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Predispositions to Degenerative Lumbosacral Stenosis in Dogs: An Investigation of Breed, Gender and Age Factors

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ABSTRACT

The study was focused in degenerative lumbosacral stenosis (DLSS) in dogs, a condition clinically evident by lower back pain and other neurological issues due to narrowing of the spinal canal. This research was aimed to identify predispositions to DLSS in dogs of different breeds, gender and age. The study included 194 dogs subjected to clinical, neurological, and radiographic evaluations to diagnose DLSS with particular focus on their size, age, and gender differences in the occurrence of DLSS. The findings reveal a significantly higher prevalence of DLSS in large breeds ($p=0.0008$), specifically German Shepherd, with a significant predominance in male dogs ($p=0.0228$). Age-wise, the condition was most common in dogs aged 7-10 years, with no cases detected in dogs under 3 years of age. The results underscore a significant breed and gender disparity in DLSS occurrence, with large dog breeds and males being more susceptible. Conclusively, the study highlights the need for breed-specific health strategies and emphasizes the importance of early diagnosis, especially in predisposed breeds like German Shepherd. This research offers valuable insights for veterinarians, breeders, and dog owners in managing DLSS in susceptible dog populations.

Key words: Degenerative lumbosacral stenosis; Low back pain; Gender predisposition; Breed predisposition

INTRODUCTION

Degenerative lumbosacral stenosis (DLSS) in dogs represents a condition characterized by lower back discomfort encompassing different degrees of neurological dysfunction. It is identified as a syndrome arising from an acquired narrowing of the vertebral canal, intervertebral foramina, or both (Gomes 2022). This morphological issue can pose a risk factor for disability, arising from the compression of underlying neural and/or vascular tissues leading to compressive radiculopathy of cauda equina (Worth et al. 2019). As the elastic and fibrous annulus fibrosus weakens and the central gelatinous nucleus pulposus undergoes dehydration, it results in the development of a protrusion (known as Hansen type II disc protrusion) of the annulus fibrosus in the L7-S1 intervertebral disc, along with a reduction in the space between the vertebrae. This can lead to compression of one or more nerve roots in the cauda equina due to pathological changes of disc and surrounding tissue linked to the L7-S1 articulation (Worth et al. 2019). The proliferation of surrounding soft tissues increases the pressure on spinal canal, resulting in neuropathic pain and further changes in biomechanics. A persistent cycle of pain and neurological dysfunction arises due to nerve root compression and impaired blood supply (Henderson et al. 2015). However, the term 'cauda equina syndrome' does not equate to DLSS. Instead, it represents a syndrome resulting from a primary lesion in the cauda equina or from secondary ailments impacting the L5-L7, sacral, or caudal vertebrae, along with adjacent soft tissue. DLSS stands as one among various potential differential diagnoses for this condition (Worth et al. 2019). Pathological processes in the caudal lumbar region of the spine are quite common in dogs. Spinal pain is frequently a consistent clinical indicator of diseases affecting the lumbosacral and caudo-lumbar spine. Since lameness is often the only clinical sign, these processes might be wrongly presented as being associated

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with musculoskeletal disorders. DLSS syndrome lacks pathognomonic clinical characteristics, which makes it challenging to diagnose without proper diagnostic imaging technique (Reints et al. 2020).

As previously described, DLSS is most prevalent in medium to large males, with a recognized breed predisposition found notably among German Shepherd dogs (GSDs), based on the particular morphology of the articular facets (Worth et al. 2019). The orientation and asymmetry of facet joints in the GSD impact the biomechanics of the lumbosacral joint, potentially leading to heightened strain during specific activity levels and contributing to disc degeneration within this breed (Henderson et al. 2015; Schaub et al. 2021). Moreover, highly active or working dogs seem to exhibit a higher susceptibility to DLSS (Steffen et al. 2007; Henderson et al. 2015). Additionally, it has been suggested that specific breeds like the GSD are prone to early intervertebral disc degeneration and DLSS due to an abnormal movement pattern at the lumbosacral junction (Schaub et al. 2021). Despite numerous studies, the precise cause of DLSS and the factors contributing to the predisposition of the GSD to this condition remain uncertain.

Some studies suggest that the intensity of physical activity may play a crucial role in the disorder's pathophysiology, potentially rivaling the significance of the dog's breed (Steffen et al. 2007). In some institutions that employ working dogs, the Belgian Malinois has replaced the German Shepherd. Intriguingly, this breed was found to be as frequently affected by DLSS as the German Shepherd in a comprehensive pathological survey (Steffen 2009).

The aim of this study was to understand the diversity of breed and gender distribution in DLSS cases so it could identify populations at increased risk of developing DLSS. Additionally, it could contribute to development of preventive measures and improvement of diagnostic and therapeutic approaches for DLSS.

