Cervical arthroplasty in two dogs with disk-associated cervical spondylomyelopathy

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Case Description—A 4-year-old sexually intact male Doberman Pinscher (dog 1) was evaluated for signs of recurrent cervical pain and ataxia, and a 12-year-old neutered male mixed-breed dog (dog 2) was evaluated for a 4-month history of ataxia and tetraparesis.

Clinical Findings—Examination via magnetic resonance imaging (MRI) revealed spinal cord compression due to disk-associated cervical spondylomyelopathy at C6-7 in dog 1 and at C5-6 in dog 2.

Treatment and Outcome—Both dogs were surgically treated with a ventral slot procedure and spinal cord decompression, followed by insertion of a titanium cervical disk prosthesis at the affected site. Evaluation of radiographs obtained immediately after surgery indicated that each prosthesis was appropriately placed and provided adequate distraction. Radiographic and neurologic evaluations were performed 2 weeks and 3, 6, and 12 months after surgery in both dogs and 18 months after surgery in dog 1. Distraction of the vertebral bodies decreased moderately over time in both dogs. Intervertebral mobility determined via radiographic assessment of the prosthetic disk during neutral positioning, flexion, and traction of the cervical vertebral column was lost over time in dog 1 and was not achieved in dog 2. Eighteen months after surgery, results of MRI in dog 1 indicated adequate spinal cord decompression with no degeneration in other cervical disks.

Clinical Relevance—Cervical arthroplasty was well tolerated with no complications, and outcome was excellent in both dogs; prosthesis presence did not affect ability to reassess the area via MRI. Studies of cervical arthroplasty in dogs with disk-associated cervical spondylomyelopathy are warranted. (*J Am Vet Med Assoc* 2011;239:808–817)

A 4-year-old 31-kg (68.2-lb) sexually intact male Doberman Pinscher (dog 1) was referred to the hospital with a history of signs of recurrent cervical pain nonresponsive to conservative management. Two weeks prior to referral, the dog was evaluated by the referring veterinarian for acute onset of these clinical signs. Evaluation of plain cervical radiographs revealed a narrow intervertebral disk space at the level of C6-7. Intervertebral disk disease was suspected, and the dog was medically treated with carprofen[a] (2 mg/kg [0.9 mg/lb], q 12 h) and activity restriction. The dog's condition initially appeared to improve with medical treatment, but a few days before referral, the dog was reported to have episodic signs of cervical pain and was reluctant to walk.

Results of a physical examination were unremarkable. Neurologic examination findings included mild ataxia, tetraparesis, signs of pain during cervical manipulation, decreased range of motion of the cervical vertebral column, and resistance to extension of the neck. No other neurologic abnormalities were detected. Because no spinal reflex abnormalities were detected in the thoracic limbs, the lesion was localized to the C1-C5 spinal cord segment; however, because mild lesions of the caudal cervical spinal cord may sometimes not affect spinal reflexes, a more caudal (C6-T2) cervical segment localization could not be excluded. Differential diagnoses included intervertebral disk herniation, disk-associated CSM, infectious or inflammatory diseases, and neoplasia. Results of a CBC and serum biochemical analysis were within laboratory reference ranges, and 3-view thoracic radiography did not reveal any abnormalities.

Abbreviations

CSM	Cervical spondylomyelopathy
MRI	Magnetic resonance imaging
PMMA	Polymethyl methacrylate

The dog was anesthetized for an MRI. Anesthesia was induced with propofol[b] (3.0 mg/kg [1.4 mg/lb], IV) and midazolam[c] (0.15 mg/kg [0.07 mg/lb], IV) and was maintained with isoflurane[d] in oxygen. The following sequences were obtained: pre- and postcontrast T1-weighted (in sagittal and transverse planes), T2-weighted (in sagittal, coronal, and transverse planes), and short tau inversion-recovery–weighted (in sagittal and coronal planes). The T1-weighted postcontrast sequence was obtained after IV administration of gadolinium (0.1 mmol/kg [0.045 mmol/lb]). Magnetic resonance myelography was also performed. Results of MRI evaluation revealed dorsal disk protrusion with spinal cord compression at the C6-7 intervertebral space (**Figure 1**). Kinematic traction was applied by use of a neck harness and a sandbag to exert a force equivalent to approximately 8% of the dog's body weight, and sagittal and transverse T2-weighted MRI revealed attenuation

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Dr. Adamo holds the patent for the cervical prosthesis described in this report.

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of the spinal cord compression. Intervertebral disk protrusion at C6-7 and spinal cord compression with a mild dynamic component were diagnosed.

Because neurologic signs were mild and there were risks associated with surgery, the owner elected to continue conservative treatment with the same dosage of carprofen and activity restriction. However, during the following 3 weeks, the dog had multiple episodes of signs of cervical pain, and the surgical option was pursued. The owner consented to have the dog enrolled in a preliminary clinical study in which a prosthetic cervical disk was implanted after spinal cord decompression.

The cervical prosthesis used was a titanium alloy version (Ti-6AI-4V-ELI)[e] of a prosthesis evaluated in an in vitro study[1] and consisted of 2 end plates, with a range of movement of 30° between plates (**Figure 2**). The cranial surface of the cranial end plate and the caudal surface of the caudal end plate were convex to avoid prosthesis migration and had concentric grooves to allow bone ingrowth into the prosthesis. The concavity and convexity of the central aspects of the end plate surfaces resulted in a ball-and-socket type of connection between end plates. Two L-shaped stainless steel fins on the ventral aspect of the prosthesis allowed handling of the prosthesis during implantation. The short end of 1 fin was attached to each end plate of the prosthesis at a single point of fusion, so that the fins were detachable by means of repetitive twisting along the long axis of the prosthesis.[1]

