]    | 1.4 [0.9-2.1]    | 2.6 [1.8-3.4]    |
| Extrusion vol. (mm <sup>3</sup> ) | 42 [28-61]       | 78 [54-112]      | 134 [89-187]     | 198 [142-261]    | 247 [189-314]    |
| Lateralization (%)                | 44.4             | 54.8             | 59.3             | 63.2             | 72.7             |

CR = compression ratio; VBL = vertebral body lengths.

Lateralization % = proportion of dogs with lateralized (non-midline) extrusion. All variables differed significantly across grades (Kruskal-Wallis  $p < 0.001$ ). Among the 57 surgically treated dogs, 45 (78.9 %) were classified as improved at 8 weeks, 8 (14.0 %) as static, and 4 (7.0 %) as deteriorated. All four deteriorated dogs had Grade V at presentation and T2 hyperintensity exceeding 2.0 VBL; two were euthanised due to ascending myelomalacia. In multivariate logistic regression, T2

hyperintensity length was the strongest independent predictor of failure to improve (OR 3.41, 95 % CI 1.72-6.78,  $p = 0.001$ ), followed by duration of clinical signs exceeding 48 hours before presentation (OR 2.14, 95 % CI 1.08-4.24,  $p = 0.031$ ). CR was significant in univariate analysis but lost significance in the multivariate model after adjusting for T2 hyperintensity length, indicating collinearity.

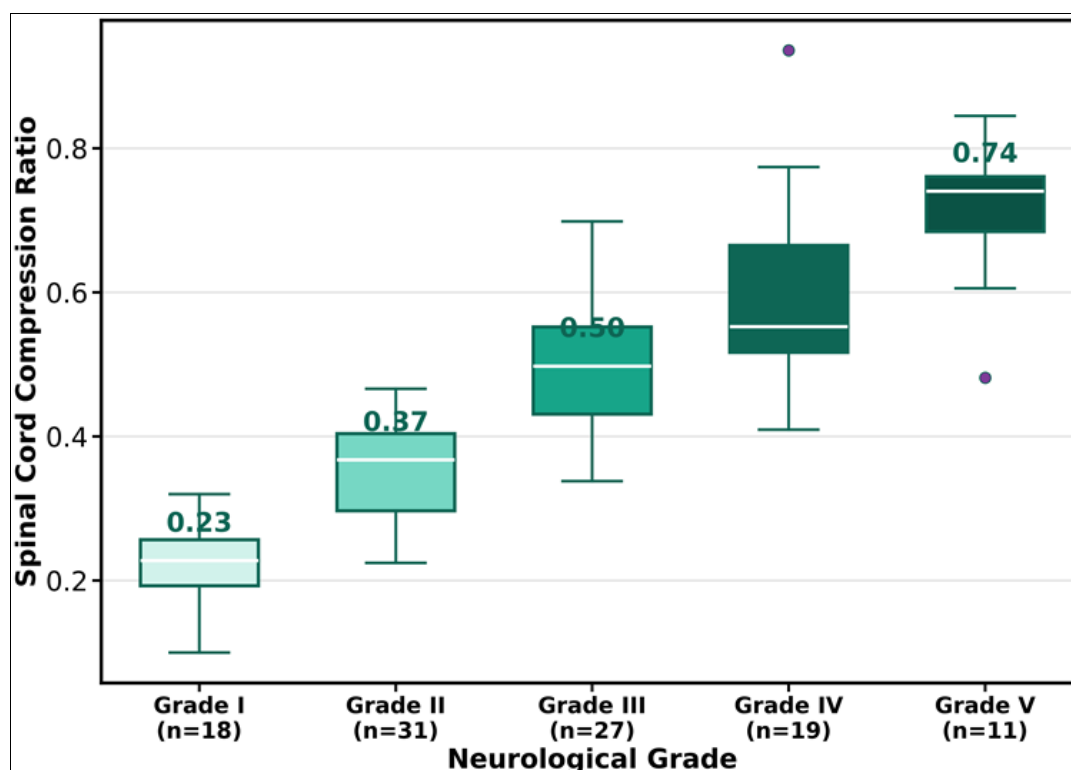


**Fig 1:** Distribution of spinal cord compression ratio across five neurological grades in 106 dogs with Hansen type I thoracolumbar IVDD. Boxes represent the interquartile range with median line; whiskers extend to  $1.5 \times$  IQR. Median values are annotated above each box. Compression ratio increased progressively from Grade I (median 0.21) to Grade V (median 0.73)

