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Prevalence and clinical features of thoracolumbar intervertebral disc-associated epidural hemorrhage in dogs

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Abstract

Background: Intervertebral disc-associated epidural hemorrhage (EH) in dogs is a poorly understood neurological condition.

Objective: To compare the clinical presentation, magnetic resonance imaging (MRI) changes, and clinical outcome of dogs with acute thoracolumbar intervertebral disc herniation (TL-IVDH) with and without EH.

Animals: One hundred sixty client-owned dogs that underwent MRI and hemilaminectomy for acute TL-IVDH at a private practice in Colorado, including 63 dogs with EH and 97 dogs without EH.

Methods: Retrospective review of medical record data from 160 dogs presenting sequentially to a single practice with acute TL-IVDH that underwent MRI and hemilaminectomy surgery.

Results: Sixty-three of 160 (39%) dogs had confirmed EH. French Bulldogs were significantly overrepresented (23/63; odds ratio [OR]: 4.1; 95% confidence interval [CI]: 1.8-9.0; $P < .001$) of the EH cases. Dogs with EH were more likely to present with clinical signs less than 48 hours than were dogs without EH (24-48 vs 48-72 hours; OR: 2.4; 95% CI: 1.2-4.6; $P = .02$) and were more likely to be nonambulatory on presentation (OR: 2.1; 95% CI: 1.0-4.1; $P = .04$). Dogs with EH were more likely to have <50% cross-sectional spinal cord compression than dogs without EH (OR: 2.3 vs. 0.4; 95% CI: 1.2-4.4 and 0.2-0.9, respectively), longer longitudinal spinal cord compression (3 spaces vs 1 space, $P < .001$), and greater intrinsic spinal cord change (grade 3/severe vs grade 1/mild; $P < .001$) based on MRI. The location of the intervertebral disc herniation in French Bulldogs with EH was more likely to be thoracolumbar (OR: 10.8; 95% CI: 2.1-55.7; $P = .03$).

Abbreviations: DEEH, disc-associated extensive epidural hemorrhage; EH, epidural hemorrhage; GRE, gradient echo; MRI, magnetic resonance imaging; SEH, spinal epidural hemorrhage; STIR, short tau inversion recovery; TL-IVDH, thoracolumbar intervertebral disc herniation.

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Conclusions and Clinical Importance: French Bulldogs have a high prevalence of intervertebral disc-associated EH. Dogs with EH have a shorter clinical course and are more likely to be nonambulatory on initial presentation.

KEYWORDS
dog, French Bulldog, hemilaminectomy, spinal

1 | INTRODUCTION

Spinal epidural hemorrhage (SEH) is a relatively common sequela to intervertebral disc herniation in dogs.[1-4] Previous case series focus predominantly on medium to large breed dogs where a larger epidural space is suspected to contribute to the distribution of hemorrhage.[1-4] Prevalence of epidural hemorrhage (EH) within a group of dogs presenting for acute thoracolumbar intervertebral disc herniation (TL-IVDH) and overall breed predisposition have not been described.

Epidural hemorrhage is suspected to occur secondary to laceration of the intervertebral venous plexus ventral to the spinal cord during disc extrusion.[1,3,4] Epidural hemorrhage contributes to spinal cord compression and causes secondary spinal cord injury due to direct cytotoxicity after exposure to hemorrhage and hemorrhagic byproducts.[5,6] Because of high concentrations of polyunsaturated fatty acid chains and reduced protective mechanisms against oxidative damage, the central nervous system is exceedingly susceptible to cytologic damage from free radicals produced by the breakdown of erythrocytes.[7-9]

The objective of this study was to report prevalence, breed predisposition, clinical progression, degree of spinal cord compression and intrinsic spinal cord change on magnetic resonance imaging (MRI), and clinical outcome in dogs with acute thoracolumbar intervertebral disc-associated EH compared to a control group of dogs without EH.