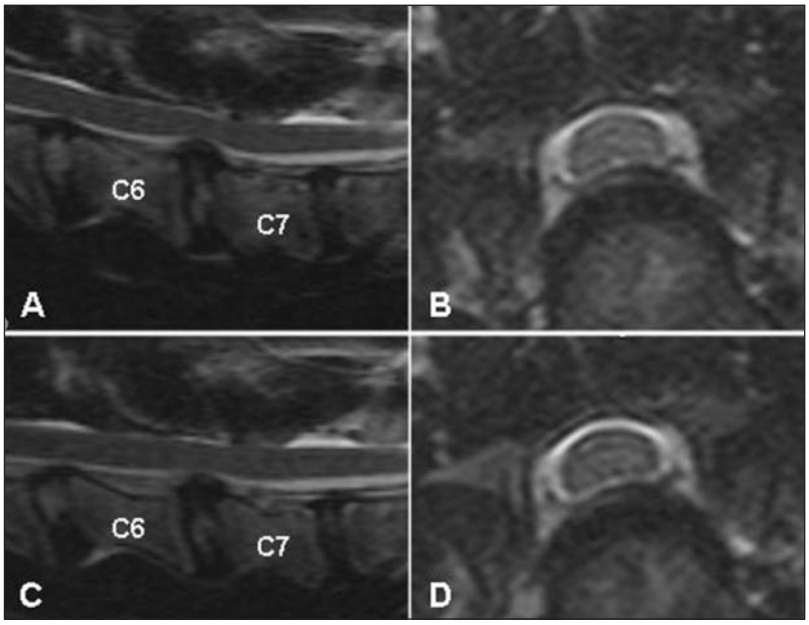

Figure 1—Magnetic resonance images of the cervical vertebral column of a 4-year-old male Doberman Pinscher with disk-associated CSM (dog 1) prior to surgery. Ventral spinal cord compression is evident at the C6-7 disk space in midsagittal and transverse T2-weighted images (panels A and B, respectively) obtained prior to surgery. Compression is attenuated after application of kinematic linear traction (panels C and D).

The dog was treated preoperatively with cefazolin[f] (22 mg/kg [10 mg/lb], IV), and a fentanyl patch[g] (150 g) was applied on 1 pelvic limb. Anesthesia was induced and maintained as described for the MRI. After routine surgical preparation, the ventral aspect of the C6 and C7 vertebral bodies was accessed via a standard approach for a ventral slot procedure.[2] To improve visual assessment, a high-powered head lamp[h] and magnification loops were used throughout the procedure. The C6-C7 vertebrae were identified, and the ventral surfaces of the C6 and C7 vertebral bodies were exposed. The longus colli muscles were kept retracted by use of 2 Gelpi retractors, and the ventral process of C6 was removed with a rongeur. A partial diskectomy was performed across the C6-7 intervertebral space with a No. 11 scalpel blade used to remove the degenerated annulus fibrosus, and burring was completed with a high-speed air drill. Burring was conducted in a slightly oblique direction following the angle of the intervertebral space, and as much as possible of the caudal ventral border of the C6 end plate was spared.

The slot was extended in a cranial to caudal direction by removing the midportion of both end plates of C6 and C7 to the cancellous bone. Length of the slot extended ≤ 25% of the length of the C6 and C7 vertebral bodies, and width of the slot extended ≤ 50% of the width of the vertebral bodies (maximum width,

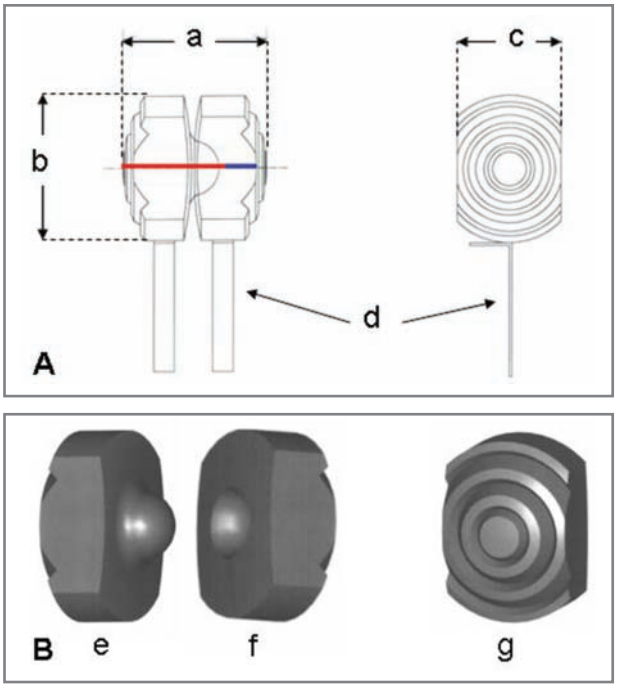

Figure 2—Schematic and 3-D representation (panels A and B, respectively) of the titanium alloy cervical prostheses used in the treatment of disk-associated CSM in dog 1 and a 12-year-old neutered male mixed-breed dog (dog 2). The same size prosthesis was implanted in both dogs. In panel A, dimensions of the prosthesis are indicated as follows: length of the assembled end plates = 9 mm (a); long axis length = 10.5 mm (b); short axis length = 7.4 mm (c); thickness of the convex end plate = 6.3 mm (red line); and thickness of the concave end plate = 4.5 mm (blue line). The 2 removable fins attached to the ventral portion of each end plate (d) facilitate handling of the prosthesis during implantation. The breaking point of the fins is at the attachment to each end plate. Each fin is twisted along the sagittal axis to detach it from the prosthesis immediately after placement. In panel B, 3-D reconstruction of the cervical prosthesis shows the ball-and-socket type of connection between end plates (e and f) and concentric grooves in the cranial surface of the cranial end plate and caudal surface of the caudal end plate to allow bone ingrowth into the prosthesis (g).

≤ 8.5 mm; **Figure 3**).[1] To facilitate exposure and removal of the dorsal annulus, distraction of the vertebral bodies was maintained with a self-retaining right-hand model Caspar distractor.[i] The 2 distractor pins of the Caspar distractor were inserted parallel to each other at midbody of the 2 affected vertebrae, after the ventral cortex of the 2 involved vertebrae was perforated with a small (1.2-mm) carbide burr. The Caspar distractor was then placed over the 2 pins, and the vertebrae were distracted approximately 2 to 3 mm, as previously described.[2] Decompression was completed by gently removing the thin layer of cortical bone at the caudal and cranial edges of C6 and C7, respectively, with a 1-mm Kerrison rongeur.

