Constrictive myelopathy secondary to hypoplasia or aplasia of the thoracolumbar caudal articular processes in Pugs: 11 cases (1993–2009)

Stephen C. Fisher, DVM, MS, DACVS; Andy Shores, DVM, PhD, DACVIM; Stephen T. Simpson, DVM, MS, DACVIM

Objective—To report thoracolumbar caudal articular process malformations with secondary constrictive fibrosis of the spinal cord in Pugs.

Design—Retrospective case series.

Animals—11 Pugs with neurologic dysfunction resulting from constriction of fibrous tissue secondary to thoracolumbar caudal articular process malformation and 5 Pugs with no neurologic dysfunction.

Procedures—Medical records of dogs with myelopathy presumably caused by constriction of fibrous tissue secondary to thoracolumbar caudal articular process malformation at 2 referral institutions between 1993 and 2009 were reviewed. Dogs were included in the study if hypoplastic or aplastic thoracolumbar caudal articular processes were present on radiographs, CT images, or MRI images.

Results—The most common neurologic examination findings were paraparesis with ataxia or paraplegia but no evidence of hyperpathia along the vertebral column. All dogs' neurologic lesion localization was to the T3-L3 spinal cord segments. Median age at examination was 7.7 years (range, 2 to 11 years). Five of 11 dogs had a history of unrelated trauma. Four of 11 dogs had urinary or fecal incontinence. Eight of 11 dogs underwent surgical exploration. Despite surgical intervention, all dogs that survived surgery continued to have neurologic deficits.

Conclusions and Clinical Relevance—In the present study, presence of aplastic or hypoplastic articular processes in the thoracolumbar region did not always produce neurologic signs. However, fibrous constrictive myelopathy should be considered in Pugs with pelvic limb gait and postural reaction deficits and lack of hyperpathia upon palpation of the vertebral column. Additional studies are warranted to further characterize the disease process and determine the most effective means of treatment. (*J Am Vet Med Assoc* 2013;242:223–229)

Congenital vertebral malformations occur commonly in small animals, but many produce no evidence of neurologic dysfunction.[1] When neurologic dysfunction ensues because of a compressive lesion or instability, however, the cause-and-effect relationship between the congenital vertebral malformation and spinal cord disease becomes important. Congenital anomalies of the vertebral articular processes are well documented.[1–3] Neurologic dysfunction secondary to these vertebral anomalies has only been reported relatively recently.[4–6]

Myelopathies in the thoracolumbar spinal cord region occur routinely in small animals and cause neurologic dysfunction of the pelvic limbs. These disorders are characterized by postural reaction deficits, micturition impairments, normal to exaggerated spinal reflexes, and paresis and ataxia or paralysis in the pelvic limbs, sparing the thoracic limbs.[6–8] Chronic progressive thoracolumbar myelopathies are more often seen in older animals. Differential diagnoses for a dog with chronic progressive thoracolumbar spinal cord disease include degenerative diseases (degenerative myelopathy, demyelinating diseases, and neuronopathies), neoplasia (primary CNS, skeletal, and metastatic), inflammatory processes (canine distemper and protozoal myelitis, granulomatous meningoencephalomyelitis, and rickettsial diseases), diskospondylitis, and anomalies of the vertebral column.[8] Neurologic dysfunction secondary to caudal articular process malformation has been documented,[4,5] but this myelopathy has not been documented specifically in Pugs. Therefore, the purpose of the study reported here was to retrospectively document thoracolumbar caudal articular process malformation with secondary constrictive fibrosis of the spinal cord in Pugs.

From the Department of Clinical Sciences, College of Veterinary Medicine, Mississippi State University, Mississippi State, MS 39762 (Fisher, Shores); and the Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, Auburn, AL 36849 (Simpson).

Address correspondence to Dr. Fisher (fisher@cvm.msstate.edu).

Materials and Methods

Criteria for selection of cases—The medical records of all dogs that were managed with medical management or surgical treatment for dysplasia or aplasia of thoracolumbar caudal articular processes at Auburn University Small Animal Teaching Hospital and Mississippi State University College of Veterinary Medicine Animal Health Center between 1993 and 2009 were reviewed. Radiographs of the thoracolumbar region as well as advanced imaging (myelography, CT, postmyelographic CT, or MRI) were used to confirm the diagnosis.

In addition to the dogs having aplastic or hypoplastic thoracolumbar caudal articular processes with neurologic dysfunction, 5 other Pugs examined at the veterinary teaching hospital for reasons unrelated to neurologic dysfunction but having aplastic or hypoplastic caudal articular processes were used for comparison purposes (orthogonal radiographs alone were used to view the aplastic or hypoplastic thoracolumbar caudal articular processes).

Medical records review—Information retrieved from the medical records included signalment, clinical history, type of onset (chronic or acute), medical treatment prior to admission, results of clinical examination at time of admission, results of laboratory testing, type of advanced imaging each patient underwent, treatment performed, and neurologic status at time of discharge.