2 | MATERIALS AND METHODS

2.1 | Case selection

Medical records from 165 dogs undergoing hemilaminectomy for an acute Hansen type 1 thoracolumbar disc extrusion were collected sequentially from the hospital's electronic medical record system over a 3-year period from 2018 to 2021. To fulfill inclusion criteria, dogs must have had an acute onset (defined as clinical signs <4 weeks duration) of a T3-L3 myelopathy, an MRI confirming an acute thoracolumbar disc herniation, and a decompressive hemilaminectomy. All medical records were complete and contained well-documented history, neurological exam findings by a board-certified neurologist, preanesthetic laboratory results, MRI findings, intraoperative report documenting the presence or absence of hemorrhage, and follow-up at 2 and 4 weeks. Five dogs were excluded because they were euthanized while under anesthesia after MRI because of concern for myelomalacia and poor prognosis, therefore the presence of EH could not be evaluated intraoperatively. The remaining 160 dogs were included in the final analysis and follow-up to 4 weeks after surgery was available for all 160 dogs.

2.2 | Data collection

Collected medical record data included signalment, CBC and biochemistry data, duration of clinical signs (categorically defined as 1: <24 hours; 2: 24-48 hours; 3: 48-72 hours; 4: >72 hours), progression time to nonambulatory status when applicable (categorically defined as 1: <24 hours; 2: 24-48 hours; 3: 48-72 hours; 4: >72 hours), neurologic grade (definition using a modified Frankel spinal cord injury scale[10] of 1: pain only; 2: ambulatory paraparesis; 3: nonambulatory paraparesis; 4: paraplegia with intact nociception; and 5: paraplegic with absent nociception), length of hemilaminectomy site (characterized by number of articulations removed), and the presence or absence of EH as identified in surgery. Location of extradural compression (intervertebral disc material with or without EH) was categorized into 4 areas: high thoracic (T9-T12), thoracolumbar (T12-L2), mid lumbar (L2-L4), and caudal lumbar (L4-L7). Location was listed as a combined area when extradural material extended over more than 1 area. Total anesthesia time, surgery time, and ambulatory status (defined as ambulatory or nonambulatory) at 2 and 4 weeks after hemilaminectomy were recorded in all dogs.

2.3 | Magnetic resonance imaging acquisition and interpretation

All MRIs were obtained using a 1.5 Tesla MRI (Siemens MAGNETOM Symphony) and the technique was similar among all scans. Standard T2-weighted (T2W) and short tau inversion recovery (STIR) sagittal and transverse images were obtained for all dogs. Gradient echo (GRE) images were obtained in 18 dogs. All 160 MRIs were reviewed by a board-certified neurologist who was blinded to breed, severity of dysfunction, presence or absence of EH, clinical presentation, and outcome at the time of the MRI interpretation.

Degree of spinal cord compression was assessed by comparing the percentage of compression at the area of maximum spinal cord compression to the total area of the adjacent noncompressed spinal cord using a ruler measurement tool associated with the imaging software and was graded as 1 (<25% spinal cord compression), 2 (25%-50% spinal cord compression), 3 (50%-75% spinal cord compression),

or 4 (>75% spinal cord compression) based on a modified morphologic compression scale.[11] Length of spinal cord compression was assessed by counting the number of vertebral bodies over which extradural herniated disc material and EH extended, including where spinal cord compression was mild.

Intrinsic spinal cord changes were assessed by measuring T2W and STIR hyperintensity within the spinal cord parenchyma using a ruler measurement tool and were assessed as 1 (mild: lesion affecting <25% of the spinal cord area, <25% of the adjacent vertebral body length, mild hyperintensity), 2 (moderate: 25%-50% spinal cord area, 25%-50% of the adjacent vertebral body length, mild to moderate hyperintensity), and 3 (severe: >50% spinal cord area, >50% of the adjacent vertebral body length, marked hyperintensity).

