

Application of a Modified Dorsal Wiring Method in Toy Breed Dogs With Atlantoaxial Subluxation

DONGWOOK KIM¹, SEOUNGJIN LEE² and GONHYUNG KIM¹

¹Department of Veterinary Surgery, College of Veterinary Medicine,
Chungbuk National University, Cheongju, Republic of Korea;

²Lee Animal Medical Center, Ulsan, Republic of Korea

Abstract. *Background/Aim:* Atlantoaxial subluxation (AAS) is a congenital or traumatic condition that often requires surgical stabilization. Surgery is performed via a ventral or dorsal approach. A ventral approach is challenging in toy breed dogs due to their small-sized bones. Reducing AAS by orthopedic wire via a dorsal approach can cause iatrogenic spinal cord damage. Due to these limitations, a Kishigami atlantoaxial tension band (Kishigami AATB) that remains in the epidural space has been devised. Similar to the Kishigami AATB, the present study developed a modified dorsal wiring method and evaluated it in toy breed dogs with AAS. *Materials and Methods:* Medical data of toy breed dogs with AAS that underwent surgical stabilization using the modified dorsal wiring method from 2017 to 2020 were retrospectively reviewed. *Results:* A total of 10 dogs were analyzed. Regarding the history of these dogs, six dogs had congenital AAS, and the remaining four dogs had traumatic AAS. Evaluation via computed tomography was available for five dogs, of which two dogs were identified as having incomplete ossification of their atlas. Although four dogs required a revision surgery because of recurrence of clinical signs or fracture of the atlas, final functional improvement was achieved in nine dogs. One dog showed worsened neurological status that led to death. *Conclusion:* Clinical results with the modified dorsal wiring method were similar to those with the Kishigami AATB. The modified dorsal wiring method is versatile as it could be applied to various shapes of dogs' atlas.

Considering the shape of the atlas, it is recommended to apply the implant as far from the midline of the dorsal arch as possible to avoid fractures. With selection of suitable patients, this modified dorsal wiring method can be applied to dorsal stabilization of AAS in toy breed dogs.

Atlantoaxial subluxation (AAS) is a well-recognized disease first reported in veterinary medicine in 1967 (1). The condition of instability in the atlantoaxial joint generally occurs congenitally in young toy breed dogs (2, 3). During the development period, structural anomalies of the bones or ligaments within the atlantoaxial joint might cause congenital AAS (1, 4-6). Traumatic AAS has also been reported (7). Congenital or traumatic instability between the atlas and axis can cause neck pain and neurological dysfunction in dogs. Management of the AAS includes conservative treatment and surgery. A conservative treatment is performed by applying strict cage rest with a support collar (8). Dogs with severe neurological dysfunction often require surgery rather than conservative management. Surgical stabilization can be divided into dorsal or ventral fixation of the atlantoaxial joint (9). A previous study has documented that ventral fixation is safer than dorsal fixation as dorsal fixation has a higher risk of inducing respiratory or cardiac arrest when the implant crosses the atlas (9). However, ventral fixation is also challenging in toy breed dogs due to their small-sized bones (10). To reduce the risk of damaging the spinal cord, the Kishigami atlantoaxial tension band (Kishigami AATB) was described by Kishigami in 1984 (11). This implant does not cross the atlas. It remains in the epidural space. A recent study has evaluated the effectiveness and safety of commercially available Kishigami AATB and found that it is an attractive surgical method for toy breed dog with AAS (10). Similar to the Kishigami AATB method with which the implant does not cross the atlas, the present study devised a modified dorsal wiring method. As the shape of atlas varies between breeds (12), the implant of the modified dorsal wiring method can be easily made with a Kirschner wire according to individual dog's shape of the atlas. The present

Correspondence to: Gonhyung Kim, DVM, Ph.D., Department of Veterinary Surgery, College of Veterinary Medicine, Chungbuk National University, Cheongju 28644, Republic of Korea. Tel: +82 432613171, Fax: +82 432613224, e-mail: ghkim@cbu.ac.kr

Key Words: Atlantoaxial subluxation, Kirschner wire, Kishigami atlantoaxial tension band, toy breed dog.



This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY-NC-ND) 4.0 international license (<https://creativecommons.org/licenses/by-nc-nd/4.0>).

