Review and retrospective analysis of degenerative lumbosacral stenosis in 156 dogs treated by dorsal laminectomy

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Summary

The medical records of 156 dogs with degenerative lumbosacral stenosis (DLS) that underwent decompressive surgery were reviewed for signalment, history, clinical signs, imaging and surgical findings. The German Shepherd Dog (GSD) was most commonly affected (40/156, 25.6%). Pelvic limb lameness, caudal lumbar pain and pain evoked by lumbosacral pressure were the most frequent clinical findings. Radiography showed lumbosacral step formation in 78.8% (93/118) of the dogs which was associated with elongation of the sacral lamina in 18.6% (22/118). Compression of the cauda equina was diagnosed by imaging (epidurography, CT, or MRI) in 94.2% (147/156) of the dogs. Loss of the bright nucleus pulposus signal of the L7-S1 disc was found on T2-weighted MR images in 73.5% (25/34) of the dogs. The facet joint angle at L7-S1 was significantly smaller, and the tropism greater in GSD than in the other dog breeds. The smaller facet joint angle and higher incidence of tropism seen in the GSD may predispose this breed to DLS. Epidurography, CT, and MRI allow adequate visualization of cauda equina compression. During surgery, disc protrusion was found in 70.5% (110/156) of the dogs. Overall improvement after surgery was recorded in the medical records in 79.0% (83/105) of the dogs. Of the 38 owners that responded to questionnaires up to five years after surgery, 29 (76%) perceived an improvement.

Keywords

Degenerative lumbosacral stenosis, cauda equina, dog

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Introduction

Degenerative lumbosacral stenosis (DLS) is the most common cause of cauda equina syndrome in dogs. The abnormalities found in DLS include lumbosacral (LS) Hansen type II intervertebral disc degeneration and protrusion, sclerosis of the vertebral end plates and articular processes, ventral subluxation of the sacrum, and hypertrophy of the ligamentum flavum and joint capsules (1–4). DLS leads to compression and entrapment of cauda equina nerve roots. The clinical signs include: caudal lumbar pain, pelvic limb lameness, reduced endurance, reluctance to perform activities, such as jumping, rising and climbing stairs, and neurological deficits, such as urinary and faecal incontinence and self mutilation (2, 5, 6).

Diagnosis of DLS is based on the history, clinical signs, clinical examination, and imaging. Imaging techniques that have been used include: radiography, myelography, vertebral venography, epidurography, computed tomography (CT), and magnetic resonance imaging (MRI) (7–9). The most common surgical treatment of DLS consists of dorsal laminectomy. Additional surgical procedures to further relieve cauda equina compression include dorsal fenestration (i.e. incision and removal of dorsal annulus) and partial discectomy with nucleus pulpectomy (10–12). Facetectomy and foraminotomy have been described to further relieve lateralized cauda equina root compression (12–14). Surgical techniques that stabilize the seventh lumbar (L7) and first sacral (S1) vertebrae include: distraction-fusion procedures, cross-pin fixation, vertebral body fixation with a lag screw, and pedicle screw fixation (15–17).

The aim of this study was to analyze the signalment, clinical signs, imaging findings and surgical findings of a large group of dogs with DLS treated by decompressive surgery, and to identify predictors for outcome after decompressive surgery.

Materials and methods

The medical records of 156 dogs that were treated surgically for DLS at the Department of Clinical Sciences of Companion Animals, Utrecht University between 1989 and 2004 were reviewed. Dogs with LS diseases, other than DLS, such as discospondylitis, neoplasia, and traumatic injuries, were excluded.

The written medical records and imaging studies were retrieved from the patient archives and reviewed in a systematic manner. Collection of data included: signalment, history, findings on clinical examination (18), results of imaging studies, surgical findings and follow-up evaluation. The results of orthopaedic examination (pelvic limbs and caudal lumbar spine) and neurological examination (proprioception, knuckling, withdrawal reflex, perineal reflex) were extracted from the patient records.

The retrospective study spanned a period of 15 years during which time computed tomography (CT) and magnetic resonance imaging (MRI) became available at the university clinic. Imaging studies (radiography, myelography, epidurography, discography, CT and MRI) were reviewed by one investi-