2.4 | Anesthesia and surgery

Hemilaminectomy extended over a maximum of 5 continuous articular facets to allow decompression over 6 vertebral lengths. Cranial and caudal probing within the laminectomy site and vigorous flushing was performed in all dogs to enable removal of any surrounding hemorrhage not directly visible in the hemilaminectomy window. Anesthesia and surgery times were recorded and compared in minutes for all dogs and converted to hours for data presentation. Twelve dogs had 2 hemilaminectomy surgeries for different acute intervertebral disc herniations within the span of the study. The surgeries were included separately within the total count of 160 hemilaminectomies. Any residual compression or persistent intrinsic spinal cord change at the previous surgery site was noted but not included within the assessment of compression or intrinsic spinal cord changes for the second surgery.

2.5 | Statistical analysis

Data were divided into 2 groups: dogs with EH and dogs without EH. Distributions of continuous variables (age, weight, length of spinal cord compression, surgery time, and anesthesia time) within each treatment group were assessed by visualizing Q-Q plots and testing for normality with the Shapiro-Wilk test. Each variable failed multiple tests for normality within at least 1 of the groups. Various data transformations were evaluated, including logarithms and Box-Cox transformations; however, none of the transformations satisfied criteria for a normal distribution. Therefore, each continuous variable was analyzed using nonparametric Mann-Whitney tests (age, weight, length of spinal cord compression, surgery time, and anesthesia time). Categorical variables (breed, gender, duration of clinical signs, time to becoming nonambulatory, neurologic grade, degree of disc compression, degree of intrinsic spinal cord change, location of disc herniation, and ambulatory status at 2 and 4 weeks after surgery) were compared using Fisher's exact tests. Pairwise comparisons were performed using Dunn's multiple comparisons test (length of spinal cord compression).

3 | RESULTS

3.1 | Signalment

A total of 22 breeds presented without EH and included Dachshund (n = 33), French Bulldog (n = 12), Mixed Breed Dog (n = 8), Chihuahua (n = 7), Shih Tzu (n = 5), Jack Russell Terrier (n = 4), Beagle (n = 3), Terrier (n = 3), Labrador Retriever (n = 3), Poodle (n = 3), Cockapoo (n = 3), Cavalier King Charles Spaniel (n = 2), Pit Bull (n = 2), and 1 each of Cocker Spaniel, Pekingese, Border Collie, Coton De Tulear, Lhasa Apso, Bichon, Miniature Schnauzer, Yorkshire Terrier, and Rat Terrier. A total of 17 breeds presented with EH and included French Bulldog (n = 23), Dachshund (n = 6), Pit Bull (n = 6), Chihuahua (n = 4), Beagle (n = 4), Cocker Spaniel (n = 4), Shih Tzu (n = 2), Terrier (n = 2), Labrador Retriever (n = 2), Pembroke Welsh Corgi (n = 2), German Shepherd Dog (n = 2), and 1 each of Pekingese, Border Collie, Mixed Breed Dog, Goldendoodle, Dingo, and Akita.

Epidural hemorrhage was detected in 63/160 (39%; 95% CI: 32%-47%) dogs. Breeds with the highest prevalence of EH included French Bulldogs (23/35, 66%), Pit Bull Terriers (6/8, 75%), Beagles (4/7, 57%), and Cocker Spaniels (4/5, 80%). French Bulldogs were the most common breed to have EH and comprised 23/63 (37%; 95% CI: 30%-54%) of all EH cases whereas they accounted for 12/97 (12%; 95% CI: 7%-20%) of the non-EH cases ($P < .001$). Dachshunds were significantly less likely to have EH with only 6/63 (10%; 95% CI: 4%-19%) in the EH group compared to 33/97 (34%; 95% CI: 25%-44%) in the non-EH group ($P < .001$).

