SMART Neuro and the AA Lux Challenge

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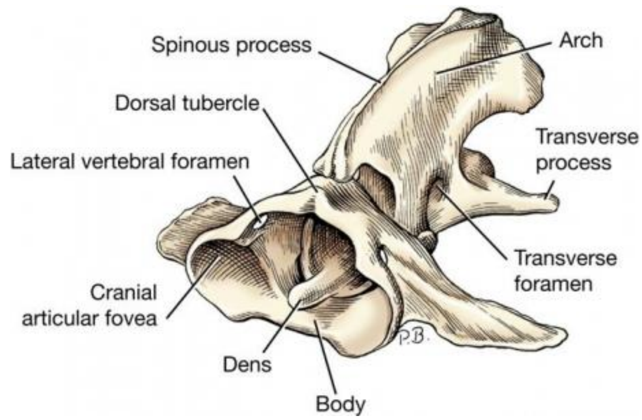
Introduction (Re-introduction) to the Cranial Cervical Anatomy



In the field of Neurology and Neurosurgery one of the most challenging regions we work with is located at the cranial most section of the spine. The anatomy of this region is both unique and complex. The atlas is the first cervical vertebra made of a dorsal and ventral arch with wide lateral processes or wings. The atlas is maintained in position with the occipital condyles by articulation with the depressions on the ventral aspect of the atlas (fovea) surrounded by a joint capsule. The ventral portion of the atlas also has fovea on the dorsal aspect that articulate with the cranial portion of the axis surrounded by a loose joint capsule. The axis is the largest vertebra identified by two unmistakably unique features: the large spinous process and protruding odontoid process or the dens. The tip of the dens or proatlas is its own center of ossification and can be confused for a fracture in early development. The dens of the atlas is secured with several ligaments: the transverse, the apical and the paired alar ligaments. A dorsal membrane also aligns the two vertebra at the level of the arches.

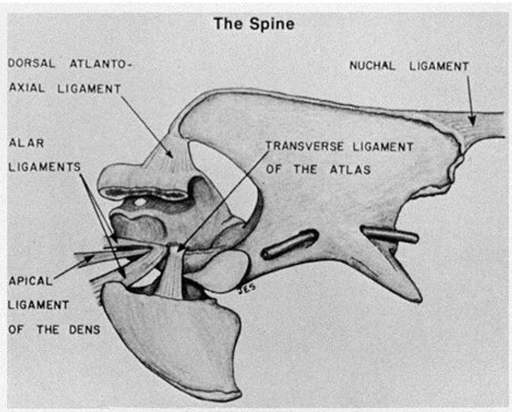


FIG. 19-3 The normal relationship of the atlas and axis and the major anatomical structures. (Gage ED, Smallwood TE: Surgical repair of atlantoaxial subluxation in a dog. Vet Clin North Am [Small Anim Pract] 65:583, 1970. Veterinary Medicine and Small Animal Clinician (VM-SAC) 65:583, 1970)

AA Instability

The structure of this region allows for complicated movements such as longitudinal pivoting as well as bending and rotation. However, when there is malformation or trauma to any piece of this complex puzzle, the structures can become unstable. Common malformations include dens hypoplasia or aplasia, incomplete ossification of the atlas, block vertebrae and absence of ligaments. Trauma can lead to fracture/luxation of vertebrae and tearing or failure of the ligaments.