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gator (NS) without knowledge of the surgical findings. Contrast medium (Iopamiro 200, Bracco Altana Pharma GmbH, Konstanz, Germany) was injected in the subarachnoid space between L5-L6 for myelography (0.3 ml/kg), in the epidural space between L7-S1 or S3-Cd1 for epidurography (0.2 ml/kg), and in the nucleus pulposus of L7-S1 for discography (in a normal lumbosacral disc 0.1 to 0.2 ml of contrast medium was injected whereas in an abnormal LS disc 1.0 to 2.0 ml of contrast medium was injected). In case of epidurography and myelography, additional radiographs were taken with the LS spine in flexion and extension. CT was performed with a third-generation CT scanner (Tomoscan CX/S, Philips NV, Eindhoven, The Netherlands) with the dog in sternal recumbency and the pelvic limbs extended caudally. Contiguous 2-mm thick CT slices were obtained from the middle portion of the last lumbar to the caudal sacral vertebrae. MRI was performed using a 0.2 Tesla open magnet (Magnetom Open Viva, Siemens AG, Erlangen, Germany) with the dog in the same position as for CT (sternal recumbency, pelvic limbs extended). Three-mm thick contiguous sagittal T1– and T2-weighted and transverse T1-weighted images were made. The following data were recorded: lumbosacral stenosis (measured by the LS canal ratio), lumbosacral step formation (measured by the LS step), 'telescoping' of the cranial spinal canal of the sacrum relative to the caudal spinal canal of L7, degree of spondylosis deformans, narrowed intervertebral disc space, end plate sclerosis, transitional vertebrae segments (TVS), vacuum phenomenon (i.e. radiographic lucency in the intervertebral disc space due to central accumulation of nitrogen gas in a ruptured disc with an intact outer ring of annulus fibrosus), osteochondrosis, discographic findings, degree and site of disc protrusion, position of dural sac (centre, lateralized left or right), presence or absence of epidural fat dorsal to the dural sac, and spinal nerve root swelling. Disc protrusion was graded on CT and MRI as a percentage obstruction of the spinal canal by the bulging disc on transverse and sagittal images (none, slight: <25%, moderate: 25–50%, severe: > 50%). The signal intensity of the nucleus pulposus on T2-weighted MR images was graded (normal, reduced, absent). On lateral radiographs, sagittal CT reconstructions and sagittal MR images, the length of the sacral lamina was assessed, and the LS canal ratio and LS step were measured. The sacral lamina was elongated and sloped cranially when the cranial end of the sacral lamina reached up to or under the caudal end of the lamina of L7, resulting in attenuation of the lumbosacral spinal canal from caudal to cranial. This so-called telescoping of the cranial spinal canal of the sacrum relative to the caudal spinal canal of L7 was recorded and has been described previously (19). The LS canal ratio was defined as the ratio between the spinal canal height at the cranial end plate of the first sacral vertebra and the height of the spinal canal at the caudal end plate of the last lumbar vertebra (Fig. 1). The LS step was measured as the distance in millimetres between the horizontal level of the spinal canal floor of the last lumbar vertebra and that of the sacrum (Fig. 1). Measurements from the radiographs were performed using a vernier calliper with a scale that was accurate to 0.1 mm, and corrected for geometric magnification. CT and MRI computer software was used for CT and MRI measurements. The left and right facet joint angle at L7-S1 between the midsagittal line and a line parallel with the cranial articular process (Fig. 2) was measured in transverse CT images at the middle of the LS junction in 16 German Shepherd Dogs (GSD), seven dogs of other Shepherd breeds, and 17 dogs of other breeds (six Golden Retrievers, five Labrador Retrievers, three Rottweilers, three Bernese Mountain dogs). Facet joint tropism, defined as the difference (in degrees) between the left and right facet joint angles (20), was determined.

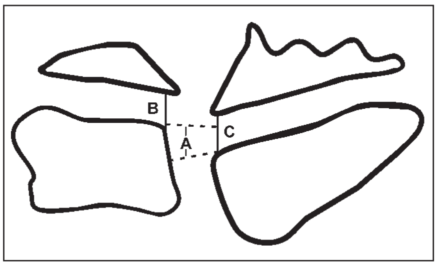

Fig. 1 A) LS step – the distance between a line on the bottom of the spinal canal of L7 and the sacrum; B) Height of the spinal canal at the caudal end plate of L7, C: Height of the spinal canal at the cranial end plate of S1.

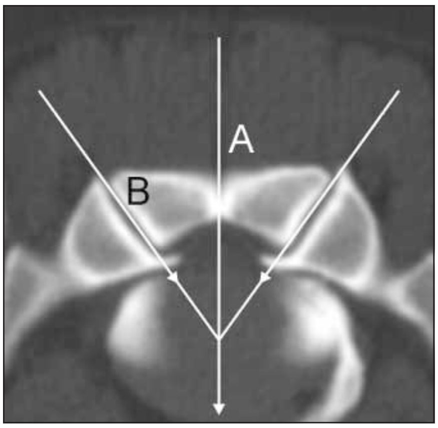

Fig. 2 The facet joint angle was measured between the midsagittal line (A) and the line connecting the edges of the cranial articular process (B) in the transverse plane.

All of the dogs underwent dorsal laminectomy; details of additional decompressive procedures to further relieve cauda equina compression were recorded. Surgical findings were obtained from the written surgical reports, i.e. disc protrusion, presence or absence of epidural fat dorsal to the dural sac, and spinal nerve root swelling. The surgical findings were assessed subjectively by the surgeon. The results of microbiological and histopathological examinations were obtained from the medical records.

The follow-up data were collected from the medical records or by using questionnaires to owners. The follow-up data that was recorded in the medical records was obtained by re-examination of the dog and by interviewing the owners by telephone. Questionnaires for follow-up evaluation were sent to 51 owners of dogs with DLS that had undergone surgical treatment within the last five years. The questionnaire included questions regarding the history and clinical signs before surgery, the status of neuro-orthopaedic functioning after surgery, and satisfaction of the owner with the result of surgery. The questionnaire contained questions that resulted in YES or NO answers, free text answers, and answers on a five-point frequency scale (i.e. 1–5 ranging from 'always' to 'never') or a five-point qualitative scale (i.e. 1–5 ranging from 'very bad' to 'very good').

