Traumatic atlanto-occipital subluxation and cranial cervical block vertebrae in a Golden Eagle *(Aquila chrysaetos)*

Traumatische atlanto-occipitale subluxatie en craniale cervicale blokwervels bij een steenarend (Aquila chrysaetos)

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ABSTRACT

A Golden Eagle (*Aquila chrysaetos*) was evaluated for a balance/equilibrium disorder after suffering trauma due to a hard landing during fitness training. Magnetic resonance imaging and computed tomography demonstrated a chronic atlanto-occipital subluxation with craniodorsal displacement of the atlas (atlanto-occipital overlapping) causing dynamic brainstem and spinal cord compression and an old malunion fracture with fusion of C1 and C2. The bird was euthanized because of clinical deterioration and poor prognosis.

SAMENVATTING

Een steenarend (*Aquila chrysaetos*) werd onderzocht voor evenwichtsproblemen die ontstaan waren na trauma door een harde landing tijdens de fitnesstraining. Met magnetische resonantie en computertomografie werd een chronische atlanto-occipitale subluxatie aangetoond met een craniodorsale verplaatsing van de atlas (atlanto-occipitale overlapping) en secundair een dynamische compressie van de hersenstam en het ruggenmerg. Bovendien werd een malunion van een oudere fractuur gezien met fusie van C1 en C2. De vogel werd geëuthanaseerd omwille van de klinische achteruitgang en een slechte prognose.

INTRODUCTION

Traumatic dislocation of the atlanto-occipital joint is often fatal in humans and small animals. Even in survivors, severe persistent neurological deficit is common (Crane, 1978; Greenwood et al., 1978; Lappin and Dow, 1983; Camp et al., 1991; Papadopoulos et al., 1991; Dickman et al., 1993; Hosono et al., 1993; Matava et al., 1993; De Govender et al., 2003;Steffen et al., 2003; Rylander and Robles, 2007). Atlanto-occipital subluxation is rare in dogs and cats, probably because of the stable nature of this joint, which is attributable to the multiple, strong ligaments associated with it (Greenwood et al., 1978; Lappin and Dow, 1983; De Camp et al., 1991; Rylander and Robles, 2007). To the authors' knowledge, a case of traumatic dislocation of the atlanto-occipital joint has not been reported previously in birds.

CASE REPORT

A 38-year-old female Golden Eagle (*Aquila chrysaetos*) was referred to The Royal (Dick) School of Veterinary Studies (University of Edinburgh) for a balance/equilibrium disorder.

The eagle had been illegally captured from the wild at four years of age, spending most of her life (20 years) in a rescue center because she could not be returned to the wild. The bird had been occasionally flown at quarry during those 20 years but was mainly kept in an outdoor aviary. After unsuccessful attempts to breed her at the rescue center, she was passed to a falconry center, where falconers worked on her fitness to the lure. The falconer reported only one episode of landing hard after a long training session. However, the symptoms manifested shortly after that episode. Initially, the bird was able to fly and glide in a normal manner but she was unsteady when kept on the fist. The condition progressed over time to the point that she was sitting in a lopsided fashion with the right wing extended in an effort to maintain her balance at rest. She remained alert and responsive, able to eat on her own but she started spending most of the time on the floor being unable to balance on a perch. On presentation at the referring veterinarian's clinic, the eagle was in good body condition, and her weight was 7 kg. Physical and orthopedic examinations performed under general anesthesia were unremarkable, nor did the neurological examination reveal any significant abnormalities. The bird remained alert, and manually manipulating the head did not affect her balance. Whole body radiographs were taken with ventrodorsal and lateral views, but significant abnormalities were not observed. The referral veterinarian decided to treat her empirically with daily injections of a 0.5 mg/kg of prochlorperazine. The eagle was clinically unremarkable when on the drug, but reverted to how she had been previously when the drug administration was ceased. A second course of injections was not as effective as the previous course, and she steadily deteriorated subsequently.