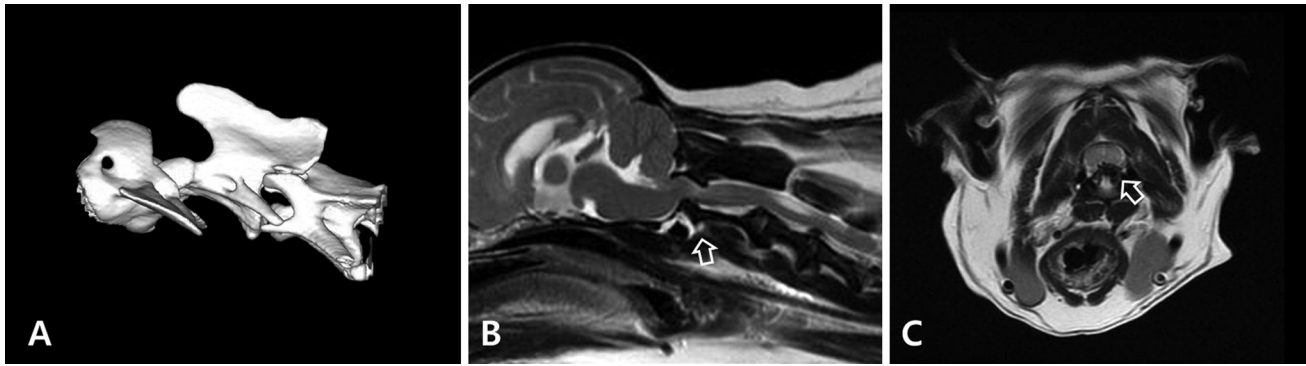


Figure 1. Computed tomography showing atlantoaxial subluxation (A) and magnetic resonance imaging (B and C) revealing compression of the spinal cord (arrow).



Figure 2. Pre-operative radiograph of a dog with atlantoaxial subluxation (A) and radiograph taken at three years after the surgical stabilization by the modified dorsal wiring method (B and C).

study evaluated this method for dorsal stabilization of the AAS in toy breed dogs. The purpose of this study was to report the effectiveness, long-term clinical outcomes, and related complications of the present wiring method.

Materials and Methods

Inclusion criteria. Medical records of dogs with AAS that underwent dorsal stabilization by the modified dorsal wiring method in the Veterinary Teaching Hospital from 2017 to 2020 were reviewed. Medical data included dogs' breed, age, sex, body weight, and neurological status. The neurological status of each dog was graded following a previous study (3): normal gait (grade 5), ataxia or spasticity (grade 4), ambulatory paresis (grade 3), non-ambulatory paresis (grade 2), and tetraplegia (grade 1). Dogs that had pain from the neck with normal gait were considered to have grade 4 neurological status. AAS was diagnosed via radiography, computed tomography (CT), and/or magnetic resonance imaging (Figure 1). Dogs with other concurrent diseases that might affect their neurological status were excluded. Incomplete ossification (IO) of the dorsal arch of the atlas was defined according to previous studies (12-14).

Surgery. Surgical repair was performed by the same surgeon. Dogs were pre-medicated with midazolam (0.2 mg/kg, IV). Anesthesia

was induced with propofol (6 mg/kg, IV) and maintained by isoflurane. After anesthetic stabilization, dogs were positioned in sternal recumbency. Perioperative pain management was performed using ketamine (0.6 mg/kg/h, IV) combined with lidocaine (2 mg/kg/h, IV) and tramadol (5 mg/kg, IV). The atlantoaxial joint was exposed via a dorsal approach. The device was made with a Kirschner wire (0.8 or 1.0 mm in diameter) according to the shape of the atlas of each dog before surgery. The implant was modified during surgery if necessary. After careful retraction of the atlas, the device was firstly applied in the dorsal arch of the atlas. To place the device, a bone tunnel was made in the spinous process of the axis. The device was then fixed in the bone tunnel of the axis using a 2-0 FiberWire (Arthrex, Naples, FL, USA). Pre- and post-operative radiographs were obtained for verifying anatomic reduction of the AAS (Figure 2). Post-operative pain was managed with a fentanyl transdermal patch (2 µg/kg/h) and/or meloxicam (0.1 mg/kg, SC, SID). A neck brace and cage rest were applied for at least one week. After cage rest with neck brace for a week, dogs were managed according to their neurological status.

