Risk factors for early postoperative neurological deterioration in dogs undergoing a cervical dorsal laminectomy or hemilaminectomy: 100 cases (2002-2014)

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Abstract

Early postoperative neurological deterioration is a well-known complication following dorsal cervical laminectomies and hemilaminectomies in dogs. This study aimed to evaluate potential risk factors for early postoperative neurological deterioration following these surgical procedures.

Medical records of 100 dogs that had undergone a cervical dorsal laminectomy or hemilaminectomy between 2002 and 2014 were assessed retrospectively. Assessed variables included signalment, bodyweight, duration of clinical signs, neurological status before surgery, diagnosis, surgical site, extent of surgery, and duration of procedure. Outcome measures were neurological status immediately following surgery and duration of hospitalisation. Univariate statistical analysis was performed to identify variables to be included in a multivariate model.

Diagnoses included osseous associated cervical spondylomyelopathy (OACSM; *n*=41), acute intervertebral disk extrusion (IVDE; 31), meningioma (11), spinal arachnoid diverticulum (10) and vertebral arch anomalies (7). Overall 55% (95%CI 45.25-64.75) of dogs were neurologically worse 48 h postoperatively. Multivariate statistical analysis identified four factors significantly related to early postoperative neurological outcome. Diagnoses of OACSM or meningioma were considered the strongest variables to predict early postoperative neurological deterioration, followed by higher (more severely affected) neurological grade before surgery and longer surgery time.

This information can aid in the management of expectations of clinical staff and owners with dogs undergoing these surgical procedures.

Keywords: cervical; dog; dorsal; hemilaminectomy; laminectomy

Introduction

Dorsal decompressive surgery for the treatment of cervical spinal diseases is a well-established surgical approach (Sharp and Wheeler, 2005). Cervical dorsal laminectomies and hemilaminectomies are indicated for lesions located dorsally or laterally in the cervical vertebral canal. Disorders commonly treated by this approach include osseous associated cervical spondylomyelopathy (OACSM), intervertebral disc extrusions with lateralised or dorsally located disc material, vertebral arch anomalies, spinal arachnoid diverticula (SAD), or where multiple ventral intervertebral disc protrusions are present (Gill et al., 1996; de Risio et al., 2002; da Costa, 2010; De Decker et al., 2012a).

There have been differing reports pertaining to the outcome of dorsal cervical decompressive surgeries. Several reports have suggested that cervical dorsal laminectomy should be considered an invasive procedure with a high risk of postoperative morbidity, many complications and prolonged hospitalisation and recovery times (de Risio et al., 2002, da Costa, 2010, Delamide Gasper et al., 2014). The most important complication associated with this surgical approach is early postoperative neurological deterioration with prolonged recumbency after surgery. Other complications include marked tissue disruption, intraoperative haemorrhage, prolonged surgery times, excessive scar tissue formation and cardiorespiratory compromise (de Risio et al., 2002; Delamide Gasper et al., 2014). However other studies have reported more favourable outcomes with limited hospitalisation and recovery times (Gill et al., 1996; Faissler, 2011, De Decker et al., 2012a).

It remains unclear why some patients undergoing dorsal cervical procedures experience early postoperative neurological deterioration whilst others do not. The aim of this study was to evaluate potential risk factors for early neurological deterioration in dogs following cervical dorsal laminectomy or hemilaminectomy. It was hypothesised that the specific diagnosis would influence outcome, with those dogs diagnosed with acute intervertebral disc extrusions (IVDE) less likely to have early postoperative neurological deterioration following surgery compared to dogs diagnosed with the more chronic condition OACSM. Other assessed variables thought to impact on early postoperative outcome included signalment, duration of clinical signs and neurological status before surgery, surgical site, extent of surgery and duration of procedure.

