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Intervertebral Disc Disease in Dogs

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KEYWORDS

• Intervertebral • Disc • Disk • Herniation • Fenestration • Neurosurgery

Intervertebral disc (IVD) herniation is a common cause of neurologic dysfunction in dogs. During the last 60 years, IVD herniation has been the focus of significant research aiming to describe and understand this debilitating condition and to improve imaging and therapeutic options for clinical patients. This article is a summary of the clinically relevant literature that aims to guide clinicians in their decision making when diagnosing and treating canine IVD disease.

PATHOPHYSIOLOGY

Anatomy of the IVD

The IVDs are interposed between each vertebral body except the first and second cervical vertebrae (C1-C2) and each of the fused sacral vertebrae.[1,2] In a craniocaudal view, the cervical discs are nearly circular in shape, the thoracic discs are more oval, and the lumbar discs are bean shaped.[1] Thoracic discs are narrower than cervical and lumbar discs.[1,3] The caudal cervical discs (C4-C5 and C5-C6) along with the L2 to L3 disc space are the widest, whereas C2 to C3 and L4 to L5 are the narrowest.[4] Dachshunds are reported to have wider IVDs than other breeds.[4] The IVD is composed of an outer fibrous ring, the annulus fibrosus (AF), which surrounds an eccentric amorphous gelatinous center, the nucleus pulposus (NP).[1] Each disc is bound cranially and caudally by hyaline cartilaginous vertebral end plates,[1–3] and dorsally and ventrally by dorsal and ventral longitudinal ligaments.[1] The intercapital (conjugal) ligaments connect the rib heads from T2 to T10 crossing over each IVD and course between the AF and the dorsal longitudinal ligament.[1,2] This additional dorsal constraint is believed to reduce the rate of disc herniations between T2 to T3 and T10 to T11.[3,5–7] In contrast to King's findings,[1] Hansen[3] reported that the intercapital ligament at T10 is thin or nonexistent.

The AF is 1.5 to 2.8 times thicker ventrally than it is dorsally (**Figs. 1** and **2**), which results in the eccentric localization of the NP within the IVD and is believed to increase the risk for extrusion or herniation dorsally toward the vertebral canal.[1,2] Histologically,

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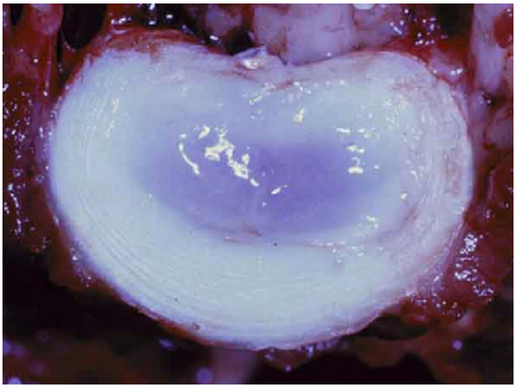

Fig. 1. Transverse section of a normal IVD. The AF bands surround the globoid and gelatinous NP. The ventral annulus is significantly thicker than the dorsal AF.

the AF is composed of an outer layer of densely packed collagen fibers in a fibrous matrix with a narrow inner layer of fibrocartilage located adjacent to the NP.[3,8] Seventy percent of the AF dry weight is from collagen.[9]

The NP is a remnant of the notochord that forms the central region of the IVD. Young, healthy discs contain a NP that is globoid and gelatinous with a high water content, allowing the disc to function as a hydroelastic cushion that maintains its width during loading (see **Fig. 1**).[9] Histologically, the NP is separated from the AF by a transitional or perinuclear zone (TZ).[3,8] Nonchondrodystrophic dogs have a narrow TZ, which consists of fibrocartilage, whereas the TZ of beagles and dachshunds is 3 to 4 times wider than that of greyhounds, is disorganized, and occupies the major portion of the AF.[3,8]

Only the outer layers of the AF are supplied by blood vessels.[3,10] The remainder of the AF and the NP are believed to receive their nutrition by diffusion through the cartilaginous end plates.[3,11,12] The peripheral third of the AF may be sparsely innervated,

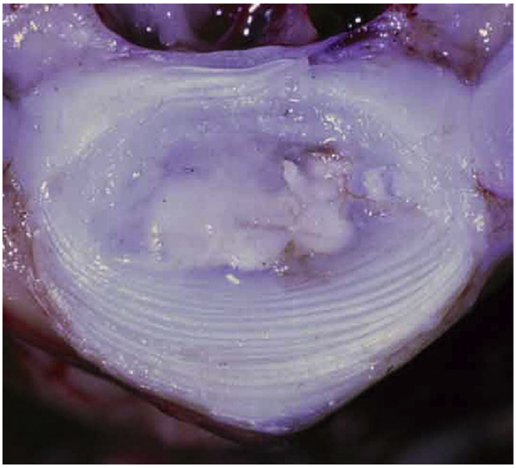

Fig. 2. Transverse section of a degenerate IVD from a chondrodystrophic dog. The gelatinous NP has been replaced by mineralized and chondroid material.

whereas the inner layers of the AF and NP are not innervated.[3,10] The dorsal longitudinal ligament overlying the IVD is extensively innervated and stretching and tearing of the outer AF and dorsal longitudinal ligament are proposed as a cause of discogenic pain in dogs.[10]

IVD Degeneration

IVD degeneration is a normal process that occurs with aging.[5,13] Degenerative changes in chondrodystrophic and nonchondrodystrophic IVD are generally referred to as chondroid metaplasia and fibrous metaplasia, respectively.[3,5,14]

Chondroid metaplasia is characterized by a loss of glycosaminoglycans, an increase in collagen content, and a decrease in water content, resulting in a general loss of the hydroelastic properties of the disc and its ability to withstand pressure.[9,14] The progressive transformation of the gelatinous NP to hyaline cartilage can begin as early as 2 months of age in dachshunds and involves the replacement of mesenchymal cells of the NP with chondrocyte-type cells.[3] The process begins in the TZ but eventually spreads to most of the NP and inner AF.[3,8] Grossly, the transparent gelatinous NP is transformed to a gray-white to yellow fibrocartilaginous tissue (see **Fig. 2**).[1,3] Chondrodystrophic dogs have 75% to 90% of their gelatinous NP transformed to a more hyaline and cartilaginous tissue by 1 year of age, whereas nonchondrodystrophic greyhound discs maintain high noncollagenous protein levels into old age.[3,9,14–17] Chondroid metaplasia occurs along the entire vertebral column. A total of 24% to 90% of dachshunds develop mineralization of one or more IVD, with a mean of 2.3 calcified discs per dog.[3,14,18–20] Calcifications have been reported in all discs,[3,18–20] but the discs of the thoracic region, especially between T10 and T13, are most frequently calcified radiographically.[18–21]

Fibrous metaplasia is an age-related degenerative process that occurs independently of breed but is documented more commonly in nonchondrodystrophic dogs 7 years and older.[3,5,14] It is characterized by a fibrous collagenization of the NP with concurrent degeneration of the AF and can occur anywhere along the vertebral column.[3,14] This degenerative process leads to bulging of the NP within the weakened AF and ultimately dorsal IVD protrusion.[3,14] Unlike its chondroid counterpart, fibrous metaplasia affects only a small number of discs and mineralization is infrequent.[3] A total of 40% to 60% of dogs aged 7 years or older show biochemical evidence of NP degeneration and 10% to 30% exhibit macroscopic IVD protrusion.[14]

