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Post-surgical outcome and recurrence rates in thoracolumbar arachnoid diverticula undergoing durotomy alone or alongside a modified technique of subdural shunt-placement in dogs

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Abstract

Objective: The aims of this study were two-fold. First, to describe a modified technique of subdural shunt (SDS) placement for canine thoracolumbar arachnoid diverticula (TL-AD). Second, to compare outcome and recurrence of dogs following durotomy and debridement of meningeal attachments alone or in combination with SDS.

Animals: A total of 27 surgically managed TL-AD affected dogs.

Study design: Retrospective non-randomized descriptive case series.

Methods: Magnetic resonance imaging (MRI) TL-AD diagnosed dogs undergoing surgery, with 4–8 weeks postoperative recheck and follow-up time of >6 months. Two groups were compared: a control group, where durotomy and debridement of subdural adhesions alone was performed; a shunting group (SG) where SDS was utilized. The surgical technique was adapted from Meren et al., differing in access (hemilaminectomy), incision shape (longitudinal) and no suturing of the SDS or dura.

Results: A total of 12 dogs were included in the control group and 14 in the SG. One case, excluded, developed suspected postoperative surgical infection that resolved when the SDS was removed. Immediate postoperative and short-term outcome was not significantly different between groups. In the SG, long-term outcome was significantly better with dogs having improved neurologically (85.7% vs. 41.7%), and the rate of recurrence was lower (14.3%

Abbreviations: AD, arachnoid diverticulum/a; MRI, magnetic resonance imaging; SDS, subdural shunt; TL-AD, thoracolumbar arachnoid diverticulum/a.

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vs. 41.7%) although this last difference was not statistically significant (p = .19). Recurrence occurred at a median of 36 months from surgery (9–62), 5/7 recurrent cases were Pugs.

Conclusion: The adapted technique was successful in addressing TL-AD associated neurological signs in the long-term, as well as reducing recurrence of TL-AD.

Clinical significance: Shunt-placement appears to have a positive role in outcome and possibly recurrence prevention in cases of TL-AD.

1 | INTRODUCTION

Arachnoid diverticulum (AD) is the localized abnormal dilation of the subarachnoid space with accumulation of fluid, causing compressive myelopathy leading to alterations of cerebrospinal fluid flow and neurological dysfunction.[1–5] Long recognized,[6,7] it has been known by several names including spinal meningeal cyst, meningeal cyst, arachnoid cavitation, arachnoid pseudocysts, spinal intradural arachnoid cysts, and arachnoid or subarachnoid cysts.[5] Etiology for AD is elusive, with congenital and acquired forms having been reported although several possibilities have been indicated including AD being a congenital defect, developing secondary to biomechanical factors, trauma or hemorrhage, or presenting subsequently or concurrently to previous spinal disorders such as intervertebral disc extrusion or inflammatory disorders.[3,5]

Several surgical techniques are available for the management of AD and it is still a matter of debate which one is preferable. Surgical techniques include durotomy alone, durectomy alone, durotomy combined with intra-arachnoid shunt placement, durotomy and/or durectomy combined with marsupialization and durotomy combined with stabilization. In all techniques the meninges are incised and debridement of meningeal adhesions is performed.[8–13] Improvement after surgery is typically reported and surgery is considered superior to conservative management in AD.[13,14] Nonetheless, recurrence and reformation of an arachnoid diverticulum postoperatively is a recognized problem, with rates reported from 20% to as high as 86%, the latter reported specifically in Pugs up to 12 months (or later) postoperatively.[2,15,16] To date, no surgical techniques have proved superior in reducing the rate of AD recurrence.

Subdural shunt (SDS) placement specifically was first described over 5 years ago, initially for the management of constrictive myelopathy. Constrictive myelopathy also termed meningeal fibrosis, presents similarities to AD, being described as an acquired, circumferential constriction of the spinal cord that is presumed to develop secondary to pia-arachnoid fibrosis.[9,17–19] Nonetheless, it is currently considered a distinct condition with characteristic imaging features, and hypothesized to have a worse long-term prognosis and higher recurrence rate than arachnoid diverticula.[9,18–21] Despite having been developed for a different condition, there are increasing accounts of SDS usage in the management of AD.[13,22] It has been suggested that shunt placement could act as a stent to prevent future recurrence or provide a conduit for cerebrospinal fluid (CSF) flow and potentially prevent recurrence, at least in cases of constrictive myelopathy.[9] There is currently no data on long-term outcome or recurrence rates when SDS placement is employed in arachnoid diverticulum surgery.[13]

The aims of this study were two-fold. First, to describe a modified technique of shunt-placement for dogs with thoracolumbar arachnoid diverticulum (TL-AD), based on the previously reported Meren et al.[9] technique. Second, to compare the outcome and recurrence rates of dogs managed surgically with durotomy and debridement of meningeal attachments alone or in combination with subdural shunting placement.

