INCOMPLETE OSSIFICATION OF THE ATLAS IN DOGS WITH CERVICAL SIGNS

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Osseous defects affecting the atlas were identified in computed tomography and magnetic resonance images of five dogs with cervical signs including pain, ataxia, tetraparesis, or tetraplegia. Osseous defects corresponded to normal positions of sutures between the halves of the neural arch and the intercentrum, and were compatible with incomplete ossification. Alignment between the portions of the atlas appeared relatively normal in four dogs. In these dogs the bone edges were smooth and rounded with a superficial layer of relatively compact cortical bone. Displacement compatible with unstable fracture was evident in one dog. Concurrent atlantoaxial subluxation, with dorsal displacement of the axis relative to the atlas, was evident in four dogs. Three dogs received surgical treatment and two dogs were treated conservatively. All dogs improved clinically. Incomplete ossification of the atlas, which may be associated with atlantoaxial subluxation, should be considered in the differential diagnosis of dogs with clinical signs localized to the cranial cervical region. *Veterinary Radiology & Ultrasound, Vol. 50, No. 6, 2009, pp 635–638.*

Key words: atlantoaxial subluxation, atlas, dog, incomplete ossification, vertebra.

Introduction

The atlas is formed by fusion of three centers of ossification: the body (intercentrum) of the axis, and the left and right neural arches, which fuse to complete the neural arch. These ossification centers are visible radiographically at birth. In beagles, fusion of the suture at the dorsal midline is normally complete by 106 days after birth, and fusion of the ventral sutures complete by 115 days after birth.[1]

Absence of the neural arch of the atlas has been described in a dog with neurologic signs but no abnormal movement on flexion/extension of the cervical spine.[2] The tentative diagnosis was traumatic myelopathy. Most congenital conditions affecting the atlas in dogs are characterized by combined occipito-atlantoaxial malformations rather than abnormalities affecting the atlas alone.[3] Incomplete ossification of the atlas is a well-recognized condition in humans that is usually asymptomatic unless there is a history of cervical trauma.[4–6] Computed tomography (CT) is the optimal modality for examination of the atlas in humans and is more sensitive than radiography for detection of osseous lesions.[7] Here we describe five dogs with cervical signs and incomplete ossification of the atlas.

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Case Histories

Medical records of five dogs that had incomplete ossification of the atlas in either CT or magnetic resonance (MR) images were reviewed. Radiographs of these dogs were also reviewed when available (Table 1). Dogs were between 4 months and 4 years of age. Blunt trauma was observed in one dog and suspected in another. Four of the five dogs had neurologic deficits compatible with a C1–C5 myelopathy, and three of the five dogs had cervical pain.

Imaging results are summarized in Table 2. Osseous defects affecting the atlas were identified in CT images (four dogs) (Fig. 1) and MR images (four dogs) (Fig. 2). Defects corresponded to normal positions of sutures between the halves of the neural arch and the intercentrum, hence were compatible with incomplete ossification. Defects in the atlas were variable in width. Alignment between the portions of the atlas appeared relatively normal in four dogs. In these dogs the bone edges were smooth and rounded with a superficial layer of relatively compact cortical bone. Displacement of parts of the atlas, angular bone edges, and exposure of cancellous bone compatible with unstable fracture was evident only in one dog (Fig. 3). Concurrent atlantoaxial subluxation, with dorsal displacement of the axis relative to the atlas, was evident in four dogs.

Three dogs received surgical treatment with the aim of stabilizing the atlas and atlantoaxial joint. These procedures involved insertion of screws, cerclage wires, and polymethylmethacrylate. Two dogs were treated conservatively with confinement. All dogs improved clinically.