Clinical and neurologic evaluation—Duration of clinical signs and prior history of trauma were obtained for each dog. If trauma had occurred at any time in the animal's life before clinical examination, an accurate depiction of the insult as well as the approximate date associated with the trauma was obtained from the owner. Presence and duration of incontinence were obtained. Each dog underwent a minimum of diagnostic testing (CBC, serum biochemical analysis, and urinalysis). If bacteria were seen on urinalysis, bacteriologic culture of urine and antimicrobial susceptibility testing were performed with the appropriate antimicrobial. Thoracic radiographs were obtained if deemed necessary. Neurologic examination with lesion localization was performed. Neurologic status was further classified as postural reaction deficits only, paraparetic (ambulatory or nonambulatory) with ataxia, or paraplegic (nociception status). Cerebrospinal fluid collection via the cerebellomedullary cistern or lumbar puncture and analysis were performed for all dogs.

Diagnostic imaging—Survey radiographs of the vertebral region of interest (thoracolumbar region) were obtained for every dog. Computed tomography, MRI, myelography, and postmyelographic CT of the area of interest (T3 through L3) were then performed to further analyze the cause of the neurologic disease. All radiographic and advanced diagnostic imaging results and type of MRI sequences for all dogs were recorded. Once compression or constriction was confirmed, further treatment consisting of medical management (strict cage confinement with various anti-inflammatory drugs) or surgical management (decompression of spinal cord with or without stabilization) was performed in every dog.

Outcome—If surgery was pursued, surgical procedures, site or sites of surgery, and surgical outcome were recorded. If an animal was euthanized at the time of surgery, this was also recorded. If any animal was euthanized, a necropsy was performed. Neurologic status at the time of discharge was recorded for each dog. Because of the stretch of time over which data were collected, some of the follow-up history as well as neurologic status after discharge was lost. If available, each dog's neurologic status was recorded at the last recheck examination. When available, status was recorded by telephone conversations with the owners.

Results

Sixteen dogs met the criteria for inclusion in the study. Eleven of the 16 were examined at the veterinary teaching hospitals because of neurologic dysfunction. The median age of the 11 dogs with neurologic dysfunction at time of diagnosis was 7.7 years (range, 2 to 11 years). Complete blood counts and serum biochemical profiles were within reference limits for each animal. All 11 dogs had histories of chronic, nonpainful progression of paraparesis with ataxia or paraplegia, with intact nociception. Five of the 11 dogs had a history of unrelated trauma consisting of falling from an elevated surface (n = 4) or being struck by an automobile (1) months to years before onset of neurologic dysfunction. Hyperpathia on palpation of the vertebral column was not noted in any dogs. All neurologic examinations revealed normal to exaggerated reflexes in the pelvic limbs, with the thoracic limb reflexes being within normal limits, localizing a focal or diffuse lesion to the T3-L3 region. Four of the 11 dogs had urinary or fecal incontinence at the time of examination. All other components of the neurologic exam were within normal limits. All CSF analyses were considered within reference limits.

All dogs' vertebral radiographs obtained under general anesthesia showed an indistinct appearance of the caudal articular processes at each articulation (loss of appearance of the normal convex and concave shape) in the regions from T9 through L2 (**Figures 1 and 2**). Seven of the 11 dogs had a myelogram performed with nonionic iodinated contrast[a] injected via the cerebellomedullary cistern or the lumbar region (**Figures 3 and 4**). All findings of the 7 dogs that underwent myelography were similar. There was an abrupt stoppage, narrowing, or irregular course of the contrast column in the regions of T11 through L1 of the spinal cord. Seven dogs underwent myelogram and CT,[b] 2 dogs underwent both CT and MRI,[c] and the 2 remaining underwent MRI alone. The findings for the dogs that underwent CT confirmed hypoplastic or aplastic caudal articular processes in the regions of T9 through L1 (**Figures 5 and 6**). The MRI scans revealed right and

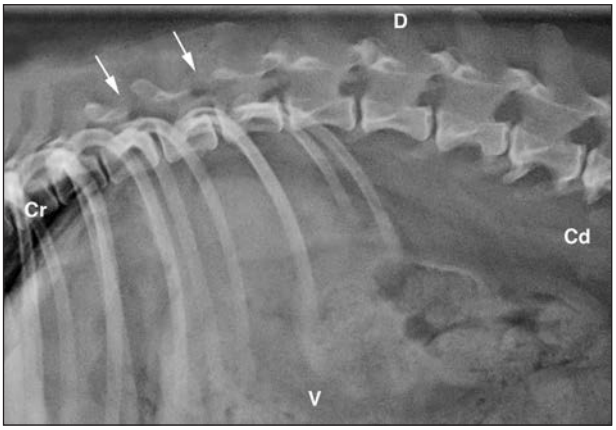

Figure 1—Lateral radiograph of an 11-year-old sexually intact male Pug examined because of paraparesis with ataxia. Note the loss of appearance of the normal convex and concave shape of the articular processes in the regions from T9 through L2. Arrows depict the absence of caudal articular processes at T11-12 and T12-13. Cd = Caudal. Cr = Cranial. D = Dorsal. V = Ventral.