Materials and methods

Criteria for inclusion

Medical records of dogs that had undergone a cervical dorsal laminectomy or hemilaminectomy at the Royal Veterinary College between 2002 and 2014 and Davies Veterinary Specialists between 2008 and 2014 were reviewed. In order to be considered for inclusion in the study each dog needed to have complete medical records and imaging studies available for review and have clear data relating to their neurological status before and after surgery. If the neurological status could not be clearly determined then cases were excluded. Further information recorded included signalment, bodyweight, duration of clinical signs prior to surgery (acute <48 h, subacute 2-7 days and chronic >7 days), diagnosis, type, location, extent (number of vertebrae operated on) and duration of the surgery, presence of perioperative complications during the period of hospitalisation and hospitalisation time.

Neurological grading

A scoring system modified from de Risio et al. (2002) was used to objectively grade the dogs' neurological status; normal neurological status (grade 0), cervical hyperaesthesia without neurological deficits (grade 1), mild ataxia without paresis and slight delay in postural reactions, with or without thoracic limb deficits and/or cervical hyperaesthesia (grade 2), noticeable ataxia and paresis with delayed postural reactions, with or without thoracic limb deficits and or cervical hyperaesthesia (grade 3), paresis or absent postural reactions, with or without thoracic limb deficits and or cervical hyperaesthesia, dogs are able to rise and make a few steps with assistance (grade 4), non-ambulatory tetraparesis, with or without cervical hyperaesthesia, patients are not able to rise independently (grade 5) and tetraplegia with respiratory compromise (grade 6). Deterioration in neurological status by one or more grades was defined as postoperative neurological deterioration.

Diagnostic imaging

Included dogs underwent diagnostics including myelography, computed tomography (CT), computed tomography-myelography (CT-m) or magnetic resonance imaging (MRI) under general anaesthesia. Although general anaesthesia protocols could vary between individual cases, a commonly used protocol included premedication with a combination of acepromazine (0.01 mg/kg IV) and methadone (0.1- 0.2 mg/kg IV), followed by induction with propofol, (4 – 6 mg/kg IV) and maintenance of general anaesthesia with isoflurane in oxygen. Myelography was performed by intrathecal injection of iohexol (Omnipaque, GE Healthcare) contrast medium between the L5-L6 articulation (0.2 ml/kg with a maximal dose of 10 ml). CT imaging was performed using a 16-slice helical CT scanner (Mx8000 IDT, Philips). After completion of the transverse CT study, sagittal and dorsal reconstructions were made. MRI was performed with a 1.5 T (Intera, Philips Medical Systems) or 0.4 T (Aperto

MRI, Hitachi) and included a minimum of T2- and T1-weighted sagittal and transverse images.

Localisation and categorisation of spinal cord compression

Information obtained from both the radiology and surgery reports was used in order to determine the site of spinal cord compression and confirm the diagnosis. In addition a board-certified neurologist (SDD) reviewed the imaging studies for diagnostic accuracy. Dogs were divided into four categories based on their diagnosis: 1: OACSM, 2: acute IVDE, 3: histopathologically confirmed meningioma, 4: SAD, 5: vertebral arch anomalies. Vertebral arch anomalies were defined as a well-defined and smooth hypertrophy of the dorsal lamina and spinous process of ≥ 2 adjacent vertebrae. No other osseous abnormalities were present in these dogs (De Decker et al., 2012). Lesions were classified according to their location within the cervical vertebral column with cranial lesions classified as those located between C1 and C4 vertebrae and caudal lesions classified as those from C4 to T1 vertebrae. If lesions affected both the cranial and caudal cervical vertebral column this was documented.

Surgery, postoperative care and outcome measures

All dogs had a dorsal laminectomy, hemilaminectomy or combination. The procedures were carried out by a board certified neurologist using published techniques (Sharp and Wheeler, 2005; Platt and da Costa, 2012). Anaesthesia protocols varied for individual dogs based on attending anaesthetist preference and specific patient requirements but typically included acepromazine (0.01 mg/kg IV) and methadone (0.1- 0.2 mg/kg IV), followed by induction with propofol, (4 – 6 mg/kg IV) and maintenance of general anaesthesia with isoflurane in oxygen. Perioperative analgesia included a combination of opioids, ketamine and non-steroidal anti-inflammatory drugs (NSAID). Postoperative analgesia typically included opioids and NSAID. Most patients received postoperative physiotherapy. All dogs underwent a daily neurological assessment by a board certified neurologist and information pertaining to their assessment was recorded in the medical records.

