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Novel transforaminal approach allows surgical decompression of an atlantoaxial band in dogs: a cadaveric study and clinical cases

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OBJECTIVES
To describe a novel transforaminal approach for surgical excision of the atlantoaxial (AA) band and examine its feasibility, safety, and mechanical advantages in an ex vivo study and clinical cases.

SAMPLES
26 canine cadavers and 2 canine patients with AA bands.

PROCEDURES
The transforaminal approach via the first intervertebral foramen was designed to avoid damaging the dorsal AA ligament (DAAL) and dorsal laminas to maintain joint stability. The cadaveric study started on December 2020 and lasted 3 months. The ligamentum flavum (LF) was removed using a novel approach; then, gross examination was conducted to verify the potential damage to the spinal cord and associated structures and the adequacy of LF removal. Subsequently, the ex vivo tension test of the DAAL was conducted to establish whether the approach induced mechanical damage to the ligaments. Finally, 2 dogs diagnosed with an AA band were surgically treated with the transforaminal approach.

RESULTS
In the cadaveric study, postsurgical evaluation verified the subtotal removal of LF without damage to the dura mater. There were no significant differences in the mechanical properties of the DAAL, including the ultimate strength (P = .645) and displacement (P = .855), between the surgical and intact groups during the ex vivo tension test. In clinical cases, clinical signs and neurologic grades improved until the final follow-up.

CLINICAL RELEVANCE
The described surgical procedure using a transforaminal approach appears to sufficiently permit the removal of an AA band while reducing damage to the DAAL and spinal cord. Our study highlights the feasibility of the transforaminal approach.

The atlantoaxial (AA) band continuously compresses the subarachnoid space and spinal cord dorsally at the AA junction, possibly inducing neurologic signs such as neck pain and cervical myelopathy.[1–3] Recent studies[1–5] on improved MRI technology have actively reported its presence and surgical procedures. The band can be diagnosed by applying MRI, particularly in the T2-weighted sagittal view. In dogs, dense collagenous connective tissue formation and participation of reactive fibroblasts cause these bands to develop from the ligamentum flavum (LF).[2,4,5] However, in human medicine, the growth of fibrous tissue, calcification, or ossification, alone or in combination, in patients with Chiari type 1 malformation causes the AA band to affect the outer layer of the dura mater (DM).[6]

Although the cause of AA bands is unknown, instability is considered a contributing factor because of the craniocervical joint deformities that are frequently associated with this disorder.[1–3,7–9] Anomaly or degeneration of the osseous structure and the joint's ligaments may cause altered AA joint stability, leading to the AA band.[7,10–13] Consequently, due to the high incidence of AA instability (AAI) in these breeds, young toy and small-breed dogs may be more frequently impacted by an AA band.[10] Notably, the correlation between the development of AA bands and Chiari-like malformation (CLM) is typical in both human and veterinary medicine.[2,6,7,14] However, the frequency of reports of CLM in canine breeds other than well-known susceptible breeds like Cavalier King Charles Spaniels and Brussels Griffon, such as Chihuahuas, Maltese, Pugs, Yorkshire Terriers, Pomeranians, Miniature Poodles, and Norwich Terriers, is increasing.[1,14–16] Additionally, these bands have been reported in 42.2% to 83.8% and 38% to 72.7% of Cavalier King Charles Spaniels and toy and small-breed dogs, respectively, with suspected CLM.[1–3,17]

Furthermore, the presence of an AA band may cause clinical signs of neuropathic pain, which include neck pain, cervical hyperesthesia, generalized dysesthesia, cervical myelopathy, proprioceptive ataxia, and tetraparesis.[2,4,18] Notably, decompressing the AA junction by excision of the AA band, which may alleviate clinical signs, is presently undergoing active investigation.[3,5,9,19,20] Fingeroth et al[21] first suggested a surgical approach to the dorsal AA junction. The approach was performed by laminotomy and elevation of the cranial two-thirds of the spinous process of C2. The transosseous wire method was used for the closure, which also involved fixing the osteotomized spinous process.[21] Moreover, a decompression technique applying partial laminectomy of the caudal atlas and cranial axis was reported by Skytte et al.[5] Lee et al[4] also reported a similar technique for removing the cranial one-third of the C2 spinous process and dorsal atlantoaxial ligament (DAAL).