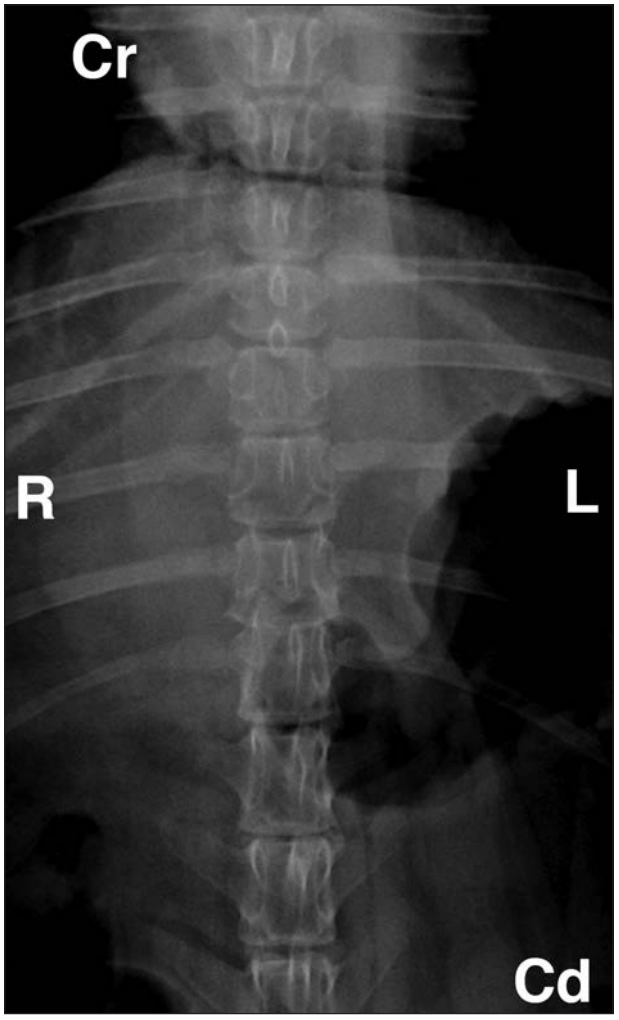

Figure 2—Ventrodorsal radiograph of the same Pug as in Figure 1. Note visualization of the cranial and caudal articular processes in ventrodorsal radiographs is difficult because of overlying structures. L = Left. R = Right. *See* Figure 1 for remainder of key.

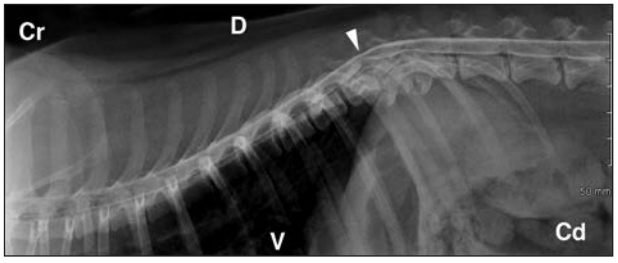

Figure 3—Lateral myelographic image of a 10-year-old neutered male Pug examined because of paraparesis with ataxia. Arrowhead depicts constriction of the spinal cord at T11-12. *See* Figure 1 for key.

left lateral narrowing of the spinal cord at the level of T11 through L1. The caudal articular processes were not distinct on MRI; however, vertebral radiography revealed indistinct articulations between the cranial and caudal articular processes in this region. Three of 11 dogs were treated with medical management alone (cage confinement with various anti-inflammatory drugs), and the remaining 8 dogs underwent surgery. A dorsal laminectomy was performed on 1 dog, whereas