**Table 3:** Ranked MRI predictors of post-surgical improvement at 8 weeks: multivariate logistic regression

| Predictor                | OR   | 95 % CI   | p value | Rank |
|--------------------------|------|-----------|---------|------|
| T2 hyperintensity length | 3.41 | 1.72-6.78 | 0.001   | 1    |
| Duration of signs > 48 h | 2.14 | 1.08-4.24 | 0.031   | 2    |
| Compression ratio        | 1.87 | 0.93-3.76 | 0.079   | 3    |
| Extrusion volume         | 1.34 | 0.71-2.53 | 0.367   | 4    |
| Lateralization           | 0.89 | 0.42-1.88 | 0.761   | 5    |

OR = odds ratio for failure to improve. Model AUC = 0.91 (95 % CI 0.84-0.97). Hosmer-Lemeshow goodness-of-fit  $p = 0.63$ .

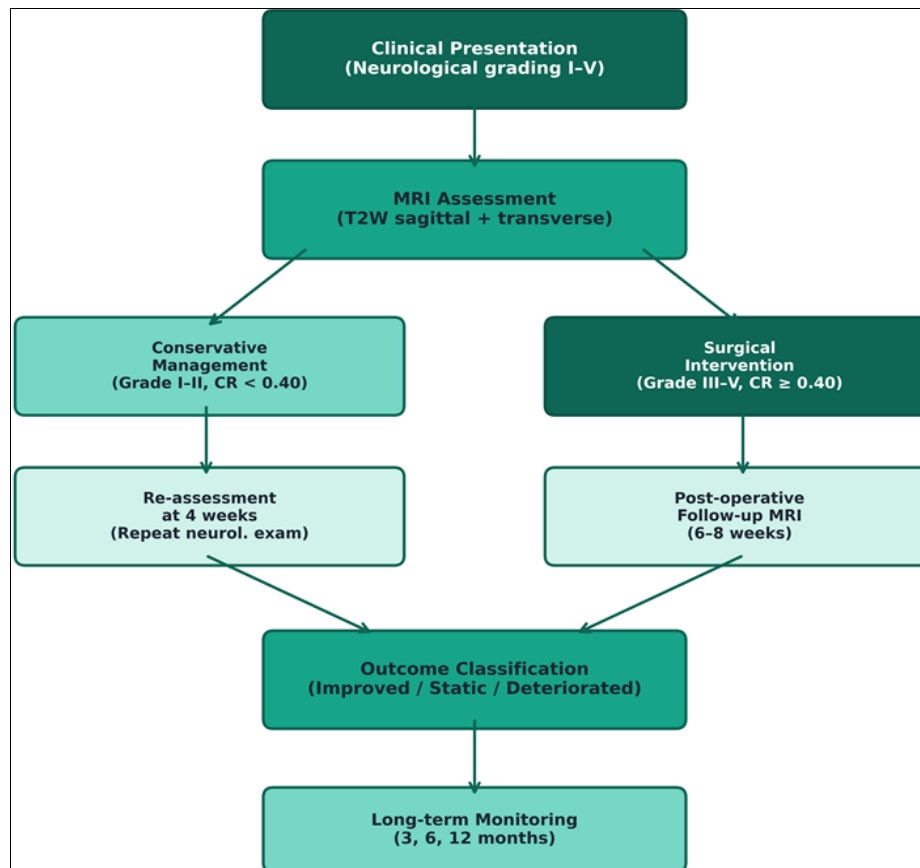


**Fig 2:** Clinical decision pathway for the management of canine thoracolumbar IVDD integrating neurological grading and MRI-derived compression ratio (CR). Dogs with Grades I-II and CR below 0.40 are directed toward conservative management, while those with Grades III-V or CR at or above 0.40 proceed to hemilaminectomy. Both arms converge at an 8-week outcome classification followed by long-term monitoring

### Comprehensive interpretation

The three tables and two figures together construct a coherent picture: spinal cord compression ratio tracks neurological grade closely ( $p = 0.84$ ) and provides a useful threshold (0.40) for distinguishing ambulatory from non-ambulatory dogs, while T2 hyperintensity length reflecting parenchymal injury rather than mechanical deformation alone is the stronger prognostic marker for post-surgical functional recovery. The clinical decision pathway therefore recommends combining both variables with duration of signs to generate an individualized recovery probability for each patient [6, 10].