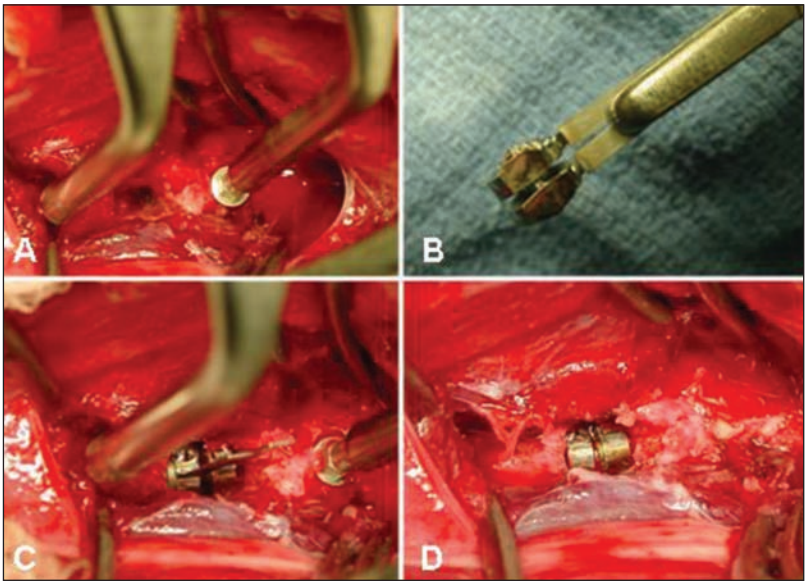

Figure 3—Photographs depicting the technique used for placement of a cervical prosthesis during surgical treatment of disk-associated CSM in dog 1 (panels A through D). After identification of the C6-7 disk space, partial diskectomy was performed, followed by a ventral slot procedure. The C6 and C7 vertebrae were distracted by use of a Caspar distractor (A). A large needle holder was used to keep the ventral fins of the 2 end plates of the prosthesis together (B) and insert the prosthesis into the slot (C). After the prosthesis was in place, distraction was released, allowing end plates of the 2 adjacent vertebrae to collapse on the prosthesis. The fins were then detached from the prosthetic end plates by means of repetitive twisting. The prosthesis was seated in place, and the 2 distractor pins of the Caspar distractor were removed (D).

The length, height, and width of the affected intervertebral space measured on the MRI images by use of computer software[j] were used to preselect the size of prosthetic disk that would best fit in the slot. The final selection of prosthesis size was made during surgery via evaluation of the prosthesis against 2 radiographic projections of the affected cervical region, and by means of placement and visual inspection of the prosthesis in the slot. For this dog, the size of prosthesis used was 9.0 mm (assembled width) X 10.5 mm (long axis) X 7.4 mm (short axis; Figure 2). Before prosthesis placement, a 2-mm carbide air burr was used to remove additional cancellous bone as needed from both ends of the slot to fit the convexity of the external surface of the prosthesis. The intervertebral space was maintained by use of the Caspar distractor during this phase of surgery. A large needle holder was used to keep the ventral fins of the 2 prosthetic end plates together and to force the prosthesis into the slot with application of gentle manual pressure.[1] After implantation, the distraction was released, allowing the 2 adjacent vertebral end plates to collapse on the prosthesis. After assessment that the prosthesis was correctly seated in position, the ventral fins were detached from the 2 prosthetic end plates as described. The longus colli, sternohyoideus, and sternocephalicus muscles and subcutaneous and subcuticular tissues were closed in a routine manner.

Cefazolin (22 mg/kg, IV) was administered every 2 hours during surgery. Analgesia was maintained with hydromorphone[k] (0.05 mg/kg [0.023 mg/lb], IV, q 6 h) during the 24-hour postoperative period. Immediately after surgery, evaluation of lateral and ventrodorsal radiographs indicated that the prosthesis was correctly seated in position and that vertebrae adjacent to the affected disk space were adequately distracted (**Figure 4**). To restrain activity and provide protection from external trauma, a rigid cast that was dorsally reinforced with fiberglass was applied along the neck and thorax (the cast extended from the first cervical vertebra to the last thoracic vertebra). At discharge, the owner was instructed to administer carprofen (2 mg/kg, PO, q 12 h) for 5 days, to remove the fentanyl patch 4 days after application, and to restrict the dog's activity for 6 weeks, allowing only short walks on a leash and harness.

The cast was inspected 2 and 6 weeks after surgery and was removed at the 6-week visit. Neurologic and radiographic examinations were performed at 2 and 6 weeks as well as 3, 6, 12, and 18 months after surgery. All postoperative radiographic studies were performed with the dog under heavy sedation with dexmedetomidine[l] (11 g/kg [5 g/lb], IV), and effects were subsequently reversed with atipamezole[m] (110 g/kg [50 g/lb], IV). In postoperative radiographic studies, the kinematic evaluation was conducted as follows. Radiographic images of the cervical vertebrae (lateral and ventrodorsal views, and lateral view during manual linear traction) were obtained and evaluated 2 weeks and 3 months after surgery. During the 6-, 12-, and 18-month postoperative examinations, these same radiographic views and additional lateral views obtained during flexion and extension of the neck were assessed.

Two-week and 3-month postoperative evaluation of lateral radiographs revealed a mild degree of collapse of the C6-7 intervertebral disk space, with both components of the prosthesis (the caudal end plate more than the cranial) intruding into the soft cancellous bone of the vertebral bodies (Figure 4). The caudal prosthetic end plate was also detectably shifted along its sagittal axis in the ventrodorsal radiographic view. These changes did not affect the dog's neurologic status, which continued to be considered normal 3, 6, 12, and 18 months after surgery. Intervertebral mobility was assessed via radiographic evaluation of the recipro-