2 | MATERIALS AND METHODS

2.1 | Animals

This was a retrospective non-randomized descriptive case-series study. Ethical approval was provided by the CVS Ethical Review Committee (CVS-2023-103). Medical records of dogs diagnosed with TL-AD at Dovecote Veterinary Referrals and Hospital Referência Veterinário Montenegro between February 2016 and July 2024 were reviewed.

Inclusion criteria for TL-AD cases were dogs presenting consecutively with: (1) a suspected thoracolumbar myelopathy; (2) diagnosis of TL-AD based on thoracolumbar magnetic resonance imaging (MRI); (3) surgical treatment by means of a hemilaminectomy, durotomy and debridement of subdural adhesions alone or alongside subdural shunting; (4) a minimum of a 4 to 8 weeks postoperative recheck neurological assessment and a total follow-up time of >6 months post-surgery. MRI diagnosis of TL-AD was based on characteristic MRI features indicative including a combination of: (1) enlargement or dilation of the subarachnoid space causing a compressive myelopathy; (2) enlargement with MRI intensity of hypertense on T2w and hypointense on T1w compatible with a CSF filled dilation.[13,15] Cases in which MRI features were compatible with constrictive myelopathy were excluded.[18,20,23]

Depending on the surgical technique, two groups were devised for comparison. The control group, included cases managed surgically with durotomy and debridement of subdural adhesions alone. The shunting group included cases managed surgically with durotomy and debridement of subdural adhesions with SDS. Individual surgical technique selection was based on performing clinician preference and therefore not randomized. All surgeries were performed by board-certified veterinary neurologists or ECVN residents in training. All cases undergoing durotomy with subdural shunting were performed from 2017 onwards following an adaptation of a surgical technique reported that same year.[9]

Information retrieved from the medical records included signalment, duration of clinical signs, weight, affected spinal cord region, lateralization on neurological signs, neurological grading at presentation, neurological grading the day immediately following surgery, duration of hospitalization and neurological grading at discharge. The presence of urinary and fecal continence was also recorded. Neurological grading was obtained through a previously described five-point scale: spinal hyperesthesia only (grade 1), ambulatory paraparesis and ataxia (grade 2), non-ambulatory paraparesis (grade 3), paraplegia with intact deep pain perception (grade 4), and paraplegia without deep pain perception (grade 5).[24] Specific information on the usage of steroid medication was collected, classed as given or not given, and in terms of timing if steroids were given before and/or after surgery. Following surgery, dogs were discharged with instructions for 4–6 weeks of cage rest with rehabilitation and concurrent analgesia as required. Dogs would then be allowed to gradually resume a regular exercise and routine.

2.2 | Presurgical diagnostics

All dogs underwent neurological examination by an ECVN Neurology Resident, Board-Eligible or Diplomate of the European College of Veterinary Neurology, proceeding to obtain a neurolocalization. Lateralization of the clinical signs was carefully sought by means of the neurological examination and anamnesis with the owners. Each dog underwent MRI of the thoracolumbar spinal cord (0.25 T Esaote Vet-MR Grande, Genova, Italy or 1.5 Tesla Siemens MAGNETOM Sempra, Erlanger, Germany) prior to surgery. Diagnostic features described above were used to decide surgical sites. The lateralization of the AD on imaging or lateralization of clinical signs was utilized in order to determine the side of surgery.