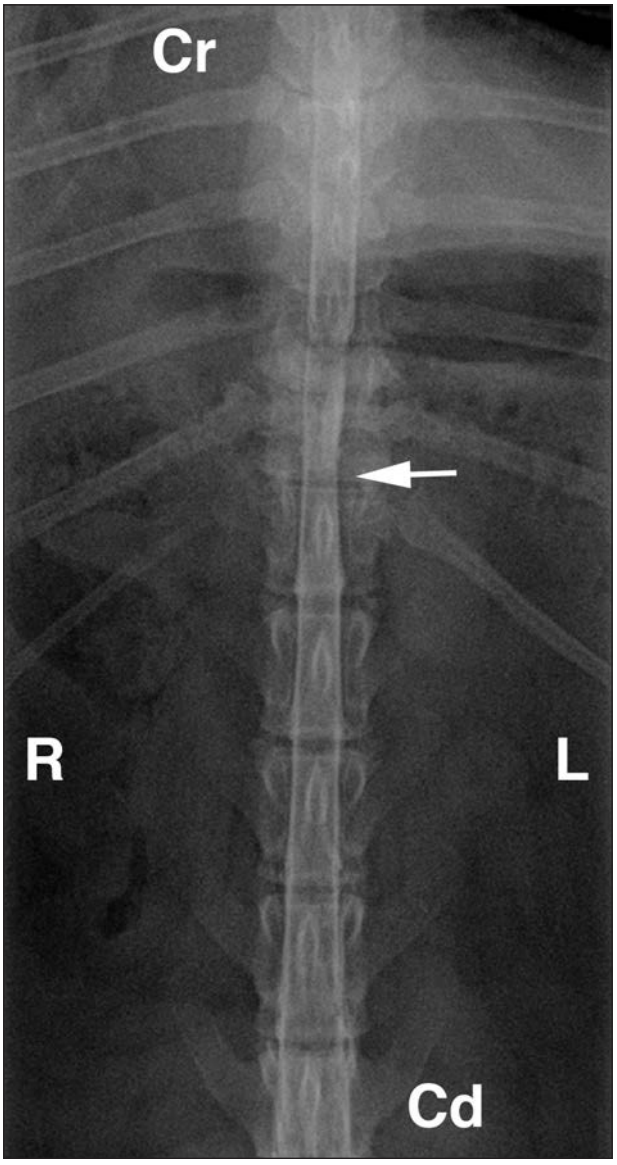

Figure 4—Ventrodorsal myelographic image of the same Pug as in Figure 3. Arrow depicts obvious constriction of spinal cord at T12-13. Closer examination reveals constriction from T11 through T13. *See* Figures 1 and 2 for key.

the other 7 had a unilateral or bilateral hemilaminectomy performed. Surgery also revealed constrictive lesions encompassing the spinal cord in the regions of the hypoplastic or aplastic articular processes. The lesions were debulked and vertebral column stabilization was achieved if deemed necessary by the surgeon. Six dogs survived surgery. One underwent cardiopulmonary arrest during surgery, and the other was euthanatized under anesthesia after the owners were consulted because of the extent of the constrictive lesion. Samples from the region of the constrictive area were submitted for histologic examination (n = 3), revealing fibrous cartilage in the area of the hypoplastic or aplastic articular processes. The tissue constricting or compressing the spinal cord consisted of fibrous connective tissue and granulation tissue originating from the dura mater. In 4 out of 8 dogs, the granulation tissue was invading the

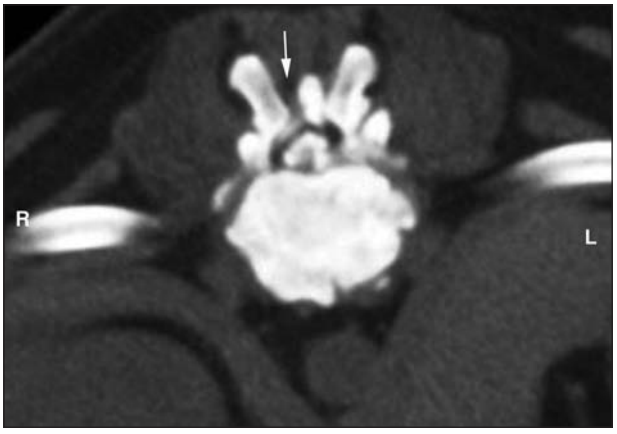

Figure 5—Postmyelographic CT image at the T12-13 intervertebral space of the same Pug as in Figure 3. The cranial articular processes of T13 are in full view. The left caudal articular process of T12 is hypoplastic, and the right caudal articular process of T12 is not visible (aplastic). Arrow denotes aplastic caudal articular process. There is also lateral deviation of spinal cord away from the midline toward the right side. The diameter of the spinal cord parenchyma appears reduced with increased filling of the subarachnoid space by the contrast agent. These findings suggest a loss of spinal cord parenchyma in this region caused by chronic constrictive compression. *See* Figure 2 for key.

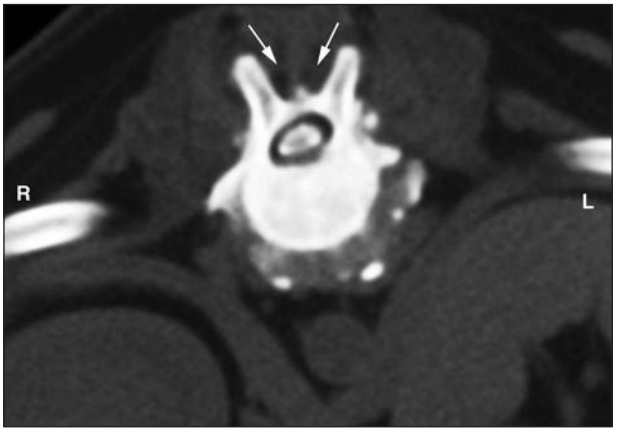

Figure 6—Postmyelographic CT image at the T11-12 intervertebral space of the same Pug as in Figure 3. The cranial articular processes of T12 are in full view. The caudal articular processes of T11 are not visible (aplastic). Arrows denote area where the caudal articular processes normally are located. There is also lateral deviation of spinal cord away from the midline toward the right side with mild circumferential compression. The diameter of the spinal cord parenchyma appears reduced with increased filling of the subarachnoid space by the contrast agent. These findings suggest a loss of spinal cord parenchyma in this region caused by chronic constrictive compression. *See* Figure 2 for key.

