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Vertebral fixation does not affect recovery or recurrence of cervical intervertebral disc herniation in small dogs (< 15 kg)

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OBJECTIVE
To compare the prognosis of small dogs with cervical intervertebral disc herniation (C-IVDH) when treated with ventral slot decompression (VSD) alone or with concomitant vertebral fixation (VF).

ANIMALS
Small dogs (n = 303) weighing < 15 kg diagnosed with C-IVDH and treated with VSD.

PROCEDURES
We recorded signalment, cervical myelopathy grade, surgical site, use of VF, degree of adjacent disc degeneration, recovery, recurrence, recurrence site, and postoperative course, including the time elapsed from recovery to recurrence. We examined factors associated with recovery and recurrence during the 30-month postoperative period using multivariate logistic regression analysis.

RESULTS
VF did not affect recovery (P = .79). However, nonchondrodystrophic breeds had poorer recovery (OR, 5.89; P = .023) than chondrodystrophic breeds, and a higher preoperative cervical myelopathy grade (grade 3 or 4) was associated with poorer recovery (OR, 7.09 or 3.46, respectively; P = .019 or .042, respectively), compared with grade 1. VF did not affect recurrence (P = .79); however, increasing age was associated with recurrence (OR, 1.79; P = .001).

CLINICAL RELEVANCE
In small dogs weighing < 15 kg, there was no difference in postoperative recovery and recurrence rates after VSD with or without concomitant VF. Therefore, in small dogs with C-IVDH, even if the slot volume is increased to remove sufficient disc material during VSD, a good prognosis can be achieved with or without VF.

Cervical intervertebral disc herniation (C-IVDH) accounts for approximately 15% of disc herniations, and ventral slot decompression (VSD) is the surgical procedure most commonly performed to remove the disc material on the ventral side of the spinal cord in C-IVDH.[1–4] This technique decompresses the spinal cord by removing the herniated disc material (nucleus pulposus), which often allows for rapid resolution of clinical signs.[5] The presence of a large slot width after VSD (slot size larger than 33% to 50% of vertebral body width) can increase the risk for serious complications, such as postoperative instability, vertebral body subluxation, and fracture; vertebral fixation (VF) can prevent these complications.[6,7] Depending on the amount and direction of disc material extrusion, in small dogs with a corresponding small vertebral body size, the limited slot width may be insufficient to allow complete retrieval of extruded disc material. However, C-IVDH might recur in the adjacent intervertebral region after VF in large dogs because it creates an abnormal mechanical environment between adjacent vertebrae and contributes to instability.[8–10] The effect of combined VSD and VF on the mobility of the adjacent intervertebral region in large dogs has been reported in biomechanical studies and clinical cases, but there are few reports on their effect in small dogs.[8,9,11,12] To our knowledge, whether use of VF combined with VSD in small dogs that undergo VSD affects recovery of initial neurologic signs and is associated with recurrence at adjacent sites after surgery, compared with dogs that undergo VSD alone, has not been evaluated using sufficient numbers of cases. In addition, with respect to C-IVDH in small dogs, there are 2 known types of chondrodystrophic breeds (CDBs) that commonly develop type 1 hernias and non-CDBs (NCDBs) that commonly develop type 2 hernias.[13–15] However, it is not known whether there is a difference between outcomes of CDBs and NCDBs undergoing VF combined with VSD. To investigate the prognosis of C-IVDH in small dogs (< 15 kg) that underwent VSD with or without concomitant VF and test our hypothesis that concomitant VF might predispose to recurrence in adjacent vertebral segments in small dogs, we conducted a retrospective study of data extracted from medical records.

Materials and Methods

Case selection

This study included 303 dogs each weighing < 15 kg that presented to YPC Tokyo Animal Orthopedic Surgery Hospital between January 2007 and December 2020, were diagnosed with C-IVDH, treated with VSD, and survived 30 months after surgery. All owners provided written informed consent for treatment before dogs underwent surgery. Diagnosis was based on each dog's history, clinical signs, radiography, MRI, and CT. All 303 patients underwent MRI and CT. The MRI included IV paramagnetic contrast administration to identify lesions. Because CT was used as an aid to determine slot size at surgery, myelography with subarachnoid contrast injection was not performed.

Cervical myelopathy grade

Cervical myelopathy grade (CMG) severity was evaluated before and after surgery according to the methods reported by Rossmeisl et al.[16] CMG was classified on a 5-point scale: grade 1 (G1), no gait ataxia but neck pain, hypersensitivity, or neck contractures; grades 2 and 3 (G2 and G3), ability to walk independently without assistance with mild to moderate gait disturbance; grade 4 (G4), nonambulatory quadriplegic or quadriplegic but without respiratory impairment; and grade 5 (G5), neuropathic respiratory impairment or complete quadriplegia with respiratory failure.