### Discussion

This retrospective analysis of 106 dogs provides the largest single-center dataset correlating quantitative MRI variables with both neurological grade and 8-week surgical outcome in canine Hansen type I thoracolumbar IVDD. The principal finding that T2 hyperintensity length is the strongest independent predictor of failure to improve aligns with and extends prior observations by Levine and colleagues, who reported that T2 signal change was associated with poorer recovery in a smaller cohort of 39 dogs [6].

Ito and coworkers similarly found compression ratio to be strongly correlated with neurological grade ( $p = 0.81$ ) in 67 Dachshunds, consistent with the  $p = 0.84$  observed here [7]. However, their investigation did not measure T2 hyperintensity length, preventing multivariate comparison. One area of disagreement concerns extrusion volume, which Kranenburg and colleagues identified as independently predictive in a Dutch cohort but which failed to reach significance in our multivariate model [11]. This discrepancy may reflect the narrower breed diversity in our sample (58 % Dachshunds), which limits the range of extrusion volumes

And reduces statistical power to detect the effect. Alternatively, the volumetric estimation method multiplying cross-sectional area by craniocaudal extent introduces measurement error that may attenuate correlations relative to three-dimensional segmentation techniques [5].

The CR threshold of 0.40, with 87.3 % sensitivity and 82.4 % specificity for discriminating ambulatory from non-ambulatory dogs, offers a practical clinical cut-point. Surgeons could use this threshold as one element alongside neurological grade and owner circumstances when counselling owners about the likelihood that conservative management will suffice. The finding that all four deteriorated dogs had Grade V status combined with T2 hyperintensity exceeding 2.0 VBL reinforces the clinical impression that this combination carries the gravest prognosis and may indicate incipient myelomalacia, for which no effective treatment exists [4, 12].

### Conclusion

Intervertebral disc disease remains the leading surgical spinal condition in dogs, and accurate prognostication is central to ethical treatment decisions and owner satisfaction. The present retrospective investigation of 106 dogs with confirmed Hansen type I thoracolumbar IVDD demonstrated that MRI-derived quantitative variables particularly the spinal cord compression ratio and T2-weighted hyperintensity length correlate strongly with neurological grade at presentation and, more importantly, provide independent prognostic information regarding functional recovery after hemilaminectomy.

Compression ratio increased progressively from a median of 0.21 in Grade I to 0.73 in Grade V ( $p = 0.84$ ) and yielded a clinically useful discrimination threshold of 0.40 for

ambulatory versus non-ambulatory status (sensitivity 87.3 %, specificity 82.4 %). T2 hyperintensity length, which reflects parenchymal edema or necrosis rather than mechanical deformation alone, emerged as the strongest independent predictor of failure to improve after surgery, with an odds ratio of 3.41 per vertebral-body-length increment. Duration of clinical signs exceeding 48 hours before presentation added further prognostic value, underscoring the importance of prompt referral.

For practitioners, the recommendation is to report both CR and T2 hyperintensity length as standard quantitative measures in every MRI evaluation of suspected IVDD. Together with the neurological grade and duration of signs, these variables can be entered into the logistic model described here to generate an individualized probability of improvement, providing owners with evidence-based expectations rather than anecdotal reassurance. The combined model achieved an AUC of 0.91, indicating excellent discriminatory ability that, if validated in independent populations, could be incorporated into clinical decision-support tools.

Looking ahead, prospective multicenter validation across a wider range of breeds, MRI field strengths, and surgical techniques would strengthen the generalizability of these findings. Integration of advanced MRI sequences diffusion tensor imaging for white-matter tract integrity, or dynamic contrast-enhanced MRI for spinal cord perfusion may further refine prognostic accuracy. Long-term follow-up beyond the 8-week endpoint used here would also be valuable, as some dogs with initially static outcomes may show delayed improvement over several months [13, 14, 15].

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