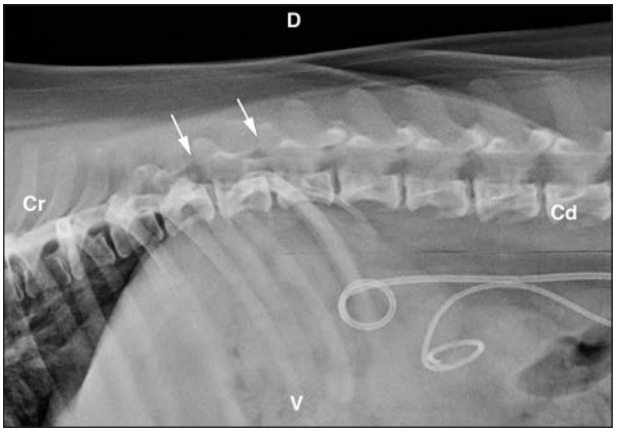

Figure 7—Lateral radiograph of a 7-year-old spayed female Pug examined because of stranguria with no evidence of neurologic dysfunction. Arrows depict the absence of caudal articular processes at T12-13 and T13-L1. *See* Figure 1 for key.

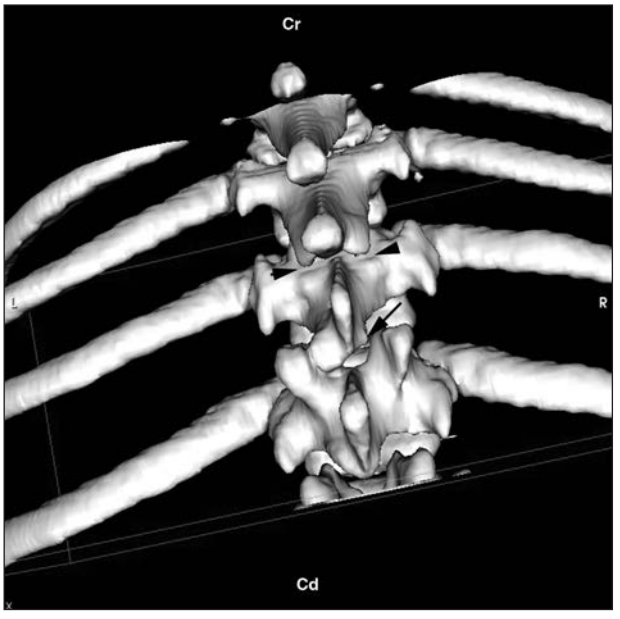

Figure 8—A 3-D CT reconstruction of the thoracolumbar portion of the vertebral column of an 11-year-old spayed female Pug with aplastic articular processes at T11-12 and hypoplastic articular processes at T12-13. Arrowheads depict where the cranial articular processes of T12 would normally articulate with the caudal articular processes of T11. Arrow depicts the hypoplastic caudal articular process. *See* Figures 1 and 2 for key.

spinal cord parenchyma, causing neuronal and axonal necrosis. Histologic evaluation of the spinal cord lesion revealed diffuse congestion and marked dorsolateral flattening with significant loss of substance. Moderate numbers of myelin sheaths were dilated, and the axons of several were swollen, containing elliptical eosinophilic bodies (spheroids). There was a mild increase in glial cells associated with the degenerate axons and focally extensive neuronal necrosis and central chromatolysis involving the ventral horn nuclei.

Four of 9 dogs were lost to follow-up but had no neurologic improvement at last recheck examination (2 to 7 months after surgery), 1 dog was euthanatized 2.5 years after surgery because of no improvement in neurologic status with fecal incontinence, 1 dog returned to normal neurologic status after surgery over the course of 3 months, 1 dog died of unrelated causes 1.5 years after surgery with same neurologic status at time of death as before surgery, and 2 dogs remained the same neurologically after surgery (2.5 years after surgery). One of the latter 2 dogs is regularly evaluated and undergoes rehabilitation (underwater treadmill, neuromuscular electro-stimulation, passive range of motion and ball therapy) at the veterinary teaching hospital. Its neurologic status improved after surgery but remains static at the time of writing (ambulatory paraparetic).

Radiographs of 5 other Pugs with aplasia or hypoplasia of the thoracolumbar caudal articular processes

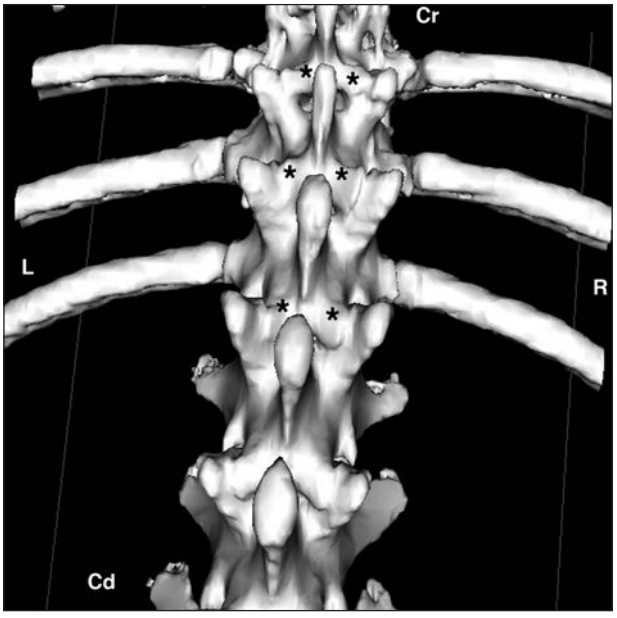

Figure 9—A 3-D CT reconstruction of the thoracolumbar portion of the vertebral column of a 10-year-old male neutered English Bulldog. Asterisks denote caudal articular processes. *See* Figures 1 and 2 for remainder of key.