2.3 | Anesthesia, peri- and postoperative medication

Each dog was premedicated with methadone (0.3 mg/ kg IV), acepromazine (0.02 mg/kg IV) or medetomidine (3–5 μg/kg IV), and omeprazole (1 mg/kg IV), then induced using propofol (6–10 mg/kg IV to effect) and maintained using inhaled isoflurane. Each dog received prophylactic intraoperative cefazolin (22 mg/kg IV every 90 min from commencement of surgery until skin closure, applied a second time even in cases where surgery lasted less than 90 min). During surgery further boluses of methadone (0.1–0.2 mg/kg IV), ketamine CRI (5 μg/kg/min IV) or paracetamol (15 mg/kg IV) were given for extra pain-relief to effect. Postoperatively, each dog was hospitalized for at least 24 h, continuing to receive methadone (0.3 mg/kg IV every 4 h) and oral analgesia which included gabapentin (10–20 mg/kg orally TID) and/or meloxicam (0.1 mg/kg orally SID) or prednisolone (0.5 mg/kg orally BID). Dogs remained in the hospital until comfortable on oral medication alone, becoming ambulatory or being non-ambulatory paraparetic with independent urination or an easily expressed bladder by the owners.

2.4 | Surgical technique

Surgical technique was an adaptation of the surgical technique previously reported by Meren et al.,[9] differing in that the access to the vertebral canal was via hemilaminectomy rather than dorsal laminectomy, the dural incision was longitudinal without the extension to I-shape edges and neither the shunt tube or the dura was sutured.

Following diagnosis of TL-AD on MRI, owner consent for surgery was obtained. Dogs were positioned in sternal recumbency, and routinely prepared for aseptic spinal surgery. The spinal cord was exposed in all cases by a standard dorsolateral hemilaminectomy, performed on the side of most severe spinal cord compression based on MRI or in cases where lateralization was not clear on diagnostic imaging the hemilaminectomy was performed on the more clinically affected side. Continuous hemilaminectomy encompassed the extent of the MRI-identified lesion

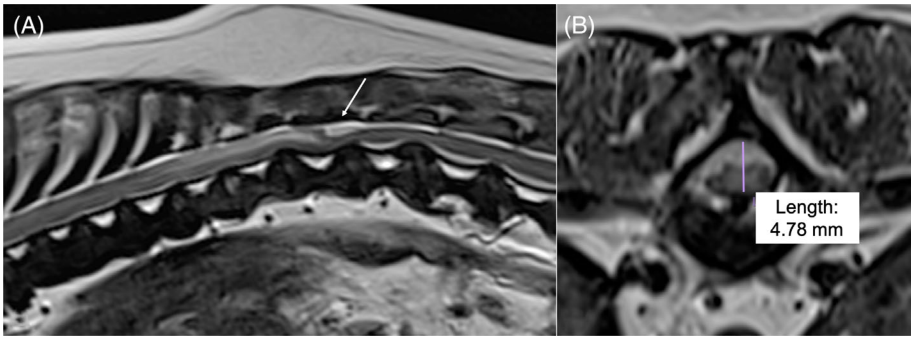

FIGURE 1 Sagittal (A) and transverse (B) T2-weighted images of an arachnoid diverticulum centered at T12–T13 (white arrow). Measurements indicated the need of a tube-shunt with a maximal 3.5 Fr size ($0.25 \times 4.78 = 1.1$ mm ≈ 3.5 Fr).

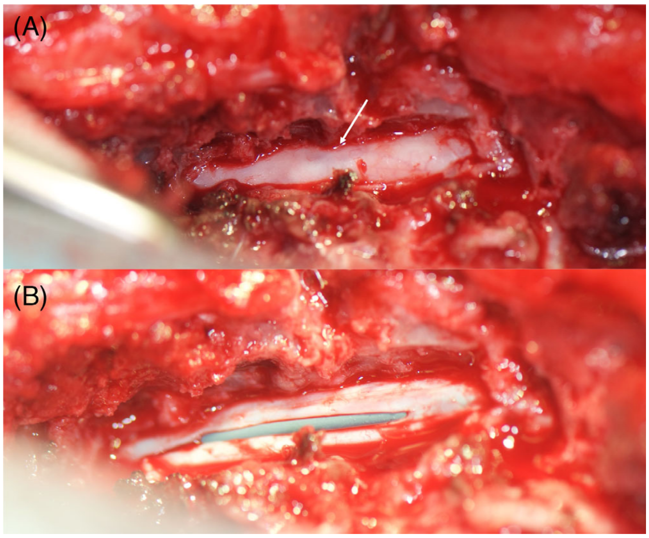

FIGURE 2 Intraoperative images with macroscopically visible blueish spinal cord coloration at the same level of the magnetic resonance imaging (MRI)-identified arachnoid diverticulum (arrow). Predurotomy (A) and post-durotomy and shunt-placement (B).

and presumed unaffected spinal cord cranial and caudal to the lesion. The lateral and dorsolateral aspect of the dura was exposed by removing epidural fat. The region of the lesion was identified macroscopically, typically characterized by a slightly blueish color when compared with unaffected dura (Figure 1). A durotomy was then performed mid-lateral across the lesion site and extending cranial and caudal to the lesion, to what the surgeon considered unaffected dura typically 5–10 mm from the cranial and caudal margins, as described by Meren et al.[9] The dura was reflected with forceps and adhesions were broken down with blunt dissection by means of a hook until the dura and arachnoid were separated from the spinal cord parenchyma throughout the durotomy length. The dural edges were not sutured together and the remainder of the closure was routine. In the control group, routine surgical closure was then performed.