Results

A total of 10 dogs (mean weight of 2.7 kg; mean age of 25 months; 6 males and 4 females) were reviewed in the present study. These dogs consisted of Maltese (n=4), Yorkshire

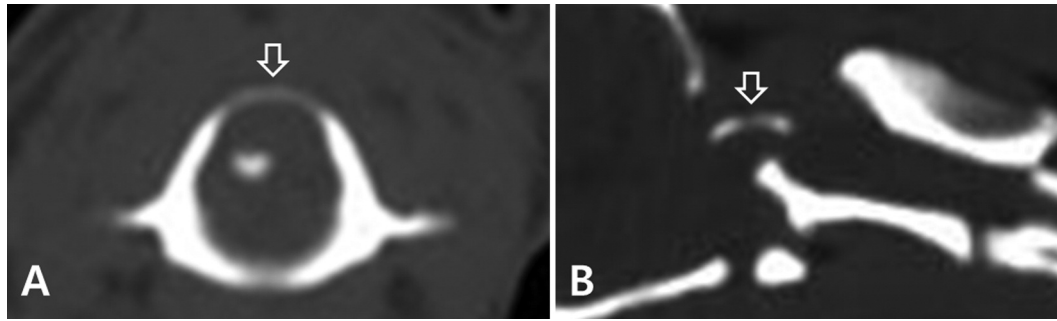


Figure 3. Transverse (A) and sagittal (B) computed tomography images of a dog with incomplete ossification of its atlas.

Table I. Summary data of ten toy breed dogs with atlantoaxial subluxation.

Dog	Breed	Sex	Age (months)	Weight (kg)	Cause	Neurological status		Complication
						Pre-operative	Post-operative	
1	Yorkshire Terrier	Female	9	1.9	Traumatic	3	5	Recurrence of clinical signs [†] Fracture of atlas [†]
2	Yorkshire Terrier	Female	62	2.6	Congenital	2	5	
3	Mixed-breed	Male	36	3.6	Traumatic	2	5	
4	Maltese	Female	12	3.7	Congenital	3	5	Fracture of atlas [†]
5	Maltese	Female	48	2.6	Congenital	3	5	
6	Pomeranian	Male	27	4.2	Congenital	4	5	Fracture of atlas, death [†]
7	Maltese	Male	27	1.6	Congenital	4	5	
8	Maltese	Male	10	1.1	Congenital	3	N/A	
9	Pomeranian	Male	12	2.0	Traumatic	2	4	
10	Bichon Frise	Male	11	3.5	Traumatic	4	5	

N/A: Not applicable. [†]Dog that underwent a revision surgery.

Terrier (n=2), Pomeranian (n=2), Bichon Frise (n=1), and Mixed-breed (n=1). Three of these dogs showed clinical symptoms of pain from the neck (neurological grade 4). Others showed non-ambulatory or ambulatory tetra-paresis (neurological grade 2 or 3). Regarding the history of these dogs, four were diagnosed as traumatic AAS. Evaluation by CT was available for five dogs. Among these five dogs, IO of the atlas was identified in two dogs (Figure 3). After surgical reduction of AAS, nine dogs showed improvement of their neurological status. The average operation time was two hours. The improvement of their post-operative neurological status was generally observed within a month. The neck pain of all three dogs was resolved. One dog with non-ambulatory tetra-paresis had proprioceptive ataxia after surgery but showed a gradual improvement over the follow-up period. Other dogs regained their normal gait. During the follow-up period, four of the 10 dogs required a revision surgery. One dog showed recurrence of clinical signs. The same wiring method was applied by tightening the gap between the atlas and axis more than the previous surgery. Clinical signs of the

dog resolved after the revision surgery. The other three dogs showed recurrence of clinical signs concurrent with fracture of the dorsal arch of the atlas. A wider implant with the same method was applied beyond the fracture site in these dogs. Recovery of two dogs was uneventful. They regained their normal gait. One dog developed dyspnea that led to death (Table I). After surgical stabilization of the AAS, the follow-up period of dogs ranged from 2 to 48 months (mean, 16 months). None of these dogs that underwent primary or revision surgery required an additional surgical reduction.