with no neurologic dysfunction examined at the veterinary teaching hospital for other disease entities were reviewed. These dogs were examined because of difficulty urinating (n = 1), diarrhea (1), and abdominal pain (3). The median age at examination was 7.8 years (range, 4 to 12 years). Owner consent was confirmed at time of visit. Abdominal radiographs with view of the vertebral column were available for every dog. All dogs had aplastic or hypoplastic caudal articular processes in the thoracolumbar area. No proliferation or evidence of degenerative joint disease involving the articulation of the cranial or caudal articular processes was noted (only aplastic or hypoplastic thoracolumbar caudal articular processes; **Figure 7**).

Discussion

The present study documented the presence of aplastic or hypoplastic caudal articular processes in the thoracolumbar region of Pugs with and without neurologic dysfunction. This anomaly does not always produce neurologic dysfunction; however, fibrous constrictive myelopathy of Pugs should be considered when it is found in association with neurologic dysfunction that localizes to the T3-L3 spinal cord segments and lack of hyperpathia. Fibrous constrictive myelopathy secondary to hypoplasia or aplasia of the caudal articular processes of caudal thoracic vertebrae in Pugs is a disease that has not been described or documented in current literature to our knowledge. No sex or age predilection was noted in the dogs of the present study, but because of its chronic course, the consequences of this presumed congenital defect are usually recognized in older animals. Other findings from the present study revealed this myelopathy to be characterized by a fibrous constrictive band that surrounds, compresses, and interferes with the micromovement of the spinal cord. All lesions in the present study occurred within the thoracolumbar region of the vertebral column. Because of presumed chronic instability of the vertebral column, the fibrous constrictive band surrounds the dura and, on occasion, penetrates the subarachnoid space to become in direct contact with the neuropile. All the affected animals in the present study had specific malformation of the caudal articular processes in the caudal thoracic vertebral column.

Constrictive myelopathy causes neurologic deficits difficult to distinguish from other spinal cord diseases, such as intervertebral disk disease, arachnoid diverticula (cysts), or neoplasia. The signs associated with the fibrous constrictive myelopathy included pelvic limb paresis with ataxia, proprioceptive deficits, and exaggerated spinal reflexes in the pelvic limbs. Unlike type I intervertebral disk disease, the onset in all dogs of the present study was insidious and slowly progressive, and signs of pain and discomfort usually were not noted on palpation of the vertebral column. Urinary and fecal incontinence commonly occurred prior to development of nonambulation in the course of this disease in several dogs of the present study. We speculate that this constrictive myelopathy is best characterized by postmyelographic CT or a combination of CT and MRI of the spinal cord. Hypoplastic or aplastic thoracolumbar caudal articular processes are commonly noted on plain film radiography but are better defined with 3-D CT reconstruction (**Figures 8 and 9**), allowing the surgeon to identify these anatomic anomalies more readily.[9]

On the basis of this study, we suggest that fibrous constrictive myelopathy of Pugs is a consequence of a congenital anomaly, consisting of hypoplasia or aplasia of the thoracolumbar caudal articular processes and resultant chronic, low-grade presumed instability in most patients resulting in a constrictive fibrous tissue band involving the dura. Formation of the vertebral column is of great interest in understanding this disease process.

Ossification of the centra begins on day 38 of gestation.[10] Every vertebra, with the exception of the atlas and axis, has 3 primary centers of ossification (middle of the centrum and the base of each neural arch) formed from somitic sclerotomes (early embryonic vertebrae). Ossification of the centrum appears first in the caudal thoracic and cranial lumbar region. Ossification develops at a faster pace caudally and a slower pace cranially. Usually, as a result of the slow progression of cranial ossification, the cranial cervical vertebrae are the last to ossify their centrum. Ossification of the neural arches first appears in the cervical region and increases in a craniocaudal sequence beginning as early as day 38 of gestation.[10] Ossification of the neural arches begins at the base of each neural arch, and articular process ossification occurs as the neural arch ossification progresses.[10,11]

We speculate that the instability in these dogs occurs as a result of a congenital anomaly of the vertebral column in which the caudal articular processes fail either to form or to ossify. The cause of this is unknown. Another hypothesis that needs to be further explored is the role of Homeobox genes of the *Hox* class. Previous research[12] has shown the role in cartilage regulation is *Hox* gene specific. Cells in the chondrocyte lineage specifically respond to alterations in *Hox* gene expression. These results strongly indicate altered *Hox* gene expres-

sion affects differentiation of cells specifically within the chondrocyte lineage. *Hox* gene expression during skeletogenesis is of critical importance for both the formation and differentiation of cartilage.[12] If disturbance in the development of cartilage takes place, ossification will be incomplete and instability at this site will occur.