TABLE 1. Summary of Dogs, History, and Clinical Signs

Dog	Breed	Sex	Age	History	Clinical Signs
1	Rough Collie	FN	4 years	Nonambulatory after generalized seizure	Nonambulatory tetraparesis and positional dystonia compatible with C1–C5 myelopathy
2	Cavalier King Charles spaniel	M	4 months	Trauma	Cervical pain
3	Bearded Collie	F	12 months	Abnormal gait following possible collision with stationary object 3 months previously	Ambulatory tetraparesis and ataxia compatible with C1–C5 myelopathy
4	English Springer spaniel	M	2 years	Found recumbent. No known trauma	Signs of cervical pain and nonambulatory tetraplegia compatible with C1–C5 myelopathy
5	Bull Mastiff	M	6 months	Acute progressive cervical pain. No known trauma	Signs of cervical pain, ambulatory tetraparesis, and hyperreflexia compatible with C1–C5 myelopathy

F, female; M, male; N, neutered.

Discussion

The sites of osseous defects in the atlas of each of these dogs, and the morphology of the bone edges in four dogs, support a diagnosis of incomplete ossification of the atlas. Similar features have been described in CT images of dogs with incomplete ossification of the humeral condyle.[8] Incomplete ossification of the atlas could be similar to incomplete ossification of the humerus in spaniels, in which fibrous tissue is present between the sections of the condyle, as opposed to normal bone.[8] No periosteal reaction was seen and no soft tissue bands were seen as had previously been reported.[2] However, in traumatized dogs, a soft tissue band may have been present but subsequently damaged and thus not visualized. Pathologic examination of the atlas was unwarranted because of the satisfactory clinical outcome in each of these dogs.

In the remaining dog, the appearance of the bone edges in CT images was consistent with a recent fracture through previously normal bone; however, the sites of presumed fracture also corresponded exactly to the sites of sutures (Fig. 4). The age of the dog (4 months) corresponded to the

TABLE 2. Summary of Imaging Findings

Dog	Radiography	CT	MR Imaging
1	Dorsal lamina of atlas appeared rounded and foreshortened. Stressed views not acquired.	Atlantoaxial subluxation. Lack of ossification affecting suture of neural arch and left suture of intercentrum, which had thickened, flared ends.	Atlantoaxial subluxation. Focal narrowing and displacement of spinal cord by dorsally displaced dens; focal hyperintensity at same site in T2-weighted images.
2	Initially appeared normal. Stressed views not acquired. Repeat radiographs 2 months later characterized by callus affecting neural arch.	Atlantoaxial subluxation. Moderately displaced fractures affecting dorsal suture of neural arch and suture between left neural arch and intercentrum.	ND
3	Atlantoaxial subluxation evident on ventroflexed lateral view. Neural arch of atlas appears foreshortened. Sagittal radiolucent line compatible with open suture superimposed on atlas to right of midline.	Atlantoaxial subluxation. Lack of ossification of caudal aspect of neural arch. Incomplete ossification of suture between right neural arch and intercentrum, which was thickened.	Atlantoaxial subluxation. Focal displacement of spinal cord by dorsally displaced dens; focal hyperintensity at same site in T2-weighted images. Spinal cord appeared normal.
4	ND	Atlantoaxial subluxation. Dorsal suture of neural arch is wide with blunted ends. Incomplete ossification of suture between right neural arch and intercentrum, which was thickened.	Atlantoaxial subluxation. Narrowing and slight dorsal displacement of spinal cord by dorsally displaced dens. Focal hyperintensity at same site in T2-weighted images
5	ND	ND	Dorsal suture of neural arch is wide with thick blunted ends. Incomplete ossification of suture between right neural arch and intercentrum, which is also thickened. Spinal cord appeared normal.

CT, computed tomography; MR, magnetic resonance; ND, not done.