MATERIALS AND METHODS

The study was conducted over a two-year period and involved 194 dogs showing clinical signs of the DLSS syndrome. DLSS was suspected based on the patients' medical history and comprehensive clinical evaluations involving general, orthopedic, neurological, and radiologic examinations to exclude conditions that might affect their gait or spinal movement. The clinical history and physical examination revealed pelvic limb lameness, disorders of continence and tail motion and discomfort.

Animals

A total of 194 dogs, comprising 109 males and 85 females, underwent examination. Based on size, the dogs were divided into two groups: large and small breeds (Breit 2002). The representatives of small-breed dogs were Dachshund, Pekingese, Yorkshire Terrier, Cocker Spaniel, Schnauzer, Maltese, Poodle, Shih Tzu, and Beagle, whereas the large-breed dogs encompassed German Shepherd, Dalmatian, Belgian Shepherd, Doberman Pinscher, Labrador Retriever, Irish Setter, Boxer, and mixed breed dogs. According to their age, the dogs were categorized into four age groups: from 1 to 2 years, from 3 to 6 years, from 7 to 10 years, and over 10 years old.

The radiologic diagnostic examinations included plain and contrast radiography (myelography) of the lumbar and lumbosacral parts of the spine. Depending on the success of these imaging techniques, and to establish a diagnosis as necessary and with the owner's consent, computerized tomography (CT) scans of the spine were performed. These CT scans were conducted with or without the application of myelographic technique, involving multiplanar (MPR) and 3D reconstructions.

Diagnostic imaging of the lumbosacral junction was conducted while the patients were under general anesthesia. All dogs were sedated using medetomidine (5 to 10µg/kg, IV) and propofol until the desired effect was achieved. At the conclusion of the radiographic evaluation, atipamezole (5 to 10µg/kg, IV) was administered to counteract the effects of medetomidine.

Myelography was administered either via atlanto-occipital or lumbar injections (at L4-L5 or L5-L6 levels). Iohexol (Omnipaque 200 or 240mg/mL; Nycomed, Oslo, Norway) served as the contrast agent for all the studies.

Imaging involved two radiographic views, centered on the lumbosacral junction, whereas one was obtained while the dog was in lateral recumbency, positioning the femurs perpendicular to the vertebral column; and the second with the dog in dorsal recumbency, with the stifle joints abducted, and the X-ray beam angled cranially by 7 to 10° to align it parallel to the lumbosacral endplates. Three radiologists evaluated the radiographs. Radiographic manifestations of degenerative lumbosacral stenosis, ascertained through native imaging, encompassed intervertebral space narrowing or collapse, vertebral surface sclerosis adjacent to the intervertebral disc, elongation of the sacral lamina into the caudal aperture of the L7 vertebra, lumbosacral "step" formation with ventral subluxation of S1, and ventral spondylosis. The three examiners, unaware of each other's results, assessed each research participant using the standardized criterion examination along with supplementary clinical tests. If examiners encountered any diagnostic discrepancies, the images were re-evaluated together and mutually discussed until reaching a final consensus diagnosis.

Data analysis

The Chi-square test for the comparison of two proportions from independent samples (N-1 Chi-square test), as recommended by Campbell (2007) and Richardson (2011) was used to statistically test the differences in the proportional involvement of all the dogs diagnosed with DLSS with regard to their age, gender, and size. The level of statistical significance was 5% (α=0.05), and the tested differences were considered statistically significant if $P<0.05$. Statistical analyses were performed using the MedCalc® Statistical Software version 22.019 (MedCalc Software Ltd, Ostend, Belgium).

RESULTS

The study involved 194 dogs, comprising 109 males and 85 females of 17 different breeds (Table 1). Moreover, examined dogs differ according to age, involving dogs aged from 1 to 14 years. Out of the 194 examined dogs, DLSS was diagnosed in 30 (15.46%) cases. The series of images presented in the text encapsulate diverse pathological

Table 1: Breed and gender distribution of dogs examined for musculoskeletal disorders or neurological episodes (n=194)

Dog Breed	Male		Female		Total	
	n	%	n	%	n	%
Mix breed	19	9.79	20	10.31	39	20.10
Dachshund	6	3.09	4	2.06	10	5.15
Pekingese	5	2.58	8	4.12	13	6.70
Beagle	1	0.52	0	0.00	1	1.52
Maltese	5	2.58	5	2.58	10	5.15
Standard Poodle	11	5.67	5	2.58	16	8.25
German Shepherd	17	8.76	15	7.73	32	16.49
Dalmatian	2	1.03	3	1.55	5	2.58
Yorkshire Terrier	4	2.06	1	0.52	5	2.58
Shih Tzu	2	1.03	0	0.00	2	1.03
Belgian Shepherd	2	1.03	3	1.55	5	2.58
Doberman Pinscher	12	6.19	0	0.00	12	6.19
Cocker Spaniel	6	3.09	4	2.06	10	5.15
Schnauzer	2	1.03	2	1.03	4	2.06
Labrador Retriever	10	5.15	12	6.19	22	11.34
Irish Setter	1	0.52	2	1.03	3	1.55
Boxer	4	2.06	1	0.52	5	2.58
TOTAL	109	56.19	85	43.81	194	100.00

Diagnostic imaging.