Diagnostic imaging

Scans were performed under general anesthesia with an 80-row/160-slice CT system (Aquilion PRIME; Toshiba Medical Systems) and Brivo MR 355 Inspire 1.5 T MRI system (GE Healthcare Japan). T2-weighted sagittal images were taken with a slice thickness of 2.0 mm, slice spacing of 0.4 mm, repetition time of 2,800 milliseconds, and echo time of 82 milliseconds. T2-weighted transverse images were taken with a slice thickness of 2.5 mm, slice spacing of 0.5 to 1.5 mm, repetition time of 3,400 milliseconds, and echo time of 85 milliseconds. The degree of disc degeneration between the vertebrae adjacent to the treatment area was assessed using T2-weighted midsagittal section images and classified according to the Pfirrmann classification used in human medicine.[17,18] Open-source medical imaging software (OsiriX; Pixmeo) was used to analyze the images.

Anesthesia and surgery

All patients received IV atropine sulfate (0.02 mg/kg) and midazolam (0.2 mg/kg) as a preanesthetic, followed by propofol (4 to 8 mg/kg) and endotracheal intubation. Anesthesia was maintained using sevoflurane in oxygen (2.5% to 3%). Cefazolin (20 mg/kg, IV) was administered 20 minutes before and after surgery. Continuous IV fentanyl (1 to 10 µg/kg/min) was administered intraoperatively.

VSD was performed using an operating microscope (X 8.5 magnification; OPMI pico S100; Carl Zeiss Meditec AG). Slot creation was performed using an ultrasonic aspirator (Sonopet UST-2001; Stryker Japan) and a round bur. At the beginning of slot creation, a shallow slot was created in the vertebral body using an ultrasonic aspirator until the trabecular bone was exposed to prevent the round bur from rebounding against the cortical bone and engulfing the surrounding soft tissue. After trabecular bone was exposed, the slot was gradually enlarged using a round bur, taking care not to narrow the dorsal side of the slot and create a conical shape. If persistent bleeding from the trabecular bone was observed, hemostatic treatment was performed using an ultrasonic aspirator at key points to ensure an adequate field of view. After ventral longitudinal ligament removal, the herniated disc material was carefully removed using a nerve hook and graspers. The spinal dura mater was then visually examined. If no disc material remained around the slot, the removal of disc material was judged to be sufficient and the VSD was completed. The tip diameter of the ultrasonic aspirator used was 2.8 mm. Therefore, if the vertebral width was expected to be < 8.4 mm or the slot width to be created was < 2.8 mm based on the prior CT examination, the slot was created using only a round rod without using an ultrasonic aspirator. The criteria for the slot width to be created were planned approximately preoperatively based on size, location, and herniation types (disc extrusions or protrusions), as confirmed using CT/MRI. For disc extrusions, the goal was to ensure that all herniated disc material was removed. Therefore, we decided in advance to use VF even when the transverse diameter of the herniated disc material was > 33% of the vertebral width, because the technique was intended to create a slot with a width equivalent to the transverse diameter of the herniated disc material, measured using MRI. For disc protrusions, the herniation protrusion width was measured using MRI and the same criteria were used to determine whether VF was used **(Figure 1)**. In other cases, even cases where it was anticipated in advance that the slot volume would not exceed 33% of the vertebral body width, priority was given to removing the disc material between the intervertebral disc space and the dorsal aspect of the slot, and the slot volume was enlarged, as necessary. VF was combined with VSD when the slot volume exceeded 33% of the vertebral body width, resulting from expansion of the slot volume. Metal implants and polymethylmethacrylate (PMMA) were used for fixation.[12] Two or 3 titanium screws were used for each vertebra, with screw diameters of 1.5 mm (SophiaTech; Platon Japan), 2.0 mm, or 2.4 mm (both Matrix Mandible; DePuy Synthes Japan VET) depending on the size of the vertebra **(Figure 2)**.