The data were pooled in a database and analyzed. Statistical analysis was performed using SPSS 11 for Windows (SPSS Inc., Chicago, IL, USA). The numerical data were presented as mean ± standard deviation (SD) (i.e. LS canal ratio, LS step, facet joint angle and tropism). The LS canal ratios were not normally distributed. The Friedman test followed by the Wilcoxon signed ranks test was used in order to compare the LS canal ratio. The Kruskal-Wallis H test was used followed by the Mann-Whitney U test in order to compare the facet joint angles and tropism at the LS junction. Correlation between facet joint tropism and disc degeneration was tested by the Fisher's exact test. A *P* value for multiple comparisons was corrected for Wilcoxon signed ranks test and Mann-Whitney U test. The logistic regression model was used to test the correlation between outcome after surgery and the following parameters: type of clinical signs (i.e. pelvic limb lameness, LS pain, atrophy of the thigh muscles of the pelvic limbs and urinary incontinence), the duration of clinical signs before surgery, the imaging findings (i.e. LS step, LS canal ratio, degree of disc protrusion and spinal nerve root swelling), and the type of surgical decompressive procedure. A *P* value < 0.05 was considered significant.

Table 1 History, clinical signs, and results of clinical examinations in 156 dogs with DLS.

History / Clinical signs	N (%)
Pelvic limb lameness	92/156 (59.0)
Pelvic limb weakness	54/156 (34.6)
Abnormal gait of pelvic limb	75/156 (48.1)
Caudal lumbar pain	65/156 (41.7)
Hypersensitive caudal lumbar spine	24/156 (15.4)
Difficulty sitting down	36/156 (23.1)
Reluctance in getting up	79/156 (50.6)
Difficulty climbing stairs	46/156 (29.5)
Difficulty jumping	83/156 (53.2)
Urinary incontinence	9/156 (5.8)
Pain during urination	8/156 (5.1)
Faecal incontinence	2/156 (1.3)
Pain during defecation	20/156 (12.8)
Results of clinical examination	
Pelvic limb lameness	64/156 (41.0)
Posterior paresis	37/156 (23.7)
Pain evoked by lumbosacral pressure	104/156 (66.7)
Pain on hyperextension of the caudal lumbar spine	107/156 (68.6)
Pain on hip joint extension	65/156 (41.7)
Pain on tail extension	5/156 (3.2)
Atrophy of the thigh muscles of the pelvic limbs	48/156 (30.8)

Table 2 Imaging findings on conventional and contrast radiography in dogs with DLS.

Radiography (n = 132)	N (%)
Normal radiographic findings	14/132 (10.6)
Abnormal radiographic findings	118/132 (89.4)
Step formation L7-S1	93/118 (78.8)
Downward elongation of the sacral lamina	25/118 (21.2)
Spondylosis at L7-S1	
• Slight	23/118 (19.5)
• Moderate	20/118 (16.9)
• Severe, bridging	16/118 (13.6)
• Severe, non-bridging	20/118 (16.9)
Narrowed intervertebral disc space	22/118 (18.6)
End plate sclerosis	21/118 (17.8)
Transitional vertebral segment	13/118 (11.0)
Vacuum phenomenon	15/118 (12.7)
Osteochondrosis	1/118 (0.8)
Myelography (n = 12)	
Compression on cauda equina	
• No compression	3/12 (25.0)
• Compression	9/12 (75.0)
Epidurography (n = 55)	
Compression on cauda equina	
• No compression	1/55 (1.8)
• Slight compression	26/55 (47.3)
• Moderate compression	19/55 (34.5)
• Severe compression	9/55 (16.4)
Discography (n = 29)	
Normal disc	4/29 (13.8)
Ruptured disc	25/29 (86.2)

Results

Signalment, history, and clinical findings

There were 99 (63.5%) male dogs (65 intact, 34 neutered) and 57 (36.5%) female dogs (26 intact, 31 neutered), (male: female ratio 1.7:1) with a mean (± SD) age of 5.8 ± 2.5 years, and a mean (± SD) body weight of 34.2 ± 10.8 kg. Mean body weight of male dogs was higher than that in female dogs for the GSD, Golden Retriever, Bouvier des Flandres, Rottweiler, Bernese Mountain Dog, Great Dane, and Border Collie. The type of dogs included companion animals (138/156, 88.5%), aid dogs (8/156, 5.1%), and working dogs (10/156, 6.4%). The GSD was the most commonly (40/156, 25.6%) affected breed, followed by other Shepherd breeds (12/156, 7.7%), Labrador Retriever (11/156, 7.1%), Golden Retriever (11/156, 7.1%), Bouvier des Flandres (9/156, 5.8%), Rottweiler (5/156, 3.2%), Bernese Mountain Dog (5/156, 3.2%), Great Dane (4/156, 2.6%), and Border Collie (4/156, 2.6%).

The most common clinical sign of the dogs with DLS was pelvic limb lameness (unilateral or bilateral), including weakness, stiffness, and narrowed gait. The owners frequently noticed reluctance with jumping into the car, getting up or climbing stairs, and difficulty with assuming a sitting position. The duration of clinical signs before referral ranged from five days to three years (median: 9.5 months). On clinical orthopaedic examination, the dogs most often revealed signs of caudal lumbar pain (107/156, 68.6%), pain evoked by LS pressure (104/156, 66.7%), and pain on hip joint extension (65/156, 41.7%) (Table 1). Neurological clinical signs were less frequent than orthopaedic clinical signs. The most consistent neurological signs were atrophy of the thigh muscles of the pelvic limbs (48/156, 30.8%), posterior paresis (37/156, 23.7%), and urinary (9/156, 5.8%) and faecal (2/156, 1.3%) incontinence.