IVD Extrusion and Protrusion

IVD extrusion (also known as Hansen type I) is typically associated with chondroid degeneration and involves the herniation of nuclear material through all layers of the ruptured AF into the vertebral canal.[3,5] The abnormal forces generated by the degenerate and mineralized NP cause tears to develop within the AF; as each break aligns, they form a channel through which the abnormal NP can eventually extrude.[3,5] Extruded disc material can be dispersed, showing no clear association with the parent disc space (sometimes classified as Funkquist type III), or nondispersed and located in close proximity to the affected disc space (Hansen type I).[22–24] Gross descriptions of Hansen type I IVD extrusion suggest that the rupture can be through, or lateral to, the dorsal longitudinal ligament[3,5,14,25] and that it may extrude in an irregular, flat, raised, circular, or conical pattern.[25] On gross sagittal section, the remaining NP appears yellow and is often mineralized.[3] Occasionally, tracts from this material through the inner and outer AF are seen at post mortem but they are rarely straight and are generally difficult to follow.[3,25] The extruded disc material is irregular, brittle, grainy, sometimes plasterlike, and varies from white-yellow to gray-yellow or even gray-red if blood from a damaged venous sinus mixes with it.[3,26] In chronic extrusions, the nuclear material may adhere fibrinously or fibrously to the dura mater or it can be resorbed.[3,25,26] The chemical composition of acute Hansen type I extradural material and of the remaining intervertebral NP are identical, confirming the migration of the NP through the AF.[25] With time, fibrous tissue develops at the edge of the extruded NP and can become interspersed with collagen fibers from the dorsal longitudinal ligament.[25] The cytologic and histopathologic appearance of extruded degenerate disc material was recently compared to determine if cytology was a reliable intraoperative tool to differentiate between degenerate disc material and a neoplastic process.[27] The variability in cytologic findings and frequent presence of dysplastic spindloid cells displaying cytologic criteria of malignancy suggest that impression smears from extruded disc material are cytologically indistinguishable from a mesenchymal neoplasm.[27]

IVD protrusion (also known as Hansen type II) is typically associated with fibroid degeneration and is characterized by a shift of the NP secondary to a partial rupture and weakening of the AF, causing a focal extension of the AF and NP into the vertebral canal either ventral or ventrolateral to the dorsal longitudinal ligament.[3,5,14,25] Protrusions are usually smooth, firm, and round and are rarely adhered to the dura mater.[3,25] On transverse section, the outer AF and the dorsal longitudinal ligament are intact, there is no evidence of hemorrhage, and nuclear mineralization is rare.[3,25]

Although Hansen's[3,5,14] postmortem studies suggested that type I extrusions occur more commonly in chondrodystrophic breeds and that type II protrusions occur more commonly in nonchondrodystrophic breeds,[3,5,14] more recent studies have shown that 62% to 92% of nonchondrodystrophic dogs weighing more than 20 kg with thoracolumbar (TL) IVD herniation experience nuclear extrusion as opposed to annular protrusion.[28,29] Chondrodystrophic dogs can also develop Hansen type II annular protrusions but do so less commonly.[14,24,30]

Incidence and Patient Predisposition

The overall prevalence of disc herniation in the dog has been reported as 2%.[31] A total of 19% to 24% of dachshunds (up to 62% within certain lineages)[32,33] are expected to display clinical signs relating to IVD herniation in their lifetime and account for 45% to 73% of all cases of acute disc extrusion in dogs.[3,6,32–38] Dachshunds are 12.6 times more likely to develop IVD herniation than other breeds[34] followed by the Pekingese, beagle and cocker spaniel, which are reportedly 10.3, 6.4, and 2.6 times more likely to develop IVD herniation, respectively, than other breeds.[34] Beagles reportedly have a 10-times-higher incidence of cervical disc herniation than TL herniation.[6] A few studies[39,40] reported the beagle as the breed most commonly treated for cervical IVD herniation, but dachshunds still predominate in most studies.[6,41–44]

Chondrodystrophic canine breeds include the dachshund, Pekingese, French bulldog, and beagle.[5,8] The American cocker spaniel is often included in the chondrodystrophic classification because of its predisposition for IVD herniation but this has not been confirmed.[14,26,34] Other small breeds reported to be at increased risk of developing IVD herniation include the Lhasa apso, Jack Russell terrier, bichon frisé, Maltese, miniature poodle, and shih tzu.[33–36,45,46] The most common large-breed dogs reported to develop type I IVD are mixed breeds, German shepherd dogs, Labrador retrievers, rottweilers, dalmatians, and Doberman pinschers.[28,29,42] Hansen type II IVD protrusion develops most commonly in German shepherd dogs.[29]

IVD herniation is rare before 2 years of age; it peaks between 3 and 7 years of age in chondrodystrophic patients and generally develops in nonchondrodystrophic patients at a mean of 6 to 8 years of age.[6,28,29,35,37] Older dogs reportedly have a higher incidence of cervical disc disease.[6] A strong sex predilection has not been reported[5,6,26,37] although some reports found that males and spayed females were at higher risk of developing IVD herniation than females.[33,35,40,47] The risk of extrusion is not related to parameters such as body weight, condition score, or activity level.[26,30,48,49]

DIAGNOSTIC TECHNIQUES FOR IVD HERNIATION

Survey Radiography

Lateral and ventrodorsal survey radiography should be performed under general anesthesia to decrease motion and to ensure proper positioning.[50] Radiographic evidence of IVD mineralization is supportive of degeneration but not disc herniation.[18–21] Calcification of the affected IVD space is rarely noted at the time of diagnosis.[51] An increased prevalence of disc mineralization exists in dachshunds, with an average of 2.3 mineralized discs per dog.[20] Disc calcification was a significant predictor of disc herniation[21] and also a risk factor for recurrent herniation following surgery.[52,53] Radiographic mineralization of thoracic discs has been reported to disappear without signs of extrusion and is believed to result from progressive disc degeneration rather than disc regeneration.[18,19,21]

Other radiographic changes supportive of IVD herniation include narrowing or wedging of the IVD space, narrowing of the articular facets, narrowing or increased opacity of the intervertebral foramen, presence of mineralized disc material within the vertebral canal, and vacuum phenomenon.[50,54,55] Narrowing of the IVD space is considered to be the most useful radiographic sign but it has only a moderate sensitivity and predictive value, whereas the vacuum phenomenon is rare but accurate in identifying the herniated disc.[54] Survey radiographs have a reported accuracy of 51% to 94.7% for the correct identification of the herniated disc space for surgical decompression.[35,54,56–61] Despite the high reported sensitivity of radiography for localizing the lesion in some studies, this modality cannot be used alone for diagnosing IVD herniation because it does not provide information on lateralization of the extrusion, extent, and degree of spinal cord compression and presence of other lesions.[61] Although spondylosis deformans is not associated with Hansen type I IVD herniation, an association between radiographically visible spondylosis deformans and Hansen type II IVD herniation may exist.[62]

Myelography

Myelography has been the standard imaging modality for diagnosing IVD extrusion in dogs. The reported accuracy of myelography for lesion localization ranges from 72% to 97% and its accuracy for lateralization of the lesion ranges from 53% to 100%.[46,55,57–61,63–69]

Lumbar myelography is more technically demanding than cervical myelography but it is more likely to show TL lesions because the injection can be performed under pressure with a reduced risk of seizure.[58] Punctures up to T13 to L1 can reportedly produce a diagnostic myelogram, with no side effects.[64] However, injections cranial to L5 to L6 lead to a canalogram in 4.4% to 20% of cases, potentially worsening the neurologic deficits.[57,64] Fluoroscopy can be used to direct needle placement, confirm subarachnoid contrast flow, and localize the site of herniation during injection. Ventrodorsal and lateral radiographic projections of the area of concern are obtained immediately after contrast injection.[55,57] Attenuation, thinning, or deviation of the contrast column suggesting an extradural compression is considered diagnostic for IVD herniation but axial deviation of the contrast column in the ventrodorsal or oblique projections is required to determine lateralization of the lesion and guide the surgical approach (**Fig. 3**).[46,55,57,64] Eight ventrodorsal myelographic contrast patterns have been reported in small-breed dogs with confirmed TL IVD extrusion.[46] Six of the 8 patterns were consistent with a lateralized or ventrolateral extrusion, whereas 2 were consistent with ventrally located disc extrusions.[46] The reported overall accuracy of the ventrodorsal projection in this study was 89%.[46] In 83% of dogs with unequal gaps in the contrast column, disc material was found on the side with the shorter gap; this phenomenon was termed paradoxic contrast obstruction.[46] Oblique myelographic projections are reportedly of greater benefit than the ventrodorsal projection for circumferential localization and have been recommended for all cases.[55,57,69] Combined oblique and ventrodorsal projections are considered more useful than either projection alone.[69]

Loss of the myelographic contrast in an area 5 times the length of the second lumbar vertebra has been associated with a negative outcome in dogs with TL IVD extrusion that have lost deep pain perception (DPP).[70] In this study, dogs with spinal cord swelling/L2 ratios less than 5.0 had a recovery rate of 61%, whereas dogs with a ratio greater than or equal to 5.0 had a recovery rate of 26%.[70] In contrast, the extent of spinal cord swelling determined by myelography was not found to be a useful prognostic indicator in another study.[71]