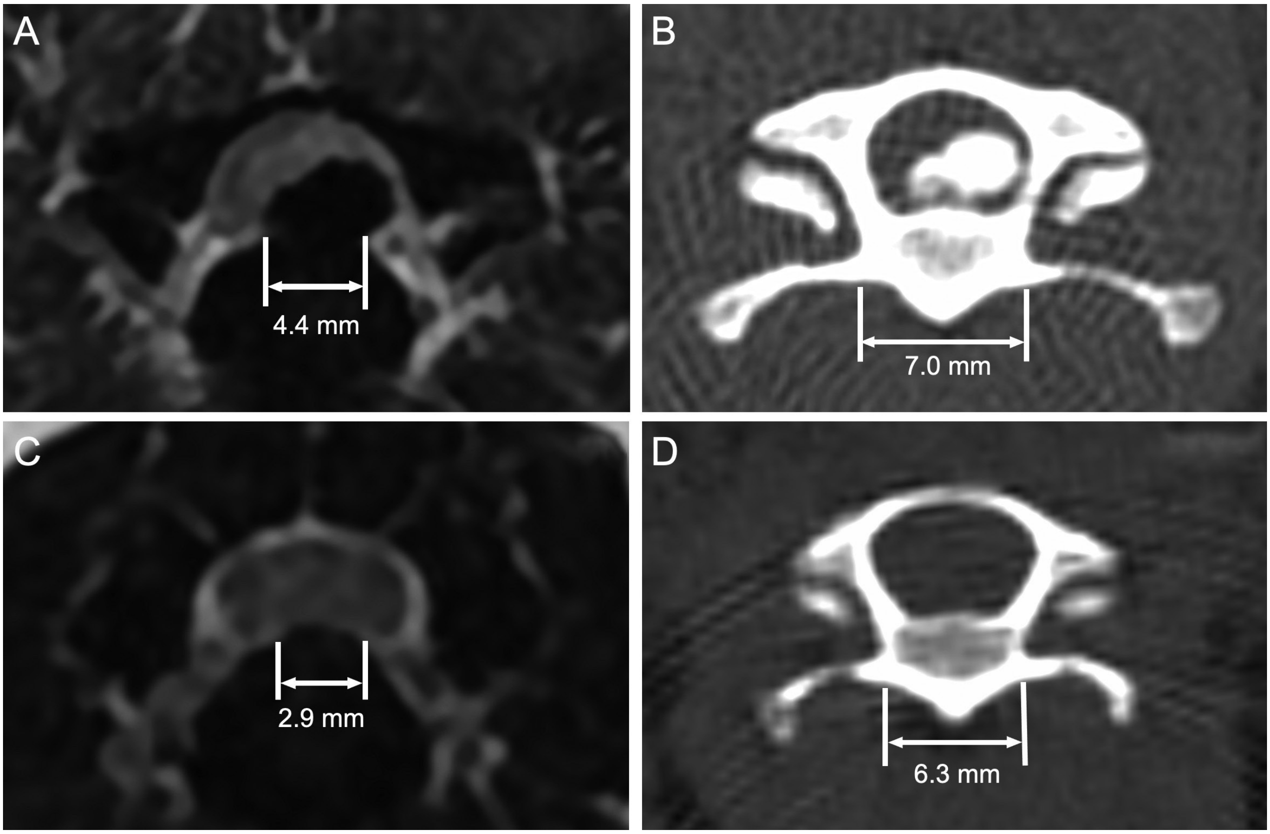

Figure 1—Example of slot width measurement method using MRI images and vertebral width measurement method using CT images. Transverse T2-weighted MRI images of the cervical spine obtained before contrast administration (A) and CT images (B) in a 5-year-old 4.2-kg Pekingese with disc extrusion. Transverse T2-weighted MRI images of the cervical spine obtained before contrast administration (C) and CT images (D) in a 10-year-old 3.2-kg Yorkshire Terrier with disc protrusion. The transverse width (= slot width) of the herniated disc material in the Pekingese was 4.4 mm and the vertebral width was 7.0 mm, and vertebral fixation (VF) was combined because the slot width was 62.8% (> 33.3%) of the vertebral width. The transverse width (= slot width) of the herniation protrusions in the Yorkshire Terrier was 2.9 mm and the vertebral width was 6.3 mm, and VF was combined because the slot width was 46.0% (> 33.3%) of the vertebral width.