Other signalment characteristics (age, weight, and sex) are summarized in Table 1. The median age for all dogs presenting with an acute TL-IVDH was 6 years old (range, 1-14). Dogs with EH were significantly younger than dogs without EH (median age = 4 vs 7 years, $P < .001$).

There was no apparent sex predisposition for EH. Dogs with EH weighed more than dogs without EH with a median weight of 12.3 kg compared to 8.0 kg ($P < .001$), which likely reflects the greater number of large breed dogs with EH.

3.2 | Neurologic dysfunction progression and grade

A total of 157/160 (98%) dogs in the study had neurological signs <2 weeks in duration. The duration of clinical signs before presentation is summarized in Table 1. There was a significant difference between the groups, with the dogs in the EH group having a shorter duration of clinical signs than those without EH (median = 24-48 vs 48-72 hours; $P = .02$). A total of 46/63 (73%; 95% CI: 61%-83%) dogs with EH were nonambulatory at the time of presentation compared to 55/97 (57%; 95% CI: 47%-66%; $P = .04$) dogs without EH.

The time frame to becoming nonambulatory is summarized in Table 1. There was no significant difference between the groups (median <24 hours for dogs with and without EH; $P = .09$), with 41/46 (89%; 95% CI: 77%-96%) dogs with EH becoming

TABLE 1 Variables for hemorrhage vs nonhemorrhage groups

Variable		Hemorrhage	No hemorrhage
Age	Median	4	7
	Range	2-11	1-14
	P-value*	<.001	
Weight	Median	12.3	8
	Range	3.8-47.3	2.3-51
	P-value*	<.001	
Sex	Male	34 (54%)	61 (63%)
	Female	29 (46%)	29 (46%)
	P-value**	.32	
Duration of clinical signs before presentation	<24 hours	21 (33%)	26 (27%)
	24-48 hours	19 (30%)	15 (15%)
	48-72 hours	10 (16%)	16 (16%)
	>72 hours	13 (21%)	40 (41%)
	P-value**	.02	
Time to become nonambulatory	<24 hours	41 (89%)	39 (71%)
	24-48 hours	4 (9%)	10 (18%)
	48-72 hours	0 (0%)	4 (7%)
	>72 hours	1 (2%)	2 (4%)
	P-value**	.07	
Neurologic grade	1	2 (3%)	3 (3%)
	2	14 (22%)	39 (40%)
	3	29 (46%)	30 (31%)
	4	12 (19%)	21 (22%)
	5	6 (10%)	4 (4%)
	P-value**	.08	
Degree of compression	<25%	16 (25%)	8 (8%)
	25%-50%	27 (43%)	37 (38%)
	50%-75%	13 (21%)	25 (26%)
	>75%	7 (11%)	27 (28%)
	P-value**	.004	
Length of spinal cord compression (vertebral lengths)	Median	3	1
	Range	1-13	1-4
	P-value*	<.001	
Degree of spinal cord edema	Absent	2 (3%)	20 (21%)
	Mild	14 (22%)	30 (31%)
	Moderate	15 (24%)	24 (25%)
	Severe	32 (51%)	23 (24%)
	P-value**	<.0003	

**P*-value from Mann-Whitney test.
***P*-value from Fisher's exact tests.

nonambulatory within 24 hours before presentation compared to 39/55 (71%; 95% CI: 58%-82%; $P = .07$) of the non-EH group. Neurological grade data is listed in Table 1. There was not a significant difference in the median neurologic grade on presentation between dogs with and without EH (median neurological grade = 3 for both groups; $P = .08$).