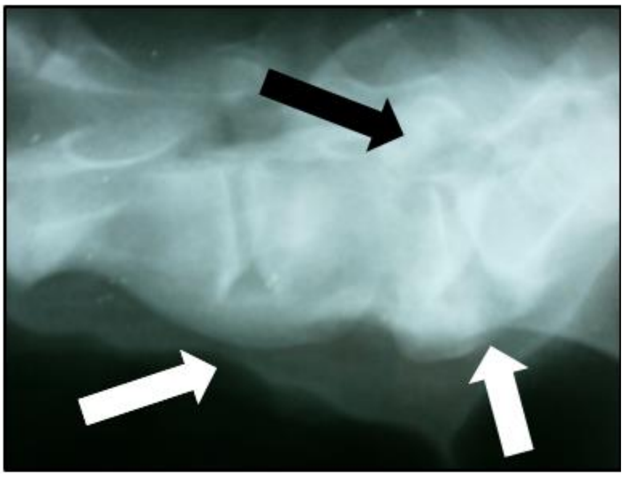

Fig. 1: In the profile projection of the lumbosacral spine, collapse of the intervertebral space, sclerosis of vertebral surfaces, lumbosacral "step" formation with ventral subluxation of S1 (black arrow), and ventral spondylosis (white arrow) are observed. Additionally, ventral ankylosing spondylosis at L5 and L6 (white arrow) is also noted.

conditions affecting the lumbosacral spine region of dogs (Figs. 1-8). Diagnostic imaging analyses of canine lumbosacral vertebrae revealed several degenerative conditions. Fig. 1-8 depict a collapsed intervertebral space, sclerosis, and an abnormal lumbosacral step with subluxation at S1. Ankylosing spondylosis at L5 and L6, bilateral foramina stenosis, and extensive ventral bone growth were noted. Disc degeneration with dorsal protrusion was evident, causing vertebral canal narrowing and bilateral spinal cord compression at the L7-S1 level. These findings collectively elucidate the complex interplay of degenerative and proliferative pathologies compromising the canine vertebral health. The results showed that 63.33% of the dogs with DLSS were between ages of seven to 10 years, while the disease was not diagnosed in either male or female dogs aged under 3 years (Table 2).

Among all the 30 dogs diagnosed with DLSS, a significantly higher proportion of DLSS cases was observed in dogs aged from 7 to 14 years than in dogs younger than 7 years (Table 3).

Table 2: Breed and age distribution of dogs with DLSS (n=30). There were no diagnosed cases of the disease in dogs younger than 3 years.

Dog Breed	Age					
	3-6 years		7-10 years		> 10 years	
	n	%	n	%	n	%
Large-breed dogs						
Mixed breed	2	6.67	3	10.00	2	6.67
German Shepherd	1	3.33	6	20.00	2	6.67
Dalmatian	0	0.00	2	6.67	0	0.00
Belgian Shepherd	0	0.00	1	3.33	0	0.00
Doberman Pinscher	0	0.00	1	3.33	0	0.00
Labrador Retriever	1	3.33	3	10.00	1	3.33
Boxer	0	0.00	2	6.67	0	0.00
Total	4	13.33	18	60.00	5	16.67
Small-breed dogs						
Standard Poodle	0	0.00	1	3.33	2	6.67
Total	4	13.33	19	63.33	7	23.34

Table 3: Comparison of proportion of dogs diagnosed with DLSS (n=30) with regard to their age (N-1 Chi-square test; α = 0,05).