At this point, the eagle was referred to The Royal (Dick) School of Veterinary Studies (University of Edinburgh) for advanced imaging examination with computed tomography (CT) and magnetic resonance imaging (MRI) and further work-up. MR images of the brain and spinal cord were acquired with a 1.5 Tesla field strength MR scanner (Philips Intera, Philips Medical Systems, Reigate, Surrey, UK) using a human wrist surface coil (Sense-Flex-S) that was well fitted to the avian head. The bird was anesthetized, and placed in dorsal recumbency. The following MRI sequences were performed: sagittal T2-weighted (3 mm slice thickness, TE 100 ms, TR 2213.6 ms), transverse T2 (2 mm slice thickness, TE 100 ms, TR 4137.57 ms); T1-weighted and T1-post gadolinium sequences of the brain (2 mm slice thickness, TE 10 ms, TR 746.34 ms); sagittal T2-weighted (2 mm slice thickness, TE 125 ms, TR 2266.16 ms), dorsal T2-weighted (3.5 mm slice thickness, TE 120 ms, TR 7840.14 ms); short-tau inversion-recovery (STIR) (3.5 mm slice thickness, TE 12 ms, TR 4210.37 ms); transverse T2 (2 mm slice thickness, TE 100 ms, TR 2932.58 ms); T1-weighted (2.5 mm slice thickness, TE 12 ms, TR 437.79 ms); sagittal T1-post gadolinium (2.5 mm slice thickness, TE 12 ms, TR 404.62 ms) sequences of the spine. Contrast-enhanced T1-weighted images were obtained following an intravenous bolus of 0.1 mmol/kg of gadobenate dimeglumine (Magnevist, Bayer Health-Care Pharmaceuticals Inc., Wayne, NJ, US). On the MR images, the cranial border of the atlas was cranial to the level of the foramen magnum on mid-sagittal images, and indented the cerebellum. The junction between the medulla and the cervical spinal cord was dorsally displaced, and kinked to a level of 112 degrees at the atlanto-occipital junction, and the cerebellomedullary cistern (cisterna magna) was compressed (Figure 1). The subarachnoid space was obliterated throughout the length of the atlas. Mild distension of the fourth ventricle was also present but no syringomyelia was identified (Figure 2). The remainder of the spinal cord was within normal limits.

CT images of the head and vertebral column were acquired by the use of a multidetector CT scanner (Siemens SOMATOM Volume Zoom, Siemens AG, Munich, Germany) with the bird in dorsal recumbency. Pre-contrast and post-contrast CT examinations were completed in transverse contiguous slices from

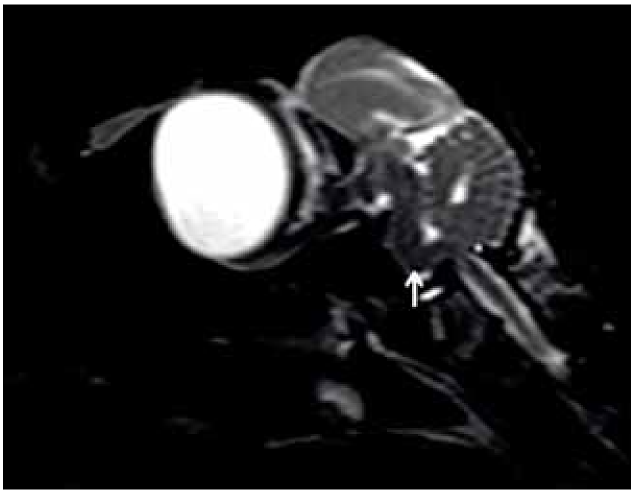

Figure 1. Mid-sagittal T2-weighted magnetic resonance image of the head and cranial cervical region. The cranial border of the atlas (*) is to the level of the foramen magnum and indents the cerebellum. The medulla oblongata is kinked (arrow), and the cisterna magna is compressed. The subarachnoid space is obliterated throughout the length of the atlas.