The reported incidence of postmyelographic seizures following iohexol myelography ranges from 0% to 10% and has been associated with patient weight (larger

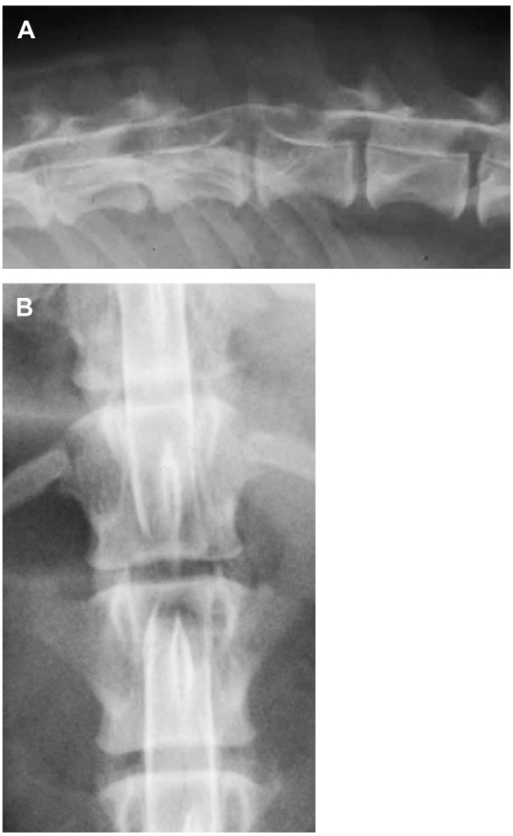

Fig. 3. Lateral (*A*) and ventrodorsal (*B*) myelographic projections showing deviation of the contrast column at T13 to L1 on the right side.

patients), volume of contrast injected (higher volumes), cerebellomedullary injection, lesion location (cervical more likely), sex (higher risk in males), and breed (higher risk in Doberman pinschers).[58,68,72–76] Injection at L5 to L6 and myelography in dogs lighter than 20 kg are associated with lower rates of postmyelographic seizures.[68,73] Supporting this finding, a recent study found a 1.61% and 9.29% rate of postmyelographic seizure in dogs weighing 9 to 20 kg and more than 20 kg, respectively, with an overall rate of 2.98%.[76] Although it has been suggested that surgical intervention and prolonged anesthesia may be protective after iohexol myelography,[72,74] surgery did not independently lower the prevalence of seizures in a more recent study.[73]

Cerebrospinal Fluid Analysis

Cerebrospinal fluid (CSF) is sometimes collected before myelography. Based on previously published results, it is recommended to collect the fluid caudal to the suspected lesion to maximize the yield of diagnostic information from CSF analysis.[77] A recent report on lumbar CSF analysis in dogs with type I IVD revealed pleocytosis in 51% of dogs, including 23% with cervical lesions and 61% with TL lesions.[78] Increase in protein concentration was more common in dogs with cervical (60%) than TL (16%) IVD extrusion, and a predominance of lymphocytes was significantly more common in dogs examined more than 7 days from the onset of signs, which might suggest an immune-mediated response to chronically herniated disc material.[78]

Computed Tomography Imaging

Computed tomography (CT) is a sensitive and noninvasive diagnostic tool that can be used as an adjunct to myelography or as the sole diagnostic procedure to avoid the potential side effects of myelography.[79] CT is quick, has no known side effects (other than exposure to radiation), provides information about lesion lateralization, and has the potential for the images to be reformatted into other imaging planes and three-dimensional images to improve their diagnostic value.[61,68,79,80] Median examination times for myelography, CT, and helical CT were 32 minutes, 8 minutes, and 4 minutes, respectively, in one study, making CT an attractive imaging method.[61] Failure to include the entire spine and inability to identify transitional TL vertebra on the lateral CT scout view can limit the ability to determine accurate vertebral anatomy and complicate lesion localization at surgery.[61] CT generates high-quality bone imaging but is not considered the modality of choice to image soft tissues. A recent study comparing CT and myelography revealed similar diagnostic sensitivities (83.6% and 81.8%, respectively) for localizing the site of disc herniation; however, CT was more sensitive than myelography (80% vs 38%) in detecting chronic lesions because of disc mineralization, and myelography was more sensitive in dogs weighing less than 5 kg (100% vs 50%).[68] Similarly, another study reported that the agreement of myelography, CT, and helical CT with surgical findings was 94.7%, 100%, and 94.7%, respectively, for lesion localization and 78.9%, 87.4%, and 85.3%, respectively, for lesion localization and lateralization.[61] The accuracy of CT and myelography to determine lateralization of the lesion were also comparable at 95.6% and 91.7%, respectively, in an earlier study.[63] Olby and colleagues[79] reported that extruded disc material can be visualized as a heterogeneous hyperattenuating extradural mass using CT without contrast enhancement; these findings are supported by those of Israel and colleagues.[68] In this study, it was possible to differentiate hemorrhage from extruded disc and the spinal cord.[79] Attenuation also increased as mineralization of the IVD material increased, allowing differentiation between acute and chronic extrusions (**Fig. 4**A, B).[79] Intrathecal contrast injection (**Fig. 4**C) has been recommended if the

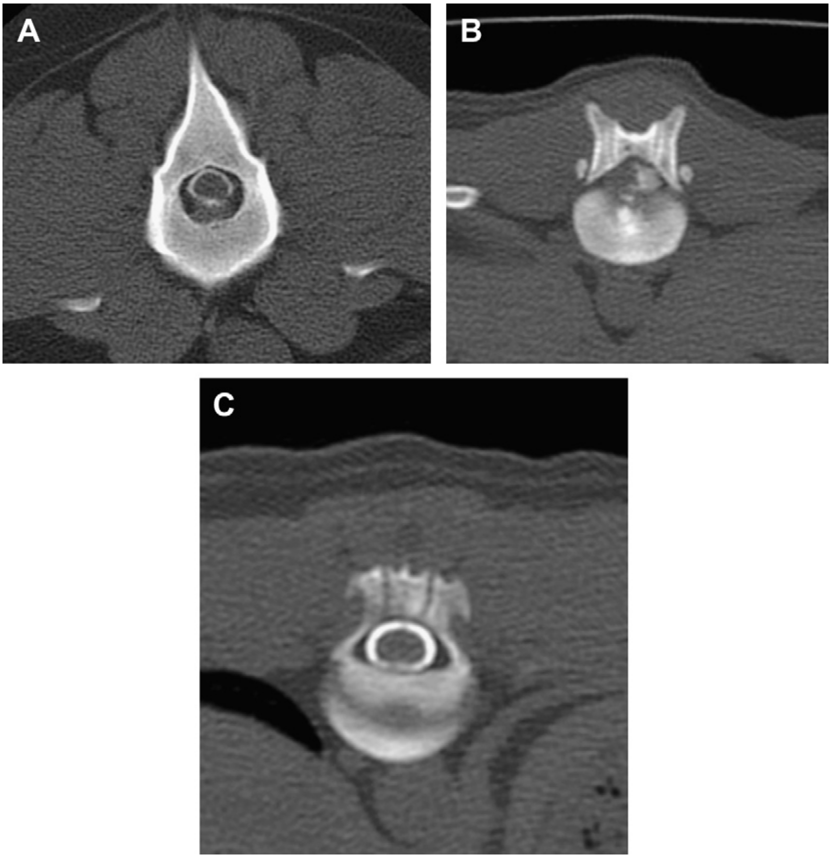

Fig. 4. CT image of a soft (nonmineralized) disc extrusion (*A*), mineralized disc extrusion (*B*), and a normal CT myelogram (*C*).

scan is not definitive but some investigators recommend that it be performed in all cases because contrast enhancement can delineate lesions that were not visible before contrast injection.[68,81] A 3% to 11% increase in certainty score for correct diagnoses was reported when surgeons read multiplanar (MPR) CT images compared with two-dimensional CT images to diagnose TL IVD extrusions in dogs.[80] In addition, the MPR CT images subjectively required less time to interpret.[80] The oblique transverse and curved dorsal MPR views were considered most helpful.[80]

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is considered the best diagnostic method for early detection of disc degeneration in dogs[82] and for imaging the cervical spinal cord, discs, and associated structures (**Fig. 5**).[83] Complete agreement between MRI and surgical findings was reported with regard to the affected TL IVD and lesion lateralization in 2 studies.[23,84] Besalti and colleagues[23] reported complete agreement between dispersion pattern predicted on MRI and the surgical findings, whereas Naude and colleagues[84] found complete agreement with regard to craniocaudal distribution in 69% of cases. A study comparing consecutive MRI and myelography in 24 small-breed dogs admitted for first-time TL IVD extrusion confirmed that MRI is consistently