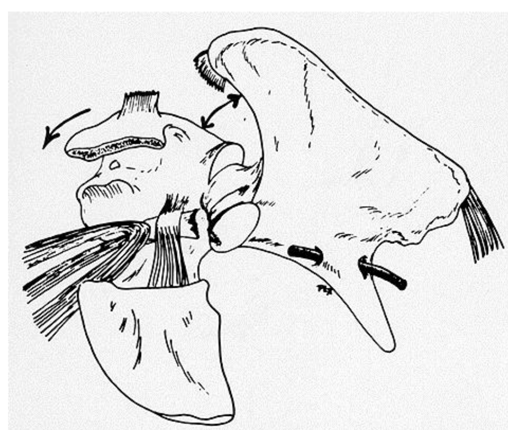
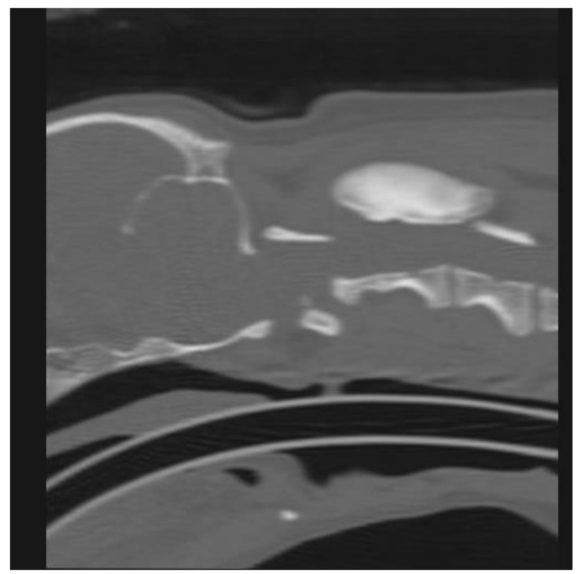


FIG. 19-5 Fractured odontoid with subsequent subluxation of the joint. (Gage ED: Atlantoaxial subluxation. In Bojrab MJ (ed): Current Techniques in Small Animal Surgery, Vol 1, p 377. Philadelphia, Lea & Febiger, 1975)

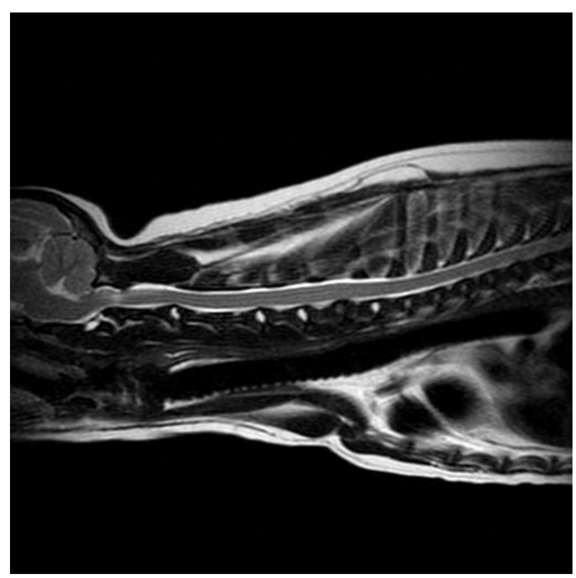
A range of clinical signs occurs with AA instability and are associated with the severity of the instability. Mild instability can produce signs of neck pain alone, while progressively worsening signs include ataxia, or tetraparesis to plegia. In tetraplegic patients respiratory compromise and arrest can occur quickly. Differential diagnoses for these clinical signs include: intervertebral disk herniation, myelitis, diskospondylitis, acute stages of a vascular incident and trauma without AA instability.

Diagnosis



Radiographs can provide evidence of malformation or luxation. In cases where instability is not immediately recognized, fluoroscopy can be helpful and reduces the risk of luxation when obtaining dynamic views. Gentle and mild flexion can show an increased distance between the spinous process of the axis and the dorsal arch of the atlas. Advanced diagnostic imaging like computed tomography (CT) can be obtained and used for 3D reconstructions, 3D prints and surgical planning, while MRI can provide soft tissue information regarding the spinal cord or any concurrent lesions or diseases. Because of CT's superior imaging of bony structures this is the preferred imaging of AA instability, allowing analysis of potential fractures and identifying corridors for surgical stabilization.