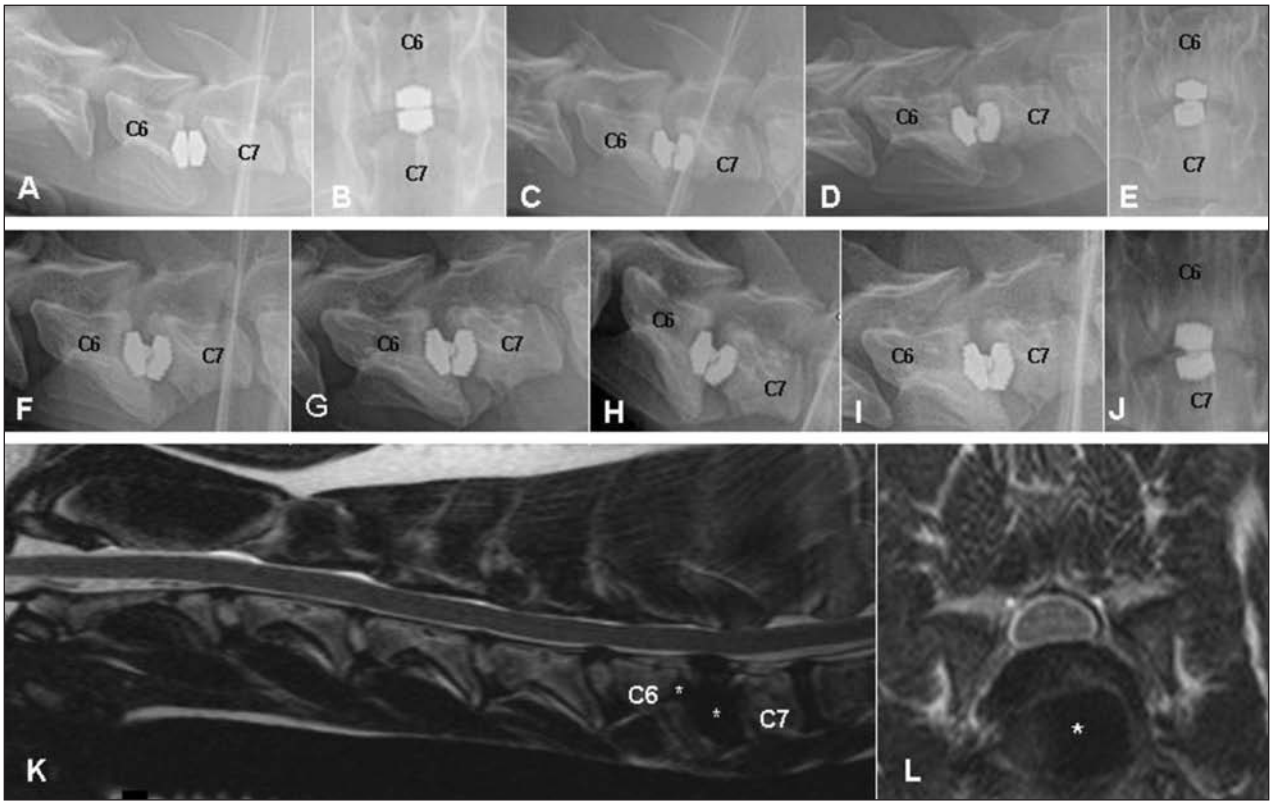

Figure 4—Radiographic (panels A through J) and magnetic resonance images (panels K and L) obtained after surgery in dog 1. The prosthesis is properly seated in position, and vertebrae adjacent to the affected disk space are adequately distracted in lateral (A) and ventrodorsal (B) radiographic views obtained immediately after surgery. Three months after surgery, lateral radiographic views of the implantation site in neutral position (C) and during linear traction (D) as well as the ventrodorsal radiographic view (E) reveal a mild degree of collapse of the treated disk space, with cranial and caudal end plates of the prosthesis intruding into the soft cancellous bone of C6 and C7, respectively, and shifting of the caudal prosthetic end plate around its sagittal axis. Eighteen months after surgery, relative positions of the 2 components of the prosthesis show no evidence of intervertebral mobility in lateral radiographic views of the treated site in neutral position (F), during linear traction (G), or during extension (H) and flexion (I) of the neck; findings are similar in the ventrodorsal view (J). In midsagittal (K) and transverse (L) T2-weighted magnetic resonance images obtained 18 months after surgery, low signal intensity and magnetic susceptibility artifacts (asterisks) associated with the prosthesis at the C6-7 disk space are evident. There are no signs of spinal cord compression at the treated site and no signs of degeneration in other cervical disks.

cal positions of the 2 prosthetic end plates. An increase of the distance (mm) between prosthetic end plates during linear traction or a change in distance between the dorsal or ventral edges of these end plates in lateral radiographic views obtained during flexion and extension of the neck, compared with the neutral position, was considered indicative of intervertebral mobility. Intervertebral mobility at the disk space was evident and well maintained through 6 months after surgery. However, intervertebral mobility decreased over time and was minimal at 12 months and absent at 18 months after surgery.

Repeated MRI performed 18 months after surgery included evaluation during linear kinematic traction by use of sandbags to exert a linear traction force equivalent to approximately 20% of the dog's body weight. No signs of clinically relevant spinal cord compression at the treated site and no signs of degeneration in other cervical disks were detected (Figure 4). Dog 1 had a complete neurologic recovery, with only 2 episodes of signs of cervical pain reported during the first 2 weeks after surgery; these signs resolved with carprofen administration. The owner reported that it was very difficult to enforce activity restriction during the 2-month postoperative period because of the dog's active temperament. At a 22-month follow-up examination, the dog continued to be neurologically normal.

A 12-year-old 23-kg (50.6-lb) neutered male mixed-breed dog (dog 2) was referred to the hospital with a 4-month history of progressive ataxia and tetraparesis nonresponsive to treatment with deracoxib[n] (3 mg/kg, PO, q 24 h). Physical examination was unremarkable. Neurologic examination findings included a tetraparetic gait, general proprioceptive ataxia with concurrent nail scuffing of both thoracic limbs, and postural reaction deficits in all 4 limbs that subjectively appeared worse in the left thoracic limb. Spinal reflexes were hyperreflexive in both pelvic limbs. No signs of pain were elicited via palpation of the cervical vertebral column. Other results of the neurologic examination were considered normal. Because of the lack of detectable spinal reflex abnormalities in the thoracic limbs, the lesion was localized to the C1-C5 spinal cord segments; however, as in dog 1, localization to a more caudal cervical segment could not be excluded. Because of the chronic nature of the clinical signs, differential diagnoses included disk-associated CSM, neoplasia, and subarachnoid cyst; infectious or inflammatory diseases were considered less likely. The results of 2-view plain cervical radiography revealed a mildly narrowed disk

space at C7-T1. Results of a CBC and serum biochemical analysis were within laboratory reference ranges, and no abnormalities were detected via 3-view thoracic radiography.

The dog was anesthetized for MRI following the same protocol as described for dog 1; MRI findings indicated a marked extradural compressive lesion of the ventral spinal cord caused by protruded intervertebral disk material at C5-6, with articular process remodeling resulting in dorsolateral crowding of the spinal cord and concurrent intraparenchymal, ill-defined, focal, T2-weighted hyperintensity, which was considered likely to be secondary to edema or gliosis. Examination of the sagittal image revealed degeneration at the C6-7 intervertebral space with mild extradural compression of the dorsal spinal cord at the same site (**Figure 5**). Unfortunately, kinematic evaluation with linear traction was not performed in dog 2. On the basis of MRI findings, chronic disk–associated CSM at C5-6 and C6-7 disk degeneration with minimal dorsal spinal cord compression were diagnosed. The owner consented to having the dog enrolled in the same clinical study as dog 1.