Statistical analysis

All variables were treated as categorical except for age, weight, number of vertebrae on which surgery was performed, duration of surgery and duration of hospitalisation, which were continuous. Early postoperative neurological deterioration by one or more grades was defined as the primary outcome measure. A secondary outcome measure was defined as duration of hospitalisation. Univariate analysis identified variables associated with early postoperative neurological deterioration. Statistical comparisons between mean values of normally distributed data were made using a one-way analysis of variance (ANOVA), with additional pairwise comparisons with Bonferroni adjustment as required for significant variables. Median values for non-parametric data were compared with either Mann-Whitney or Kruskal-Wallis tests with post-tests as required. Statistically significant results are displayed where $P<0.05$. Unless otherwise stated normally distributed data is presented as mean ± standard deviation and non-parametric data as median and range. Computations were performed using SPSS (Statistical Package for the Social Sciences v. 21.0.1; SPSS Inc.).

Prior to inclusion in a binary logistic regression model multinomial modelling was performed to identify associations between input variables. All biologically important confounders (age, weight, surgery time) and independent factors (onset of clinical signs, neurological grade preoperatively) with $P<0.3$ were included in the multinomial model. Factors shown to be significantly associated with diagnosis included: age ($P=0.001$), weight

(*P*=0.001) and onset of clinical signs (*P*=0.009). These variables were substituted for the single input variable ‘diagnosis’ in subsequent binary logistic regression.

Binary logistic regression modelling was performed to identify factors associated with early postoperative neurological deterioration. Variables were considered for inclusion in binary logistic regression if *P*<0.30 and retained in the final model if *P*<0.05, based on the likelihood ratio test. Binary logistic regression was carried out using a Forced Entry Method to examine associations between included variables with a significance level of *P*<0.05. Results are presented with odds ratios (OR) and 95% confidence intervals (CI) for variables associated with early postoperative neurological deterioration.

Results

The study population comprised 100 dogs. Breeds included were Dalmatian (*n*=10), Labrador Retriever (*n*=9), Great Dane (*n*=8), Dogue de Bordeaux (*n*=7), Bull Mastiff (*n*=7), Rottweiler (*n*=6), English Cocker Spaniel (*n*=6), Dobermann (*n*=4), Boxer (*n*=3), Basset Hound (*n*=3), English Pointer (*n*=3), Jack Russell Terrier (*n*=2), Dachshund (*n*=2), West Highland White Terrier (*n*=2), Beagle (*n*=2) and Bernese Mountain Dog (*n*=2); there were 13 breeds represented by one dog each and 11 crossbreeds. Of the study population 75 dogs were male and 25 dogs female; overall 45 of the dogs were neutered. At the time of surgery the median age of dogs was 5.2 years (range 0.4 to 11 years; Table 1). Dogs with OACSM were significantly younger than dogs with IVDE (*P*=0.001) or meningioma (*P*=0.006). The median weight was 32.5 kg (range 5 to 80 kg; Table 1). Dogs with OACSM were also significantly heavier than dogs with IVDE (*P*=0.001), meningioma (*P*=0.004) or vertebral arch anomalies (*P*=0.024).

Duration of clinical signs prior to surgery was classified as acute (*n*=15), subacute (*n*=21) or chronic (*n*=64). Dogs underwent a range of advanced imaging diagnostics including myelography (*n*=8), CT-m (*n*=1), MRI (*n*=87) and a combination of CT and MRI (*n*=4). Of those dogs that had myelography or CT-m three had surgery immediately following diagnostics. Diagnoses included OACSM (*n*=41), acute IVDE (*n*=31), meningioma (*n*=11), SAD (*n*=10) and vertebral arch abnormalities (*n*=7; Table 1).