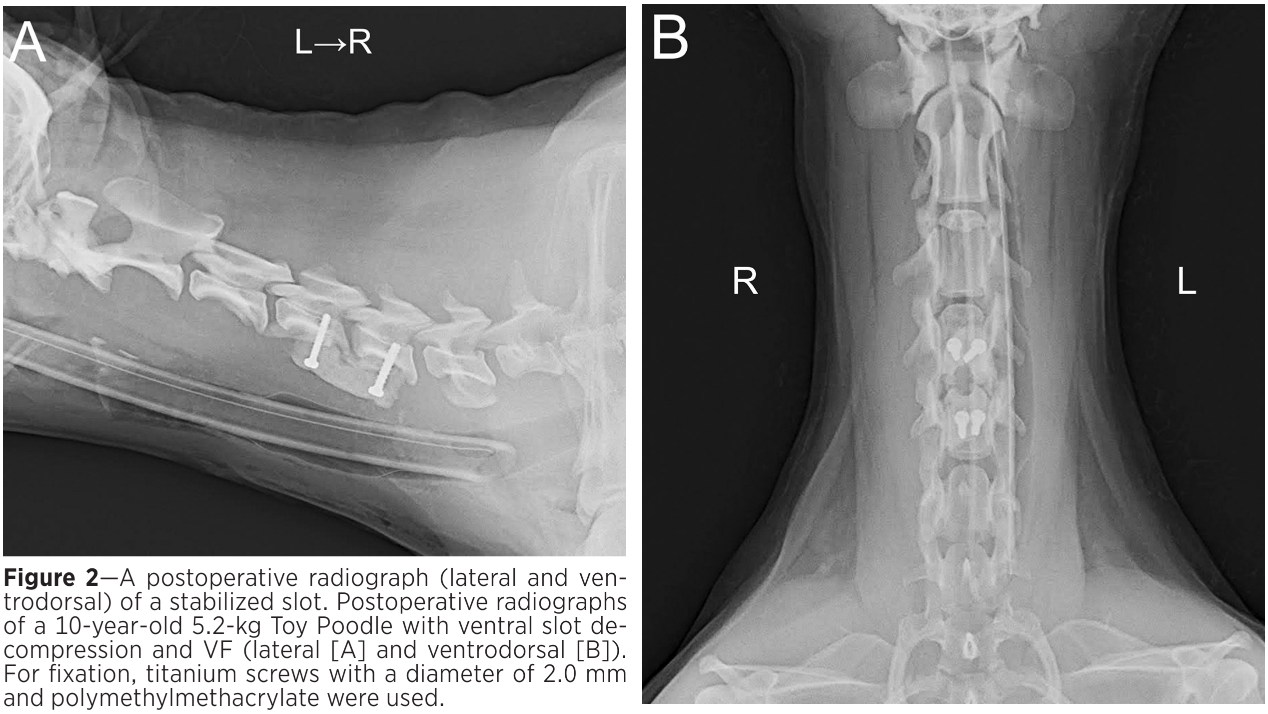

Figure 2—A postoperative radiograph (lateral and ventrodorsal) of a stabilized slot. Postoperative radiographs of a 10-year-old 5.2-kg Toy Poodle with ventral slot decompression and VF (lateral [A] and ventrodorsal [B]). For fixation, titanium screws with a diameter of 2.0 mm and polymethylmethacrylate were used.

A surgical loupe (X 2.5 magnification) was used during VF implant insertion. After screw insertion, VF was performed using PMMA after covering the ventral aspect of the slot with free fat to prevent the flow of PMMA into the slot. The amount of PMMA was adjusted so that the inserted screw was fully embedded, and the longus colli muscle was sutured. To prevent damage to the surrounding soft tissue from the heat generated during PMMA polymerization, refluxing was continued in sterile saline at 4 °C for approximately 15 minutes until polymerization was complete. The surgical field was carefully cleaned, and the wound was closed.

Postoperative management

All dogs were hospitalized for approximately 1 week after surgery. The day after surgery, all animals received prednisolone (1.0 mg/kg/d) subcutaneously and continuous crystalloid infusion. From postoperative day 2, prednisolone (0.5 to 1.0 mg/kg, once daily) was administered SC or PO for 2 to 7 days, depending on the clinical signs. Cefazolin sodium (20 mg/kg, twice daily) was administered by IV or cephalexin (20 mg/kg) PO twice a day for 2 weeks postoperatively. Patients able to walk postoperatively were kept on strict cage rest. In patients with tetraplegia after surgery, a urethral catheter was placed to facilitate continuous urinary drainage to prevent dysuria or contamination of the perineum by urination. To prevent pressure ulcers, the patient was repositioned 4 times a day and actively massaged. Daily neurological assessments were performed during hospitalization. After discharge, activity restriction was prescribed for 8 weeks, with regular checkups at 2 weeks; 1, 3, and 6 months; 1 year; and every year thereafter. Routine checkups included radiography of the surgical site and neurological assessments.

Outcome

Recovery was defined as postoperative improvement in the severity of CMG. Recurrence was defined as worsening of CMG severity once recovery was achieved, and C-IVDH in another intervertebral disc space was revealed by MRI. The time to recurrence was defined as the time between the first surgery and the next visit when clinical signs reappeared. VF can cause disc degeneration and adjacent segment pathology (ASP) on the cranial or caudal side of the treated intervertebral region; when ASP causes clinical signs, it is termed adjacent segment disease. Because adjacent segment disease reportedly occurs between 8 months and 30 months postoperatively, we selected patients who underwent checkups at 30 months postoperatively. Patients without recurrence after 30 months were recorded as having no recurrence.[5,8–10]

Statistical analysis

Statistical analyses were performed using Stata version 14 (StataCorp LLC). With recovery and relapse as the objective variables, a single regression analysis was performed for each item, and multiple regression analysis was performed for strongly related items. The study parameters included sex, age, body weight, CMG severity, surgical site, degree of disc degeneration (Pfirrmann score), concomitant VF, recovery, recurrence, site of recurrence, number of days between surgery and recovery, and number of days between recovery and recurrence. Miniature Dachshunds, Beagles, French Bulldogs, Shih Tzus, Miniature Schnauzers, and Pekingese are considered CDBs.[19] Other breeds were considered NCDBs. Sex was categorized as intact male, neutered male, intact female, or spayed female. Age (years) and weight (kg) were recorded at the time of the surgery. Multivariate logistic regression analysis was performed to examine factors associated with postoperative recovery and recurrence. Postoperative recovery and recurrence were objective variables, and breed, sex, age, weight, affected disc, CMG severity, concomitant VF, days to recovery, and time to recurrence were explanatory variables. ORs and their 95% CIs were calculated for each variable. Statistical significance was set at $P < .05$.