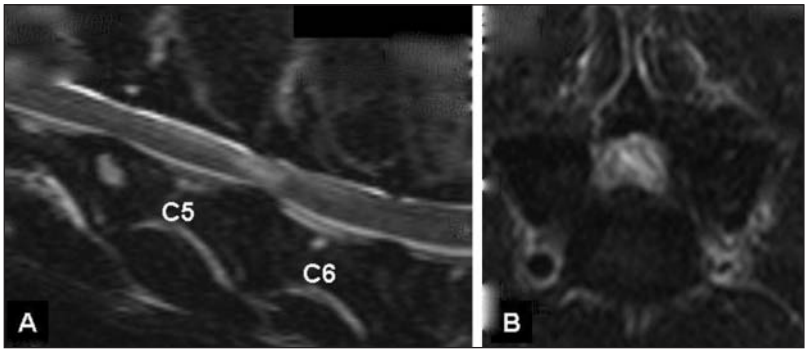

Figure 5—Magnetic resonance images of the cervical vertebral column of dog 2 prior to surgery (panels A and B). Midsagittal (A) and transverse (B) T2-weighted images show ventral compression of the spinal cord at the C5-6 disk space. Articular process remodeling and dorsolateral crowding of the spinal cord are evident in the transverse image. Note spinal cord parenchymal edema or gliosis (evident as hyperintensity of the affected region) in both images. In panel A, signs of degeneration at the C6-7 disk space and mild dorsal spinal cord attenuation at the same site are also evident.

Anesthetic and analgesic protocols were used as described for dog 1, and spinal cord decompression at C5-6 and placement of the prosthesis were performed by use of the same surgical technique. The prosthesis implanted was the same size as that used in dog 1. Evaluation of lateral and ventrodorsal radiographs of the cervical vertebral column immediately after surgery indicated that the prosthesis provided adequate distraction; however, the disk space appeared larger than the adjacent disk spaces and the ventral edge of the caudal prosthetic end plate protruded beyond the ventral limit of the cranial aspect of the C6 vertebral body (**Figure 6**). This caused concern that the prosthesis might be too large for the dog. To limit activity and provide protection from external trauma, a cast similar to that used for dog 1 was applied. At discharge, the dog's owner was instructed to administer gabapentin[o] (5 mg/kg [2.3 mg/lb], PO, q 24 h) for 7 days, tramadol[p] (4 mg/kg [1.8 mg/lb], PO, q 12 h) for 10 days, and cephalexin[q] (30 mg/kg [13.6 mg/lb], PO, q 12 h) for 14 days. Activity restriction with short walks on a leash and harness was recommended for 6 to 8 weeks after surgery. Seven days after surgery, the owner tripped and fell over the dog. The dog vocalized during the episode, but radiographic evaluation did not reveal any changes, compared with the radiographs obtained during the immediate postoperative period.

The cast was inspected 2 and 6 weeks after surgery and was removed during the

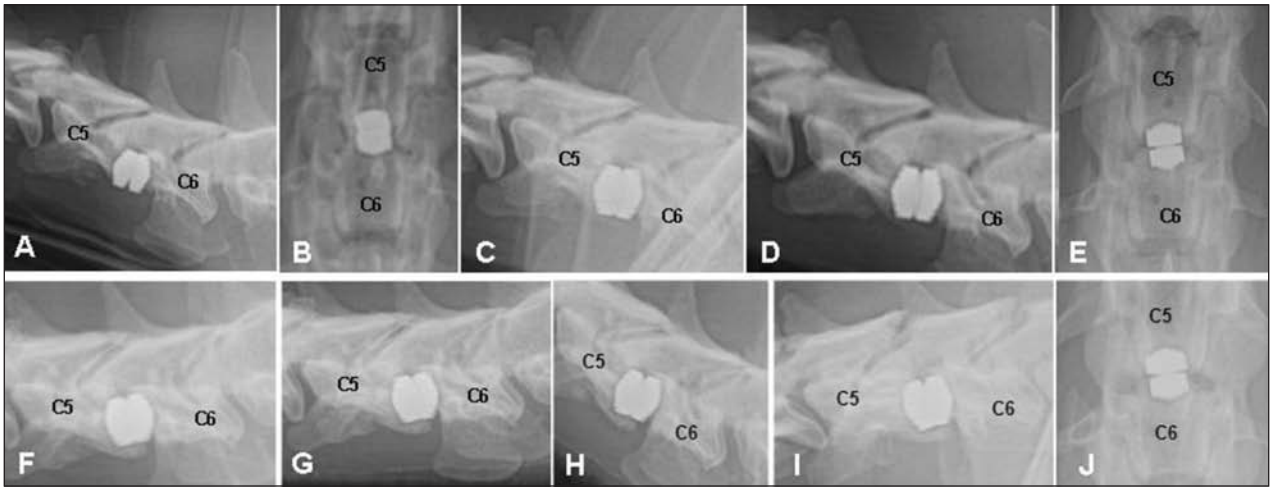

Figure 6—Radiographic views obtained after surgery in dog 2 (panels A through J). The prosthesis is properly seated in position, and vertebrae adjacent to the affected disk space are adequately distracted in lateral (A) and ventrodorsal (B) radiographic views obtained immediately after surgery. However, the ventral edge of the caudal prosthetic end plate protrudes beyond the ventral limit of the cranial aspect of C6, suggesting this prosthesis may be too large for the intervertebral space. Three months after surgery, lateral radiographic views of the implantation site in neutral position (C) and during linear traction (D) as well as the ventrodorsal radiographic view (E) show minimal collapse of the C5-6 disk space with no evidence of intervertebral mobility during traction. Twelve months after surgery, lateral radiographic views of the treated site in neutral position (F), during linear traction (G), and during extension (H) and flexion (I) of the neck show collapse of the disk space, with cranial and caudal end plates of the prosthesis intruding into the end plates of C5 and C6, respectively; findings are similar in the ventrodorsal view (J). No evidence of intervertebral mobility is seen.