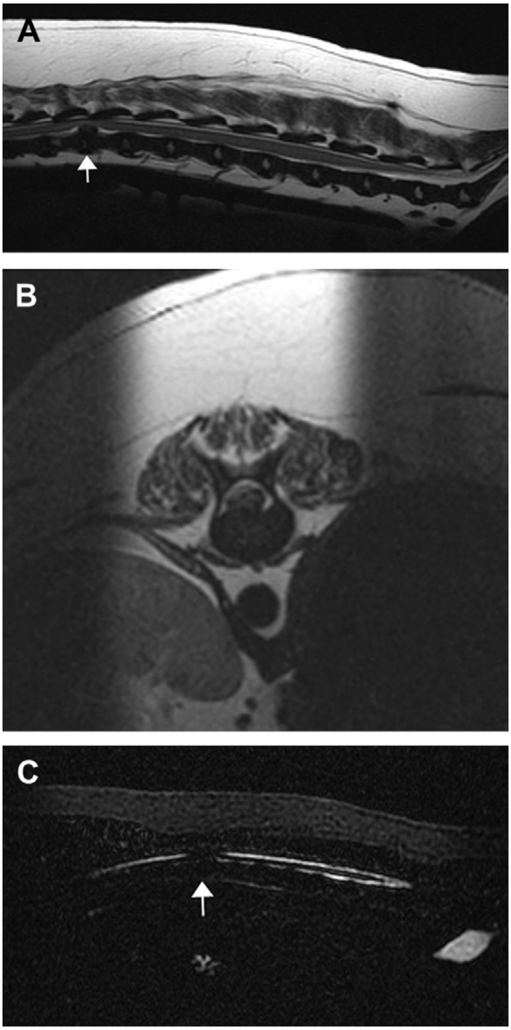

Fig. 5. Sagittal (*A*) and transverse (*B*) T2-weighted MR images of an extruded disc at T12 to T13 (*arrow*) with evidence of disc degeneration at T10 to T11, T11 to T12, T12 to T13 and T13 to L1. Heavily weighted T2 sequence (MR myelogram) showing the absence of CSF signal ventrally and dorsally at T12 to T13 (*arrow*) (*C*).

more accurate than myelography for determining the site and side of the lesion.[51] Compared with T1-weighted and short time inversion recovery images, T2-weighted images are reportedly more accurate and precise, and therefore potentially more reliable for determining the length of extruded disc material.[84] Overall, MRI is considered a good tool to guide surgical decision making with regard to the size and location of TL laminectomy but because MR images tend to underestimate the size of the extruded material, a slightly larger surgical window than that indicated on MRI is recommended to ensure that all extruded disc material is removed.[23,84]

Although dispersed extruded IVD material is believed to be associated with more concussive lesions than nondispersed extrusions, an association was not found between the MRI dispersion pattern and the preoperative and postoperative neurologic status or outcome and should therefore not be used to make treatment or prognostic recommendations.[23] Increased MRI signal intensity in the TL spinal cord has been associated with a poor prognosis for recovery in paraplegic dogs.[23,38,85] Successful recovery of dogs with no DPP that had a hyperintense lesion on T2-weighted images was only 31%.[85] In contrast, the absence of hyperintensity within the spinal cord on T2-weighted images was associated with a successful recovery for all paraplegic dogs regardless of DPP.[85] Similar to what has been reported with myelography,[86] the degree of spinal cord compression seen on MRI in dogs with IVD extrusion was not associated with the rate of onset, duration of clinical signs, or postoperative outcome.[87,88] Although the degree of spinal cord compression noted on MRI was not associated with the severity of neurologic signs at presentation for TL lesions,[87] it was for cervical lesions.[88]

Although MRI is considered superior to myelography for diagnosing unilateral single compressions, in an older study, myelography was the modality of choice to accurately determine the active lesion in 12 of 53 human patients with multilevel disease.[89] MRI is considered superior to myelography for diagnosing extradural compressions caused by hemorrhage.[90,91] Vertebral sinus hemorrhage can result in a filling defect that extends over several vertebral bodies and cannot be differentiated from an extensive extradural compression or spinal cord swelling on myelography.[29,79,90,91] By identifying varying signal intensities, MRI sequences such as the gradient-echo sequence can enable the differentiation between disc material and hemorrhage.[90,91]

CERVICAL IVD DISEASE

Clinical Presentation

Cervical disc herniation is reported in 12.9% to 25.4% of dogs with IVD herniation.[5,6,34] A total of 15% to 61% of cervical IVD herniation cases present with signs of cervical hyperpathia, guarding of the neck, and muscle fasciculations without neurologic deficits.[40,88,92–94] The lower rate of neurologic deficits compared with patients with TL IVD herniation is believed to be related to the large vertebral canal/spinal cord ratio of the cervical vertebral column. Thus, larger disc extrusions can occur without severely compromising the spinal cord. Unilateral or bilateral lameness caused by lower cervical nerve root compression (nerve root signature) has been reported in 15% to 50% of cases.[41,88,92,93] Results of a recent study suggest that the withdrawal reflex in dogs with cervical disc herniation is not reliable for differentiating C1 to C5 or C6 to T2 lesions because a decreased withdrawal reflex does not always indicate a lesion from C6 to T2.[95] Although infrequent, ataxia with tetraparesis or even tetraplegia can develop and has been reported in 9.1% to 17.6% of patients undergoing surgery for cervical disc disease.[39,40,42,44,96] Nonambulatory tetraparesis is reported less frequently in dachshunds than in other breeds.[96] Loss of DPP and respiratory difficulty is possible in extreme cases but is rarely reported.[44] Small-breed dogs, especially dachshunds and beagles, are most commonly affected, but recent studies show that 24% to 50% of cases involve nonchondrodystrophic, large breeds, with Labrador retrievers and rottweilers being most commonly affected.[39,40,42–44,88,92,93] The mean age at the time of diagnosis is 6 to 8 years.[42–44,88,92,93]

Diagnosis

Although both Hansen type I and II disc herniations occur in the cervical region, Hansen type I extrusions are most common in both small- and large-breed dogs.[42] C2 to C3 is the most commonly affected disc space in the cervical spine of small-breed dogs,[6,42,88,92,93] whereas C6 to C7 is the most commonly affected disc space in large-breed dogs.[42] Recent studies have reported C5 to C6[44] and C6 to C7[88] as the most commonly affected disc spaces among all dog breeds presenting for cervical IVD herniation.

Diagnosis of cervical disc herniation is based on lesion localization from the neurologic examination, radiography, and myelography ± CT or MRI. Disc calcification and narrowing of the affected disc space are commonly noted on survey radiography and are generally believed to correlate with the myelographic findings.[93,97] However, a study evaluating the accuracy of localization of cervical IVD herniation using survey radiographs alone found an overall accuracy of only 35%.[98] In cases in which multiple sites of extrusion were confirmed myelographically, the active lesion was incorrectly identified in 16% to 31% of cases using survey radiographs alone.[98] Of 50 dogs with neck pain but with no evidence of neurologic deficits, 94% showed a deviation of the ventral contrast column at myelography, with 60% of 50 dogs having a moderate to severe deviation of the spinal cord.[93] Based on these findings, it has been recommended that all dogs presenting with neck pain and a suspicion of cervical IVD herniation undergo diagnostic imaging regardless of their neurologic status.[93] Most studies report a single cervical disc herniation on myelography.[92–94] Nondiagnostic myelography has been reported in dogs with lateral or intraforaminal cervical disc extrusions.[97] For this reason, oblique radiographic views should be performed in all patients with clinical signs supportive of cervical IVD that do not have a compressive lesion on lateral and ventrodorsal myelographic projections.[97] Oblique projections allow the visualization of mineralized disc material within the affected foramina.[97] MRI would also allow its visualization and would represent the only diagnostic tool capable of identifying nonmineralized foraminal or lateral extrusions.[83,99] MRI findings of cervical IVD herniation include narrowing of the IVD, displacement or loss of the epidural fat, and a change in the shape of the spinal cord.[83] A recent MRI study found that the degree of cervical spinal cord compression was significantly associated with the presurgical neurologic status but not with speed of onset, duration of signs, postoperative neurologic status, or outcome.[88] A moderate agreement was found between lateralization of cervical lesions from clinical signs and MRI findings, with 9 of 33 cases having lateralization noted on MRI but not clinically.[88]

Conservative Treatment

Conservative treatment focuses on exercise restriction, typically confining the patient to a small cage for 2 to 6 weeks to reduce the risk of continued extrusion while the ruptured AF heals.[43,100] Physical therapy, administration of analgesics, muscle relaxants, and antiinflammatory drugs have also been advocated but are of unknown benefit. The use of a harness instead of a neck collar and leash is important.