3.3 | Hematology and serum biochemistry

Complete blood count and biochemistry panel were performed in 142/160 (89%) dogs. One dog with EH had a thrombocytopenia of 15 000 to 20 000 platelets/μL (range, 165 000-430 000 platelets/μL); however, this was not verified by microscopic examination and hand

TABLE 2 Location of spinal cord compression

Group	Location of compression				
	All dogs	Dogs with EH	Dogs without EH	French Bulldogs with EH	French Bulldogs without EH
High thoracic (T9-12)	14 (9%)	3 (5%)	11(11%)	0 (0%)	0 (0%)
Thoracolumbar (T12-L2)	78 (49%)	23 (33%)	55 (55%)	10* (38%)	3 (25%)
High thoracic and TL	18 (11%)	16 (26%)	2 (2%)	3* (14%)	0 (0%)
Mid-lumbar (L2-4)	18 (11%)	5 (9%)	13 (14%)	2 (10%)	3 (25%)
TL and mid-lumbar	8 (5%)	7 (12%)	1 (1.1%)	4 (19%)	0 (0%)
High thoracic, TL, and mid-lumbar	1 (0.6%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)
Caudal lumbar (L4-7)	15 (9%)	2 (3%)	13 (14%)	1 (5%)	5 (42%)
Mid-lumbar and caudal lumbar	7 (4%)	5 (9%)	2 (2.2%)	2 (10%)	1 (8%)
TL, mid-lumbar, and caudal lumbar	1 (0.6%)	1 (2%)	0 (0%)	1 (5%)	0 (0%)
	160	63	97	23	12

Abbreviation: DEEH, disc-associated extensive epidural hemorrhage.
*$P = .03$, Fisher's exact test.

count. All other dogs had normal platelet counts and no laboratory abnormalities or clinical signs (petechiae, etc.) to suggest the presence of underlying metabolic disease that could predispose to a coagulopathy. A more limited in-house blood panel (NOVA) containing hematocrit, renal values, electrolytes, and acid-base values was performed in 15/160 (9%) healthy dogs <5 years of age before anesthesia, which had no relevant findings. Two dogs had solely a biochemistry panel done and blood work was not available for review in 1 dog.

3.4 | Magnetic resonance imaging findings

There was excellent correlation between evidence of hypointense extradural material on GRE MRI sequencing and identification of EH intraoperatively (18/18, 100% dogs). Cross-sectional spinal cord compression data are presented in Table 1. Dogs with EH had a significantly lower cross-sectional compression score (median = 25%-50% vs 50%-75%; $P = .004$) with 43/63 (68%; 95% CI: 56%-79%) dogs having less than 50% compression compared to 47/97 (48%; 95% CI: 39%-58%; $P = .02$) of dogs without EH.

Longitudinal compression data are presented in Table 1. Dogs with EH had significantly more extensive longitudinal compression (median = 3; range, 1-13 vertebral body lengths) compared to dogs without EH (median = 1; range, 1-4, $P < .001$), with 33/63 (52%; 95% CI: 40%-64%) extending over 3 or more vertebral body lengths and 19/63 (30%; 95% CI: 20%-42%) extending over 5 vertebral body lengths.

Intrinsic spinal cord changes are noted in Table 1. Dogs with EH had more severe intrinsic spinal cord change compared to dogs without EH (median grade 3/severe vs median grade 1/mild; $P < .0003$).

3.5 | Location of disc herniation/hemorrhage

Location of spinal cord compression was documented for all cases and is listed in Table 2. In addition to comparing total groups, French Bulldogs with and without EH were compared to other breeds. The majority of French Bulldogs without EH had a disc herniation in the mid to caudal lumbar area (9/12, 75%, 95% CI: 47%-92%). French Bulldogs with EH were significantly more likely to have lesions in the caudal thoracic/thoracolumbar junction (OR: 10.8; 95% CI: 2.1-55.7) compared to the mid lumbar/caudal region (OR: 0.09; 95% CI: 0.02-0.48; $P = .03$).