Age	DLSS-positive (n)	DLSS-positive (%)
7-14 years	26	86.67
< 7 years	4	13.33
Total	30	100.00
	Difference (%)	73.34
	95% Confidence Interval (%)	22.36 - 87.84
	Chi-square test	10.144
	Degrees of Freedom	1
	P-value	0.0014

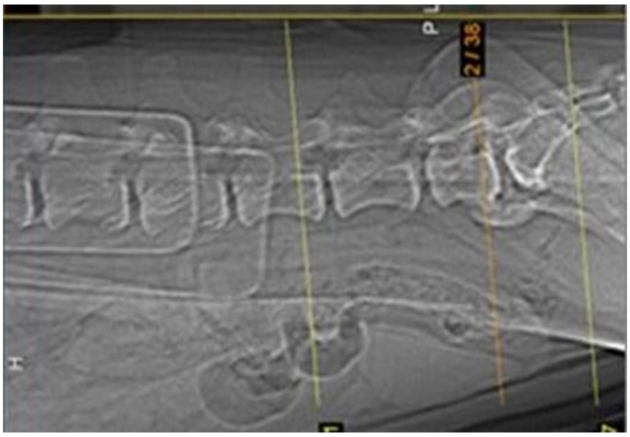

Fig. 2: Topogram of the lumbar and lumbosacral spine of a dog in profile projection. The central cursor is located in the plane of the intervertebral foramina L7-S1.

The distribution of DLSS in males and females of different breeds is displayed in Table 4. The most affected breeds were: German Shepherd (30%, n=9), Mixed breed (23.3%, n=7) and Labrador Retriever (16.67%, n=5). Among all small breeds represented in the study, DLSS was only diagnosed in 3 male Standard Poodles, while all other cases of the disease were identified in dogs of larger breeds.

Comparison of the difference in proportions of DLSS cases among large-breed dogs (mixed-breed, German Shepherd, Dalmatian, Belgian Shepherd, Doberman pinscher, Labrador Retriever, and Boxer) and small-breed dogs (Standard Poodle) in the total of 30 cases of DLSS is presented in Table 5. The observed proportion of DLSS cases in large breed dogs was significantly higher than the proportion in small breeds.

Table 4: Breed and gender distribution of dogs with DLSS.

Dog Breed	Male		Female		Total	
	n	%	n	%	n	%
Large-breed dogs						
Mixed breed	5	16.67	2	6.67	7	23.33
German Shepherd	6	20.00	3	10.00	9	30.00
Dalmatian	1	3.33	1	3.33	2	6.67
Belgian Shepherd	1	3.33	0	0.00	1	3.33
Doberman Pinscher	1	3.33	0	0.00	1	3.33
Labrador Retriever	4	13.33	1	3.33	5	16.67
Boxer	1	3.33	1	3.33	2	6.67
Small-breed dogs						
Standard Poodle	3	10	0	0.00	3	10.00
Total	22	73.33	8	26.67	30	100.00

Table 5: Difference in proportions of dogs of large* and small** breeds diagnosed with DLSS (n=30) (N-1 Chi-square test; α =0.05).

Breed	DLSS-positive(n)	DLSS-positive (%)
Large*	27	90.00
Small**	3	10.00
Total	30	100.00
	Difference (%)	80.00
	95% Confidence Interval (%)	23.26 – 91.49
	Chi-square test value	11.317
	Degrees of Freedom	1
	P-value	0.0008

*Mixed-breed, German Shepherd, Dalmatian, Belgian Shepherd, Doberman, Labrador Retriever, and Boxer; **Standard Poodle

Table 6: Difference in proportions of male and female dogs in diagnosed DLSS cases (n=30) (N-1 Chi-square test; α = 0.05).

Gender	DLSS-positive (n)	DLSS-positive (%)
Male	22	73.33
Female	8	26.67
Total	30	100.00
	Difference (%)	46.66
	95% Confidence Interval (%)	6.88 – 70.01
	Chi-square test value	5.185
	Degrees of Freedom	1
	P-value	0.0228

Fig. 3: On the axial tomogram, a degenerated disc with dorsal protrusion is observed (white arrows). Ventral to the body of the 7th lumbar vertebra, there are abundant bone proliferations (black arrows).

As for the gender involvement in the 30 diagnosed cases of DLSS, proportion of DLSS cases in males was significantly higher compared to the occurrence of this condition in females (Table 6).

DISCUSSION

Results of our study are consistent with previous research by other authors who have reported similar trends in the prevalence of DLSS cases according to breed and gender, indicating a specific breed-dependent predisposition for this condition in dogs (da Costa and Moore 2010).

