

Study on the diagnosis and surgical treatment for atlantoaxial instability in the dog

Summary of Doctoral Thesis

Fumitaka Takahashi

Graduate School of Veterinary Medicine and Life Science

Nippon Veterinary and Life Science University

In the field of veterinary neurosurgery, atlantoaxial instability (AAI), which commonly affects young toy breed dogs (TBDs), results in variable degrees of cervical spinal cord injury associated with dynamic instability of the atlantoaxial joint (AAJ). In some cases, AAI may be asymptomatic. However, dislocation of the AAJ, a potentially life-threatening condition, generally presents with acute clinical signs (neck pain or tetraplegia). AAI results from congenital dysplasia of the atlas or axis. Treatment of AAI includes conservative and surgical management; surgical treatment is recommended for cases with neurological abnormalities, severe neck pain, and lack of response to conservative treatment.

The two primary methods used for surgical treatment are ventral stabilization and dorsal stabilization. Ventral stabilization is currently widely used because the dislocated AAJ can be repositioned visually, the success rate of this surgery is high, and the necessity for re-operation and surgery-related mortality rate are low. The purpose of ventral stabilization of the dislocated AAJ is reduction and stabilization, with the final goal being bony fusion of the AAJ. Because the AAJ has torsional mobility centered on the odontoid process of the axis, it is important in ventral fixation surgery for AAI to ensure resistance against both flexural and torsional loading until the AAJ bone is fused. Dorsal decompression may also be performed if necessary and preoperative planning is based on advanced imaging. In most cases of AAI, ventral fixation of the AAJ results in a favorable prognosis.

In recent years, the widespread use of magnetic resonance imaging and computed tomography (CT) in veterinary medicine has enabled preoperative diagnosis of various forms of craniocervical junction abnormality (CJA) in cases of AAI. However, the underlying pathophysiology of these abnormalities and their association with AAI is unclear, and effective treatments for CJA have not yet been established. In some cases, patient outcome following surgical treatment of AAI was

worse than expected. In these cases, the pathologic contribution of concurrent CJA in the absence of AAI is suspected.

The purpose of this study was to clarify the diagnosis and treatment of AAI in dogs with pathologic causation of AAI and CJA. In chapter 2, we focused on dens abnormality as a common etiology of AAI, and studied the morphologic characteristics of the dens. In chapter 3, among the various types of incomplete ossification of the atlas reported as an etiology of AAI, we focused on incomplete ossification of the dorsal neural arch of the atlas (IODA) in TBDs. In this respect, we investigated the epidemiological and morphological features and outcome of surgical treatment of IODA in AAI-affected TBDs. In chapter 4, we reviewed the mechanical strength of implants in various techniques for ventral fixation of the AAJ. We studied the mechanical strength of implants used in three kinds of surgical fixation techniques, including atlantoaxial plate fixation (APF) using the AAJ fixation plate based on our original design; multiple metallic implant and polymethylmethacrylate (PMMA) fixation (PMF); and transarticular fixation (TAF), using an atlas-axis model of a healthy Beagle dog. In chapter 5, because it was suggested in chapter 4 that APF is an alternative to PMF, we focused on fusion outcomes of the AAJ after ventral fixation. In this chapter, we investigated diachronic changes in the CT value and histology of the AAJ in euthanized, healthy Beagle dogs that had undergone APF and PMF. In chapter 6, because it is difficult to simultaneously evaluate the etiologies of various CJA, we focused on atlantooccipital overlapping (AOO), which is known to affect the clinical signs and prognosis for dogs with abnormalities of the junction between the head and neck. We investigated the effects of concurrent AOO and AAI on the clinical outcomes of ventral fixation of AAJ in TBDs. In chapter 7, we investigated cerebral ventricle size in TBDs with AAI with or without AOO; we determined that cerebral ventricle size seemed to be related to AOO. The results of the above-mentioned investigations are presented below.

1. Morphologic characteristics of the dens

We calculated the ratio of the dens length to the axis body length (DALR) and the dens angle (DA) using CT images of 80 AAI-affected and 40 non-affected TBDs and 40 healthy Beagle dogs, and studied the morphologic characteristics of the dens. We did not detect a significant difference between the mean DALR in non-AAI-affected TBDs compared with healthy Beagle dogs. The mean DALR in AAI-affected TBDs was significantly lower than that for non-affected TBDs. The mean DA of AAI-affected TBDs was significantly greater than that of healthy Beagle dogs and non-affected TBDs. These findings therefore suggest that in AAI-predisposed TBDs with low DALR and great DA, the DALR and DA might be important factors for predicting the development of AAI in dogs.