Lesions were located in the cranial cervical region (*n*=27), the caudal cervical region (*n*=59) and affecting both cranial and caudal cervical regions (*n*=14). Seventy dogs had a cervical dorsal laminectomy, 28 had a hemilaminectomy and two dogs had combination of a dorsal laminectomy and hemilaminectomy. A continuous laminectomy was performed in 35 dogs; comprising two sites (*n*=22), three sites (*n*=10) and four sites (*n*=3). Surgical time ranged from 65 to 655 min (median 215 min).

Prior to surgery neurological grade ranged from grade one to five: one (*n*=6), two (*n*=19), three (*n*=46), four (*n*=9) and five (*n*=20). Of the 97 dogs that survived 48h postoperatively, 55% (*n*=52) experienced early postoperative neurological deterioration (Table 1). Postoperative neurological grades ranged from grade one to six: one (*n*=4), two (*n*=6), three (*n*=20), four (*n*=25), five (*n*=41) and six (*n*=1). Of those dogs that demonstrated deterioration in neurological grade, 24 dogs deteriorated by one grade, 23 dogs deteriorated by two grades and five dogs deteriorated by three grades. Of the 52 dogs that experienced early postoperative neurological deterioration 49 dogs had an improved neurological grade at the time of discharge. The remaining three dogs were euthanised during hospitalisation.

Other complications included postoperative death within 24 h of surgery (*n*=3), euthanasia due to neurological deterioration or lack of improvement during hospitalisation (*n*=3), respiratory compromise requiring postoperative mechanical ventilation (*n*=1), wound infection requiring antibiosis (*n*=3), severe intraoperative haemorrhage requiring blood transfusion (*n*=2) and requirement of subsequent surgery at the same site due to incomplete decompression (*n*=6).

Duration of hospitalisation ranged from 2 to 28 days (median 7 days; Table 1). Occurrence of early postoperative neurological deterioration was the only variable significantly associated with a longer duration of hospitalisation (P=0.023).

Univariate analysis showed that higher bodyweight, younger age, longer duration of clinical signs, longer surgery times, a higher (more severely affected) neurological grade before surgery, and diagnosis were significantly associated with early postoperative neurological deterioration (Table 2). After performing multivariate statistical analysis, four variables were withheld as independent risk factors for early postoperative neurological deterioration: diagnosis of OACSM, diagnosis of meningioma, higher (more severely affected) neurological grade before surgery and longer surgery (Table 3). Diagnoses of OACSM or meningioma were considered the strongest variables to predict early postoperative neurological deterioration, followed by higher (more severely affected) neurological grade and longer surgery time (Table 3).

Discussion

The results of this study confirm that early postoperative neurological deterioration is the most frequent complication in dogs undergoing cervical dorsal laminectomy or hemilaminectomy. Identified risk factors for development of this postoperative complication were diagnosis of OACSM, diagnosis of meningioma, higher (more severely affected) neurological grade, and longer surgery time.

The results of this study offer new insights into the controversy surrounding the morbidity of cervical laminectomies and hemilaminectomies. Previous studies have reported varying short-term outcomes, complication rates, and hospitalisation times (Gill et al., 1996; de Risio et al., 2002; da Costa, 2010; Faissler, 2011; De Decker et al., 2012a; Delamide Gasper et al., 2014). This study indicates that overall 55% of patients undergoing dorsal cervical decompressive surgeries will experience early postoperative neurological deterioration, which may be interpreted as a consequence of its invasive nature. Of major importance is that these results suggest that the specific diagnosis of dogs undergoing these procedures should be considered the strongest independent variable to predict occurrence of early postoperative neurological deterioration. Over 75% of patients diagnosed with OACSM or meningioma experienced postoperative neurological deterioration compared to only 22% of dogs with acute IVDE. Previous studies reporting high postoperative morbidity with up to 70% of dogs experiencing postoperative deterioration included exclusively patients with cervical spondylomyelopathy (de Risio et al., 2002). In contrast, those studies that have suggested more favourable outcomes have predominantly focused on patients diagnosed with acute IVDE (Gill et al., 1996; Tanaka et al., 2005; Faissler, 2011) or vertebral arch anomalies (De Decker et al., 2012a). It is therefore possible that the variability in reported postoperative complications and associated short-term outcomes could largely be explained by the specific diagnoses of dogs undergoing these procedures.