Results

Cases

We evaluated 303 dogs (age, 9.0 ± 3.0 years; weight, 5.9 ± 3.1 kg): 80 (26.4%) were Miniature Dachshunds, 39 (12.9%) Chihuahuas, 32 (10.6%) Toy Poodles, 29 (9.6%) Yorkshire Terriers, 25 (8.3%) French Bulldogs, 18 (5.9%) Shih Tzus, 17 (5.6%) Miniature Pinschers, 15 (5.0%) Beagles, 14 (4.6%) mixed breeds, and 34 (11.2%) other breeds **(Table 1)**.

Table 1—Breakdown of dog breeds in the vertebral fixation (VF) and no vertebral fixation (nVF; ventral slot decompression alone) groups.

VF Breed	n (%)	**nVF** Breed	n (%)
Chihuahua	31 (19.9)	Miniature Dachshund	66 (44.9)
Toy Poodle	26 (16.7)	Shih Tzu	13 (8.2)
Yorkshire Terrier	22 (14.1)	French Bulldog	11 (7.5)
French Bulldog	14 (9.0)	Chihuahua	8 (5.4)
Miniature Dachshund	14 (9.0)	Beagle	8 (5.4)
Miniature Pinscher	11 (7.1)	Yorkshire Terrier	7 (4.8)
Mixed	8 (5.1)	Miniature Pinscher	6 (4.1)
Beagle	7 (4.5)	Mixed	6 (4.1)
Shih Tzu	5 (3.2)	Toy Poodle	6 (4.1)
Other	18 (11.5)	Other	16 (11.6)
Total	**156 (100)**	**Total**	**147 (100)**

There were 115 (38.0%) neutered males, 95 (31.4%) intact males, 61 (20.1%) spayed females, and 32 (10.6%) intact females.

Of 303 dogs, 156 (51.5%) had concomitant VF (VF group) and 147 (48.5%) had VSD alone (nVF group). The breakdown of each group by breed is shown (Table 1). In the VF group, 53 (34.0%) dogs were CDBs (9 breeds) and 103 (66.0%) were NCDBs (30 breeds). In the nVF group, 99 (67.3%) dogs were CDBs (8 breeds), and 48 (32.7%) were NCDBs (15 breeds).

Demographics

The VF group included 40 intact males, 69 neutered males, 16 intact females, and 31 spayed females, whereas the nVF group included 54 intact males, 47 neutered males, 16 intact females, and 30 spayed females. The mean age of the VF group was 8.9 ± 2.8 years (range, 1.7 to 14.8 years); the mean age of the nVF group was 9.2 ± 3.1 years (range, 2.3 to 14.2 years). Peak onset occurred at the age of 9 years **(Figure 3)**.

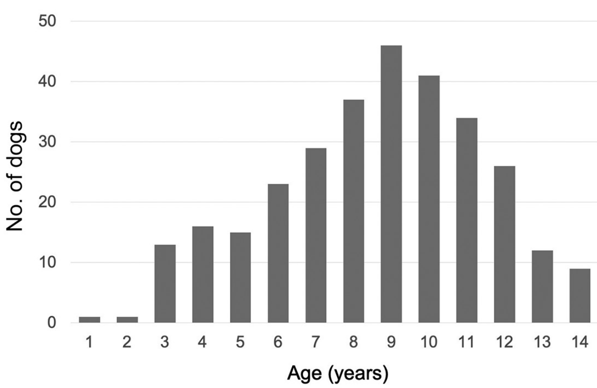

Figure 3—Dog age at time of surgery.

The mean body weight for the VF group was 5.4 ± 3.3 kg (range, 1.6 to 14.9 kg); mean body weight of the nVF group was 6.5 ± 2.8 kg (range, 2.1 to 14.8 kg). The χ^2 test and Student *t* test results were not significant for between-group differences for gender, age, or weight (χ^2 test, $P = .14$ for gender; Student *t* test, $P = .34$ for age and $P = .13$ for weight).

Affected intervertebral sites

In the VF group, the affected intervertebral disc space was C2–C3 in 25 (16.0%) cases, C3–C4 in 45 (28.8%) cases, C4–C5 in 43 (27.6%) cases, C5–C6 in 27 (17.3%) cases, C6–C7 in 15 (9.6%) cases, and C7–T1 in 1 (0.6%) case. In the nVF group, the affected intervertebral disc space was C2–C3 in 29 (19.7%) cases, C3–C4 in 34 (23.1%) cases, C4–C5 in 36 (24.5%) cases, C5–C6 in 37 (25.2%) cases, C6–C7 in 10 (6.8%) cases, and C7–T1 in 1 (0.7%) case. A χ^2 test revealed that the between-group difference for affected site was not significant ($P = .14$).