6-week postoperative examination. Neurologic and radiographic evaluations and the methods of sedation and traction were as described for dog 1 at 2 and 6 weeks as well as 3, 6, and 12 months after surgery. No clinically relevant collapse of the C5-6 disk space was evident in radiographs obtained 2 weeks and 3 months after surgery, and the caudal end plate of the prosthesis seemed to be better accommodated in the body of C6. No intervertebral mobility at the treated site was detected in radiographs obtained during linear traction (Figure 6).

Results of radiography performed 6 and 12 months after surgery revealed that the treated intervertebral disk space was collapsed and that the cranial and caudal end plates of the prosthesis had intruded into the end plates of C5 and C6, respectively (Figure 6). No evidence of mobility at the treated site was detected during traction, extension, or flexion of the neck, and no signs of infection were detected. Progressive improvement of clinical signs was noted during the follow-up examinations. Six months after surgery, mild ataxia was detected during neurologic examination, with a mild delay in hopping on the left thoracic limb and normal knuckling postural reactions in all 4 limbs. Results of a similar evaluation 18 months after surgery indicated that the dog was still mildly ataxic; however, the delay in hopping on the left thoracic limb was no longer evident.

Discussion

Disk-associated CSM, also called disk-associated wobbler syndrome, predominantly affects middle-aged or older large-breed nonchondrodystrophoid dogs, particularly Doberman Pinschers.[2–13] Many other breeds, including small dogs, are reportedly affected by this condition.[14] The C5-6 and C6-7 intervertebral disk spaces are most frequently affected, with lesions in both locations present in approximately 20% of affected dogs.[2] Although the pathogenesis of this disease is not well understood, chronic degenerative disk disease seems to be such an important factor that use of the term disk-associated CSM has been suggested.[2,4,5,15] Spinal cord compression in disk-associated CSM is often dynamic and secondary to a combination of degenerative disk diseases and the relative hypertrophy or infolding of ligamentous structures (dorsal longitudinal ligament, dorsal annulus, interarcuate ligament, and joint capsule) because of collapse of the disk space.[2–4]

Clinical signs of disk-associated CSM have been reviewed elsewere.[3,5] The disease is usually chronic and progressive if left untreated, and prognosis is typically worse for dogs with chronic ataxia and nonambulatory tetraparesis. Diagnosis of disk-associated CSM can be made by use of myelography with views obtained during traction (ie, stress myelography), myelography combined with computed tomography, or MRI.[3,4,15–20] Compared with other imaging methods, MRI better defines the site, severity, and nature of spinal cord compression and allows visualization and characterization of intraparenchymal spinal lesions, which have been associated with abnormal histologic findings.[20,21] Kinematic studies may also be performed during MRI evaluation. It has been suggested that a force equivalent to 20% of a dog's weight is sufficient to produce adequate traction for this evaluation.[19,20]

Medical treatment with activity restriction and corticosteroid administration may be indicated in dogs with a first episode of neurologic deficits; otherwise, surgery is the treatment of choice for disk-associated CSM.[18,22,23] In recent studies,[22,23] a greater percentage of dogs treated with surgery were shown to have improvement of clinical signs, compared with those that received only medical management, although differences between the 2 groups were not statistically significant.

Many surgical techniques have been described for treatment of disk-associated CSM, and these can be broadly divided into 2 categories: direct access decompressive surgeries and distraction-stabilization-fusion surgeries.[6,18] Direct access decompressive surgeries involve dorsal decompression via dorsal laminectomy and ventral decompression via a ventral slot procedure.[24–28] In contrast, distraction-stabilization-fusion techniques distract the vertebrae to stretch the hypertrophied tissue and relieve spinal cord compression; the vertebrae are then stabilized with appropriate implants, and fusion is promoted with autologous bone grafts (cancellous, cortical, or corticocancellous)[18] or cancellous bone allografts.[2] Various techniques have been used to maintain vertebral distraction or graft retention to allow for bony fusion across the affected disk space.[2,6,9,18,28–33]

Success rates of 70% to 90% have been reported[6,8–10,18,32] for surgical treatment of disk-associated CSM in dogs by use of direct or indirect decompression methods. A meta-analysis of dogs treated surgically for disk-associated CSM revealed an 80% short-term success rate, with approximately 20% of dogs that had successful surgeries having a clinically important recurrence during long-term follow-up[14]; the type of surgery performed (decompression vs distraction-stabilization-fusion) did not influence outcome. Recurrence can be caused by compression at the original site or by adjacent segment disease (a so-called domino lesion) at an adjacent intervertebral disk space.[14,18,34,35] Adjacent segment disease is believed to result, at least in part, from abnormal stresses imposed on an intervertebral disk space by fixation of the adjacent disk space.[18] These stresses can exacerbate any preexisting subclinical instability and produce either disk extrusion or hypertrophy of annular or ligamentous structures.[9,18] Recurrence of paraparesis to tetraparesis develops in up to one-third of dogs after ventral decompression or metal implant insertion and bone cement fixation.[2,18] This is typically reported between 6 months and 4 years after the original surgery, with a mean time to recurrence of approximately 2 years.[8–10,27,30] Because of the high rates of surgical failure and long-term recurrence, new methods are continually investigated for the treatment of disk-associated CSM in dogs.[2,18,33]

Cervical arthroplasty involves, after spinal cord decompression and diskectomy, placement in the intervertebral space of a device able to maintain distraction and preserve intervertebral mobility at the treated space. The goal of cervical arthroplasty is to preserve intervertebral mobility after neural decompression while providing distraction and stability.[36–38]

The dogs of this report were enrolled in a preliminary clinical study in which a prosthesis specifically designed and manufactured for use in the canine cervical

vertebral column was implanted in dogs clinically affected by disk-associated CSM. This type of prosthesis was used and tested in an earlier in vitro study[1]; results of that study revealed that cervical vertebral column specimens from canine cadavers in which the prosthesis was implanted had biomechanical actions more similar to those of an intact vertebral column, compared with specimens in which ventral slot and pin-PMMA fixation procedures were performed. The dogs of this report were surgically treated with a ventral slot procedure and spinal cord decompression, followed by the insertion of the prosthesis. The titanium alloy prosthesis was selected because of its high strength, good corrosion resistance, biological compatibility, and low expense. Because titanium is MRI compatible, it was also considered a good choice for purposes of follow-up if subsequent MRI procedures were needed.