In the shunting (treatment) group, a shunt-tube was placed following durotomy and debridement of adhesions, as described above. The shunt-tube consisted of a urinary Jackson catheter (Vet Direct) of appropriate diameter for the individual dog (3–4 Fr). Tube size varied depending on the size of the dog, this was defined as corresponding to a maximum of 25% of the total diameter of the spinal cord at that level (Figure 2). The tube was cut to span the length of the durotomy made, plus 5 mm on either side of the durotomy. The cranial end of the tube was passed into the cranial non-exposed subarachnoid space. During placement of the tube, CSF flow through the tube, from cranial to caudal, was sought. Subsequently, the caudal end of the tube was inserted into the caudal subarachnoid space, introducing at least 5 mm distally within the subarachnoid space. For tube manipulation, Adson non-toothed forceps were used. The dural edges were not sutured together and the remainder of the closure was routine.

2.5 | Outcome and follow-up

Three outcome categories were created: immediate postoperative, short-term and long-term.

Immediate postoperative was measured on neurological examination 24 h post-surgically during hospitalization, being defined as: (1) improved, if neurological grade decreased (e.g., 3 to 2); (2) static, if neurological grade remained the same and (3) deteriorated, if neurological grade increased. Short-term outcome was acquired from postoperative consultations with a board-certified veterinary neurologist performed within the first 4–8 weeks following surgery. Following this period of time, long-term outcome (>6 months) was obtained through telephonic interviews with the owners or history provided by the referring vets. In case of recurrence, subsequent consultations data was utilized. Surgical short or long-term outcome was defined as: (1) improved, if the owner considered the dog to be better than before surgery; (2) static, if the owners considered the dog to be the same as before surgery and (3) deteriorated, if the dog deteriorated further following surgery.

Recurrence of clinical signs attributable to AD was defined as clinical deterioration or further development of neurological signs which were not apparent at the time of short-term outcome. Newly developed neurological signs had to be identified as a non-painful thoracolumbar myelopathy, including pelvic limb ataxia, paraparesis or paraplegia or development of urinary or fecal incontinence.[25]

2.6 | Statistical analysis

Exploratory analysis of data was carried out using statistical software (SPSS 29.0). Continuous variables were assessed for normality graphically and using the Shapiro–Wilk test. Median and range are reported and differences in median values were compared using Mann–Whitney U tests. Categorical data are reported as counts and corresponding percentages. Associations between two categorical variables were assessed using χ^2 tests. If there were fewer than five dogs in a category, Fisher's exact test was used instead of a χ^2 test. Statistical significance was set at a *p*-value of less than .05.

3 | RESULTS

A total of 26 dogs were included; 12 dogs were included in the control group and 14 in the shunting group. Within the shunting group, one case initially received a shunt-tube placement but developed pyrexia (39.9°C) and worsening of neurological signs (becoming non-ambulatory paraparetic, grade 3) within 48 h from surgery. Repeat surgery for tube removal was performed, followed by improvement. Swab samples for bacterial culture and sensitivity of urine, surgical wound and vertebral canal were negative. This was interpreted as a possible suspected infection considering pyrexia and improvement on antibiotics, following shunt-tube removal. This case, a French Bulldog, was excluded from analysis as its inclusion could have biased the results. This case initially improved but developed a presumed recurrence of neurological signs 22 months later.