Imaging findings

Radiographs were available for analysis in 132 dogs. Radiographic abnormalities were seen in 89.4% (118/132) of the dogs (Table 2), of which 29.7% (35/118) were GSD. The LS step was seen in 78.8% (93/118) of the dogs. Telescoping of the cranial spinal canal of the sacrum relative to the caudal spinal canal of L7 was present in 21.2% (25/118) of the dogs of which 52.0% (13/25) were GSD. In 22 dogs (22/118, 18.6%) a LS step and telescoping of the cranial spinal canal of the sacrum relative to the caudal spinal canal of L7 were found (Table 3) and 12 of these affected dogs (54.5%) were GSD. Spondylosis deformans was seen in 66.9% (79/118) of the dogs and a narrowed intervertebral LS disc space was seen in 18.6% (22/118) of the dogs. End plate sclerosis was seen in 17.8% (21/118) of the dogs (Fig. 3), of which 19.0% (4/21) was associated with disc degeneration. The mean age of dogs with end plate sclerosis (male: 6.4 ± 2.6 years, female: 6.5 ± 2.2 years) was higher than that in those dogs without end plate sclerosis (male: 5.8 ± 2.3 years, female: 5.2 ± 2.5 years). Thirteen dogs (four GSD, one Belgian Shepherd Dog and eight dogs of other breeds) had TVS at the LS junction (five symmetrical and eight asymmetrical). Cauda equina compression was diagnosed in nine of 12 dogs (75.0%) in which myelography was performed, and in 54 of 55 dogs (98.2%) in which epidurography was performed (Fig. 4). Cauda equina compression was pronounced with the LS spine in extension and relieved with the LS spine in flexion.

CT was performed in 115 dogs and MRI in 34 dogs, including 32 dogs that had both CT and MRI. Disc protrusion was detected by CT (106/115, 92.2%) and MRI (34/34, 100%) and was central or lateralized (Table 4, Figs. 5 and 6). The vacuum phenomenon was detected on CT images (42/115, 36.5%), but was not detectable on MR images. Loss of the bright signal of the nucleus pulposus at L7-S1 on T2-weighted MR images was seen in 73.5% (25/34) of the dogs (Fig. 7).

The mean measurement of the LS step was 2.85 ± 0.97 mm on radiography, 2.12 ± 0.84 mm on CT, and 2.45 ± 0.75 mm on MRI. The LS canal ratio measured on radiographs (0.69 ± 0.12) was significantly lower than that on CT (0.73 ± 0.11) and MRI (0.89 ± 0.10) (P< 0.016). The mean facet joint angle in GSD was significantly smaller than that of other Shepherd breeds and that of dogs of other breeds (Table 5). Facet joint tropism at L7-S1 in GSD was significantly greater than that of the other breeds (P<0.016). There was not any significant correlation between the presence of tropism and disc degeneration.

Table 3 Telescoping of the sacrum relative to L7 and lumbosacral step on radiographs in dogs with DLS (n=118).

Telescoping of the sacrum relative to L7	Lumbosacral step (%)	
	+	–
+	22 (18.6)	3 (2.5)
–	71 (60.2)	22 (18.6)

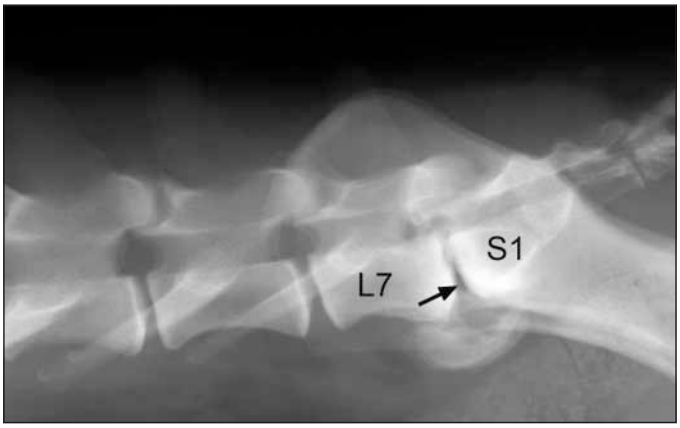

Fig. 3 Lateral radiograph of the lumbosacral region of a dog showing a LS step (sacrum subluxated ventral to L7), telescoping of the sacrum relative to L7, extensive spondylosis deformans, a narrowed intervertebral disc and the vacuum phenomenon indicating accumulation of nitrogen gas in a ruptured disc (arrow).

Fig. 4 Lateral radiograph of the lumbosacral region of a dog. The epidurogram shows a bulging disc and there is a positive discogram (arrow).