On the basis of history, clinical signs, and MRI findings, dogs 1 and 2 each had a diagnosis of disk-associated CSM. In dog 1, the recommended force to exert linear traction[19,20] was not applied during the first MRI, but the force applied was sufficient to detect a traction-responsive lesion. In dog 2, the kinematic MRI evaluation was not performed; however, the history and results of MRI analysis were consistent with disk-associated CSM. Spinal cord hyperintensity on T2-weighted images was detected in dog 2, in which chronic neurologic signs were reported, but was not observed in dog 1, in which acute cervical hyperesthesia was detected. It has been proposed that hyperintensity on T2-weighted images reflects chronic and reversible pathologic changes, whereas the combination of hyperintensity on T2-weighted images and hypointensity on T1-weighted images suggests irreversible spinal cord changes and poor prognosis.[39,40] Results of MRI analysis in the dogs of this report appeared to correspond to those of a previously reported study[16] in dogs. Dog 1 had no evidence of intraparenchymal changes and had a complete resolution of clinical signs within 2 weeks after surgery. Dog 2 had intraparenchymal hyperintensity on T2-weighted images without hypointensity on T1-weighted images and had clinical signs that gradually resolved, with residual mild ataxia 18 months after surgery.

Surgical treatment was recommended in both patients because of the multiple episodes of recurrence of cervical pain in dog 1 and the chronic history and progressive deterioration of the neurologic status in dog 2. Dog 1 had a full recovery with complete resolution of its clinical signs; however, those clinical signs were mild and without spinal cord intraparenchymal abnormalities on MRI. These features are usually associated with a good prognosis following surgical treatment. Dog 2 had a more chronic history, more severe neurologic deficits, more pronounced ventral and lateral spinal cord compression, and evidence of intraparenchymal focal signal changes detected via MRI. Clinical improvement in dog 2 was detectable beginning 2 months after surgery, and marked improvement was apparent 1 year after surgery. This may also be expected with other surgical techniques if no complications develop.

The advantage of a ventral slot procedure with cervical arthroplasty over the standard ventral slot procedure is that the prosthetic disk acts as a spacer, preventing early collapse of the intervertebral disk space associated with the ventral slot procedure alone. Collapse of the disk space can compress the nerve roots in the intervertebral foramen, which in turn may cause cervical hyperesthesia and focal spinal cord ischemia.[3,40,41] Clinical effectiveness of the ventral slot procedure is typically evident over time, and instability, if present, may be alleviated because many of these disk spaces will fuse, even without autologous cancellous bone grafts.[2,18,27] Because the prosthesis is retained in the slot without the use of any additional fixation, advantages of the described arthroplasty over the use of pins or screws and techniques involving PMMA distraction fixation, metallic plates, and bone grafting include elimination of the main potential complications associated with impingement on neurovascular structures, plate fractures, screws pulling out, and delayed graft incorporation.[2,18,33,42]

Additional advantages of arthroplasty over these techniques are that the prosthesis is relatively easy to implant, is cost-effective (its cost may be equivalent to the cost of the pins and PMMA), doesn't require special instrumentation used for plating, and could be applied to multiple sites if needed. This is particularly important in the event of multiple lesions or when signs of mild spinal cord impingement are evident in adjacent intervertebral disk spaces during MRI.

Possible complications associated with this type of cervical arthroplasty may be similar to those reported in humans. Although there has been increasing interest in prosthetic intervertebral disk replacement to treat cervical degenerative disk disease in humans and clinical outcomes have been reported regarding many types of cervical prostheses, few reports describe potential complications of the prosthetic devices. The most commonly reported complications include prosthesis or vertebral end plate subsidence[43,44] (sinking of the implant into the softer cancellous bone of the vertebral body), splitting of a vertebral body during prosthesis implantation,[45] heterotopic ossification and ankylosis at the treated site,[46–48] adjacent disk degeneration including new formation or enlargement of osteophytes,[46–49] and prosthesis migration.[50] A case of delayed hyperreactivity to metal ions after cervical arthroplasty was also reported.[51] A potential contraindication of cervical arthroplasty with metal end plates is osteoporosis, which can potentially increase the risk of implant subsidence.[43]

In both dogs of this report, the prosthesis was well tolerated, and there were no signs of infection at the treated site during follow-up evaluations. The cervical external cast was also well tolerated, but it may not be necessary and could hinder postoperative rehabilitation; in 1 study,[16] a similar device was not tolerated in up to 28% of dogs. Despite the reported high level of activity in dog 1 and the accident the owner had with dog 2, no clinically relevant prosthetic displacement developed.

Collapse of the intervertebral disk space was radiographically evident at 2-week and 6-month follow-up examinations in dog 1 and dog 2, respectively. However, these changes did not affect outcome. Even though collapse of a disk space may cause infolding of ligamentous structures, if this is mild or moderate, it may not result in recurrence of spinal cord compression. Disk space collapse in these dogs was most likely due to

a combination of intrusion of the prosthesis into the soft cancellous bone of adjacent vertebral bodies secondary to natural forces and bone resorption around the prosthesis. A lesser degree of disk collapse could be potentially achieved by selecting a prosthesis that is not overly thick when assembled. This could prevent excessive distraction, which may decrease the load of the cancellous bone on the prosthesis and decrease the likelihood of intrusion into the cancellous bone. A prosthesis with a larger surface area would exert less pressure per unit area on adjacent bones and be less likely to cause subsequent intrusion of the prosthesis into bone. Preserving adjacent vertebral end plates may avoid end plate subsidence and consequent distraction failure. Because dynamic spinal cord compression can be successfully treated with a distraction-stabilization-fusion technique without removal of adjacent end plates, a less thick prosthesis could be placed following diskectomy and removal of the cartilage from the end plate with curettes.[2,33] However, prevention of intervertebral disk space collapse may be more difficult in quadrupeds than in humans; it has been suggested that muscle and tensile forces that control posture in the horizontally oriented quadruped vertebral column cause an inherent axial compression of the spine.[52]

Shifting of the prosthesis around its sagittal axis in dog 1 was likely a consequence of imperfect fit of the prosthetic end plate surface within the slot. Shifting could potentially be prevented by use of a custom-made burr appropriately designed for milling the slot to precisely accommodate the external convexity of the prosthesis.