2. The epidemiological and morphological features and outcome of surgical treatment of IODA in TBDs with AAI

We retrospectively reviewed 106 AAI-affected TBDs that underwent ventral fixation of the AAJ, and investigated the epidemiological and morphological features and outcome of surgical treatment of IODA. Of the 106 AAI-affected TBDs, 75 did (IODA group) and 31 did not (non-IODA group) have IODA. The age at surgery for AAI-affected TBDs with central IODA was significantly higher than that of the non-IODA group. The severity of spinal cord injury before and after ventral fixation of the AAJ did not differ between the IODA and non-IODA groups. These findings indicate that concomitant dens abnormality or IODA is common in TBDs with AAI. There was no association with time to convalescence, but the possibility of IODA as an etiology of AAI that developed at middle to advanced age was suggested.

3. The mechanical strength of implants in ventral fixation of AAJ

In this study, we prepared 6 APF models, 6 PMF models, and 6 TAF models using the atlas and axis harvested from 18 healthy Beagle dogs, and evaluated the mechanical strength of the implant in the three kinds of ventral fixation techniques for AAJ. In the flexural strength test, the PMF group withstood significantly higher maximum load than did the APF group and the TAF group. In the torsional strength test, the maximum load did not differ significantly between the APF group and the PMF group, but the APF group had a higher maximum load compared with the others. Therefore, the currently used PMF was once again proven to be a useful method for fixation of the AAJ. The APF is considered an alternative fixation method to the PMF, because considering the drawbacks of using PMMA, resistance of the torsional load in the AAJ is similar to that of the PMF, and less variable results in terms of fixation strength can be obtained using the atlantoaxial fixation plate.

4. The influence of AAJ ventral fixation techniques on AAJ fusion

In this study, we performed PMF in 3 dogs and APF in 5 dogs, using 8 healthy Beagle dogs that had undergone dens resection. The dogs were euthanized at postoperative month 7, and the influence of AAJ ventral fixation techniques on AAJ fusion was evaluated. We determined that the postoperative diachronic mean CT value of AAJ did not differ significantly between the APF group and the PMF group, but the mean CT value of the APF group was higher than that of the PMF group in each observation period (2 weeks, 1, 2, 3, 4, 5, 6 and 7 months after surgery). The mean CT value of the APF group after 1 month was significantly higher than that immediately postoperatively. The mean CT value of the PMF group after 1 month did not differ significantly compared with that immediately postoperatively, but an upward trend was recognized in each observation period (2

weeks, 1, 2, 3, 4, 5, 6 and 7 months after surgery). On histologic evaluation at 7 months, bony fusion in the AAJ occurred mainly in the APF group, whereas fibrous fusion in the AAJ occurred mainly in the PMF group. Therefore, stability of AAJ was provided without clinical problems in both PMF and APF, but the possibility that APF would result in more ideal bony fusion in the AAJ histologically than PMF was suggested.

5. Effects of concurrent AOO on the clinical outcomes of ventral fixation of AAJ for TBDs with AAI

We retrospectively reviewed 41 AAI-affected TBDs that had undergone ventral fixation of the AAJ, and examined clinical outcomes after ventral fixation in TBDs with AAI on the basis of the presence or absence of AOO. As a result, of the 41 dogs diagnosed with AAI and treated with ventral fixation, 12 exhibited AOO (AOO group), and 29 did not (non-AOO group) on preoperative CT imaging. No significant difference was observed in outcomes between the groups; the recovery rate was 91.7% (11/12) in the AOO group and 86.2% (25/29) in the non-AOO group. A comparison of neurological status over time between the groups revealed that the AOO group had significantly higher neurological scores before surgery and 1 month after surgery. However, no significant difference was detected between the groups at any time after 1 month. Therefore, the findings of this study suggest that the presence of AOO affects the clinical signs among dogs with AAI but does not directly affect the outcome of the surgical stabilization of AAI.

6. Cerebral ventricle size in AAI-affected TBDs with or without AOO

We retrospectively reviewed 61 AAI-affected TBDs that underwent ventral fixation of the AAJ, and investigated cerebral ventricle size in AAI-affected TBDs with or without AOO; we determined

that cerebral ventricle size seemed to be related to AOO. As a result, of the 61 dogs diagnosed with AAI and treated with ventral fixation, 23 exhibited AOO (AOO group), whereas 38 did not (non-AOO group) on preoperative CT imaging. The ventricle/brain height ratio, the fourth ventricle height/cerebellum length ratio, and the fourth ventricle width/cerebellum length ratio were significantly higher in the AOO group compared with the non-AOO group. Therefore, AAI-affected TBDs with concurrent AOO exhibited significantly greater dilatation of the lateral and fourth ventricles than did those without concurrent AOO.

In summary, the purpose of the present study was to clarify the diagnosis and treatment of AAI in dogs with pathologic causation of AAI and CJA. Our findings in this study clarified the pathologic details of dens abnormality and IODA, the mechanical strength of implant in the three kinds of ventral fixation techniques for AAJ, the influence of AAJ ventral fixation techniques on AAJ fusion, and effects of the concurrent AOO on the cerebral ventricle size and the clinical outcomes of ventral fixation of the AAJ for AAI-affected TBDs. In future, further study of the causation of still-unexplained other CJA and AAI will be of interest.