Congenital malformations of the vertebral column occur frequently in dogs. However, most vertebral congenital anomalies cause little to no neurologic disease and are incidental findings.[1,2] The most common vertebral anomalies (hemivertebra, atlantoaxial instability, block vertebra, butterfly vertebra, transitional vertebra, and spina bifida) are well documented, and some anomalies (atlantoaxial instability, spina bifida, hemivertebra, and block vertebra) can result in relevant neurologic disease.[1,2] Congenital anomalies of the articular processes have also been documented; however, these documented anomalies were not associated with meaningful neurologic disease.[3] The clinical relevance of lack or dysplasia of caudal articular processes in the thoracolumbar region is not understood and needs further research. In the present study, over a 16-year period, only 11 dogs with neurologic dysfunction associated with hypoplasia or aplasia of the caudal articular processes were identified. The 11 dogs of the present report all had neurologic dysfunction with hypoplasia or aplasia of the thoracolumbar caudal articular processes; however, survey radiographs of other Pugs having no neurologic diseases were also evaluated. Most survey radiographs of the dogs that were reviewed showed absent caudal articular processes at the thoracolumbar vertebra but no neurologic dysfunction. We speculate that some dogs may be more clinically affected because of the amount of instability, additional trauma from external sources, or coexisting spinal cord injury such as an intervertebral disk protrusion or extrusion. In a previous study,[13] myelopathies directly associated with vertebral anomalies were generally traumatic or compressive myelopathies as a result of malalignment or instability of the vertebral column.

To our knowledge, Pugs are the only breed of dog in which this type of vertebral malformation and associated myelopathy has occurred. However, a previous report[4] indicated aplasia of the articular processes caused an intervertebral disk herniation in a Pomeranian. Another report[5] described aplasia and hypoplasia of the caudal articular processes in 4 dogs, 3 of which were found to have spinal cord compression, but no breed predilection was found. The findings of Penderis et al[5] were similar to the vertebral malformations seen in the Pugs of the present study, except that no degenerative joint disease was evident in the present study. McDonnell et al[6] described a similar disease process involving 5 young Shiloh Shepherd Dogs. In these case reports,[6] proliferation of the articular processes in the thoracolumbar region was reportedly from malarticulation. Dorsal compression of the spinal cord was caused by abnormal proliferation of the articular processes and associated vertebral arches (degenerative joint disease). The dogs described in the present case series had no radiographic or advanced imaging (myelogram, CT, postmyelographic CT, or MRI) evidence of abnormal proliferation of the articular processes. We suggest the myelopathy disorder in Pugs is derived from a different mechanism. The degenerative joint disease associated with the Shiloh Shepherd Dogs was because of malarticulation of the articular processes; however, in Pugs, aplasia or hypoplasia of the thoracolumbar caudal articular processes is evident. If no caudal articular processes are present, degenerative joint disease may not occur in the absence of a complete synovial joint. Another possibility would be degree of instability. Articular processes contribute up to 30% of the stability of the vertebral column.[5,14,15] We speculate the Shiloh Shepherd Dogs may have greater instability in the thoracolumbar region than the Pugs of the present report.

Obvious limitations of the present study include its retrospective nature and the limited number of cases. This study included records spanning 16 years at 2 teaching institutions with multiple surgeons. In addition, a limited number of control group animals were available. Because of the nature of a retrospective study, most dogs in this study were lost to follow-up, making it somewhat difficult to draw conclusions; however, the dogs' most recent neurologic status remained unchanged after surgical decompression of the area constricted. It is our belief that surgical decompression with stabilization decreases the amount of microinstability and helps diminish neurologic deterioration.

We believe the minimal improvement in neurologic status in the dogs of the present study was because of the chronic nature of the myelopathy. Compressive myelopathies may result in irreversible mechanical derangement of nervous tissue due to the loss of axons and myelin with secondary gliosis and even fibrosis associated with the blood vessel walls (as has been described histopathologically).[7,8] These vascular factors result in ischemia and edema that play a role in development of spinal cord degeneration (axonal degeneration and demyelination).[7,8] Once this degenerative process has been initiated, little or no improvement returns. Additionally, because this type of myelopathy seems to occur primarily in a single breed of dog, some form of heritability of this vertebral anomaly must be considered.[1,2]

a. Isovue (iopamidol injection), Bracco Diagnostics Inc, Princeton, NJ.
b. Aquilion Super 4, model TSX-101A, Toshiba, Tochiqi, Japan.
c. Signa, 3.0 T, General Electric, Milwaukee, Wis.