Surgical findings

Dorsal laminectomy was performed in all 156 dogs and extended from L7 to S1 in 85.9% (134/156), from L6 to L7 in 4.5% (7/156), and from L6 to S1 in 9.6% (15/156) because of concomitant cauda equina compression at L6-L7 and L7-S1 (Table 6). Dorsal fenestration was performed in 50.0% (78/156), which included partial discectomy and nucleus pulpectomy in 35.3% (55/156) of the dogs in order to further relieve compression. In addition to dorsal laminectomy, facetectomy was performed in 6.4% (10/156) and foraminotomy was performed in 5.1% (8/156) of the dogs to further relieve lateralized cauda equina root compression. Disc protrusion (HNP type II) was found in 70.5% (110/156) of the dogs. Adhesions between cauda equina and disc material and/or fat tissue were recorded in 11.5% (18/156) of the dogs.

During surgery, disc material was collected in 33.3% (52/156) of the dogs for microbiological examination. Bacterial culture was positive in 23.1% (12/52) with *Bacillus* spp. (4/12, 33.3%), and *Staphylococcus intermedius* (3/12, 25.0%) as the most common bacteria. There were not any unique features to the subset of patients with a positive bacterial culture of disc material. Histopathological examination was conducted in 35.9% (56/156) of the dogs. Specimens that were examined included: the ligamentum flavum (22/56, 39.3%), disc material (8/56, 14.3%), and other tissues (26/56, 46.4%) such as epidural fat, affected neural tissue, or bone fragments. The results showed inflammation and degenerative changes in 50.0% (28/56) of the dogs.

Table 4
Imaging findings on CT (n=115) and MRI (n=34) in dogs with DLS

Parameters	CT N (%)	MRI N (%)
Step formation at L7-S1	69/115 (60.0)	18/34 (52.9)
Degree of spondylosis at L7-S1		
• No	44/115 (38.3)	18/34 (52.9)
• Slight	15/115 (13.0)	4/34 (11.8)
• Moderate	20/115 (17.4)	4/34 (11.8)
• Severe	36/115 (31.3)	8/34 (23.5)
Symmetrical spondylosis	43/71 (60.6)	10/16 (62.5)
Asymmetrical spondylosis	28/71 (39.4)	6/16 (37.5)
Vacuum phenomenon	42/115 (36.5)	ND
Disc protrusion	106/115 (92.2)	34/34 (100.0)
Degree of disc protrusion		
• Slight	34/106 (32.1)	17/34 (50.0)
• Moderate	48/106 (45.3)	7/34 (20.6)
• Severe	24/106 (22.6)	10/34 (29.4)
Location of disc protrusion		
• Centre	67/106 (63.2)	24/34 (70.6)
• Lateralized Left	19/106 (17.9)	4/34 (11.8)
• Lateralized Right	20/106 (18.9)	6/34 (17.6)
Position of dural sac		
• Centre	51/115 (44.3)	18/34 (53.0)
• Lateralized Left	30/115 (26.1)	8/34 (23.5)
• Lateralized Right	34/115 (29.6)	8/34 (23.5)
Epidural fat dorsal to dural sac		
• Absent or reduced	12/115 (10.4)	7/34 (20.6)
• Normal	101/115 (87.8)	27/34 (79.4)
• Abundant	2/115 (1.7)	0/34 (0)
Swelling of spinal nerve roots	65/115 (56.5)	16/34 (47.1)
• Left	14/65 (21.5)	6/16 (37.5)
• Right	25/65 (38.5)	3/16 (18.8)
• Bilateral	26/65 (40.0)	7/16 (43.8)
NP signal intensity on MRI-T2 at L7-S1	ND	
• Normal		5/34 (14.7)
• Reduced		8/34 (23.5)
• Absent		17/34 (50.0)
• Unknown		4/34 (11.8)

NP: Nucleus pulposus; ND: Not detectable.

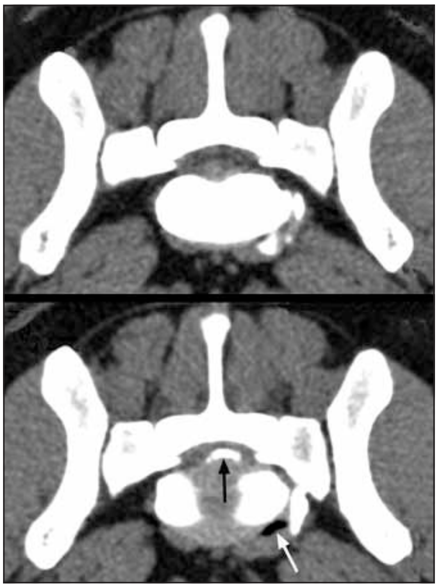

Fig. 5 Transverse images of a CT scan through the lumbosacral intervertebral disc space of a dog. Severe intervertebral disc bulging is evident. There is a suspected calcified disc fragment (black arrow), and the dural sac and nerves are displaced dorsally. There is right sided ventrolateral spondylosis and gas accumulation (vacuum phenomenon; white arrow), indicating disc rupture.