Degeneration of the adjacent intervertebral discs

A Pfirrmann score was assigned on the basis of MRI results in all 303 cases. In the VF group, Pfirrmann scores at the adjacent intervertebral space (cranial side / caudal side) were as follows: 1 (25 discs, 8.7% / 30 discs, 10.5%), 2 (29 discs, 10.1% / 34 discs, 11.8%), 3 (51 discs, 17.8% / 57 discs, 19.9%), 4 (20 discs, 6.6% / 25 discs, 8.7%), and 5 (6 discs, 2.1% / 10 discs, 3.5%). In the nVF group, Pfirrmann scores at the adjacent intervertebral space (cranial side / caudal side) were as follows: 1 (16 discs, 6.0% / 21 discs, 7.9%), 2 (24 discs, 9.1% / 30 discs, 11.3%), 3 (51 discs, 19.2% / 58 discs, 21.9%), 4 (21 discs, 7.9% / 26 discs, 9.8%), and 5 (7 discs, 2.6% / 11 discs, 4.2%). The χ^2 test found that the between-group difference for degeneration of adjacent discs was not significant ($P = .08$).

Cervical myelopathy grade

In the VF group, preoperative CMG was G1 in 57 (36.5%) cases, G2 in 51 (32.7%) cases, G3 in 27 (17.3%) cases, G4 in 20 (12.8%) cases, and G5 in 1 (0.6%) case. In the nVF group, preoperative CMG was G1 in 43 (29.3%) cases, G2 in 58 (39.5%) cases, G3 in 20 (13.6%) cases, and G4 in 26 (17.7%) cases. The χ^2 test found that the between-group difference for CMG was not significant ($P = .13$).

In the VF group, CMG at 30 months after surgery was G0 in 146 (93.6%) cases, G1 in 3 (1.9%) cases, G2 in 5 (3.2%) cases, and G3 in 2 (1.3%) cases. In the nVF group, CMG at 30 months after surgery was G0 in 138 (93.9%) cases, G1 in 4 (2.7%) cases, G2 in 2 (1.3%) cases, G3 in 2 (1.3%) cases, and G4 in 1 (0.7%) case.

Recovery rates were 95.5% (n = 156) in the VF group and 96.0% (147) in the nVF group. There was no significant difference between the 2 groups in terms of recovery rate ($P = .79$). The median (range) time to recovery was 2.2 days (1 to 16 days) in the VF group and 2.7 days (1 to 23 days) in the nVF group. There were no significant differences between the 2 groups in terms of days to recovery ($P = .85$).

Recurrence

Thirteen cases had recurrent signs of C-IVDH within 30 months of the initial surgery. The recurrence rates were 4.7% (n = 7) in the VF group and 4.3% (6) in the nVF group. There was no significant difference in recurrence rate between the 2 groups ($P = .79$). The median (range) number of days to recurrence was 539 days (241 to 788 days) in the VF group and 562 days (266 to 792 days) in the nVF group. There was no significant difference between the 2 groups in terms of days to recurrence ($P = .75$).

The recurrence sites were 6 adjacent intervertebral discs and one other intervertebral disc in the VF group and 6 adjacent intervertebral discs in the nVF group. In the VF group, 1 case was caudal to C3–C4, 1 case was cranial to C4–C5, 2 cases were caudal and 1 case was cranial to C5–C6, and 1 case was cranial to C6–C7. In another case of recurrence in nonadjacent intervertebral discs, the C5-6 intervertebral space was treated, and recurrence was in the C3-4 intervertebral space. The nVF group had 2 cases cranial to C4–C5 and 3 cases caudal and 1 case cranial to C5–C6. The preoperative Pfirrmann score result was 3 in all 12 cases with recurrence in the adjacent intervertebral space and 1 case with recurrence in nonadjacent intervertebral discs. The signalment,

Table 2—Multivariate logistic regression analysis with recovery as outcome.

Variable	Dogs with recovery, n (%)	Dogs without recovery, n (%)	Estimate coefficients and OR of risk factors by logistic regression analysis for recovery			
			SE	*P* value	OR	95% CI
VF						
No	141 (95.7)	6 (4.3)				
Yes	149 (94.9)	7 (5.1)	0.663	.786	1.167	0.383–3.556
Sex						
Intact male	90 (95.7)	4 (4.3)				
Castrated male	109 (94.0)	7 (6.0)	0.291	.218	0.453	0.129–1.597
Intact female	32 (100)	0 (0)	0.422	.407	0.406	0.480–3.430
Spayed female	59 (96.7)	2 (3.3)	0.227	.149	0.210	0.251–1.747
Age, per 1-y increase			0.119	.197	1.144	0.932–1.403
Breed						
CDB	148 (97.4)	4 (2.6)				
NCDB	142 (94.0)	9 (6.0)	4.582	.023*	5.893	1.283–27.055
Grade						
1	97 (97.0)	3 (3.0)				
2	106 (97.2)	3 (2.8)	0.543	.506	0.441	0.394–4.973
3	43 (91.5)	4 (8.5)	5.944	.019*	7.098	1.374–36.641
4	43 (93.5)	3 (6.5)	3.227	.042*	3.464	0.558–21.498
5	1 (100)	0 (0)	—	—	—	—
Surgical site						
C2–C3	54 (100)	0 (0)				
C3–C4	76 (96.2)	3 (3.8)	2.250	.575	1.925	0.195–19.014
C4–C5	74 (93.7)	5 (6.3)	4.954	.168	4.521	0.528–38.717
C5–C6	60 (93.8)	4 (6.2)	2.045	.686	1.650	0.145–18.720
C6–C7	24 (96.0)	1 (4.0)	3.110	.590	2.166	0.130–36.121
C7–T1	2 (100)	0 (0)	—	—	—	—

CDB = Chondrodystrophic breed. NCDB = Nonchondrodystrophic breed.
*Difference is statistically significant. Statistical significance set at $P < .05$.