It is unclear why patients with OACSM and meningioma are more likely to experience early postoperative neurological deterioration compared to patients with other diagnoses. Several authors have suggested that decompression of chronic spinal cord lesions can lead to reperfusion injuries resulting in acute deterioration after surgery (Rushbridge et al., 1998; Olby and Jeffery, 2012). However, other disease processes, such as vertebral arch anomalies and SAD, which are characterised by chronic spinal cord compression, were not associated with increased risk of early postoperative deterioration. This may suggest that chronicity of the disease process cannot entirely explain the occurrence of this complication. Although other reasons cannot be excluded, it is possible that removal of a meningioma is associated with more spinal cord manipulation and subsequent iatrogenic damage compared with surgical removal of other causes of spinal cord compression. However, it seems more difficult to explain the increased risk of early postoperative neurological deterioration in dogs with OACSM. It has been suggested that dogs with cervical spondylomyelopathy can have a degree of vertebral instability, which could be aggravated by performing a cervical dorsal laminectomy (de Risio et al., 2002) and contribute to the development of postoperative neurological deterioration (de Risio et al., 2002). The role of vertebral instability in the aetiopathogenesis of cervical spondylomyelopathy is controversial and has not been assessed objectively (da Costa, 2010; De Decker et al., 2012c).

Whatever the underlying pathophysiology for early postoperative neurological deterioration in dogs with OACSM and meningioma, many would consider the occurrence of this short-term complication in over 75% of patients unacceptable. Although it might be practically impossible to remove a meningioma without performing a dorsal cervical laminectomy, alternative treatment modalities can be considered for dogs with OACSM. Recent studies have evaluated medical management (Delamide et al., 2014) and distraction and stabilization techniques (Lewis et al., 2013) in dogs with OACSM. Both studies demonstrated promising results, which warrants further investigation into alternative treatment methods for this disorder. However it should be emphasised that this study evaluated the occurrence of operative and early postoperative complications in dogs undergoing dorsal cervical laminectomy or hemilaminectomy and did not evaluate long-term outcome of dogs undergoing these surgical procedures. This was deemed inappropriate because of the large variation in included diagnoses, which could have influenced this variable. It has previously been demonstrated that dogs experiencing early postoperative neurological deterioration often still experience neurological recovery with good long-term outcomes (Rushbridge et al., 1998; De Risio et al., 2002) and indeed that was the case with the dogs in this study. Considering this, it may be appropriate to justify the initial morbidity associated with cervical dorsal decompressive surgeries for dogs with OACSM and meningioma. However early postoperative deterioration was found to be significantly related to prolonged hospitalisation and this may therefore increase costs associated with the procedure.

Other identified risk factors for early neurological deterioration after cervical laminectomy or hemilaminectomy were neurological grade before surgery and duration of surgery. It is possible that a higher (more severely affected) neurological grade represents more severe spinal cord pathology and that these dogs are therefore at risk of developing early postoperative neurological deterioration. Severity of clinical signs in dogs with cervical spondylomyelopathy is however not necessarily associated with more severe electrodiagnostic abnormalities, spinal cord compression seen on MRI and worse outcome after medical treatment (De Decker et al., 2012b). Most sedative and anaesthetic products are associated with hypotensive effects (Raisis and Musk, 2013). Although special care should be taken to remain adequate spinal cord perfusion during general anaesthesia, it is possible that prolonged surgeries are associated with an increased risk of spinal hypoperfusion thereby contributing to a higher risk of early postoperative neurological deterioration (Rossmeisl et al., 2013). It is also possible that prolonged surgery times are associated with more difficult surgeries and therefore increased spinal cord manipulation. This hypothesis is however difficult to prove and remains speculative.