Details and statistical comparison between both treatment groups are described in detail in Table 1. Breed distribution was Pug (16), French Bulldog (9) and Crossbreed (1). Gender distribution was of 21 males and five females. Median age at time of diagnosis was 79.5 months (23–135). Median duration of clinical signs before presentation was of 7 weeks (1–72). Initial neurological grade was 2 in all cases but one, a grade 3. Urinary incontinence was present in 5/26 (19.2%) and fecal incontinence in 10/26 (38.5%) cases. Lateralization of neurological signs was present in 11/26 (42.3%) of cases. All arachnoid diverticula were found between T7–T13, most 20/26 (76.9%) encompassing a single space (Figure 1). No significant differences were found between the control and shunting groups in terms of signalment, weight, imaging findings and neurological status, except for neutering status. In terms of medication, fewer cases received steroids before surgery in the shunting group versus the control group, a difference close to statistical significance ($p = .052$).

3.1 | Outcome and recurrence

Comparison of outcome and recurrence between the control and shunting groups is described in detail in Table 2.

Immediate postoperative (24 h from surgery) was not significantly different between groups, with a similar percentage of cases deteriorating immediately after surgery (control group 41.7%, shunting group 42.9%). Short-term outcome (4–8 weeks recheck) was also not significantly distinct between groups, even if more improved in the shunting group (12/14, 85.7%) than in the control group (7/12, 58.3%). Long-term outcome (>6 months) was statistically significantly better in the shunting group, with most dogs improving after SDS surgery (12/14, 85.7%) whilst in the control group improvement rate was lower (5/12, 41.7%).

The rate of recurrence of clinical signs was lower in the shunting group (2/14, 14.3%) than in the control group (5/12, 41.7%), this was not found to be significantly different ($p = .19$). The follow-up time was longer in the control group (median 46 months [11–105]) than in the shunting group (median 25.5 months [11–67]), but this was not found to be significantly different ($p = .274$). Recurrence occurred at a median of 32.5 months from surgery (9–62). Most dogs suffering recurrence were Pugs 5/7 (71.4%), five in the control group and two in the shunting group. Within the control group, 3/5 (60%) cases had a repeat MRI that identified reoccurrence of the AD at the same location as initially identified, as the cause of recurrence. The cases from the shunting group with suspected recurrence, did not undergo repeat imaging. Within the control group, treatment following recurrence in the control group was non-surgical in all cases with 5/5 receiving prednisolone, one case receiving phenylpropanolamine. A total of 4/5 cases improved after prednisolone was started, one case deteriorated further despite prednisolone. In the shunting group, both cases with suspected recurrence received prednisolone and improved.

TABLE 1 Univariate statistical comparison of the signalment, neurological and imaging findings between the control group and the shunting groups.

Variable	Category	Control group ($n = 12$)	Shunting group ($n = 14$)	p-value
Signalment, gender, bodyweight				
Breed	Cross Breed	1 (8.3%)	0 (0.0%)	.395
	French Bulldog	3 (25.0%)	6 (42.9%)	
	Pug	8 (66.7%)	8 (57.1%)	
Age at onset (months) median (range)		79.5 (24–118)	77 (23–135)	.94
Gender	Male	10 (83.3%)	11 (78.6%)	.759
	Female	2 (16.7%)	3 (21.4%)	
Neutered status	Yes	5 (41.7%)	12 (85.7%)	**.019**
	No	7 (58.3%)	2 (14.3%)	
Bodyweight (kg)		9.23 (6.4–19.3)	11.6 (7.65–17.10)	.252
Neurological signs and grading				
Lateralization of neurological signs	Absent	7 (58.3%)	8 (57.1%)	.945
	Right	2 (16.7%)	3 (21.4%)	
	Left	3 (25%)	3 (21.4%)	
Neurological grade before surgery	Grade 2	11 (91.7%)	14 (100.0%)	.271
	Grade 3	1 (8.3%)	0 (0.0%)	
Neurological grade the day after surgery	Grade 2	6 (50.0%)	8 (57.1%)	.936
	Grade 3	5 (41.7%)	5 (35.7%)	
	Grade 4	1 (8.3%)	1 (7.1%)	
Neurological grade at discharge	Grade 2	8 (66.7%)	8 (57.1%)	.618
	Grade 3	4 (33.3%)	5 (35.7%)	
	Grade 4	0 (0.0%)	1 (7.1%)	
Medication				
Steroids given	Yes	8 (66.7%)	6 (42.9%)	.225
	No	4 (33.3%)	8 (57.1%)	
Steroids given before surgery	Yes	8 (66.7%)	4 (28.6%)	.052
Steroids given immediately after surgery	Yes	4 (33.3%)	4 (28.6%)	.634
Imaging and surgery details				
Length AD on MRI	1	11 (91.7%)	9 (64.3%)	.239
	2	1 (8.3%	4 (28.6%)	
	4	0	1 (7.1%)	
Durotomy extent (spaces)	1 space	6 (50.0%)	2 (25.0%)	.078
	2 spaces	2 (16.7%)	7 (70.0%)	
	3 spaces	4 (33.3%)	3 (42.9%)	
	4 spaces	0 (0.0%)	2 (100.0%)	
Shunt size	3 Fr	0	6 (42.9%)	Not applicable
	3.5 Fr	0	6 (42.9%)	
	4 Fr	0	2 (14.3%)	