Pathological changes characteristic for DLSS typically involve narrowing or collapse of the intervertebral space, sclerosis of vertebral surfaces adjacent to the intervertebral disc, pathological proliferation (elongation) of the sacral lamina into the caudal aperture of the L7 vertebra, lumbosacral 'step' formation with ventral subluxation of S1, and ventral spondylosis (Meij and Bergknut 2010; Indrieri et al. 2008; Morgan and Bailey 2000). Our study utilized imaging techniques to identify various pathological conditions affecting the lumbosacral spine region in dogs, as depicted in Figs. 1-8. A physically demanding lifestyle, similar to that followed by human athletes, has previously been linked to premature degeneration of the musculoskeletal system. Degenerative lumbar spinal stenosis stands as a prevalent spinal degenerative ailment (Mukherjee et al. 2017). While some studies have suggested a reluctance to work as a potential clinical sign of DLSS in working dogs (Mukherjee et al. 2017) scientific evidence examining the direct impact of work-related tasks on the pathology of DLSS is lacking. Our study revolves around the notion that although canine DLSS is primarily associated with age-related degenerative changes, the specific physical activity requirements of breeds such as German Shepherds might contribute to the early onset of degenerative conditions like DLSS in dogs (Fig. 1-8).

DLSS was diagnosed in 30 of the 194 (15.46%) examined dogs. Variety of the DLSS cases with regard to their breed and age is shown in Table 2, while the breed and gender diversity of DLSS cases is depicted in Table 4. It is evident that out of the total 30 DLSS cases, DLSS was diagnosed in only 3 male Standard Poodles (10.00%), while all other cases were identified in large-breed dogs (90.00%), representing a statistically highly significant proportional difference (P=0.0008; Table 5). Additionally, out of the total of 30 DLSS cases, the highest proportion was diagnosed in German Shepherds (30.00%), slightly lower in mixed-breed dogs (23.33%), and the lowest in Belgian Shepherds and Dalmatian dogs (one case each, or 3.33%). Furthermore, our results indicate that in the total number of DLSS cases, the proportional representation of affected males (73.33%) was statistically significantly higher (P=0.0228; Table 6) than the proportional representation of females (26.67%).

These findings highlight the proportional dominance of large over small dog breeds, as well as males over females, in the total number of DLSS cases in the investigated dog population. Finally, it is evident that among all the dogs diagnosed with DLSS the highest proportion of the cases was observed in the age group of 7 to 10 years (63.33%), lower in dogs older than 10 years

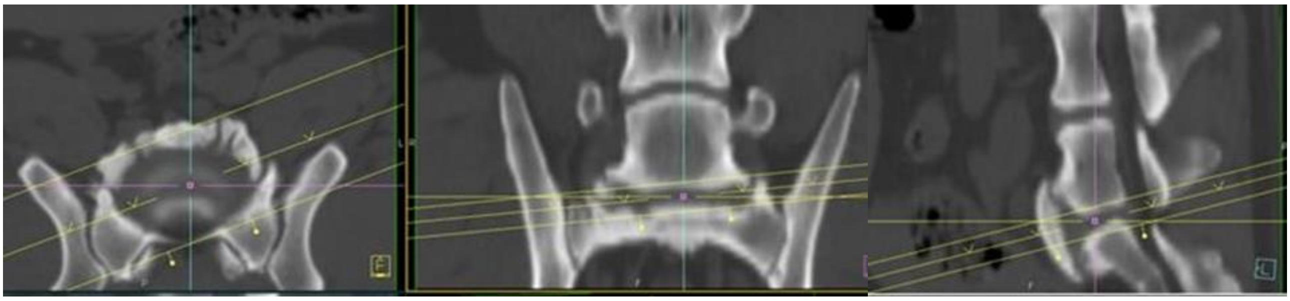

Fig. 4: Multiplanar view of the MIP reconstruction of the lumbosacral junction in a dog. In the transverse projection (left), the protrusion of the degenerated disc is indicated. Dorsally, bone proliferations of the lumbar and sacral vertebrae superimpose with the intervertebral space (middle). In the sagittal projection (right), alongside ankylosing spondylosis, signs of protrusion of the degenerated intervertebral disc L7-S1 are shown.

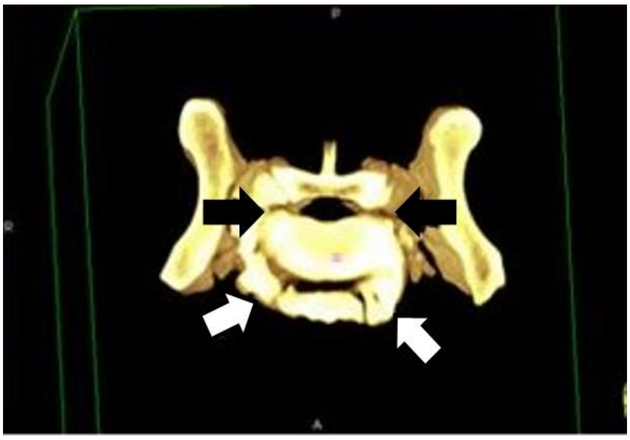

Fig. 5: Transverse VR reconstruction of the lumbosacral junction in a dog. Bilateral stenosis of the intervertebral foramina L7-S1 is clearly visible (black arrows), as well as abundant ventral bone proliferations (white arrows).