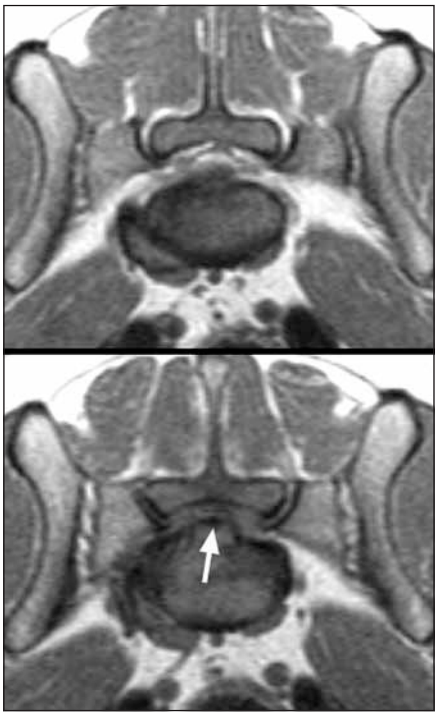

Fig. 6 Transverse T1-weighted magnetic resonance images at the level of the lumbosacral intervertebral disc demonstrating severe disc bulging (arrow), and dorsal displacement of the dural sac and nerve tissue.

Follow-up

Medical records

Follow-up information from the medical records was available in 67.3% (105/156) of the dogs. The follow-up period for these dogs ranged from two months to 3.5 years (median 1.6 years). Overall improvement after surgery was recorded in 79.0% (83/105) of the dogs. With respect to the clinical signs, caudal lumbar pain was relieved in 68.8% (22/32) of dogs; lameness of pelvic limbs improved in 65.2% (30/46); the ability to rise improved in 66.7% of patients (40/60); jumping improved in 68.5% (37/54); walking stairs improved in 69.2% (18/26); toe dragging improved in 66.7% (18/27); atrophy of the thigh muscles of the pelvic limbs improved in 56.8% (21/37); and urinary incontinence improved in 50% (4/8) of the dogs.

In 83 of 105 dogs (79%), an improvement was recorded in the clinical signs, whereas there was a lack of improvement in 22 of 105 dogs (21%). Logistic regression revealed that a dog that was affected by DLS was 1.4 times more likely to not show any improvement after surgery when the age of the dog increased by one year ($P = 0.007$).

Fig. 7 Sagittal magnetic resonance images of the lumbosacral region of a dog with degenerative lumbosacral stenosis. The T1-weighted (top) and T2-weighted (bottom) midsagittal images demonstrate severe disc bulging at L7-S1, attenuation of epidural fat in the T1-weighted image. In the T2-weighted image there is loss of signal intensity of the L7-S1 disc indicating disc degeneration.

The type and duration of clinical signs before referral were not significantly correlated with outcome after surgery.

Dogs with urinary incontinence before surgery were 3.6 times more likely to not have any improvement after surgery, but the result in this study was not significant (P = 0.118). The dogs that underwent dorsal laminectomy and partial discectomy showed significantly less improvement (P = 0.025) than those that underwent dorsal laminectomy alone. With respect to the imaging findings, it was 6.5 times more likely for dogs with severe disc protrusion (P = 0.013), and 1.8 times more likely for dogs with a LS step (P = 0.012) to not have any improvement after surgery.

Questionnaires

Thirty-eight owners responded to the questionnaires with a complete list of responses. The follow-up period ranged from three months to five years (median: 2.1 years). Of the 38 owners that responded, 29 (76%) perceived an improvement: 27/38 (71%) of owners were very satisfied, 2/38 (5%) of owners were moderately satisfied, whereas 9/38 (24%) of owners were dissatisfied with the result of surgery. With respect to the clinical signs, caudal lumbar pain improved in 69% (22/32) of the dogs; lameness of pelvic limbs improved in 67% (18/27); the ability to rise improved in 65% (20/31); jumping improved in 61% (20/33); walking stairs improved in 57% (13/23); assuming a sitting position improved in 57% (12/21); tail movements improved in 57% (8/14); stiffness improved in 50% (15/30); toe dragging improved in 50% (10/20); tail tone improved in 50% (7/14); and urinary incontinence improved in 38% (3/8).

Discussion

As is common with most retrospective studies, our study was hampered by several limitations. A surgical group was examined and the study lacked a comparison with a matched non-surgical group. It remains unknown how many dogs would have improved with medical management. Also, many large-breed dogs without any clinical signs of low back pain show LS abnormalities on radiographs, myelograms, CT and MRI. The study could have been improved by comparing imaging findings of the LS region of sub clinical large-breed dogs with the findings reported and analyzed in the present study. As in most retrospective studies there was missing information in the medical records, for example, information was incomplete in some of the surgical reports. The quality of the information contained in the medical records is another point of concern. Especially in the older reports, the follow-up information could be verified and had been entered by different persons, including final year veterinary students, interns, residents and staff. Although informative, owner questionnaires are of limited scientific value. The response group was small and some of the questions may have been too dif-

Table 5 Facet joint angles and tropism (degrees) at L7-S1 measured at transverse CT images

L7-S1 joint	GSD (n=16)	Dogs of other Shepherd breeds (n=7)	Dogs of other breeds (n=17)
Facet joint angle	31.2 ± 5.0 *	37.6 ± 4.8	38.0 ± 5.1
Facet joint tropism	3.4 ± 1.7 *	1.9 ± 0.4	1.6 ± 0.9

* Significantly (P<0.016) different from angle/tropism in dogs of other Shepherd breeds and other breeds. GSD = German Shepherd Dog.

Table 6 Surgical procedure and findings in 156 dogs with DLS.