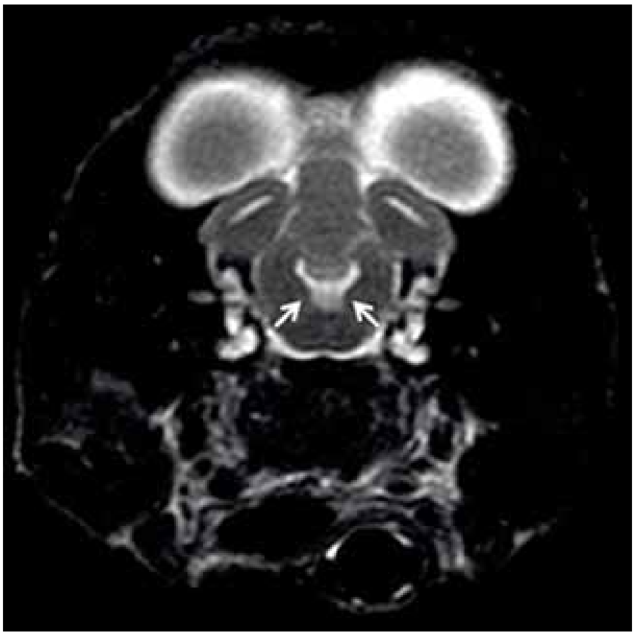

Figure 2. Transverse T2-weighted magnetic resonance image showing mild dilatation of the 4th ventricle (arrows).

the rostral end of the head to the last cervical vertebra, using the following settings: 120 kV, tube current 100 mA, 1.5 s tube rotation time, slice thickness 1 mm, 0.5 mm image reconstruction interval and a collimator pitch of 1. A non-ionic iodinated contrast medium (Ultravist 370, Iopromide, 370 mg I/ml, Bayer plc, Newbury, Berkshire, UK) was administered intravenously at a dose of 2 ml/kg. The images were acquired using standard bone and soft tissue algorithms. Image data were evaluated using a dedicated DICOM viewing software (OsiriX 3.9.2, Open Source ™) on a calibrated flat-screen LCD monitor (30 inch Apple Cinema HD display, Cupertino, CA, USA). Subsequent multiplanar reformatting was performed to obtain dorsal and sagittal images. CT images revealed a subluxation of the atlanto-occipital joint. The dorsal arc of the atlas and the ventral body protruded 3mm cranially into the foramen magnum (Figure 3), and the atlas was slightly rotated towards the left side. The occipital condyle was still located within the condyloid fossa of C1. There was also a large amount of new bone formation along the ventral aspect of the atlas (C1) and axis (C2) vertebrae, with fusion of C1 and C2. C1, C2 and C3 were sclerotic in contrast to all other vertebrae, which had a normal spongy architecture containing air. Secondary to the bony abnormalities, an elevation and compression of the medulla oblongata at the spinal cord–brainstem junction were seen, causing medullary kinking to a level of 135 degrees. Post-contrast CT images did not reveal any abnormally contrast enhancing tissue. Based on these findings, the final diagnosis was a chronic atlanto-occipital subluxation with craniodorsal displacement of the atlas (atlanto-occipital overlapping) causing dynamic brainstem and spinal cord compression. Moreover, an old malunion fracture with fusion of C1 and C2 was present.

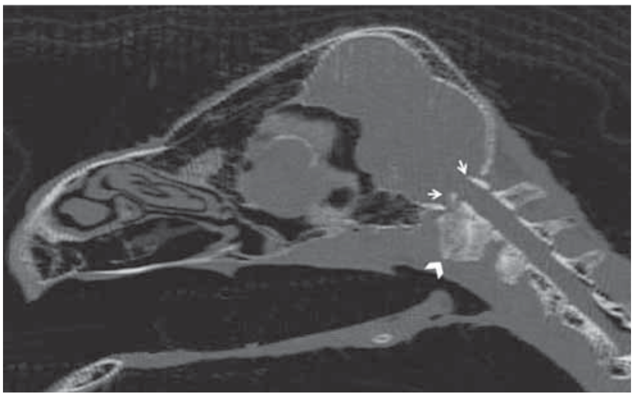

Figure 3. Sagittal computed tomographic reconstruction of the head and cranial neck, revealing a subluxation of the atlanto-occipital joint. The dorsal arc of the atlas and the ventral body protrude 3mm cranially into the foramen magnum (arrows). There is also a large amount of new bone formation along the ventral aspect of the atlas (C1) and axis (C2) vertebrae, with fusion of C1 and C2 (arrowhead). C1, C2 and C3 are sclerotic in contrast to all other vertebrae, which have a normal spongy architecture containing air.