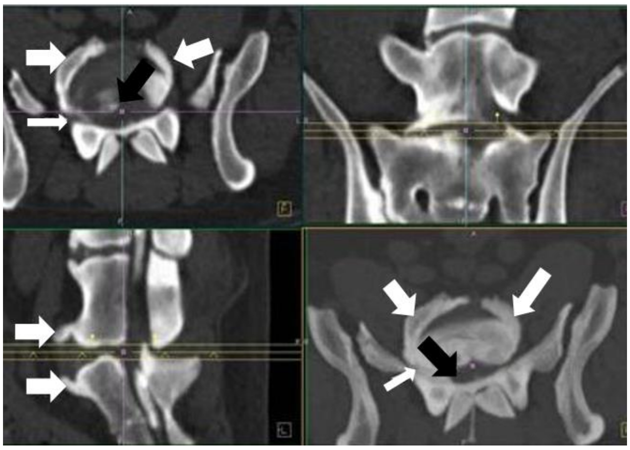

Fig. 6: Multiplanar view of the MIP reconstruction of the lumbosacral segment of the dog's spine. Thicker white arrows indicate severe changes of deformative spondylosis, while black arrows indicate degeneration of the L7-S1 intervertebral disc. In the transverse sections of the intervertebral space with a width of 6 mm (top left and bottom right), dorsal protrusion of the degenerated disc with consequent attenuation of the vertebral canal is highlighted (black arrows). Bilateral attenuation of the intervertebral foramina is also visible (thinner white arrows).

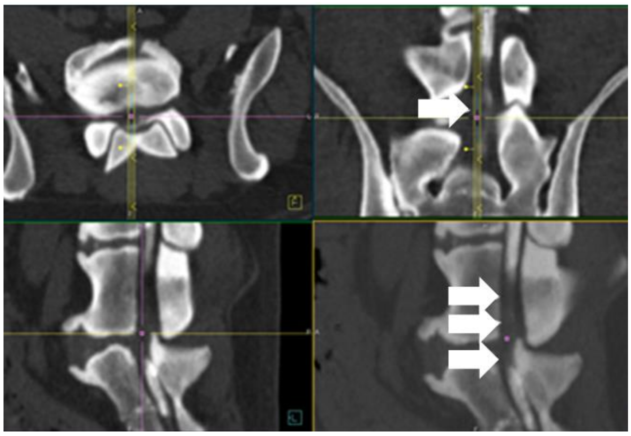

Fig. 7: Multiplanar view in MIP reconstruction of the lumbosacral segment of the dog's spine. In the dorsal projection (top right), sagittal projection (bottom right and left), and transverse projection (top left), compression of the spinal cord is visible extending from the mid-body of the 7th lumbar vertebra to the cranial end of the sacral vertebra (white arrows).

Fig. 8: Dorsal VR reconstruction of the lumbosacral junction in a dog. Bilateral compression of the spinal cord at the level of L7-S1 is further emphasized (thicker arrows). On the left, there is prominent bone proliferation closing the intervertebral foramen (white arrow). On the right, bone proliferation and degenerated disc are highlighted, compressing nerve roots and the spinal cord itself (thinner arrow).

(23.34%) and in dogs aged 3-6 years (13.33%), while DLSS was not diagnosed in any dogs aged 1-2 years (Table 2). When compared, proportional involvement of dogs diagnosed by DLSS in age ranging from 7 to 14 years (86.67%) was significantly higher (P=0.0014) than the observed proportion of the diseased dogs younger than 7 years (13.33%; Table 3).

Our results agree with findings of other authors. The significantly higher proportion of DLSS cases observed in large dog breeds than in small breeds affected by this condition is consistent with other studies where the prevalence of DLSS among large breeds over small breeds has been described (Ondreka et al. 2013; Thitaram 2018; Schaub et al. 2021; Lim and Beasley 2023). Furthermore, the demonstrated dominant proportional representation of DLSS in German Shepherds compared to other large dog breeds is in line with the findings of many other studies (Lampe et al. 2020), explained by this breed's predisposition for developing DLSS (Surer et al. 2020). However, unequivocal evidence regarding the hereditary basis of DLSS in German Shepherds is still lacking (Worth et al. 2019) with an estimated 20-30% of the German Shepherd population having a genetic basis for developing DLSS (Wigger et al. 2009).

Due to the higher prevalence of DLSS determined by our study in German Shepherds, it is possible that this syndrome occurs more frequently in physically active breeds, as indicated by research conducted on working dogs. Recent investigations suggest a higher incidence of DLSS observed in dogs primarily utilized by military and law enforcement agencies for security purposes (Steffen et al. 2007; Worth et al. 2009; Ondreka et al. 2013; Mukherjee et al. 2017).