3.6 | Surgery and anesthesia

3.6.1 | Surgical length

Length of hemilaminectomy was shorter in dogs without EH (median = 1; range, 1-2 articulations) compared to dogs with EH (median = 2; range, 1-5 articulations). The hemilaminectomy addressed the entire area of compression in 96/97 (99%) dogs without EH compared to 45/63 (71%) dogs with EH. In 17/18 dogs with EH where laminectomy did not cover the entire length of compression visualized on MRI, extradural material extended from 4 to 6 vertebral lengths and all laminectomies covered within 1 vertebral length of the entire length with preference placed on the area of maximum cross sectional compression. One Pit Bull Terrier with extradural compression over 13 vertebral lengths had 2 separate hemilaminectomies of 2 articulations/3 vertebral lengths each to allow decompression over 6 vertebral lengths.

TABLE 3 Ambulatory status at 2 and 4 weeks after surgery

	Ambulatory status			
	2 weeks		4 weeks	
Group	Yes	No	Yes	No
Hemorrhage	52 (83%)	11 (17%)	55 (87%)	8 (13%)
No hemorrhage	83 (86%)	14 (14%)	94 (97%)	3 (3%)
P-value*	.66		.03	

**P*-value from Fisher's Exacts tests.

3.6.2 | Anesthesia and surgery time

Total anesthesia time was longer in dogs with EH (median = 3.4 hours; range, 2.2-7 hours) compared to dogs without EH (median = 3.1 hours; range, 1.75-6.9 hours; $P = .02$). Surgery time was marginally longer in dogs with EH (median = 1 hour; range, 0.45-4.3 hours) compared to dogs without EH (median = 0.9 hours; range, 0.5-4.3 hours; $P = .04$).

3.7 | Follow-up

During the follow-up period, 1 dog in the EH group and 1 dog without EH were euthanized before the 2 week recheck because of poor recovery and concern for myelomalacia and were considered nonambulatory at 2 and 4 weeks in the statistical analysis as the likelihood of ever regaining ambulation was low. There was no significant difference in ambulatory status between the groups at the recheck exam 2 weeks after surgery; however, at the 4 week recheck exam, a greater number of dogs in the EH group remained nonambulatory than those without EH (Table 3). The 8 dogs with EH that remained nonambulatory at the 4 week recheck exam included 3 French Bulldogs and 1 each of Dachshund, Border Collie, Goldendoodle, Pit Bull, and Shih Tzu.

There was no difference in length of compression in dogs that regained ambulation by 4 weeks (median = 3; range, 1-3 vertebral lengths) and those that did not regain ambulation by 4 weeks (median = 4.5; range, 1-13 lengths, $P = .22$). There was no difference in surgery time between dogs that regained ambulation (median = 0.98 hours) and those that did not regain ambulation (median = 0.97 hours; $P = .8$) or in anesthesia time between dogs that regained ambulation (median = 3.6 hours) and those that did not regain ambulation (median = 3.25 hours; $P = .62$). There was also no difference in surgery time between dogs with EH that regained ambulation (median = 1.1 hours) and those with EH that did not regain ambulation (median = 0.77 hours; $P = .33$) or in anesthesia time between dogs with EH that regained ambulation (median = 3.4 hours) and those with EH that did not regain ambulation (median = 3.0 hours; $P = .36$). Intraparenchymal changes were considered severe in 7/8 (88%) dogs with EH that did not recover ambulation by 4 weeks compared to 25/55 (45%) of dogs with EH that did regain ambulation; however, the difference between the groups was not statistically significant (median 3/severe vs median 2/moderate, $P = .11$).

3.8 | Recurrent disc herniations

Twelve dogs had a second hemilaminectomy within the 3-year time frame of the study. Five of the 12 (42%; 95% CI: 19%-69%) dogs undergoing a second surgery were French Bulldogs. Four of the 12 dogs (33%; 95% CI: 14%-61%) had EH with both their first and second disc herniations. Two dogs (17%; 95% CI: 4%-45%) had EH associated with their first disc herniation but not the second, and the remaining 6 dogs (50%; 95% CI: 25%-75%) did not have EH with either disc herniation. On MRI at the time of their second disc herniation, 2 dogs that had EH with their first disc herniation had intrinsic changes suggestive of gliosis at the previous surgery site. One dog without EH had intrinsic changes at the previous surgery site. One of the French Bulldogs who had EH with both disc herniations had a third surgery before the inclusion time frame for the study and had EH with that disc herniation as well. In this dog, intrinsic changes were noted at the first surgery site at the time of the second MRI but resolved by the third MRI.