Of 32 clinical cases treated conservatively with various medications and acupuncture, 69% were assessed as having recovered in one study, but 37% of cases developed signs of recurrence.[101] A more recent study[43] retrospectively assessed 88 dogs with presumptive cervical disease and reported that 48.9% of dogs were managed successfully, 33% had recurrence, and 18.1% were deemed to have failed conservative treatment. Of the dogs included in this study, 97% were ambulatory at the time of presentation.[43] Less severe neurologic status and administration of a nonsteroidal antiinflammatory drug (NSAID) were associated with a successful outcome but steroid use and the duration of cage rest were not.[43] These results are in agreement with an older study that reported a 36.3% recurrence rate in dogs treated conservatively, which is higher than the 5.6% recurrence rate noted in surgically treated dogs.[39]

Most clinicians agree that medical management of cervical IVD herniation is best suited for mildly affected patients with an acute history.[39,43,92]

Surgical Treatment

Surgical treatment of cervical IVD herniation is typically recommended in dogs that display severe neck pain, neurologic deficits, or recurrence or deterioration of clinical signs after medical management or dogs that have a chronic history at the time of presentation.[42,44,92] Although fenestration alone has been reported to yield acceptable recovery rates,[40] it does not provide spinal cord decompression and is not considered a satisfactory therapeutic modality for cervical IVD extrusion.[92] A study of 111 ambulatory dogs with cervical IVD herniation revealed that ventral decompression was significantly superior to cervical fenestration with regard to improved neurologic status (87% vs 73%) and speed of recovery.[41] Decompressive procedures currently used to treat cervical IVD herniation include ventral slot decompression and less commonly dorsal laminectomy or hemilaminectomy.[92,94,97,102,103] Lateral approaches to the midcervical spine (C3-C6) have also been described to address lateralized or foraminal lesions.[97,104,105] A retrospective study showed no difference in outcome after ventral or dorsal cervical decompression techniques used in small- and large-breed dogs.[42]

The ventral slot procedure is performed through a ventral approach to the cervical spine and provides access for removal of ventrally located disc material but does not allow significant spinal cord decompression or removal of lateralized or dorsally located IVD material. Identification of the IVD space of interest is based on palpation of landmarks such as the ventral process of C1 and the large transverse processes of C6. A bony slot of approximately one-third the width and one-third the length of the vertebrae has been recommended to prevent postoperative instability.[106] Slots of excessive dimensions, especially in the caudal cervical spine, can lead to subluxation and postoperative neurologic deterioration.[92,107] If intact, the dorsal longitudinal ligament must be excised to access the vertebral canal for removal of the extruded disc material.[108] Prophylactic fenestration of adjacent discs can be accomplished through the ventral approach if deemed appropriate, but prophylactic fenestration of the cervical discs is currently less in favor. Resection of the cranial aspect of the manubrium to facilitate ventral access to the C7 to T1 disc space was recently described in one dog without complication.[109]

The dorsal laminectomy procedure does not allow the removal of ventrally located herniated disc material but achieves spinal cord decompression by removing the roof of the vertebral canal.[94] Some investigators believe that this approach is advantageous in small dogs, in which adequate ventral slot size may be difficult to achieve.[94] Cervical hemilaminectomy is more technically demanding and results in more tissue trauma but is reportedly the only approach that allows removal of foraminal or lateral disc extrusions.[97]

Complications associated with surgical procedures used to treat cervical IVD include worsening of the neurologic status,[41] persistent neck pain,[40] hemorrhage,[41,92,97,110] respiratory acidosis and cardiac arrhythmias,[41] hypotension and bradycardia resulting in death,[110] vertebral instability and subluxation,[92,107] and recurrence of IVD extrusion.[39,40,96] In a study evaluating intra- and postoperative mortality, an overall death rate of 8% was reported but was significantly higher in dogs treated with dorsal decompression (12%) than with ventral decompression (5%).[110] Deaths were related to intraoperative hemorrhage, respiratory arrest 3 to 10 hours postoperatively, and cardiovascular decompensation.[110] Postoperative cervical instability and subluxation are presumably related to the dimensions of the ventral slot (slot/vertebral body ratio of 0.5 or greater in most cases) and seems to affect most commonly the caudal cervical spine (C4-C7) of small-breed dogs.[107] Modifications of the ventral slot have been reported in an attempt to reduce the potential for cervical instability and subluxation.[103]

Prognosis for Surgically Managed Cervical IVD Herniation

Prognosis for dogs that present with neck pain alone or mild neurologic deficits and that retain an ambulatory status is good.[42,43,92] Ambulatory dogs undergoing surgical decompression typically remain ambulatory postoperatively.[42,92] A recent retrospective evaluation of 144 small-breed dogs and 46 medium- to large-breed dogs with confirmed cervical IVD extrusion documented resolution of signs in 99% of cases that underwent surgical decompression; only 22% of dogs in this study were nonambulatory before surgery.[42] All dogs that were nonambulatory with DPP before surgery regained the ability to walk within a mean of 6 days postoperatively in one study,[42] whereas studies focused on nonambulatory tetraparetic dogs report full recovery rates of 58% to 62%.[44,96] Of patients undergoing dorsal laminectomy with various neurologic grades, 67% recovered normal ambulation 2 weeks postoperatively and 100% were ambulatory at final recheck 5 to 44 months postoperatively.[94] Similar results were reported with ventral slot decompression, all cases of which were eventually reported to have an excellent outcome regardless of neurologic status before surgery.[92] Dogs with peracute histories had more severe neurologic dysfunction before surgery in one study[88] and took longer to return to function in another[92] but their overall neurologic status improved more as a result of surgery compared with dogs with slower clinical progression.[88] Small-breed dogs regained ambulatory status sooner than large-breed dogs (4.5 vs 7 days) in one report[42] and were as much as 5 times more likely to recover than large-breed dogs in another.[44] Dogs that regained the ability to walk within 96 hours after surgery were more than 6 times more likely to have complete recovery, compared with dogs that remained nonambulatory at 96 hours postoperatively.[44,96] Although a previous study[96] suggested that lesion localization (cranial cervical better than caudal cervical) and neurologic status were prognostic indicators of outcome, larger and more recent studies do not support these findings.[42,44] One study recently reported an 83% recovery rate for patients presenting with tetraplegia.[44] Residual deficits are reported in 17% of dogs presenting with nonambulatory tetraparesis.[96] Recurrence of cervical hyperpathia and/or tetraparesis was reported in 0% to 17% of cases after surgical decompression.[42,44,92]

TL IVD DISEASE

TL IVD herniation is reported in 66% to 87% of dogs with IVD herniation.[5,6,34] The discs located between T12 and L3 have been shown to be at higher risk of herniation but the most commonly affected disc spaces in chondrodystrophic dogs are T12 to T13 and T13 to L1.[3,6,26,35,37,38,45,55,56,111–113] Although chondrodystrophic breeds, especially the dachshund, are affected most frequently, large-breed dogs such as the German shepherd dog also develop acute Hansen type I TL IVD extrusions.[28] In large-breed dogs, L1 to L2[28,29] and T13 to L1[29] followed by L2 to L3[28,29] are most frequently affected. Although rare, IVD herniation does occur in the upper thoracic region. T9 to T10 IVD herniation has been reported in dachshunds,[7] and a recent report documented IVD herniation at T2 to T3 in 3 German shepherd dogs.[114]

Clinical Presentation

TL disc herniation can cause varying degrees of back pain and neurologic deficits that range from mild paraparesis to paraplegia with or without loss of DPP. Upper motor neuron (UMN) signs are associated with most IVD extrusions but lower motor neuron (LMN) signs are possible and indicate a lower lumbar lesion. Large-breed dogs with annular protrusions tend to be significantly older and have a significantly more chronic onset of neurologic signs and milder neurologic dysfunction than large-breed dogs with nuclear extrusions.[29]