Note: Bold in the p-value column indicates statistical significance ($p < .05$).
Abbreviations: AD, arachnoid diverticulum; MRI, magnetic resonance imaging.

TABLE 2 Univariate statistical comparison of outcome and recurrence rates between the control group and the shunting groups.

Variable	Category	Control group ($n = 12$)	Shunting group ($n = 14$)	*p*-value
Outcome				
Follow-up time (months) median (range)		46 (11–105)	25.5 (11–67)	.274
Outcome (immediate postoperative)	Deteriorated	5 (41.7%)	6 (42.9%)	.632
	Static	7 (58.3%)	8 (57.1%)	
	Improved	0	0	
Outcome (short-term)	Deteriorated	1 (8.3%)	0 (0.0%)	.241
	Static	4 (33.3%)	2 (14.3%)	
	Improved	7 (58.3%)	12 (85.7%)	
Outcome (long-term, >6 months)	Deteriorated	3 (25.0%)	0 (0.0%)	**.040**
	Static	4 (33.3%)	2 (14.3%)	
	Improved	5 (41.7%)	12 (85.7%)	
Recurrence				
Presence of recurrence	No	7 (58.3%)	12 (85.7%)	.190
	Yes	5 (41.7%)	2 (14.3%)	
Time to recurrence (months) median (range)		36 (9–62)	28 (27–29)	.571
Affected breeds				
	French bulldog	1 (20%)	0	Not applicable
	Pug	4 (80%)	1 (100%)	
Urinary and fecal Incontinence before surgery				
Urinary incontinence	Absent	10 (83.3%)	11 (78.6%)	.578
	Present	2 (16.7%)	3 (21.4%)	
Fecal incontinence	Absent	6 (50%)	10 (71.4%)	.237
	Present	6 (50%)	4 (28.6%)	
Urinary and fecal Incontinence after surgery (long-term)				
Urinary incontinence	Absent	11 (91.7%)	11 (78.6%)	.356
	Present	1 (8.3%)	3 (21.4%)	
Fecal incontinence	Absent	8 (66.7%)	10 (71.4%)	.793
	Present	4 (33.3%)	4 (28.6%)	

Note: Bold in the *p*-value column indicates statistical significance ($p < .05$).

4 | DISCUSSION

This is the largest reported population of dogs undergoing SDS for TL-AD, following a modified technique based on Meren et al.[9] In accordance with previous reports of TL-AD, cases included were composed of almost exclusively Pugs and French Bulldogs.[13]

There are several surgical techniques available for AD management and in all techniques the meninges are incised and debridement of meningeal adhesions is performed.[8–13] The durotomy is typically left open in TL-AD, with a single study describing dural closure with no reported deleterious effects.[26] In one study, placement of the subdural shunt resulted in a higher proportion of dogs becoming non-ambulatory in the immediate postoperative period than if a shunt was not used (4/6 66% vs. 5/35, 14.3%).[13] In that same study, the durotomy defect was closed after shunt placement, as the dural edges were sutured in apposition over the catheter or to the edges of the catheter.[13] This same difference was not found in our population immediately after surgery, with about half of the cases being ambulatory the day after surgery. Nonetheless, we found that about a third of cases, both from the control and the shunting groups (33.3% and 35.7%, respectively), were non-ambulatory at discharge. It is important to consider this as a possibility following TL-AD surgery, and not indicative of prognosis, as dogs still recovered ambulation later on.