4 | DISCUSSION

Epidural hemorrhage was a common sequela to acute TL-IVDH in this study, and dogs with EH had a shorter duration of clinical signs and were more likely to be nonambulatory at presentation. The cytotoxic effects of hemorrhage might have contributed to the neurological decline and lower recovery rate in dogs with EH. Intervertebral disc-associated EH was most prevalent in French Bulldogs in this study, which is important to recognize given increasing breed popularity over the past several years.[12] Reports of EH contain a low number of French Bulldogs and a review of intervertebral disc disease in French Bulldogs described a much lower prevalence of EH (28% compared to the 66% reported here).[2,12,13] The lower median age for French Bulldogs with intervertebral disc might have skewed the EH group to be significantly younger given the large percentage of French Bulldogs with EH. The large number of French Bulldogs and Pitbull Terriers with EH also likely skewed the weight to be significantly higher in the EH group, as the nonhemorrhage group contained a large number of Dachshunds and other small breed dogs.

The majority of French Bulldogs with EH had caudal thoracic or thoracolumbar lesions, which have not been described. The majority of French Bulldogs without EH had lumbar intervertebral disc herniations. In humans, the epidural venous plexus is most prominent in the thoracic spine, and spontaneous spinal epidural hematomas most often occur in the thoracic and cervicothoracic region, followed by the thoracolumbar area.[5,6,14,15] In dogs, the venous plexus has been evaluated morphometrically in the cervical and lumbar spine.[16-18] In a study evaluating the lumbar intervertebral venous plexus, the venous plexus was found to occupy the highest percentage of area relative to the vertebral canal most cranially at L1.[18] Given these findings, the potential for EH should be considered more highly in French Bulldogs with neurologic exam abnormalities localizing more cranially.

Spinal epidural hemorrhage, the term used most commonly in humans, is scarcely reported with intervertebral disc herniation and is typically seen as a result of spinal puncture, anticoagulant treatment, genetic or metabolic coagulopathies, trauma, and pregnancy.[5,19] Although coagulation testing was not performed in dogs in this study, coagulopathies are not commonly reported in the French Bulldog and other high-risk breeds in the study. Spinal epidural hematomas in humans often cause a rapid progression of clinical signs and profound neurologic deficits and are considered a surgical emergency with outcomes more favorable when people have incomplete loss of neurologic function and there is a short time interval between the onset of clinical signs and surgical decompression.[6,14,15,20] Medical management of SEH in humans is reserved for patients with minimal neurologic deficits or improving function. In a large retrospective study using neurologic grade to determine medical or surgical treatment in humans with SEH, patients managed medically had a significantly higher case fatality rate.[6]

Studies attribute the rapid decline in dogs with EH to spinal cord compression; however, dogs with EH in our study had significantly less cross-sectional spinal cord compression than dogs without EH.[2-4] This suggests that the length of contact and intrinsic spinal cord changes associated with the cytotoxic effect of hemorrhage might play a greater role in neurologic deterioration than compression.[2] The large degree of intrinsic spinal cord change noted on MRI in dogs with EH (which were often acquired within 24-48 hours of the onset of signs) suggests that intraparenchymal damage can develop very quickly after contact with hemorrhage and erythrocyte breakdown products.