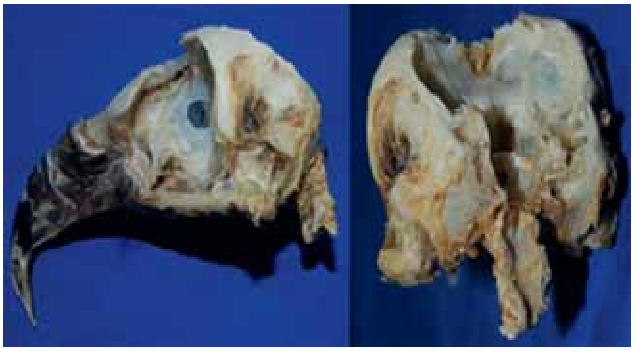

Figure 4. Boiled-out skull and cranial cervical vertebral column showing fusion of the first two cervical vertebrae and irregular bone proliferation on the ventral aspect of these bones.

Due to rapid deterioration, the bird was euthanized, and necropsy was performed. Macroscopically, there was fusion of the first two cervical vertebrae, as well as an irregular bone proliferation on the ventral aspect of these bones (Figure 4). Microscopically, multifocal meningeal proliferation, spheroid formation and suspected dural fibrosis around the spinal cord at the level of C1-C2 were present. Mild multifocal Wallerian degeneration of the spinal cord parenchyma was also evident at the level of C3.

DISCUSSION

The avian cervical column is an anatomically very complex structure. The small ring-shaped atlas articulates with a single occipital condyle, so that the atlanto-occipital joint is very mobile, which allows birds to rotate their neck to as much as 270 degrees (Scott, 1995). The avian cervical vertebral column is kinematically redundant, and comprises many more degrees of freedom than are required to move the head. Therefore, a large number of different movement patterns may move the head from one position to another, relative to the body (Bout, 1997). The avian neck comprises 12 to 24 cervical vertebrae. The vertebrae articulate around a saddle-shaped joint (articulatio intercorporalis) at the base of the vertebral body and two sliding joints at its dorsal aspect (articulatio zygapophysialis). As a result, relatively large dorsoventral and small lateral rotations are possible (Van der Leeuw et al., 2001). Boas (1929) divided the avian cervical column into three major flexion regions: the most cranial region 1 allows mainly ventral flexion, region 2 allows mainly dorsal flexion and region 3 allows limited ventral and dorsal flexion. The cervical musculature consists of a large number of muscle slips, assembled in a complex configuration, usually crossing more than one joint. Four muscle subsystems may be recognized: a cranio-cervical (between the head and rostral part of the neck), a dorsal, a ventral and a lateral subsystem (Van der Leeuw et al., 2001).

In birds, head trauma most often results in concussion and soft tissue injury. Fractures of the cranium and the cervical spine are rarely diagnosed, possibly because of the necessity of multiple radiographic views to differentiate normally superimposed structures and fracture lines (McMillan, 1994; Farrow, 2009). However, when vertebral fractures occur, they are often located in the caudal thoracic region or the synsacrum (McMillan, 1994; Stauber et al., 2007; Farrow, 2009).