Diagnosis

Diagnosis of TL IVD and lesion localization is based on the results of the neurologic examination, radiography, myelography, CT or MRI. Although 24% to 80% of dogs with TL IVD herniation reportedly present with clinical signs that are lateralized to the right or left side, [35,46,55,56,58–60] clinical lateralization is reported as the least reliable factor in determining the side on which to perform surgery.[60] Asymmetrical clinical signs contralateral to the myelographic or surgically confirmed lesion occur frequently in dogs with type I IVD extrusion,[35,59,60,115] with 2 studies reporting that surgical lateralization corresponded to the neurologic lateralization in only 48.1% and 61% of cases.[35,59] In a study that specifically examined lateralization, 35% of dogs presenting acutely had a myelographic lesion contralateral to their clinical lateralization compared with only 11% of chronic cases.[115] Other studies report that 14% to 25% of cases had myelographic and surgical lateralization contralateral to the clinical lateralization, respectively.[46,55,60] The discrepancy between the clinical, diagnostic, and surgical findings may result from a ventral or bilateral disc extrusion that causes asymmetric clinical signs in which disc material could be retrieved from either side of the vertebral canal, from an asymmetrical extrusion that leads to more spinal cord trauma on the opposite site as a result of compression of the spinal cord against the vertebral canal (contrecoup injury), or because of contralateral inflammation, hemorrhage, or spinal cord swelling.[46,58,60] The absence of clinical lateralization does not negate the possibility of myelographic lateralization.[55,60]

Reported correlation between myelographic localization and surgical findings ranges greatly and depends on the quality of the myelogram and whether there is any evidence of myelographic lateralization on the ventrodorsal or oblique projections. The results of recent studies indicate that the side of spinal cord decompression corresponds with the myelographic findings in all dogs showing myelographic lateralization.[46,69] Similarly, correlation between MRI and surgical findings is reportedly 100% for lesion localization and lateralization.[23,84] A recent study of 24 dogs receiving consecutive MRI and myelography showed that MRI was consistently superior to myelography for determining lesion localization and lateralization.[51] Although small-breed dogs with a history of several episodes of back pain tend to have a single lesion on myelography,[35] 47% of large-breed dogs with Hansen type II protrusions had multiple annular protrusions at myelography.[29] MR myelography or conventional myelography may be superior to conventional MRI sequences (eg, T2 weighted) in identifying the active lesion in dogs with multiple TL disc herniations.[51,57,89]

A total of 15.8% and 30.5% of dogs were reported to have anatomic vertebral variations such as TL transitional vertebrae, abnormal ribs, or transverse processes that could complicate surgical localization and warrant preoperative radiographs to guide surgery.[57,61] Radiographs and myelography (97.9%) were more accurate than CT (87.4%) or helical CT (88.4%) to determine vertebral numbers and anatomic variations in 19 chondrodystrophic dogs.[61]

Conservative Treatment

Conservative management of TL IVD herniation typically consists of strict confined rest, antiinflammatory drugs, muscle relaxants, analgesics, and physical therapy.[116–118] Although cage rest is the most important aspect of conservative management to prevent continued nuclear extrusion through the ruptured AF and to reduce the risk of self-trauma as a result of incoordination,[116,117] a retrospective evaluation revealed that the duration of cage rest did not affect the success of medical therapy.[117] Although conservative therapy was reportedly successful in 100% of dogs presenting with hyperpathia $\pm$ mild neurologic deficits, 50% of patients showed signs consistent with a recurrence 1 to 36 months after the first episode.[118] Other studies have reported success rates of approximately 50% in dogs suspected of TL IVD herniation, with recurrence rates of approximately 30%.[117,119] A 13% rate of residual ataxia was reported for conservatively managed dogs.[119]

A study of 78 dogs suspected of TL IVD extrusion showed that dogs treated with an NSAID or methylprednisolone had lower recurrence rates than dogs treated with other corticosteroids.[118] However, the use of corticosteroids for treating TL IVD remains controversial. Corticosteroid administration has been associated with lower quality of life score and decreased odds of successful outcome in conservatively managed patients.[117] In this study, dogs with suspected TL IVD that received an NSAID were more likely to have higher quality of life scores compared with dogs that did not receive an NSAID.[117] Electroacupuncture used in conjunction with Western medical treatments such as corticosteroids and rest was recently reported to increase neurologic recovery from 58.3% to 88.5% and to reduce the time to recovery of ambulation and DPP.[120] It is well accepted that conservative management is not appropriate for dogs that have lost DPP.[119]

Surgical Treatment

IVD fenestration was initially described as a treatment modality for disc extrusion,[121–123] but its therapeutic efficacy was later questioned because it does not provide spinal cord decompression.[124,125] Furthermore, patients presenting with neurologic deficits that were treated with fenestration alone reportedly had prolonged recovery times similar to those of patients treated conservatively[125,126] and were less likely to recover than if treated with decompressive surgery.[123,126] A more recent study described a technique for partial percutaneous discectomy and reported an 88.8% recovery rate for patients that still had DPP with a mean time for first improvement of 8.3 days.[127] Poor success was reported for dogs without DPP that were treated with percutaneous discectomy.[127] Similarly, other studies do not recommend disc fenestration alone for dogs with paralysis or loss of DPP.[126,128]

Surgical decompression with removal of extruded disc material is a well-accepted treatment modality for patients with severe or progressive neurologic deficits[22,35,56,124,129–136] and has also been recommended for patients with minimal neurologic deficits or back pain alone.[86,118,124] Positive clinical outcome has been associated with complete removal of the offending disc material rather than simple vertebral canal decompression.[56,137] Early decompression using atraumatic surgical technique is optimal for functional recovery to occur. Decompression without removal of extruded disc material does not restore normal arterial and venous hemodynamics and is not considered adequate.[56,137] Although delays before surgery did not seem to affect outcome in dogs with mild to severe neurologic deficits in some studies,[71,85,86,113,138] they are believed to be detrimental in patients with rapidly progressing neurologic dysfunction,[35,71,138] and have been shown to significantly affect the rate of recovery in dogs that have lost DPP.[70,71,111,113]

Traditional surgical decompression of TL IVD extrusion can be accomplished by dorsal laminectomy[130,131,139] and hemilaminectomy.[124] Procedures such as the pediculectomy, minihemilaminectomy, extended pediculectomy, and partial pediculectomy have aimed to achieve spinal cord decompression through less invasive approaches and by removing less vertebral bone.[65,66,135,140,141] These procedures are reportedly quicker, they provide access to the ventral and lateral aspects of the vertebral canal for removal of the extruded disc material, create less tissue trauma and less vertebral instability, and lead to a more rapid postoperative recovery.[66,133,140–142] The corpectomy procedure is described as a less invasive approach to treat chronic Hansen type I or type II disc herniations because it limits manipulation of the spinal cord during disc removal and avoids the temporary clinical worsening noted with other procedures.[143]

Hemilaminectomy is the most popular approach to the TL spinal cord. It was associated with a more satisfactory decompression by removal of disc material,[144] significantly higher rate of postoperative neurologic improvement,[145] decreased risk of laminectomy membrane formation,[144] and less postoperative biomechanical instability[146] compared with dorsal laminectomy. This procedure provides direct access to the lateral and ventral aspects of the vertebral canal, facilitating removal of the extruded material for complete spinal cord decompression and providing access to the disc space for fenestration.[144] However, it has an increased risk of venous sinus hemorrhage compared with the dorsal laminectomy procedure.[144] The dorsal approach to the spine for hemilaminectomy allows access to the contralateral side without repositioning the patient in cases in which a bilateral procedure is necessary. The hemilaminectomy procedure involves the removal of the articular facets and may therefore lead to some degree of vertebral instability. Although bilateral hemilaminectomy did not result in clinical evidence of vertebral instability in normal dogs,[147] the additional instability resulting from disc herniation may warrant some form of vertebral stabilization for bilateral or extensively long approaches. Delayed recovery or clinical deterioration noted 1 to 10 days postoperatively was recently reported in 5.8% of patients undergoing hemilaminectomy and was most commonly associated with residual spinal cord compression caused by an incorrect surgical approach, failure to remove all the extruded disc material, or recurrent disc extrusion.[148]