However, the previously described approaches may enhance instability due to the ablation of the ligaments, which may necessitate stabilization by augmentation.[4,22,23] Therefore, we recommend a novel transforaminal approach for removing the AA band, which may lessen postsurgical instability. Additionally, the technique was designed through the first intervertebral foramen to achieve AA band exposure with a minimum level of damage to the DAAL and vertebral lamina. The study was categorized into 2 parts as follows: (1) to assess the feasibility and safety of the new approach on cadavers; and (2) to determine the possible mechanical advantages of this procedure by performing a simple biomechanical study. After the cadaveric study was completed, the novel approach was applied to 2 clinically affected dogs. Finally, we proposed that the transforaminal approach would permit adequate and safe elimination of the AA band while preserving the mechanical attributes of the DAAL without damaging neural tissue.

Materials and Methods

The study was designed in 2 parts as follows: cadaveric and clinical parts. The study started on December 11, 2020, and ended on July 15, 2022. Cadavers of 26 client-owned toy or medium-sized breed dogs euthanized for reasons unrelated to this study were included in the cadaveric, ex vivo part of the study after receiving owner consent. The Chungnam National University Animal Care and Use Committee approved the study protocol. Additionally, 2 Pomeranians with AA bands were treated using the transforaminal approach in the clinical study. The procedure was explained to the owners, and their consent was obtained.

Ex vivo study

Specimens

The cadavers were stored at –20 °C and then thawed at room temperature (approx 22 °C) a day before the experiment. Laterolateral radiography of the neck in the neutral and ventroflexed positions was conducted to rule out AAI.[10,24,25] Next, samples were excluded from the study if AA joint instability or rupture of the DAAL were identified. The specimens were randomly classified into the surgery and control groups using a computer program (Excel; Microsoft, Redmond, WA). Additionally, the LF removal using the new procedure was performed in 18 cadavers. Eight cadavers used as the control group for mechanical testing were not surgically approached.

Furthermore, for biomechanical testing, the C1 through C2 segment of the vertebral columns was harvested by transecting the atlantooccipital joint and the C2-3 intervertebral disk space after surgery and in dogs in the control group. The specimens were wrapped in gauze soaked with 0.9% saline (NaCl) solution, sealed in plastic bags, stored at –20 °C until a day before the mechanical test, and refrigerated at 2 °C until testing the following day.

Ex vivo surgical procedure

The anatomic structures and landmarks used have been described in previous studies **(Figure 1)**.[12,13,26,27] The cadaver was placed in sternal recumbency with a straight alignment of the cervical vertebrae. The head and cranial cervical vertebrae were gently ventroflexed and raised using a vacuum cushion. Next, a middle dorsal incision was made from the external occipital protuberance to the caudal aspect of the spinous process of C3. The epaxial muscles were raised bilaterally from the dorsal lamina of C1 and C2.[4,21,28] Furthermore, precaution was taken to avoid damaging the Nuchal ligament in approaching and the DAAL when raising the muscle. The LF was cut using an arthroscopic punch (AR-30010; Arthrex) without magnification through the incision site. All procedures were performed by 3 surgeons randomly (YHR, HBL, and YJJ).

Ex vivo evaluation

We searched for possible perforation of tears within the DM due to the risk of damage to neural tissue, including the DM and spinal cord. Additionally, we assessed the rest of the LF postsurgery in the second step to evaluate the amount of band resected. In a randomized design, a computer program (Excel; Microsoft Corp) was used to allocate specimens into different groups. Ten specimens from the surgery group were selected to evaluate the LF excision and potential DM damage. Therefore, the cranial one-third of the C2 spinous process was detached for gross examination. A spinal hook probe and microforceps were applied to detect the presence of