Table 3—Multivariate logistic regression analysis with recurrence as outcome.

Variable	Dogs without recurrence, n (%)	Dogs with recurrence, n (%)	Estimate coefficients and OR of risk factors by logistic regression analysis for recurrence			
			SE	*P* value	OR	95% CI
VF						
No	135 (95.7)	6 (4.3)				
Yes	142 (95.3)	7 (4.7)	0.663	.786	1.166	0.382–3.556
Sex						
Intact male	85 (94.4)	5 (5.6)				
Castrated male	105 (94.6)	6 (5.4)	0.530	.757	0.818	0.230–2.914
Intact female	31 (100)	0 (0)	—	—	—	—
Spayed female	56 (96.6)	2 (3.4)	0.698	.924	0.931	0.214–4.044
Age, per 1-y increase			0.287	.001**	1.791	1.305–2.456
Breed						
CDB	140 (95.9)	6 (4.1)				
NCDB	137 (95.1)	7 (4.9)	0.672	.768	0.627	0.388–3.605
Grade						
1	92 (95.8)	4 (4.2)				
2	99 (95.2)	5 (4.8)	1.122	.580	1.509	0.351–6.484
3	43 (95.6)	2 (4.4)	1.825	.351	2.182	0.423–11.243
4	42 (95.5)	2 (4.5)	1.386	.669	1.488	0.240–9.231
5	1 (100)	0 (0)	—	—	—	—
Surgical site						
C2–C3	52 (100)	0 (0)	—	—	—	—
C3–C4	73 (96.1)	3 (3.9)	0.730	.667	0.585	0.509–6.737
C4–C5	71 (93.4)	5 (6.6)	1.921	.631	1.714	0.191–15.418
C5–C6	57 (93.4)	4 (6.6)	2.243	.537	2.001	0.222–18.025
C6–C7	22 (95.7)	1 (4.3)	0.978	.515	1.398	0.316–2.883
C7–T1	2 (100)	0 (0)	—	—	—	—

See Table 2 for key.
**Difference is statistically significant. Statistical significance set at $P < .01$.

neurologic grade, and recurrence time results for the 13 cases with recurrence were as follows: dogs with C-IVDH recurrence in the VF group (7 dogs) were of 5 different breeds (median age, 10.5 years; range, 7.8 to 12.3 years; median weight, 5.3 kg; range, 1.8 to 8.4 kg), with a median value of neurologic grade 2 (range, 1 to 4) and a median recurrence time of 18 months (range, 8 to 26 months). Dogs with C-IVDH recurrence in the nVF group (6 dogs) were of 4 different breeds (median age, 9.5 years; range, 6.4 to 10.4 years; median weight, 6.5 kg; range, 5.7 to 9.8 kg), with a median value of neurologic grade 3 (range, 2 to 4) and a median recurrence time of 16 months (range, 9 to 26 months).

Multivariate logistic regression

NCDBs had a significantly lower recovery rate than did CDBs ($P = .023$) and a significantly lower recovery rate when CMG severity was G3 ($P = .019$) or G4 ($P = .042$) than when CMG severity was G1. Other factors, including VF, had no significant effect on recovery rates **(Table 2)**. Increasing age was significantly associated with recurrence ($P = .001$), but other factors, including VF, had no significant effect on recurrence rates **(Table 3)**.

Discussion

The clinical efficacy of VSD in dogs with C-IVDH has been demonstrated in numerous clinical studies, with recovery rates of 65% to 96%.[2,4,5] However, when the slot has been excessively large, postoperative complications such as intervertebral dislocation, fractures, and associated recurrence of spinal cord disorders may occur, and concomitant VF is recommended.[6,7] This study of small dogs with C-IVDH showed high recovery and low recurrence rates for VSD both with and without concomitant VF. Our results showed that recovery and recurrence rates were similar after VSD with and without concomitant VF. Of the 12 dogs with recurrence in the adjacent intervertebral region, half had VSD only, and the other half had VF and VSD. Previous reports suggested that ASP can occur with bony fusion in the intervertebral region where the VSD was performed, albeit this was in large dogs with caudal cervical spondylomyelopathy,[5,9] which has been confirmed in long-term follow-up studies using MRI.[20] Although ASP does not necessarily induce C-IVDH recurrence, most recurrences in small dogs in this study occurred in the adjacent intervertebral region, suggesting that VSD might have a biomechanical effect on the adjacent intervertebral region, not only in large dogs but also in small dogs. The risk of C-IVDH recurrence in adjacent intervertebral segments has also been noted in large-breed dogs with C-IVDH that undergo VF. In a report on C-IVDH in large dogs, Bruecker et al found recurrence in adjacent intervertebral segments in 66% of VF cases between 8 and 30 months postoperatively.[9] However, this study of C-IVDH in small dogs found no difference in recurrence in adjacent intervertebral segments between the VF and nVF groups. This difference in results may suggest that ASP due to VF may be mild in small dogs compared with large dogs and may not have a significant effect on recurrence in adjacent intervertebral segments. Therefore, in VSD for small dogs with C-IVDH, when the slot volume is larger than recommended, the use of VF does not appear to increase the risk for recurrent disc herniation in the adjacent intervertebral space, even with concomitant VF.