Surgical procedure	N (%)
Dorsal laminectomy	
L7-S1/2	131/156 (84.0)
L6-S1/2	15/156 (9.6)
L6-L7	7/156 (4.5)
L7/8-S1	3/156 (1.9)
Dorsal fenestration	78/156 (50.0)
Partial discectomy	55/156 (35.3)
Facetectomy	10/156 (6.4)
Foraminotomy	8/156 (5.1)
Surgical findings	
Disc protrusion	110/156 (70.5)
Degree of disc protrusion	
• Slight	8/110 (7.3)
• Moderate	35/110 (31.8)
• Severe	23/110 (20.9)
• Unknown	44/110 (40.0)
Location of disc protrusion	
• Centre	16/110 (14.5)
• Lateralized Left	11/110 (10.0)
• Lateralized Right	15/110 (13.6)
• Unknown	68/110 (61.8)
Position of dural sac	
• Centre	10/156 (6.4)
• Lateralized Left	3/156 (1.9)
• Lateralized Right	2/156 (1.3)
• Unknown	141/156 (90.4)
Epidural fat dorsal to dural sac	
• Not present or reduced	23/156 (14.7)
• Normal	28/156 (17.9)
• Abundant	2/156 (1.3)
• Unknown	103/156 (66.0)
Swelling of spinal nerve roots	
• Left	5/156 (3.2)
• Right	6/156 (3.8)
• Bilateral	24/156 (15.4)
• Unknown	121/156 (77.6)
Hypertrophy of ligamentum flavum	17/156 (10.9)

ficult for some owners to answer and it can be questioned whether owners can make an adequate assessment of improvement in caudal lumbar pain or pelvic limb lameness. Owner's responses can be biased following surgery that they paid for, hoping that the surgical treatment would help their dog. Ideally, the effect of a surgical procedure should be examined in a prospective study, in which patients are randomly assigned to a surgical group and a matched placebo group or medical treatment group. The readout parameters must be objective, e.g. by assessing locomotion with measurements of ground reaction forces using force plate analysis. However, in spite of all of the aforementioned limitations of a retrospective study, the present study revealed valuable information because of the large patient group and the long time span that gave insight in the evolution of the diagnostic tools that are used for dogs suffering from degenerative lumbosacral stenosis.

The signalment of the patients with DLS in this study is in accordance with previous reports (2, 6, 21). DLS commonly affects medium sized to large breed dogs, at a mean age of six to seven years (21), and occurs more often in male dogs (2, 6, 22). Male predisposition (1.7:1) with a higher mean body weight for male dogs than for female dogs with DLS, suggests that biomechanical loading plays a role in the pathogenesis. Other factors must also play a role since there was an absence of overrepresentation of giant breeds. Also, there is not any difference between males and females in the mobility of the lumbar portions, including the LS region (23, 24). The predisposition of the GSD for DLS in our study is in accordance with previous reports (1, 2, 6). However, the apparent predisposition of the GSD for DLS found in this study may be biased since the GSD is the second most popular breed in the Netherlands (2005 data National Kennel Club) and the fourth most common dog breed in the general hospital statistics at the Utrecht University Small Animal Clinic. The LS angles, range of motion, facet joint orientation and motion pattern have been analyzed as possible causes of DLS in GSD (23–25). In our study, angles of the facet joint at L7-S1 were more sagittally oriented in GSD than in other breeds, which is in accordance with other studies (23, 25, 26). More sagittal orientation of facet joints may affect the motion pattern (i.e. flexion and extension, axial rotation) of the LS junction. According to Benninger the high prevalence of facet joint tropism in GSD may lead to DLS (23). However, a significant correlation was not found in our study between facet joint tropism and disc degeneration, which is in accordance with previous reports (25–27).

The clinical signs of dogs that are affected by DLS may show considerable variation related to the severity of compression of the cauda equina. The most common clinical signs are pelvic limbs lameness, abnormal gait, and caudal lumbar pain. Dogs that are affected with DLS may not show all clinical signs at the same time, but caudal lumbar pain is usually predominant (2, 6, 22). In our study, many dogs showed difficulty and a reluctance to get up and to jump. The dogs appeared to have more problems with extension of the caudal lumbar spine than with flexion. This can be explained by the increase in cauda equina compression that occurs when the caudal lumbar spine is extended. During clinical examination, exerting pressure over the LS region, hyperextension of the caudal lumbar spine and hip joint extension also evoked signs suggesting pain and discomfort in dogs with DLS.

Conventional radiography revealed LS step formation in the majority of dogs in our study (93/118, 78.8%). This step is considered to be a sign of LS instability, although the size of the LS step does not always correlate with the clinical signs (3, 6, 7). In our study, the LS step measured a mean of 2.9 mm on conventional radiographs. The LS step was reported previously only to be clinically relevant when greater than 4 mm (24).

In our study, telescoping of the sacral spinal canal in the spinal canal of L7 was observed frequently in GSD with DLS (13/25, 52.0%). Telescoping of the sacral spinal canal in the spinal canal of L7 contributes to cauda equina compression, especially when disc protrusion and a LS step are present, as is evident from the findings of this study.

In 19.0% (4/21) of the dogs, end plate sclerosis was associated with disc degeneration in our study. The association between end plate sclerosis and disc degeneration was also raised by Gruber et al. (28). Although it will take some time before end plate sclerosis becomes evident on radiographs, a significant difference was not found between the age of our dogs with or without end plate sclerosis on radiographs.