Assessing spinal cord trauma and localizing spinal cord lesions in avian patients present unique challenges. Complete neurologic examination with survey radiographs may help to localize lesions but is rarely satisfactory in determining the extent and severity of the trauma (Clippinger et al., 1996; Stauber et al., 2007). In human medicine, and more recently in dogs and cats, emergency CT and MRI examinations in patients with suspected spinal cord trauma are performed as they provide superior sensitivity and specificity in the diagnosis of spinal fractures compared to radiography (Bagley, 2000; Andreoli et al., 2005; Berry et al., 2005; Kinns et al., 2006, Johnson et al., 2012). In this case, the definitive diagnosis of atlanto-occipital overlapping with secondary dynamic brainstem and spinal cord compression and the presence of an old malunion fracture with fusion of C1 and C2 (block vertebrae) was possible using these advanced imaging modalities but not with radiography. Maximum MR image quality requires the use of an optimally fitted receiver coil. In the present case, the authors used a human wrist surface coil normally used for the head of small animals (less than 10 kg body weight) that provided a very good fit. As CT is the method of choice to visualize especially bony structures, it was optimal to demonstrate the spatial orientation of the luxation and the vertebral fracture; while MRI provided the best evaluation of the severity of the neural compromise as it is the modality of choice for neural soft tissues. This is similar to a recent report where fractures of the vertebral column (T5/T6 and T6/T7) and synsacrum with associated trauma to the spinal cord and adjacent tissues were readily apparent with MRI but not evident with radiography (Stauber et al., 2007).

In small animals, traumatic injuries to the neck commonly affect the cranial cervical area. Fractures and luxations of the first and second cervical vertebrae in dogs are frequently encountered (Hawthorne et al., 1999), whereas reports of traumatic luxations of the atlanto-occipital joints are rare (Crane, 1978; Greenwood et al., 1978; Lappin and Dow, 1983; De Camp et al., 1991; Govender et al., 2003; Steffen et al., 2003; Rylander and Robles, 2007).

Craniodorsal displacement of the atlas with its lamina overlapping the occipital bone may occur as a result of trauma, causing compression and elevation of the caudal aspect of the brainstem and cranial aspect of the cervical spinal cord. Rotation of the atlas in relation to the occipital condyles is a frequent finding in these patients (Greenwood et al., 1978; Steffen et al., 2003; Rylander and Robles, 2007). This condition has also been diagnosed in dogs with a spontaneous occurrence without known previous trauma (Cerda-Gonzalez et al., 2009), and may be associated with incomplete ossification of the atlas (Warren-Smith et al., 2009). In these cases, there is no evidence of occipital or vertebral fractures and/or atlas rotation, which contrasts with reports of traumatic atlanto-occipital subluxation (Greenwood et al., 1978; Steffen et al., 2003; Rylander and Robles, 2007). To the authors' knowledge, a case of traumatic or spontaneous atlanto-occipital overlapping has not been reported previously in birds. However, their significantly augmented range of motion of the atlanto-occipital articulation could be a potential predisposition factor (Bout, 1997).

The neurological signs related to the atlanto-occipital subluxation are very variable. In humans, atlanto-occipital subluxation is usually fatal. However, in some cases, the clinical signs may be mild or subclinical, and pain is not always present, causing a delay in the diagnosis (Colnet et al., 1989; Zapalowicz et al., 2003). In the eagle reported here, the neurological signs were thought to be secondary to the compression of the brain stem and the cervicomedullary junction by the occipital bone. The deterioration of the neurological status was most probably associated with repetitive trauma to the spinal cord due to the excessive and abnormal movement in this region. This theory was further supported by the microscopic findings. Wallerian degeneration is the axon's response to neuronal injury, and it may be a consequence of various types of insult, from toxic exposure to axonal transaction. However, it is often the result of compression particularly in the spinal cord. Other changes consisted of meningeal proliferation, suspected dural fibrosis and occasional spheroid formation. Spheroids are swollen axons, and can also correlate with compression or stretching. Meningeal proliferation may be an incidental finding. However, in this case, the authors speculate that it was related to the excessive and abnormal movement in this region. Finally, also in the brain stem near the subluxation point, there was extradural and dural fibrosis with fibrocartilage in which there are necrotic bone shards. These bone shards were not typical of those that occur artefactually with the removal of spinal cord, and likely originated from traumatized pre-existing vertebral bone or periosteal bone proliferation.

CONCLUSION

This report is the first documented case with supportive imaging of a chronic traumatic atlanto-occipital overlapping in a bird, causing dynamic brainstem and spinal cord compression. An old malunion vertebral fracture with fusion of C1 and C2 was also diagnosed. The combined assessment with CT and MRI allowed a detailed description of the extent of the injuries.

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