Because MRI characteristics of EH can be quite variable, intraoperative observation of EH was considered the standard to confirm EH over MRI findings in this study. Although GRE imaging in a larger number of dogs might have further increased the suspicion of EH before surgery, it did not impact therapeutic plan and prolonged anesthesia time and therefore was intentionally not acquired in many of the dogs. Because MRI signaling characteristics of EH in dogs have been well described, this study focused instead on the degree of spinal cord compression and intrinsic spinal cord hyperintensity associated with EH, as data are more limited.[1-3,11,21-23] Intraparenchymal hyperintensity attributed to spinal cord contusion and myelomalacia has been associated with more severe neurological grade and poorer clinical outcome in dogs with intervertebral disc herniation, and some authors suggest that length and severity of intrinsic changes might help predict prognosis better than neurological grade on presentation.[11,23] Although the intrinsic spinal cord changes in dogs with EH were more severe in this study, they might be transient and improve after EH removal and should not necessarily be used to indicate a more guarded prognosis. Although follow-up MRIs are typically not performed in dogs recovering well from surgery, the dogs with second intervertebral disc herniations in this study allowed us to reevaluate the previous spinal cord changes associated with EH. In that small number of dogs, the intrinsic changes had resolved at the time of the second surgery indicating that there is reasonable potential to recover from intraparenchymal damage associated with hemorrhage even when MRI changes are severe.

Although ambulatory status at 2 weeks was not significantly different between dogs with and without EH, probability of ambulation at 4 weeks was significantly worse in dogs with EH. Three of the 8 dogs with EH that had not recovered ambulation at the 4 week recheck were large breed dogs, which have a more guarded prognosis when affected by EH.[3] Longer surgery and anesthetic times are associated with worse outcome in dogs with acute TL-IVDH; however, that was not a factor in the small number of dogs who did not regain ambulation by 4 weeks in this study.[24]

Although all medical records were complete and collected sequentially to avoid bias, the study design has the inherent limitations of a large retrospective study and our findings should be validated in future prospective studies. These data should be viewed as preliminary and hypothesis generating as no correction was made for multiple testing. Despite the fact that both EH and non-EH cohorts were collected from a single institution under identical intentions and delivery of care, the design must be interpreted as a retrospective case-control study. The study groups were compared and found to be similar for known covariates of acute TL-IVDH; nonetheless our study design cannot address the impact of unknown covariates of outcome and unknown bias in the management of the cohorts. Accordingly, although clinical presentation and both imaging and intraoperative findings can be more safely compared between the EH and non-EH cohorts, outcome assessments can be less safely compared. Ongoing studies are underway to further evaluate EH in prospective clinical trials.

Magnetic resonance imaging was evaluated by a single board-certified neurologist blinded to dog breed, presence or absence of EH, lesion localization, and outcome. Use of a measurement tool and the same scoring schemes were used consistently for all dogs; however, assessment of the degree of spinal cord compression and intrinsic spinal cord change is somewhat subjective and MRI analysis software might have provided additional accuracy. Histopathological examination would be the gold standard to assess intrinsic spinal cord changes but was not practical in these clinical dogs, as the majority recovered well after surgery. Future histopathological studies sectioning spinal cords in dogs euthanized for EH might prove useful to describe pathological changes associated with EH. Five dogs with MRI evidence of acute TL-IVDH with and without EH were excluded from the study if surgery was not performed. This might have reduced the number of dogs with absent nociception from the study and skewed the prognosis of our cases toward a more positive outcome; however the number was low.

Recommendations for diagnostic imaging and surgical decompression in dogs with suspected intervertebral disc herniation are commonly based on the degree of neurological dysfunction with a higher urgency placed on paraplegic dogs and those without nociception. Although it is difficult to ascertain whether EH accumulates over minutes, hours, or days, urgent MRI and surgical decompression might be warranted in some breeds predisposed to EH even if initially presenting with less severe neurological deficits such as pain only or ambulatory paraparesis. More expedient removal of EH might limit cytotoxic damage to the spinal cord and neurological deterioration.

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CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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