The recent morphological and morphometric retrospective study by Ondreka et al. (2013) identified the existence of atypical skeletal conformation of the lumbosacral junction in German Shepherds compared to other large dog breeds. Additionally, they observed a higher prevalence and severity of certain predisposing factors for the onset of DLSS in German Shepherds (e.g., early appearance of degenerative changes and sacral osteochondrosis), which could significantly impact the breeding and selection of this breed.

Among all small dog breeds included in our research, the occurrence of DLSS was observed solely in Standard Poodles, aligning with the findings of Egenvall et al. (1998; 2000) and Egenvall and Hedhammar (1999) analyzed data from 200,000 dogs from a Swedish insurance company, evaluating the risk of DLSS occurrence in the 15 most commonly affected breeds. Among all breeds, the highest risk was identified in German Shepherds, and the lowest in Poodles, which was also the only small dog breed identified with a risk of DLSS onset. Furthermore, our research indicates that among all DLSS cases, the highest proportional representation was observed in dogs aged 7-10 years. Additionally, the proportion of males in the total occurrence of DLSS was significantly higher than the proportion of DLSS cases observed in females. According to other authors (Danielsson and Sjöström 1999; De Risio et al. 2001; Indrieri et al. 2008; Meij and Bergknut 2010) the average age of clinical manifestation of DLSS is 7 years, falling within the age group of 7 to 10 years, where our study identified the highest proportion of DLSS cases. The same authors also note a higher prevalence of the disease in males compared to females.

Conclusion

The findings of this research suggest that DLSS primarily manifests in middle-aged dogs of larger breeds. Thereby, in the total number of DLSS cases, a significantly higher proportion of this condition was identified in large compared to small dog breeds (P=0.0008), as well as in males compared to females (P=0.0228), predominantly affecting dogs aged 7 years and older (P=0.0014). Additionally, nearly one-third of all DLSS cases were recorded in German Shepherds. Despite extensive research into diagnosis, lumbosacral degeneration remains a frequent cause leading to the withdrawal or euthanasia of highly trained German Shepherd working dogs worldwide during their peak years of service.

REFERENCES

Breit S, 2002. Functional adaptations of facet geometry in the canine thoracolumbar and lumbar spine (Th10-L6). Annals of Anatomy-Anatomischer Anzeiger 184(4): 379-385. https://doi.org/10.1016/S0940-9602(02)80059-0

Campbell I, 2007. Chi-squared and Fisher-Irwin test of two-by-two tables with small sample recommendations. Statistics in Medicine 26(19): 3661-3675. https://doi.org/10.1002/sim.2832

Da Costa RC and Moore SA, 2010. Differential diagnosis of spinal diseases. Veterinary Clinics: Small Animal Practice 40(5): 755-763. https://doi.org/10.1016/j.cvsm.2010.06.002

Danielsson F and Sjöström L, 1999. Surgical treatment of degenerative lumbosacral stenosis in dogs. Veterinary Surgery 28(2): 91-98. https://doi.org/10.1053/jvet.1999.0091

De Risio L, Sharp NJ, Olby NJ, Muñana KR and Thomas WB, 2001. Predictors of outcome after dorsal decompressive laminectomy for degenerative lumbosacral stenosis in dogs: 69 cases (1987–1997). Journal of the American Veterinary Medical Association 219(5): 624-628. https://doi.org/10.2460/javma.2001.219.624

Egenvall A and Hedhammar A, 1999. Survey ofthe Swedish Dog Population: Age, Gender, Breed, Location and Enrolment in Animal Insurance. Acta Vet Scand 40: 231-240. https://doi.org/10.1186/BF03547021

Egenvall A, Bonnett BN, Olson P and Hedhammar Å, 1998. Validation of computerized Swedish dog and cat insurance data against veterinary practice records. Preventive Veterinary Medicine 36(1): 51-65. https://doi.org/10.1016/S0167-5877(98)00073-7

Egenvall A, Hedhammar A, Bonnett B and Olson P, 2000. Gender, age, breed and distribution of morbidity and mortality in insured dogs in Sweden during 1995 and 1996. Veterinary Record 146(18): 519-525. https://doi.org/10.1136/vr.146.18.519

GOMES SL ACR, 2022. Degenerative Lumbosacral Syndrome in Dogs–surgical management strategies and new insights on outcome. PhD Thesis. University of Nottingham.