It has been suggested that in most dogs with disk-associated CSM, distraction of 2 to 3 mm is enough to restore a normal disk space width of 4 to 6 mm.[2] Furthermore, a mild degree of collapse may also be desirable to allow accommodation of the prosthesis within the intervertebral disk space and to decrease biomechanical stress on the adjacent disk spaces. In the dogs of this report, the size of slots created to achieve spinal decompression and allow prosthesis placement did not exceed the low end of clinical recommendations, which range from 25% to 33% of the vertebral body.[53,54] Following these anatomic recommendations, the potential for laceration of the ventral vertebral sinus and basivertebral veins and vertebral subluxation can be minimized.[3,53,54]

In dog 1, width of the treated site was similar to that of the cranially adjacent intervertebral disk space, and distraction was considered adequate, whereas in dog 2, width of the treated site was greater than that of either adjacent disk space, and distraction may have been excessive. In dog 1, intervertebral mobility at the disk space was detectable via radiography up to 6 months after surgery, but was minimal at 12 months and was no longer evident 18 months after surgery. The gradual loss of intervertebral mobility in this dog may have been secondary to fibrosis at the prosthesis site, which could possibly be prevented by use of a prosthesis with a greater degree of mobility. In dog 2, there was no evidence of intervertebral mobility at the treated site, although the prosthesis maintained distraction of the adjacent vertebrae. Lack of intervertebral mobility in dog 2 was likely because the prosthesis was too large, causing overdistraction and impingement of adjacent structures. It is possible that, even if intervertebral mobility is not attained or is lost over time, use of the prosthesis may still be valuable because it may act as an internal vertebral distractor, while allowing the rest of the vertebral column to gradually accommodate to the new dynamic until stabilization occurs. In this regard, cervical arthroplasty may be equivalent to some distraction-stabilization-fusion techniques, such as washer-screw and PPMA plug, in which overdistraction may be accommodated by postsurgical collapse of the treated space around the implant. It may be superior to other distraction-stabilization-fusion techniques, such as use of plates and screws or pins and PPMA, in which there is no ability of the treated space to accommodate to surgical fixation in kyphosis or overdistraction over time. Persistent biomechanical stress on the adjacent intervertebral spaces may increase the possibility of developing adjacent segment disease. Thus, if cervical arthroplasty does not attain intervertebral mobility or this is lost over time, adjacent segment disease may develop. At the time of writing, no evidence of adjacent segment disease had been reported in either dog, but this potential complication may have developed at a later time.

The MRI findings in dog 1 at the 18-month postoperative examination revealed that the surgically treated area remained decompressed, the remaining cervical disks showed no signs of degeneration, and, overall, no clinically relevant changes were detected, compared with results of MRI at the time of diagnosis. The low magnetic susceptibility artifact associated with the prosthesis did not interfere with spinal cord visualization at the treated site in any of the MRI sequences. The possibility of performing MRI studies subsequent to implantation of this prosthesis allows an accurate reevaluation of the treated site or adjacent locations if clinical signs recur.

Although intervertebral mobility was not preserved after neural decompression and this was one of the goals of surgery, the prosthesis was considered clinically effective in treatment of the 2 dogs in this report. However, research into placement of prosthetics of various sizes and materials with preservation of adjacent vertebral end plates is needed to identify the optimal prosthetic devices and procedures in cervical arthroplasty. Postmortem histologic assessment is also needed to evaluate osseointegration of the prosthesis-bone interface and local biological responses. Studies that include a large number of patients with long-term follow-up over several years are necessary to investigate the effectiveness and complications of this type of cervical arthroplasty in dogs with disk-associated CSM.

a. Rimadyl, Pfizer AH, New York, NY.
b. Propoflo, Abbott Laboratories, North Chicago, Ill.
c. Midazolam, American Pharmaceutical Partners Inc, Schaumburg, Ill.
d. Isoflo, Abbott Laboratories, North Chicago, Ill.
e. Adamo K-9 artificial disk, Hybex Innovations Inc, Anjou, QC, Canada.
f. Cefazolin, Cephazone Pharma LLC, Pomona, Calif.
g. Transdermal system, Mylan Pharmaceuticals Inc, Morgantown, Wva.
h. 300W Xenon Lamp Luxtec, Integra Luxtec Inc, West Boylston, Mass.
i. Life instruments, Braintree, Mass.
j. eFilm Medical Inc, Toronto, ON, Canada.

k. Hydromorphone, Baxter Healthcare Co, Deerfield, Ill.
l. Dexdomitor, Pfizer Animal Health Inc, New York, NY.
m. Antisedan, Pfizer Animal Health Inc, New York, NY.
n. Deramaxx, Novartis Animal Health US Inc, Greensboro, NC.
o. Gabapentin, Amneal Pharmaceuticals, Hauppage, New York, NY.
p. Tramadol, Amneal Pharmaceuticals, Hauppage, New York, NY.
q. Cephalexin, Karalex Pharma LLC, Woodcliff Lake, NJ.

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From this month's *AJVR*

Pharmacokinetics of levetiracetam after oral and intravenous administration of a single dose to clinically normal cats

Michelle Brogan Carnes et al

Objective—To determine whether therapeutic concentrations of levetiracetam can be achieved in cats and to establish reasonable IV and oral dosing intervals that would not be associated with adverse effects in cats.

Animals—10 healthy purpose-bred cats.

Procedures—In a randomized crossover study, levetiracetam (20 mg/kg) was administered orally and IV to each cat. Blood samples were collected 0, 10, 20, and 40 minutes and 1, 1.5, 2, 3, 4, 6, 9, 12, and 24 hours after administration. Plasma levetiracetam concentrations were determined via high-performance liquid chromatography.

Results—Mean ± SD peak concentration was 25.54 ± 7.97 µg/mL. The mean y-intercept for IV administration was 37.52 ± 6.79 µg/mL. Half-life (harmonic mean ± pseudo-SD) was 2.95 ± 0.95 hours and 2.86 ± 0.65 hours for oral and IV administration, respectively. Mean volume of distribution at steady state was 0.52 ± 0.09 L/kg, and mean clearance was 2.0 ± 0.60 mL/kg/min. Mean oral bioavailability was 102 ± 39%. Plasma drug concentrations were maintained in the therapeutic range reported for humans (5 to 45 µg/mL) for at least 9 hours after administration in 7 of 10 cats. Only mild, transient hypersalivation was evident in some cats after oral administration.

Conclusions and Clinical Relevance—Levetiracetam (20 mg/kg) administered orally or IV to cats every 8 hours should achieve and maintain concentrations within the therapeutic range for humans. Levetiracetam administration has favorable pharmacokinetics for clinical use, was apparently tolerated well, and may be a reasonable alternative antiepileptic drug in cats. (*Am J Vet Res* 2011;72:1247–1252)

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