The surgical technique used in our population differed from the original description by Meren et al.[9] by means of access to the vertebral canal (hemilaminectomy), incision shape (longitudinal with no I-shape edges) and suturing of the shunt tube or the dura (not sutured). The choice of performing a hemilaminectomy is justified by the fact that 40.7% of our cases presented lateralization on neurological examination and that hemilaminectomy provides a good visualization of the lateral and dorsolateral aspect of the spinal cord.[27] Although a hemilaminectomy might not be indicated in every single case of an arachnoid diverticulum, particularly if the TL-AD is located dorsally and in the center of the spinal cord, if the TL-AD can be accessed by either surgical approach, possibly a hemilaminectomy can present more advantages. Hemilaminectomy compared with dorsal laminectomy has been shown to have lesser effects on the mechanical properties of the spine.[28] Incision shape and direction was chosen as being less likely to induce iatrogenic damage to the nerve fibers, as a longitudinal incision follows the direction of the spinal cord tracts and therefore is less likely to transect them.

The choice of leaving the durotomy defect open, besides being standard in TL-AD durotomy,[14] was chosen as to minimize the possibility of the SDS inducing secondary spinal cord compression. In the dog, the possible development of CSF leakage or the occurrence of orthostatic headaches in people, an indication for defect closure in people is not reported.[29] Not suturing the tube into the dura, was decided in order to leave less foreign material (suture) passive of creating fibrosis. Although a risk of migration of the shunt tube exists without a suture, this was considered minimal, as the CSF was identified to be flowing within the shunt tube and not the shunt tube being displaced by the CSF flow, and also as there was not a lot of free space within the subarachnoid space cranial and caudal to the durotomy incision for the shunt tube to move. Another important difference between the technique used in this study and the originally described,[9] was the clear indication of guidelines for shunt-tube size measurement. The choice of a maximum of 25% of the total diameter of the spinal cord at the level of the AD, meant that in most cases the tube size utilized was of 3 or 3.5 Fr (Figure 1). This was a decision based on our own experience with placing shunt-tubes in constrictive myelopathy cases, where it was noticeable that any tube equal or above 4 Fr, was more difficult to introduce to the subdural space safely. Similarly to the original technique, we advised that CSF flow through the tube was obtained.[9] When the shunt-tube technique was first developed, it was idealized to keep patent the CSF flow in patients with a constrictive myelopathy.[9] In cases of arachnoid diverticulum, the shunt-tube could act in a similar way, making sure CSF flow is patent even if adhesions, arachnoiditis, constrictive myelopathy or reoccurrence of the arachnoid diverticulum eventually form in the future.

In our study short-term outcome was not found to be statistically different between groups. Short-term outcome following surgery has been reported with improvement in over 60% of cases in a study looking at both cervical and thoracolumbar AD (follow-up of 4–8 weeks)[1] and in 80%–84% of thoracolumbar AD cases alone (follow-up of 4–6 weeks).[13,16]

Long-term outcome was significantly better in dogs undergoing SDS placement than those without shunting, with 85.7% versus 41.7% improving following surgery. Also found in our population, was that more than half of cases in the control group were static or had worsened long-term. Long-term improvement has been reported in just over 60% of cases in two previous studies with >6 months follow-up looking at both cervical and thoracolumbar AD[2,15] and in 82% in a single large-study with long-term follow-up.[14] Although it is difficult to discern if location was relevant in the outcome of reports where cervical and thoracolumbar cases were analyzed together, the latter study reported no significant difference in outcome for cervical versus thoracolumbar ADs.[14] Taking into consideration previous literature, it seems that improvement of clinical signs can be achieved with most surgical techniques and its combinations, however recurrence seems to be a serious and pervasive issue in dogs surgically managed for AD.

The rate of recurrence was lower in the shunting group than in the control group (14.3% vs. 41.7%), with the both populations being equivalent in terms of signalment, neurological presentation and breed distribution. Recurrence in thoracolumbar AD has been shown to occur due to reoccurrence of the AD, laminectomy membrane formation, or herniation of the spinal cord through the laminectomy defect associated with a stellate appearance to the spinal cord with small multiloculated areas of dilation of the subarachnoid space.[25] MRI confirmed recurrence was reported at a median of 20.5 months after surgery (range, 9–44 months) in one study.[25] Another suggested explanation for recurrence is that of repetitive spinal cord injury as a result of dynamic lesion, therefore vertebral stabilization has also been proposed as preventative of AD recurrence.[12] In a single study looking at recurrence in these cases, 2/5 or 40% cases recurred despite stabilization.[12] In our population the three cases undergoing repeat MRI presented reoccurrence of the AD and all cases were managed conservatively with steroid therapy.