This study is obviously limited by its retrospective nature. To obtain a large number of suitable cases, data had to be collected over a number of years and different institutions. This has potentially limited standardisation of patient assessment and patient care. The majority of dogs were diagnosed with either OACSM or acute IVDE. This resulted in unequal group sizes and although this could theoretically have influenced our analysis, enough patients were included to allow for multivariate statistical analysis. Another potential limitation is that only a small number of dogs underwent advanced imaging studies after postoperative neurological deterioration was observed. We can therefore not exclude a structural cause of early postoperative neurological deterioration in these dogs. However, all dogs that did not undergo repeat imaging studies demonstrated spontaneous neurological improvement after variable amounts of time, consistent with previous reports (Rushbridge et al., 1998; de Risio et al., 2002).

Conclusions

Patients diagnosed with OACSM and meningioma are significantly more likely to experience early postoperative neurological deterioration following dorsal cervical laminectomy and hemilaminectomy than patients undergoing these procedures for the treatment of other diagnoses. Other risk factors were higher (more severely affected) neurological grade and longer duration of surgery. This information can aid in managing the expectations of clinical staff and owners with dogs undergoing these procedures.

Conflict of Interest Statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of this paper.

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Table 1: Characteristics of dogs undergoing cervical dorsal laminectomy or hemilaminectomy

Diagnosis	n	Age Years (Median, Range)	Weight kg (Median, Range)	Neurological grade preoperatively Median (Range)	Neurological grade postoperatively Median (Range)[a]	Neurologically deteriorating [b] n (%, 95% CI)	Days of hospitalisation Median (Range)
OACSM	41	2.7 (0.5-10)	44 (12-80)	3 (2-4)	5 (0-5)	32 (78%, 65-91)	9 (3-22)
IVDE	31	6.7 (2-11)	25 (6-50)	4 (1-5)	4 (1-6)	7 (23%, 7-38)	6 (2-20)
Meningioma	11	7.5 (5-11)	25 (9-40)	2 (1-5)	4 (0-5)	9 (82%, 55-109)	6 (4-16)
SAD	10	1 (0.4-10.3)	28 (5-59)	3 (3-5)	4 (2-5)	4 (40%, 3-63)	5 (2-17)
Vertebral arch anomalies	7	1.1 (0.83-6.6)	32 (22-48)	3 (2-5)	4 (2-5)	3 (43%, 7-62)	5 (3-12)

OACSM, osseous associated cervical spondylomyelopathy; IVDE, intervertebral disc extrusion; SAD, spinal arachnoid diverticulum

a: assessed at 48 h postoperatively

b: those dogs who had deteriorated by one or more neurological grades

Table 2: Univariate analysis showing factors associated with early postoperative neurological deterioration

Factor	P value
Younger age	*P*=0.030
Higher bodyweight	*P*=0.039
Higher neurological grade preoperatively (more severely affected)	*P*=0.001
Dogs having dorsal laminectomy rather than hemilaminectomy	*P*=0.018
Longer surgery time	*P*=0.001
Diagnosis	*P*=0.001

Table 3: Results of multivariate analysis showing factors significantly associated with early postoperative neurological deterioration

Factor	P value	Odds ratios	95% Confidence intervals for odds ratios
OACSM diagnosis	*P*=0.0001	11.4	3.3 to 40.4
Meningioma diagnosis	*P*=0.014	11.1	1.6 to 75.2
Higher neurological grade preoperatively(more severely affected)	P=0.002	2.3	1.37 to 3.85
Longer surgery time	*P*=0.014	1.01	1.002 to 1.016

OACSM, osseous associated cervical spondylomyelopathy