The window provided by the pediculectomy or minihemilaminectomy is adequate for visualizing the ventrolateral aspect of the vertebral canal and provides excellent access for retrieval of ventral or lateralized disc material, yet limiting intraoperative spinal cord manipulation.[135] Preservation of the articular facets reduces postoperative vertebral instability compared with the hemilaminectomy procedure.[142] The approach used for pediculectomy or minihemilaminectomy also allows direct access to the IVD for fenestration.[135,141] Like the hemilaminectomy procedure, the pediculectomy window is performed close to the vertebral sinus and foraminal structures, requiring care to prevent hemorrhage and nerve root damage. The partial pediculectomy may provide too small a window to decompress extensive lesions or ensure that all the extruded disc material is removed and has the added disadvantage that it requires blind probing of the vertebral canal, which can increase the risk of venous sinus bleeding.[141] A pediculectomy can easily be converted into a hemilaminectomy or be extended over several adjacent vertebrae if required. I have performed continuous pediculectomies over as many as 5 contiguous vertebrae without complication. Because the pediculectomy does not invade the articular facets, it can also be performed bilaterally without causing vertebral instability, assuming that a portion of the pedicle remains intact cranial and/or caudal to the pediculectomy window to prevent disconnecting the dorsal lamina from the vertebral body. A recent report has documented dorsal laminar subluxation in a dog following bilateral minihemilaminectomy and fenestration of T12 to T13 and bilateral pediculectomy at T13.[149]

The corpectomy procedure has been recommended for Hansen type II IVD protrusions and for chronic cases of type I IVD extrusions in which removal of disc material is likely to be incomplete or result in significant worsening of the neurologic status because of disc encapsulation and adhesion to the spinal cord, nerve root, and venous sinuses.[143] This technique is performed through a lateral approach to the spine and involves the removal of a portion of the adjacent vertebral bodies on either side of the affected disc.[143] This ventral access to the vertebral canal allows removal of disc material and avoids trauma to the overlying spinal cord.[143] An initial report of 15 small- and large-breed clinical cases treated by corpectomy revealed excellent results, with none of the cases showing a worsening of their clinical signs and all dogs improving neurologically after the procedure.[143]

Durotomy is no longer recommended as a therapeutic procedure for spinal cord trauma but it retains some value as a diagnostic tool for myelomalacia and as a possible prognostic indicator in patients that have lost DPP.[70,71,112,150,151] Although the potential for durotomy to cause significant morbidity has been raised,[152] it did not significantly affect postoperative recovery in cases presenting without DPP that underwent hemilaminectomy with durotomy compared with those that underwent hemilaminectomy alone.[151] The presence of extensive myelomalacia is typically associated with a poor prognosis but focal myelomalacia does not preclude neurologic recovery.[70,151] Moreover, the absence of visual evidence of myelomalacia does not ensure neurologic recovery.[70,151] A diffuse and progressive form of myelomalacia called ascending-descending myelomalacia has been reported to occur in 1% to 3.2% of patients admitted for IVD herniation,[119,153] and in 10.9% to 32.6% of those presenting without DPP.[26,70,71,138,154–156] This generalized form of myelomalacia progresses cranially and caudally within the spinal cord parenchyma within hours to days, leading to respiratory paralysis within 5 to 10 days.[119] Ascending-descending myelomalacia has been associated with Funkquist type III disc extrusions.[22,155]

Prophylactic IVD Fenestration and Recurrent Disc Herniation

IVD fenestration typically involves the mechanical removal of the NP through a window created in the lateral AF using an air drill and burr (power-assisted fenestration) or a scalpel blade (blade fenestration) (**Fig. 6**).[106,157] The effectiveness of fenestration is governed by the amount of NP removed.[158] A study comparing blade and power-assisted fenestration revealed that power-assisted fenestration removed on average 65% of the NP compared with approximately 41% of the NP being removed with blade fenestration.[157] I believe that either technique can remove large amounts of disc material as long as the surgeon is comfortable with the technique chosen. Another study determined that using the lateral approach for IVD fenestration may increase the efficiency of the procedure compared with the dorsal or dorsolateral surgical approaches by providing a better angle and working depth for fenestration.[159] Other reported techniques for prophylactic ablation of the IVD include percutaneous laser fenestration[160] and chemonucleolysis.[161]

In 1970, Funkquist[131] reported that recurrent disc herniation was at least as frequent in patients that had undergone a laminectomy alone as in patients that had been treated conservatively. Fenestration of the herniated disc space has since been encouraged to prevent further extrusion of disc material through the ruptured AF in the early postoperative period.[112,131,162] A recent study[162] that performed repeat MRI immediately and 6 weeks postoperatively confirmed recurrent disc herniation in 6 of 10 patients that did not undergo fenestration of the affected disc space at the time of surgical decompression. Three of these 6 patients displayed clinical signs (pain and/or paresis) compatible with the recurrent herniation noted on MRI.[162] Early

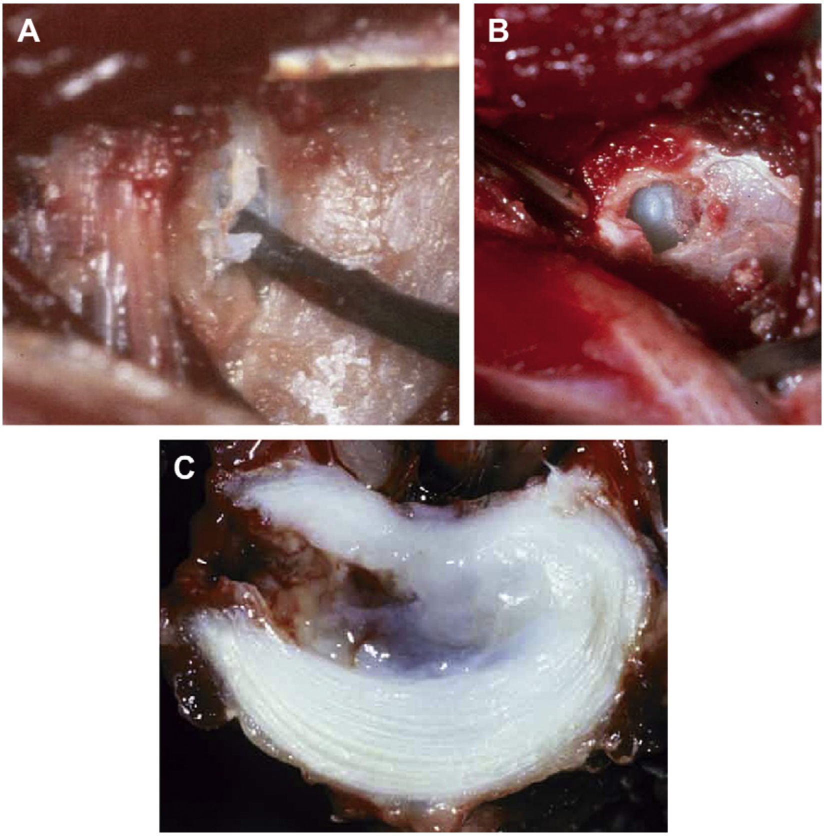

Fig. 6. Disc space during (*A*) and after (*B*) surgical fenestration through a dorsolateral approach to the spine. Transverse section of a disc space after fenestration was performed (*C*).

recurrences reportedly occur within 4 to 6 weeks of surgery and are generally related to nuclear extrusion at the site of initial IVD extrusion. [45,162,163]

All IVDs are subject to degeneration and chondrodystrophic breeds have been reported to develop on average 2.5 IVD herniations per dog.[3,5] Fenestration of IVD spaces adjacent to the surgical lesion has been advocated as a prophylactic measure to future disc herniation.[65,119,121,122,124–126,131–133,164] Recurrence rates of 0% to 24.4% with prophylactic fenestration[65,119,125,126,128,164] and 2.67% to 41.7% without prophylactic fenestration[35,112,119,131,134,163–165] have been reported. The most recent retrospective studies report unconfirmed recurrence rates of 19.2% without prophylactic fenestration[52] and confirmed recurrence rates of 4.4% in a population of dogs that frequently underwent prophylactic fenestration.[45] The latter study also revealed that 15.8% of dog owners reached by telephone follow-up reported their dog developed signs compatible with recurrent IVD herniation and that 44% of these dogs were euthanized elsewhere for suspected recurrence.[45] A recent prospective study randomized 207 small-breed dogs undergoing surgical decompression for TL IVD extrusion to either receive single-site fenestration at the site of decompression (n = 103) or multiple-site prophylactic fenestration of all disc spaces between T11 and L4 (n = 104) with a median follow-up for recurrence of 3.4 years.[53] The surgically confirmed recurrence rate in this study was 12.7% with a significantly lower recurrence rate for dogs in the multiple-site fenestration group (7.45%) compared to dogs in the single-site fenestration group (17.89%).[53] In addition, only dogs from the single-site fenestration group developed more than one recurrence in this study.[53] The reported rate of recurrent IVD herniation for large-breed dogs is 11% to 12%.[28,29]