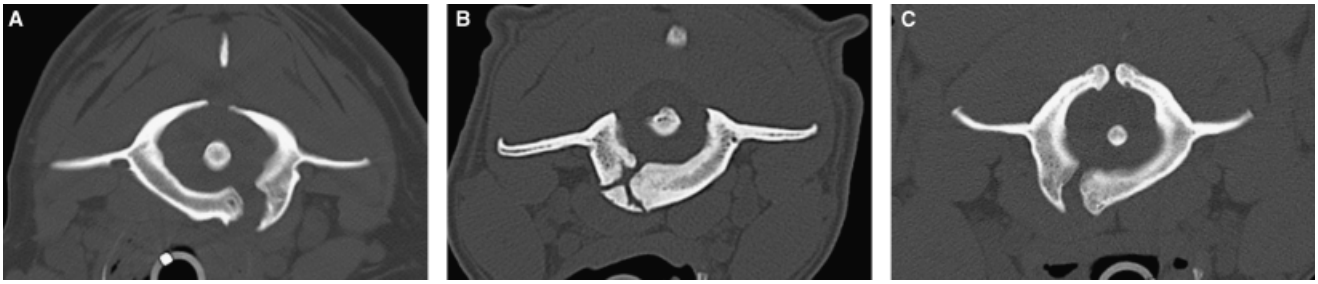

FIG. 1. Transverse computed tomography images of dogs with incomplete ossification of the atlas (A, dog 1; B, dog 3; C, dog 4). In each instance there are gaps of variable width affecting the midline of the neural arch and the vertebral body to the left or right of midline. These defects correspond to normal sites of sutures. In each instance there is also dorsal displacement of the dens compatible with atlantoaxial subluxation.

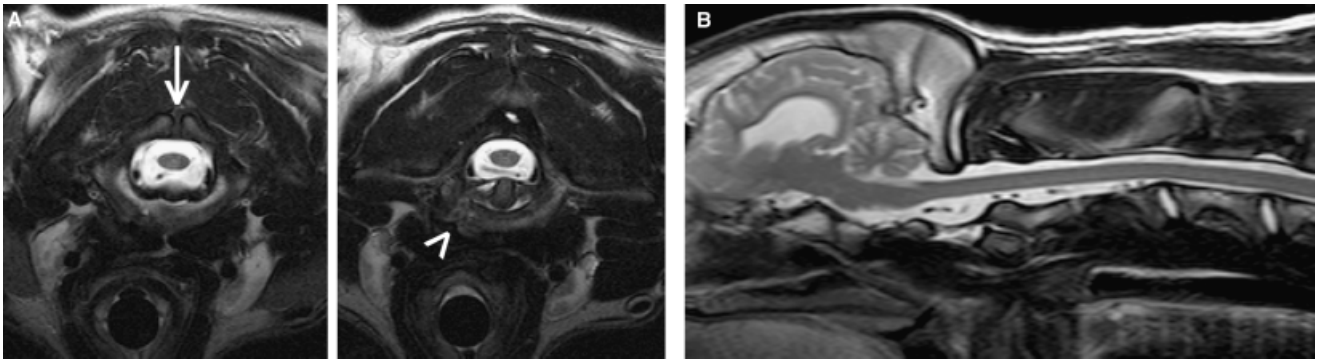

FIG. 2. Transverse (A) and sagittal (B) magnetic resonance images of a dog with incomplete ossification of the atlas (dog 5). The gap affecting the midline of the neural arch (arrow) and the vertebral body just to the right of midline (arrowhead) are less conspicuous than in computed tomography images. The spinal cord appears normal. There is no visible atlantoaxial subluxation.

usual age of closure of the atlas sutures. Hence, although there was a definite history of blunt trauma, the sites of fracture in this dog suggest that the sutures were points of relative weakness in the bone. For these reasons, incomplete ossification of the atlas also appears to be a relevant part of the pathophysiology of this dog's clinical condition. Incomplete ossification of the atlas should be considered in the differential diagnosis of dogs with clinical signs localized to the cranial aspect of the cervical spine.

In humans, defects in the posterior arch of the atlas range from simple gaps at ossification centers to absence of the entire vertebral arch.[5] A classification scheme distinguishes five types of posterior arch defect. Because this classification system applies only to defects affecting the posterior arch, which corresponds to the dorsal arch in dogs, it is unsuitable for categorizing dogs with abnormalities affecting the sutures of the intercentrum.