Our results showed that NCDBs had a significantly lower recovery rate than CDBs and that CMG of severity G3 and G4 had worse recovery rates than CMG of severity G1. Disc extrusions occur more frequently in CDBs, whereas disc protrusions occur in older dogs of both CDBs and NCDBs.[13–15] Clinically, CMG in C-IVDH is generally less severe in NCDBs than in CDBs.[21,22] However, disc protrusions can induce Wallerian degeneration of the spinal cord white matter due to chronic spinal cord compression and permeability disorders. When this occurs, the degenerative effects can persist postoperatively even if spinal cord compression is relieved; thus, there may be poor improvement after surgical treatment.[23] In the present study, we did not determine whether the herniated discs arising in NCDBs were disc extrusions or protrusions, but NCDBs that have a predilection for disc protrusions might have a lower postoperative recovery rate than do CDBs. With respect to preoperative CMG severity, our results were similar to those of previous reports, in which higher preoperative CMG severity is associated with a poorer postoperative recovery rate regardless of breed. Our results revealed that increasing age is also a risk factor for C-IVDH recurrence after VSD surgery. Intervertebral disc degeneration progresses with age, and C-IVDH usually results from disc degeneration.[13] Although disc degeneration is a common finding in clinically normal dogs,[24,25] when changes are observed in the vertebral endplates, the likelihood of disc disease in the adjacent disc increases.[26] Therefore, it can be inferred that older dogs with C-IVDH are more likely to have disc degeneration in the adjacent intervertebral region and age-related changes in the vertebral endplates, increasing the risk for C-IVDH to recur. The Pfirrmann score is widely used in human medicine for scoring disc degeneration and is suitable for scoring in dogs.[27] We found 12 C-IVDH recurrences in discs adjacent to the treatment area, all of which had Pfirrmann scores of 3 on the first MRI scan. A score of 3 indicates that the distinction between the nucleus pulposus and fibrous ring is unclear on T2-weighted MRI, but the contour of the intervertebral disc is visible and the intervertebral space is maintained.[17,18,27] The degenerative process of the intervertebral disc affects the stability of the intervertebral region. This process can be divided into 3 phases: inflammation, destabilization, and restabilization.[28] Therefore, a score of 3 can indicate the most unstable state in the degenerative process, where the function of the disc is maintained before stabilization. Surgical procedures in the adjacent intervertebral region might have mechanical effects in the same area, triggering C-IVDH recurrence. It was also considered that nucleus pulposus with Pfirrmann grade 3 degeneration might be susceptible to the mechanical environment of the adjacent vertebral structure.

This study had several limitations. First, as this was a retrospective study of clinical cases, follow-up CT/MRI was performed only in cases with evidence of recurrence of clinical signs and when the owner agreed to surgery. Long-term follow-up and repeat CT/MRI scans are needed to assess the development of C-IVDH after VSD and VF; however, it is an ethical challenge to perform another CT/MRI scan in cases without clinical signs suggestive of recurrence. We also only evaluated the patients' basic physical information, CMG severity, affected region, and degree of disc degeneration as factors involved in the recurrence and recovery of C-IVDH after VSD surgery, without considering the presence of spondylosis deformans or the degree of spinal cord compression in the treated intervertebral region. In addition, the screw diameter varied; the selection criterion was the largest screw size that could be inserted into the vertebral body, but there was no absolute indicator. Additionally, there might have been differences in the amount of PMMA used for VF among the individual cases. In this study, we used the amount of bone cement that we judged would not cause problems when suturing the cervical longissimus, which might have resulted in differences in the stiffness of the intervertebral region after VF.

No differences in recovery or recurrence rates were observed in small dogs with C-IVDH that underwent VSD with or without concomitant VF. Cases of C-IVDH in small dogs are often encountered in which extruded disc material cannot be retrieved within the limited slot range associated with their small vertebral body size. Our results suggest that slot volume could be increased and VF could be applied in combination with VSD to sufficiently remove disc material in small dogs with C-IVDH without increased risk for adjacent, recurrent C-IVDH.

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