Although in some studies dachshunds were more likely to develop recurrent TL IVD herniation compared with other breeds,[45,163] this was not found to be the case in others.[52,53] Disc mineralization at the time of first surgery has been associated with recurrent IVD herniation in dogs.[52,53] Late recurrent IVD herniation occurs at a mean time of 8 to 14 months after the first surgery and typically within 36 months of the first event.[45,52,53,125,163,165] Recurrences occur at a new disc space in 88% to 100% of cases,[45,53,163,165] and more than 70% of recurrences occur in a region that could have been readily fenestrated at the first surgery.[163] Most recurrences occur at a site immediately adjacent to or one disc space away from the first lesion or from a fenestrated disc space, suggesting that disc herniation and fenestration may have a biomechanical effect on adjacent disc spaces.[45,52,53,163] This finding is supported by the fact that the AF has been shown to be an important stabilizing structure and that fenestration significantly contributes to vertebral instability.[142] The incidence of recurrence at L4 to L5 and L5 to L6 in dogs prophylactically fenestrated between T11 to T12 and L3 to L4 is reportedly 45.5% to 57.1%[45,53]; this is considered high because the reported rates of spontaneous disc extrusion at these disc space are between 3.7% and 7%.[5,6,35,45]

Reported complications associated with fenestration include increased anesthetic and surgical times,[112] displacement of disc material into the vertebral canal and/or spinal cord trauma causing worsening of neurologic grade,[166,167] hemorrhage,[45,53] pneumothorax,[45,166] soft-tissue and nerve-root trauma leading to postoperative pain, scoliosis and abdominal wall weakness,[53,65,166] diskospondylitis,[125,168] and difficulty identifying one or more disc spaces for fenestration.[45,53] Most reported complications are minor and have no long-term negative effects.[45,53,65,166]

Laminectomy Membrane Formation

Laminectomy membrane formation is believed to result in an 8% failure rate after vertebral surgery in humans.[169,170] Three of 187 (1.6%) dogs were surgically confirmed as having complications that responded to removal of a laminectomy membrane in one report.[35] Although this condition is suspected in clinical patients displaying signs of spinal cord compression following a laminectomy procedure, an actual rate of occurrence has not been reported in veterinary patients.[129,139] A variety of materials have been implanted in an effort to reduce the occurrence of laminectomy membrane formation but several remain of questionable value. Although free fat grafts have been most popular, these have been reported to lead to significant spinal cord compression, especially in the first few weeks after implantation.[152,171] No advantage has been reported to support the use of a pedicled fat graft rather than a free fat graft.[152] Free fat grafts and cellulose membrane are somewhat effective at reducing laminectomy membrane formation but experimentally the free fat grafts are associated with a high rate of significant neurologic complications that seem to resolve within 3 to 10 days after implantation.[171] Neither the free fat graft nor the cellulose membrane is recommended to cover a modified dorsal laminectomy.[171]

Prognosis for Surgically Managed TL IVD Herniation

Reported recovery rates for nonambulatory chondrodystrophic or small-breed dogs that retain DPP before decompressive surgery vary between 86% and 96%.[45,47,49,111,112,165,172,173] The overall recovery rate for nonchondrodystrophic large-breed dogs with Hansen type I IVD extrusions is slightly lower at 78% to 85%,[28,29] whereas the overall recovery rate for nonchondrodystrophic large-breed dogs with Hansen type II IVD protrusions is between 22% and 52%.[29]

The presence of DPP has been reported by many as the most important prognostic factor for return to function.[28,37,49,70,111,112] A recent study showed that dogs with preoperative DPP had a 1.7-times-better chance of becoming ambulatory than those without.[49] Although duration of clinical signs and severity of neurologic dysfunction were not associated with outcome in some studies,[85,112,174] peracute (<an hour) loss of motor function in dogs with no DPP has been associated with a poorer prognosis compared with dogs with a slow, progressive loss of ambulatory function.[71] This finding is likely related to the significant spinal cord injury caused by a sudden, high-velocity IVD extrusion compared with a slow, gradual IVD extrusion.[71] Other studies state that speed of onset and duration of clinical signs should not be used to advise owners about prognosis.[85,138]

The overall reported recovery rates for dogs undergoing TL decompressive surgery with questionable or absent DPP range between 0% and 76%.[35,37,45,49,59,62,70,111–113,119,126,138,145,151,165,175,176] In contrast, only 25% of large-breed dogs with Hansen type I TL IVD extrusion having lost DPP are reported to recover after undergoing decompressive surgery.[28] Although recovery has been reported in dogs that lost DPP more than 72 hours preoperatively,[59,71,175] functional recovery is rare in patients that are treated conservatively or that undergo decompressive surgery more than 48 hours after losing DPP.[37,70] Dogs undergoing surgery within 12 hours of losing DPP have a higher recovery rate.[37,70,71,111] One study[111] reported a 55.6% rate of recovery for dogs that underwent surgery within 12 hours of losing DPP, whereas only 25% of dogs treated 12 to 36 hours after losing DPP recovered. Similarly, Duval and colleagues[70] reported a 53% recovery rate if surgery occurred less than 12 hours after losing DPP and 38% and 43% recovery rates between 12 and 24 hours and 24 and 48 hours, respectively. The prognosis for recovering function is poor if DPP does not return within 2 to 4 weeks.[71,138,176]

Time to ambulation after decompressive surgery is important to owners wishing to pursue surgical treatment. The mean time required to recover ambulatory status in dogs that lose purposeful movement but retain DPP reportedly varies between 6.7 and 12.9 days.[47,172,173] However, a more recent study noted that many patients return to ambulatory function only 2 to 4 weeks postoperatively.[49] Olby and colleagues[138] reported a mean time to ambulation of 7.5 weeks for 87 dogs with severe spinal cord injury, with 62% of dogs walking within 4 weeks of surgery. In contrast, large-breed dogs that were ambulatory before surgery took on average 5.6 weeks to recover and those that were nonambulatory but retained DPP before surgery took 7 weeks to recover.[28] Residual deficits are reported in 20% to 25% of chondrodystrophic dogs presenting with severe neurologic deficits.[112,141] The fecal and urinary incontinence rates for dogs presenting without DPP and undergoing surgery were 41% and 32%, respectively.[138] A 40% rate of residual neurologic and gait deficits was reported in larger-breed dogs and should be discussed with owners.[28]

Administration of dexamethasone or methylprednisolone sodium succinate did not reveal an improved outcome in dogs with surgically treated TL IVD but was associated with a higher rate of gastrointestinal and urinary tract complications as well as longer hospital stay and increased cost to the owners.[177,178] In contrast, postoperative physical therapy seems to have a positive effect on return to ambulatory status.[49]

Lower motor neuron lesions have historically been associated with a poorer prognosis compared with UMN lesions. Although LMN lesions may be associated with a slower return to function compared with UMN lesions,[179] lesion localization does not seem to affect the rate of recovery.[138,179] A more recent study looking at outcome and prognostic factors in 308 cases of TL IVD herniation supported this finding by showing that the affected IVD space did not have an effect on the ability to ambulate or the time to ambulation.[49] This study showed that patients presenting with LMN lesions were 2 times more likely to regain strong ambulatory status sooner than patients presenting with UMN lesions.[49]

Functional recovery after repeat surgery for recurrent TL IVD extrusion is generally identical to that of first-time extrusion.[45,49,53,179]

SUMMARY

Despite the large body of knowledge gained in the last 60 years, canine IVD disease remains a common and challenging condition. MRI has improved our ability to diagnose IVD herniation more accurately and a variety of medical and surgical options allow clinicians to customize the treatment plan specifically to each patient. Although it is difficult to predict, the prognosis for many patients affected by IVD herniation is positive. The significance of recurrent IVD herniation and the role of fenestration are still questionable.

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