In the patient in this report, all lesions were clearly visible in either CT or MR images. Two of the five dogs also had radiographic studies and atlantoaxial subluxation was evident in two, but it was not possible to fully characterize osseous defects.

Four dogs had atlantoaxial subluxation associated with dorsal displacement of the axis relative to the atlas. This

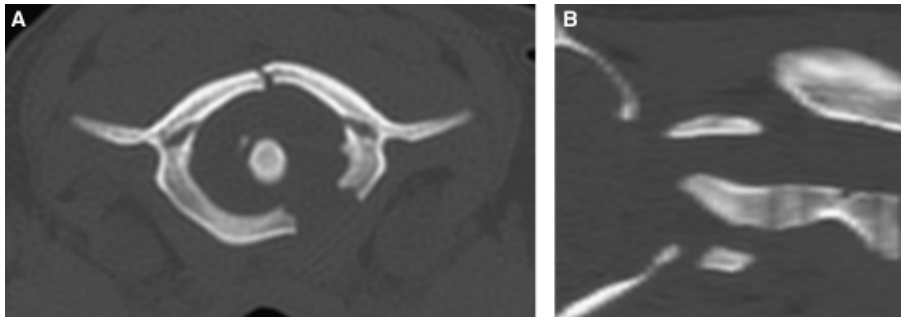

FIG. 3. (A) Transverse computed tomography image of dog 2. There are moderately displaced fractures of the neural arch and vertebral body to the left of midline. The appearance of the bone edges is compatible with a recent fracture through previously normal bone, but the sites of fracture correspond exactly to the sites of sutures. (B) Sagittal reconstruction. Note the dorsal displacement of the dens compatible with atlantoaxial subluxation.

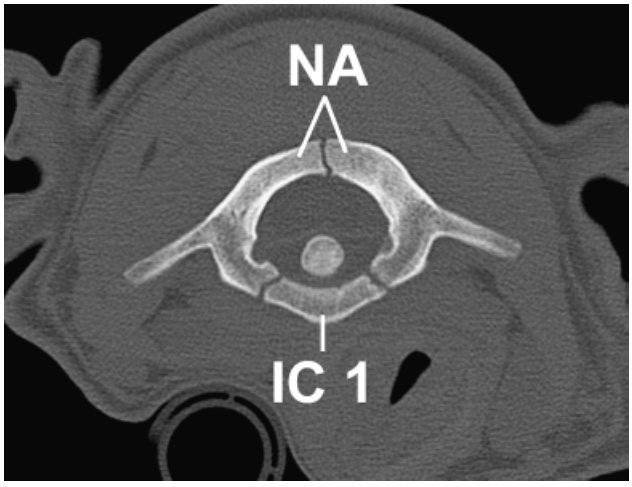

FIG. 4. Transverse computed tomography image of the atlas of a normal 3-month-old dog. Note the normal sutures between the halves of the neural arch (NA) and the intercentrum (IC1).

finding, affecting dogs of breeds not typically affected by atlantoaxial subluxation, suggests that incomplete ossification of the atlas was a contributory factor. In dogs with incomplete ossification of the neural arch, there may be an associated deficiencies of the various atlantoaxial ligaments or their attachments allowing laxity of the atlantoaxial joint,[2] which may predispose affected dogs to spinal cord damage following trauma.[2,9,10] One dog in this series was normal until it had a generalized seizure, at which point it developed acute, nonambulatory tetraparesis. It is plausible that lack of ligamentous support for the atlantoaxial joint associated with incomplete ossification of the atlas predisposed this dog to spinal cord trauma that would not have occurred in a dog with seizures and a normal atlas.

Three dogs received surgical treatment and two were treated conservatively. There are no established guidelines for choosing between surgical and conservative management of patients with atlantoaxial subluxation or fractures, but the presence of vertebral displacement/spinal cord compression, evidence of instability, severity of neurologic signs, and patient size, are all factors that should be considered when making this decision. In this series, the three dogs treated surgically had marked neurologic signs at presentation, whereas the two dogs treated conservatively had only relatively mild neurologic deficits.

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