Henderson AL, Hecht S and Millis DL, 2015. Lumbar paraspinal muscle transverse area and symmetry in dogs with and without degenerative lumbosacral stenosis. The Journal of Small Animal Practice 56(10): 618-622. https://doi.org/10.1111/jsap.12385

Indrieri R, Ness M, Tarvin G, Prata R, Wheeler S, De Risio L, Thomas W, Sharp N, Watt P and Morgan J, 2008. Review and retrospective analysis of degenerative lumbosacral stenosis in 156 dogs treated by dorsal laminectomy. Veterinary and Comparative Orthopaedics and Traumatology 21(03): 285-293. https://www.doi.org/10.1055/s-0037-1617374

Lampe R, Foss KD, Hague DW, Oliveira CR and Smith R, 2020. Dynamic MRI is reliable for evaluation of the lumbosacral spine in healthy dogs. Veterinary Radiology & Ultrasound 61(5): 555-565. https://doi.org/10.1111/vru.12891

Lim SH and Beasley M, 2023. Lumbosacral Decompression and Foraminotomy Techniques. Advanced Techniques in Canine and Feline Neurosurgery 129-142. https://doi.org/10.1002/9781119790457.ch14

Meij BP and Bergknut N, 2010. Degenerative lumbosacral stenosis in dogs. Veterinary Clinics: Small Animal Practice 40(5): 983-1009. https://doi.org/10.1016/j.cvsm.2010.05.006

Morgan JP and Bailey CS, 2000. Exercises in veterinary radiology: Venture Press, 1st ed.

Mukherjee M, Jones JC and Yao J, 2017. Lumbosacral stenosis in Labrador retriever military working dogs–an exomic exploratory study. Canine Genetics and Epidemiology 4(1): 1-14. https://doi.org/0.1186/s40575-017-0052-6

Ondreka N, Amort KH, Stock KF, Tellhelm B, Klumpp SW, Kramer M and Schmidt MJ, 2013. Skeletal morphology and morphometry of the lumbosacral junction in German shepherd dogs and an evaluation of the possible genetic basis for radiographic findings. The Veterinary Journal 196(1): 64-70. https://doi.org/10.1016/j.tvjl.2012.07.015

Reints BTE, Van Stee L, Willemsen K, Beukers M, Grinwis GC and Meij BP, 2020. Lumbosacral Fusion Using Instrumented Cage Distraction–Fixation in a Dog with Degenerative Lumbosacral Stenosis. VCOT Open 3(02): e77-e83. https://doi.org/10.1055/s-0040-1713824

Richardson JT, 2011. The analysis of 2 x 2 contingency tables – yet again. Statistics in Medicine 30(8): 890; author reply 891-892. https://doi.org/10.1002/sim.4116

Schaub KI, Kelleners N, Schmidt MJ, Eley N and Fischer MS, 2021. Three-dimensional kinematics of the pelvis and caudal lumbar spine in German shepherd dogs. Frontiers in Veterinary Science 8: 709966. https://doi.org/10.3389/fvets.2021.709966

Steffen F, 2009. Degenerative lumbosacral stenosis in dogs-contributions to epidemiology, diagnostic imaging and treatment. University of Zurich https://doi.org/10.5167/uzh -29919

Steffen F, Hunold K, Scharf G, Roos M and Flückiger M, 2007. A follow-up study of neurologic and radiographic findings in working German Shepherd Dogs with and without degenerative lumbosacral stenosis. Journal of the American Veterinary Medical Association 231(10): 1529-1533. https://doi.org/10.2460/javma.231.10.1529

Surer E, Cereatti A, Evangelisti MA, Paolini G, Della Croce U and Manunta ML, 2020. A Canine Gait Analysis Protocol for Back Movement Assessment in German Shepherd Dogs. Veterinary Sciences 7(1): 26. https://doi.org/10.3390/vetsci7010026

Thitaram N, 2018. Degenerative lumbosacral stenosis in dog. Veterinary Integrative Sciences 16(1): 47-66.

Wigger A, Julier-Franz C, Tellhelm B and Kramer M, 2009. Lumbosakraler Übergangswirbel beim Deutschen Schäferhund: Häufigkeit, Formen, Genetik und Korrelation zur Hüftgelenksdysplasie. Tierarztliche Praxis 200(29): 7-13. https://doi.org/10.1055/s-0038-1622734

Worth A, Meij B and Jeffery N, 2019. Canine Degenerative Lumbosacral Stenosis: Prevalence, Impact and Management Strategies. Veterinary Medicine: research and reports 10: 169-183. https://doi.org/10.2147/VMRR.S180448

Worth AJ, Thompson DJ and Hartman AC, 2009. Degenerative lumbosacral stenosis in working dogs: current concepts and review. New Zealand Veterinary Journal 57(6): 319-330. https://doi.org/10.1080/00480169.2009.64719