TVS was found in 11.0% (13/118) of the dogs. It has been reported that TVS may be hereditary in GSD (29). Both asymmetrical and symmetrical TVS (with bilateral, lumbar-like lateral processes) results in a weakening of the sacroiliac attachment and may contribute to premature disc degeneration (30). TVS may play a role in the development of LS instability and cauda equina compression (7, 8, 29).

The vacuum phenomenon has been associated with degenerative disc disease (31, 32) and is caused by central accumulation of nitrogen gas in a ruptured disc with an intact outer ring of annulus fibrosus. The vacuum phenomenon was observed in 12.7% (15/118) of the dogs on conventional radiography, and in 36.5% (42/115) of the dogs on CT images, but in none of the MR images for 34 dogs. This can be explained by the fact that the contrast between gas and bone is much higher on radiographs and CT images than on MR images. In our study, compression in the LS region was seen on myelography in nine of 12 cases. Myelography allows visualization of the entire spinal cord, but not the cauda equina or compressive lesions at L7-S1 that involve the intervertebral foramen or lateral recesses (8). The site of dural sac termination is variable (8). However, more than 80% of dogs have a dural sac extending well into the sacrum and extension of the LS spine helps to visualize a compressive lesion (33). Epidurography in dogs with DLS revealed elevation and/or obstruction of the contrast medium on lateral views only, especially with the LS spine in extension. Epidurography has been used for the evaluation of neural compression at the LS junction (9, 34, 35). However, the interpretation is difficult when epidural filling with contrast medium is poor (8). Discography was reliable for diagnosing LS disc degeneration, which is in accordance with other studies (34, 36). Based on experiences with the extension and flexion views in the myelographic and epidurographic studies, CT and MRI of dogs with DLS scans were preferably performed with the LS spine in extension in order to improve the visualization of the compressive lesion.

The degree and extension of the disc protrusion was adequately visualized on CT and MRI in our study. There was strong agreement between CT and MRI findings with regard to disc protrusion, position of the dural sac, and distribution of epidural fat. The bright signal on T2-weighted MR images is correlated with hydration of the nucleus pulposus (37). Reduced bright signal on T2 implicated disc degeneration. In other studies, CT and MRI were preferred over conventional radiography for diagnosis of DLS (37–39). A previous study has reported that another abnormality on CT is replacement of epidural fat with soft tissue density representing epidural fibrosis. However, loss of epidural fat (on CT) may not be a significant finding of DLS in older animals, but there are not any studies available that document the loss of epidural fat content with progressing age (40).

The mean LS canal ratio in our study measured on radiographs, CT and MRI was greater than 0.5 in all cases. Morgan and others (7, 21) report that a ratio of 0.5 or less is noted as a primary canal stenosis (i.e. due to the LS joint instability) and contributes to cauda equina compression. This study showed that in dogs with DLS, a LS canal ratio that was greater than 0.5 may cause clinically relevant spinal canal stenosis especially when combined with disc protrusion.

Dorsal laminectomy was performed in order to relieve compression. Dorsal fenestration, partial discectomy, and nucleus pulpectomy were performed in cases of moderate to severe protrusion of a degenerated disc (10, 11). During surgery, disc protrusion was less frequently observed than on CT and MRI. This is probably due to differences in positioning during imaging and surgery. Disc protrusion is more pronounced during imaging since the caudal lumbar spine is in extension during imaging, whereas the caudal lumbar spine is in a neutral position during surgery.

Bacterial cultures from intervertebral disc space swabs after partial discectomy returned positive in 12 of 52 (23%) dogs with DLS, revealing undetected discospondylitis in accordance with other studies (41, 42). Some of the bacteria cultured may have been the result of contamination of the swab (e.g. *Bacillus*), whereas other are pathogenic (e.g., *S. intermedius*). In case pathogenic bacteria are cultured from disc material removed during discectomy, it is recommended to start treatment with appropriate antibiotics to eliminate the pathogens. Without any confirmed evidence of discospondylitis, the extended use of antibiotics is not justified.

In the present study, an overall success rate of 79% was recorded after decompressive surgery in dogs with DLS, which is in accordance with other studies that reported a success rate of 70 to 93% (22, 43–45). These studies reported a median follow-up period after decompressive surgery of six months (44), 18 months (43) and 36 months (45), respectively. Evaluation was done subjectively by the surgeon or by (telephone) interview or questionnaire of the owner, similar to our study. Urinary incontinence is an infrequent finding in dogs with DLS, but may be present if sacral nerve function is impaired. In our study, the dogs with urinary incontinence showed less improvement after decompressive surgery, which is in accordance with findings in other studies (5, 45). The aim of decompressive surgery is to relieve the cauda equina compression. In this retrospective study, the outcome after more extensive surgery, such as dorsal laminectomy combined with partial discectomy, was poorer than the outcome after dorsal laminectomy alone. This may be related to the initial severe degree of disc degeneration and protrusion, or due to further accelerated degeneration of the lumbosacral junction with increasing spinal instability. In our study, imaging criteria such as the LS step and the degree of disc protrusion were found to be predictors of the outcome after decompressive surgery for DLS. Future prospective studies on the evaluation of the surgical outcome in dogs with DLS should focus on a more objective analysis of the gait of the dogs before and after decompressive surgery, for example by measurement of ground reaction forces through force plate analysis.

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