The statistically significant positive long-term outcome and the non-statistically significant lower rate of recurrence was found in our cases when a SDS was placed could be explained in different ways. One reason might be the physical presence of the tube preventing formation of a new AD or laminectomy membrane, or at least, slowing down this process. The shunt may also serve to maintain CSF-flow, across the site of durotomy, which was the initial proposed purpose for this technique in its initial report.[9] Recurrence, regardless of treatment, was more frequent in the Pug (5/7), in agreement with previous reports.[16] The Pug can present a particular challenge as myelopathies can be more insidious or unresponsive to treatment protocols that could be more effective in other breeds, also possibly having a higher rate of postoperative TL-AD deterioration than other breeds.[30] Proposed reasons are likely multifactorial including vertebral anatomical conformation leading to compressive myelopathy or suspected increased mobility/instability, a high rate of concomitant IVDD to TL-AD, and more recently a possible underlying contribution of the immune system to the development of myelopathies in the Pug.[16,21,31–34] Considering these reasons, recurrence might not necessarily be completely avoided in this breed by surgical means alone. Nonetheless, the recurrence rate within the Pug population in our study was lower in the shunting versus the control group (1/8, 12.5% vs. 4/8, 50%).

Regarding long-term urinary and fecal incontinence, there were no statistically significant differences between the control and shunting groups (urinary: 18.3% vs. 21.4%, respectively; fecal: 33.3% vs. 28.6%, respectively). However, improvement in urinary or fecal incontinence was present within the control group, (urinary incontinence: 1 case less; fecal incontinence: 2 cases less), but not on the shunting group. This was not found to be statistically significant, and it could possibly be a spurious finding due to the limited number of cases in this study. It is nonetheless possible, that the continuous presence of the shunt tube could have consequences in urinary and fecal control in the long-term.

Corticosteroids are used frequently in the management of AD, most frequently prednisolone.[4,5,14] Prednisolone is presumed to decrease cerebrospinal fluid production and increase its absorption, besides having a positive effect in vasogenic edema, although this is based mostly on empiric observations. In medical management of TL-AD, steroids are considered paramount.[14] Although anecdotally corticosteroids are often recommended before surgery, a previous study showed that perioperative prednisolone use was not associated with better outcome.[14,16] In our population most cases in the shunting group did not receive steroids before surgery, likely indicating a shift towards not prescribing prednisolone before surgery. Considering that shunting cases had an overall equivalent postoperative outcome and a better long-term outcome, this data further reinforces the notion that preoperative steroids might not be necessary in these cases.

This study was limited by its retrospective nature, and the decision to use a shunt was not randomized, being clinician dependent. Short-term follow-up information relied on the expertise of the same people that performed surgery, potentiating clinician bias and long-term follow-up was based upon telephone interviews which are both subjective and prone to a caregiver placebo effect. Recurrence was confirmed with advanced imaging in 3/7 cases, meaning that some cases of presumed recurrence may have in fact been due to a different condition. To address this, recurrence was only considered in cases where newly developed signs of a non-painful thoracolumbar myelopathy had developed since surgery. The conclusions of this study were also limited by the small number of cases included. The small number of cases included, potentiated bias and type I errors, as statistical analyses of small sample sizes yield a higher risk of false discovery. Future prospective studies involving this technique can hopefully avoid such bias, by means of randomizing case selection and adding a controlled group.

5 | CONCLUSIONS

In dogs with AD undergoing surgery, long-term outcome was superior for cases in which durotomy, debridement of subdural adhesions, and SDS placement was undertaken. The rate of recurrence was also lower in these cases when compared to those that did not receive subdural shunt. Most recurrent cases were Pugs. Despite the limited number of cases available and bearing in mind the possibly of postoperative infections, shunt-placement appears to have a positive role in the outcome and possibly recurrence prevention in cases of AD. Future prospective randomized blinded case–control studies are needed to corroborate the findings in this study.

AUTHOR CONTRIBUTIONS

Gomes SA, DVM, MRes, DipECVN: Involved with study design and concept, data acquisition, analysis and interpretation of data, and drafting of the article. Targett M, MA, VetMB, PhD, DipECVN, SFHEA: Involved with study design and concept, data acquisition and contribution of cases. Mignan T, BVM, BVS, FHEA, MRes, DipECVN: Involved with data acquisition and contribution of cases. Longo S, DVM: Involved with data acquisition and contribution of cases. James M, BVM, BVS, DipECVN: Involved with data acquisition and contribution of cases. Stee K, DVM, PhD, DipECVN: Involved with data acquisition and contribution of cases.

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