Discussion

Surgical stabilization of AAS is made via a dorsal or ventral approach (9). However, it is challenging to apply the ventral approach in small-sized toy breed dogs (10). Thus, a previous study has documented dorsal stabilization of AAS using 3-metric nylon suture and recommended it for dogs weighing under 1.5 kg (15). However, the mean weight of dogs in the present study was 2.7 kg (range=1.1-4.2 kg). In addition to

difficulty in performing ventral fixation, it was determined that several dogs might require more strength than nylon suture for reduction of AAS. From this point of view, the modified dorsal wiring method was applied in these cases. Clinical results of the present study were similar to those of other surgical methods via a dorsal approach (10, 15). Dorsal stabilization of AAS by using another type of band implant (commercially used Kishigami AATB) has been previously described (10). It might be more effective than the present wiring method. Another study has also revealed that a band implant applied to the atlas is more effective than a wire implant in force distribution (16). Despite the above facts, the modified dorsal wiring method has the advantage of being cost-efficient as a Kirschner wire is used to make the implant. In addition, the present method is relatively versatile since the implant can be made according to the individual bone of each dog and can be easily modified during surgery. Regardless of the type of implant applied, it is important to determine whether the dog is suitable for applying a metal implant to the bone through radiography or other advanced imaging techniques (17). Although most dogs in this study regained their normal gait, four dogs required revision surgery and three of them had fractured dorsal arch of atlas. Dogs with AAS may be associated with IO of their atlas (12), implying that such dogs are vulnerable to fracture. According to previous criteria for classifying the IO of atlas (12, 13), 2 of 3 dogs that developed fracture of the dorsal arch in the present study were classified as having IO of their atlas. Taken together, pre-operative evaluation of anomalies in the atlantoaxial joint, such as IO is critical in dogs with AAS when planning surgical stabilization of AAS using metal implants. When performing revision surgeries for dogs with fracture of their atlas, the same method was applied by using a wider implant to avoid ossification center of the dorsal arch and fractured site. Although the two dogs revealed IO in the central region of dorsal arch of the atlas in pre-operative evaluation, additional fracture was not identified after the revision surgery. One dog was not identified as having IO of its atlas. However, it developed perioperative respiratory arrest followed by circulatory failure and death. A previous study has analyzed the force applied to the atlas by finite element models and documented that a narrow implant close to the midline of the dorsal arch is more vulnerable to fractures than a wide implant applied far from the midline of the dorsal arch (16). In addition to anatomical characteristics that the IO of the atlas generally occurs in the midline of the dorsal arch (12, 14), it is recommended to apply the implant far from the midline of the dorsal arch during dorsal stabilization of AAS. Although the present study has a limitation due to its small number of dogs, surgical reduction of AAS by the modified dorsal wiring method might be a more attractive way than ventral fixation when applying the implant to toy breeds with small-sized bones. Like the Kishigami AATB (10), the modified dorsal

wiring method is relatively safer than other methods via a dorsal approach as the implant does not cross the atlas. In conclusion, the results of the present study suggest that the modified dorsal wiring method can be considered for surgical stabilization of AAS in toy breed dogs. The implant with the present method has the advantage of being cost-efficient and versatile in modification according to the shape of the atlas. Selection of suitable patients through pre-operative radiographic evaluation and application of the implant avoiding areas vulnerable to fractures are important when considering this method.

Conflicts of Interest

The Authors declare no conflicts of interest in relation to this study.

Authors' Contributions

DK, SL and GK designed the study. DK analyzed the data. The manuscript was written by DK and GK. All Authors critically revised the manuscript and approved the final version.