Treatment



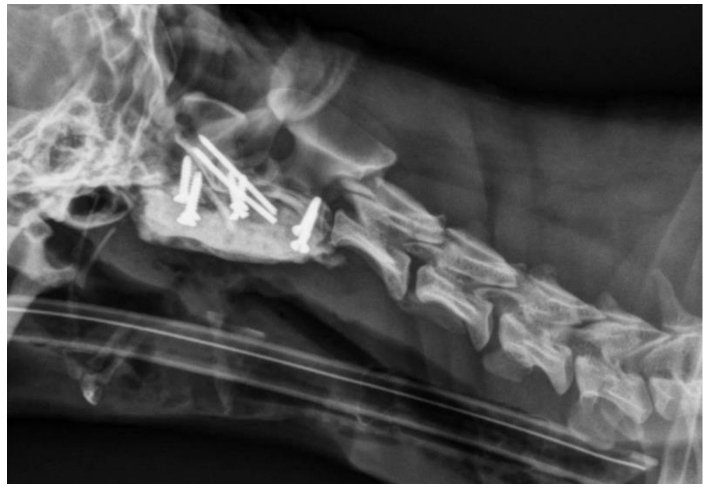
Many small case series and single reports of AA instability have been described and have compared treatment options, both medical and surgical. The goal of treatment is to stabilize the atlantoaxial joint to prevent luxation/subluxation. Surgical treatment can also aim to remove any compression on the spinal cord caused by fracture, or luxation/subluxation. Medical management consists of strict rest and use of a splint and soft padded bandaging. Bandaging and rest have a positive outcome in 71.8%. Complications are associated with maintenance of bandaging and can include: dermatitis, ulceration of the skin or decubital ulcers, and continued instability of the region.

Surgical treatment options can be summarized into dorsal and ventral approaches. The dorsal approach while attractive for its safety and ease, does not allow for access to the atlantoaxial joint for arthrodesis. At Penn Vet we can use this approach to apply either the Kishigami tension band, or use Kirschner wires passing through the dorsal arch of the atlas and attaching to the spinous process of the axis to stabilize the region until joint forms scar tissue. This approach has complications that include: iatrogenic damage to the spinal cord, vertebral fracture, and death (8%). Overall, the success rate of surgery is 65%, but deficits like ataxia (44.4%) and pain (11.1%) can remain.

The ventral approach has the benefit of access to the atlantoaxial joint space, but the tradeoff involves the complexity and risk associated with vital structures in the neck. The procedure involves the use of plates, pins, screws or wires with polymethylmethacrylate (PMMA) to stabilize the AA region. Often the patients requiring surgery are small or toy breed dogs and the first and second vertebrae in the neck are small. The average area for placing implants, or bone corridor, is about 3 to 4.5 mm wide. This makes the ideal implant size 1.5 to 2 mm and requires the utmost of precision in placement. The success rate for ventral procedures is 82.6% with remaining deficits that include ataxia (19%) and pain (9.7%). Complications of this procedure include: implant migration/failure, vertebral fracture, hemorrhage, problems with soft tissue structures in the neck and death (5%).

The Challenge

Compared to other spinal surgeries, the frequency of patients with AA instability requiring surgical intervention is low. The ability to teach a complex procedure such AA stabilization is hindered by this lack of experience. As a group, Penn Vet Neurology's challenge is to solve this problem for the future of neurosurgical training. While investigating the marriage of technology and medicine that we entitled SMART Neuro, we have found similar interest in pockets of human medicine. Most interested areas have a basis in surgery (cardiology, otolaryngology, maxillofacial, neurosurgery) and few reports have been published to show that technology can be used to improve upon training and process. Important studies have been undertaken to show that 3D printed models constructed from DICOM data are true models meaning they have correct landmark position and measurements. Other studies appear in orthopedic and cranial surgery and are focused on showing a reduction in surgical time or improved outcome.



Here we have designed a simple study to evaluate two methods of incorporating simulation and modeling in our veterinary neurosurgical approach to AA instability. During our session we will divide into three groups. The first group will receive the classic textbook description of transarticular screw placement and a 3D printed model of the atlantoaxial region. A second group will receive a 3D printed model, a 3D designed and printed jig with preprinted holes and the textbook description of the screw placement. The last group will receive the model and instructions but will also have available a visual augmented reality guide as they perform the screw placement.

Objective data will be collected from the models including: screw failure, canal penetration, and angulation of the screws. Subjective data will also be collected prior to and post-operatively regarding knowledge and comfort level with anatomy, ease of instructions, and ease of screw placement.

Aims

Together we hope to draw conclusions that will help SMART Neuro to become a regular part of neurosurgical preparation.

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