References

1. Westworth DR, Sturges BK. Congenital spinal malformations in small animals. *Vet Clin North Am Small Anim Pract* 2010;40:951–981.
2. Bailey CS, Morgan JP. Congenital spinal malformations. *Vet Clin North Am Small Anim Pract* 1992;22:985–1015.
3. Morgan JP. Congenital anomalies of the vertebral column of the dog: a study of the incidence and significance based on a radiographic and morphologic study. *J Am Radiol Assoc* 1968;4:21–29.
4. Werner T, McNicholas WT, Baird DK, et al. Aplastic articular facets in a dog with intervertebral disk rupture of the 12th to 13th thoracic vertebral space. *J Am Anim Hosp Assoc* 2004;40:490–494.
5. Penderis J, Schwarz T, McConnell JF, et al. Dysplasia of the caudal vertebral articular facets in four dogs: results of radiographic, myelographic and magnetic resonance imaging investigations. *Vet Rec* 2005;156:601–605.
6. McDonnell JJ, Knowles KE, deLahunta A, et al. Thoracolumbar

spinal cord compression due to vertebral process degenerative joint disease in a family of Shiloh Shepherd Dogs. *J Vet Intern Med* 2003;17:530–537.
7. de Lahunta A, Glass E. Small animal spinal cord disease. In: de Lahunta A, Glass E, eds. *Veterinary neuroanatomy and clinical neurology*. 3rd ed. St Louis: Saunders Elsevier, 2009;243–284.
8. Lorenz MD, Kornegay JN. Pelvic limb paresis, paralysis, or ataxia. In: Lorenz MD, Kornegay JN, eds. *Handbook of veterinary neurology*. 4th ed. St Louis: Saunders, 2004;131–174.
9. Sharp NJH, Wheeler SJ. Diagnostic aids. In: Sharp NJH, Wheeler SJ, eds. *Small animal spinal disorders diagnosis and surgery*. 2nd ed. Philadelphia: Elsevier Mosby, 2005;41–73.
10. Evans HE. Prenatal development. In: Evans HE, ed. *Miller's anatomy of the dog*. 3rd ed. Philadelphia: WB Saunders Co, 1993;32–97.
11. Williams PL, Warwick R, Dyson M, et al. Osteology: the axial skeleton. In: Williams PL, Warwick R, Dyson M, et al, eds. *Gray's anatomy*. 37th ed. New York: Churchill Livingstone Inc, 1989;315–332.
12. Kappen C. Early and late functions of homeobox genes in the development of the axial skeleton. In: Buckwalter JA, Ehrlich MG, Sandell LJ, et al, eds. *Skeletal growth and development: clinical issues and basic science advances*. Rosemont, Ill: American Academy of Orthopedic Surgeons, 1998;147–161.
13. Bailey CS. An embryological approach to the clinical significance of congenital vertebral and spinal cord abnormalities. *J Am Anim Hosp Assoc* 1975;11:426–434.
14. Hirsch C. The reaction of intervertebral discs to compressive forces. *J Bone Joint Surg* 1955;37:1188–1196.
15. Smith GK, Walter MC. Spinal decompressive procedures and dorsal compartment injuries: comparative biomechanical study in canine cadavers. *Am J Vet Res* 1988;49:266–273.

From this month's *AJVR*

Experimental determination of a subantimicrobial dosage of doxycycline hyclate for treatment of periodontitis in Beagles

Se Eun Kim et al

Objective—To identify a subantimicrobial dose of doxycycline hyclate (SDD) and dosing interval for the treatment of periodontitis in dogs.

Animals—20 healthy Beagles for measurement of serum doxycycline concentration and 15 Beagles with periodontitis for evaluation of the efficacy of the SDD.

Procedures—5 dogs each received doxycycline hyclate PO at a dose of 1, 2, 3, or 5 mg/kg. Blood samples were collected before and after administration, and serum concentrations of doxycycline were measured via high-performance liquid chromatography. Mean serum doxycycline concentrations were calculated, and SDDs were identified. In a separate trial, the identified SDDs (1 or 2 mg/kg) were administered PO once a day for 1 month to dogs with periodontitis (n = 5/group) and a control group (5) was fed vehicle only during the same period. Degree of gingival attachment and bleeding on probing (present or absent) were recorded. Gingival samples were collected before and after the 1-month period from the same anatomic sites. Degree of matrix metalloproteinase inhibition in gingival samples was determined via gelatin zymography and compared among treatment groups.

Results—Mean serum doxycycline concentrations in healthy dogs that received 1 or 2 mg of doxycycline/kg were consistently significantly lower than the minimal inhibitory doxycycline concentration for treatment of periodontitis throughout the 24-hour posttreatment period. Zymographic intensities were lower in dogs given 1 and 2 mg/kg than in the control dogs, and the degree of gingival attachment and bleeding significantly improved in dogs given 2 mg/kg, compared with in the control dogs and dogs given 1 mg of doxycycline/kg.

Conclusions and Clinical Relevance—A doxycycline dosage of 2 mg/kg daily appeared to be an appropriate subantimicrobial regimen for dogs with periodontitis. Furthermore, this dosage may be suitable for long-term treatment of gelatinolytic inflammatory diseases such as periodontitis in this species. (*Am J Vet Res* 2013;74:130–135)

January 2013

See the midmonth issues of *JAVMA* for the expanded table of contents for the *AJVR* or log on to avmajournals.avma.org for access to all the abstracts.