References

- Geary JC, Oliver JE and Hoerlein BF: Atlanto axial subluxation in the canine. *J Small Anim Pract* 8(10): 577-582, 1967. PMID: 6070656. DOI: 10.1111/j.1748-5827.1967.tb04500.x
- Slanina MC: Atlantoaxial instability. *Vet Clin North Am Small Anim Pract* 46(2): 265-275, 2016. PMID: 26631590. DOI: 10.1016/j.cvsm.2015.10.005
- Thomas WB, Sorjonen DC and Simpson ST: Surgical management of atlantoaxial subluxation in 23 dogs. *Vet Surg* 20(6): 409-412, 1991. PMID: 1369524. DOI: 10.1111/j.1532-950x.1991.tb00348.x
- Watson AG and de Lahunta A: Atlantoaxial subluxation and absence of transverse ligament of the atlas in a dog. *J Am Vet Med Assoc* 195(2): 235-237, 1989. PMID: 2768042.
- Warren-Smith CM, Kneissl S, Benigni L, Kenny PJ and Lamb CR: Incomplete ossification of the atlas in dogs with cervical signs. *Vet Radiol Ultrasound* 50(6): 635-638, 2009. PMID: 19999348. DOI: 10.1111/j.1740-8261.2009.01595.x
- Beaver DP, Ellison GW, Lewis DD, Goring RL, Kubilis PS and Barchard C: Risk factors affecting the outcome of surgery for atlantoaxial subluxation in dogs: 46 cases (1978-1998). *J Am Vet Med Assoc* 216(7): 1104-1109, 2000. PMID: 10754672. DOI: 10.2460/javma.2000.216.1104
- Schulz KS, Waldron DR and Fahie M: Application of ventral pins and polymethylmethacrylate for the management of atlantoaxial instability: results in nine dogs. *Vet Surg* 26(4): 317-325, 1997. PMID: 9232790. DOI: 10.1111/j.1532-950x.1997.tb01504.x
- Havig ME, Cornell KK, Hawthorne JC, McDonnell JJ and Selcer BA: Evaluation of nonsurgical treatment of atlantoaxial subluxation in dogs: 19 cases (1992-2001). *J Am Vet Med Assoc* 227(2): 257-262, 2005. PMID: 16047663. DOI: 10.2460/javma.2005.227.257
- Denny HR, Gibbs C and Waterman A: Atlanto-axial subluxation in the dog: a review of thirty cases and an evaluation of treatment by lag screw fixation. *J Small Anim Pract* 29(1): 37-47, 1988. DOI: 10.1111/j.1748-5827.1988.tb02262.x

- 10 Pujol E, Bouvy B, Omaña M, Fortuny M, Riera L and Pujol P: Use of the Kishigami Atlantoaxial Tension Band in eight toy breed dogs with atlantoaxial subluxation. *Vet Surg* 39(1): 35-42, 2010. PMID: 20210942. DOI: 10.1111/j.1532-950X.2009.00613.x
- 11 Kishigami M: Application of an atlantoaxial retractor for atlantoaxial subluxation in the cat and dog. *J Am Anim Hosp Assoc* 20(3): 413-419, 1984.
- 12 Parry AT, Upjohn MM, Schlegl K, Kneissl S and Lamb CR: Computed tomography variations in morphology of the canine atlas in dogs with and without atlantoaxial subluxation. *Vet Radiol Ultrasound* 51(6): 596-600, 2010. PMID: 21158229. DOI: 10.1111/j.1740-8261.2010.01711.x
- 13 Takahashi F, Hakozaki T, Kouno S, Suzuki S, Sato A, Kanno N, Harada Y, Yamaguchi S and Hara Y: Epidemiological and morphological characteristics of incomplete ossification of the dorsal neural arch of the atlas in dogs with atlantoaxial instability. *Am J Vet Res* 79(10): 1079-1086, 2018. PMID: 30256148. DOI: 10.2460/ajvr.79.10.1079
- 14 Kim D, Chang D and Kim G: Radiographic evaluation of atlas and axis anomalies in toy breed dogs with and without atlantoaxial subluxation. *In Vivo* 36(6): 2751-2755, 2022. PMID: 36309373. DOI: 10.21873/invivo.13011
- 15 Sánchez-Masian D, Luján-Feliu-Pascual A, Font C and Mascort J: Dorsal stabilization of atlantoaxial subluxation using non-absorbable sutures in toy breed dogs. *Vet Comp Orthop Traumatol* 27(1): 62-67, 2014. PMID: 24080740. DOI: 10.3415/VCOT-13-01-0009
- 16 Bae B, Kim D, Oh H and Kim G: Biomechanical analysis of atlantoaxial dorsal fixation using finite element models. *Thai J Vet Med* 52(1): 185-192, 2022. DOI: 10.14456/tjvm.2022.19
- 17 Tang A, Tobert D, Kakarmath S, Harris M and Khurana B: Radiological and clinical features of traumatic atlanto-occipital dislocation. *Emerg Radiol* 28(4): 713-722, 2021. PMID: 33538940. DOI: 10.1007/s10140-021-01912-7

Received November 7, 2022

Revised November 17, 2022

Accepted November 18, 2022