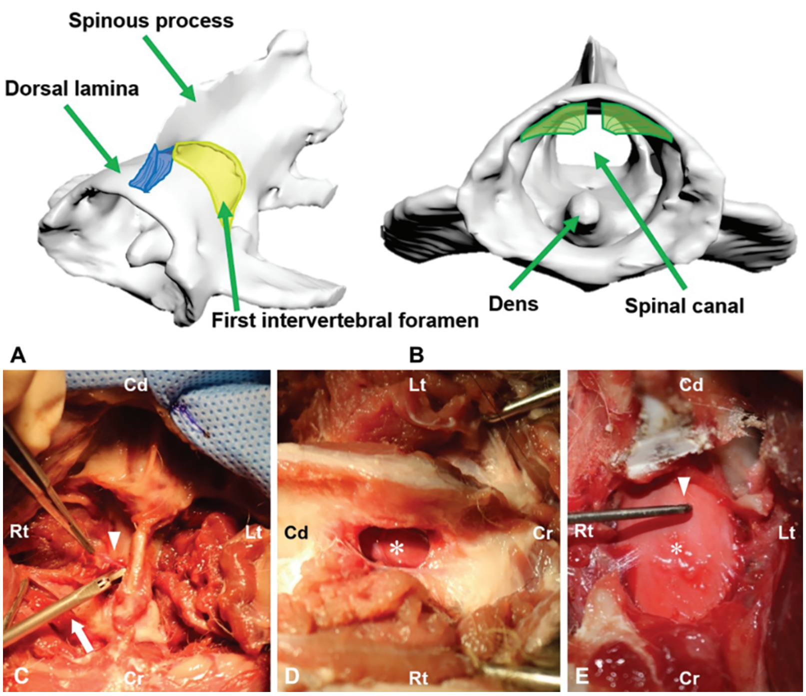

Figure 1—Schematic (A and B; based on a 3-D bone model of 5-year-old Pomeranian with chronic neck hyperesthesia [dog 1]) and cadaveric (C to E) images showing anatomic structures involved in a novel transforaminal approach evaluated for surgical decompression of atlantoaxial (AA) band in dogs between December 11, 2020, and February 19, 2021. A—Craniolateral perspective of the atlas and axis. The dorsal AA ligament (DAAL) runs between the cranial end of the axis spinous process and atlas dorsal lamina (highlighted blue). Dorsal atlantoaxial membrane covers the first intervertebral foramen (highlighted yellow). B—Cranial perspective of the atlas and axis. The ligamentum flavum (LF; highlighted green) is the origin of AA band and runs dorsally over the spinal cord. The AA band is located at the level of the first intervertebral foramen, ventral to axis spinous process, and dorsal to the spinal cord. C—Dorsal view during cadaveric surgery showing an arthroscopic punch grasper (arrow) being used to remove LF (arrowhead) through the intervertebral foramen between C1 and C2. D—Dorsolateral view during cadaveric surgery showing the spinal cord exposed (asterisk) by incision of the dorsal atlantoaxial membrane ventral to the cranial spinous process of the axis. The dorsal atlantoaxial ligament is confirmed to be intact. E—Dorsal view after removal of AA band showing gross assessment by rubbing dura mater (asterisk) with a spinal hook probe (arrowhead) to exclude iatrogenic durotomy. Cd = Caudal. Cr = Cranial. Lt = Left. Rt = Right.

iatrogenic durotomy and assess spinal cord damage and LF removal effectiveness (Figure 1). The specimens were classified by only one investigator, who used a subjective grading system developed by one of the authors (YJJ). The grading system included LF removal grade and safety grade. Sufficiency of LF removal was classified into 4 grades: (1) > 90% removal was excellent; (2) between 70% and 90% was good; (3) between 50% and 70% was fair; and 4) < 50% was poor. Safety grade was defined as the estimation of potential damage on DM and similarly classified into 4 grades: (1) clear DM was excellent; 2) only perforation on DM was good; (3) tear < 1 cm was fair; and (4) tear > 1 cm was poor.

However, iatrogenic injury of the DAAL may adversely affect its biomechanical properties. Therefore, a tension test to assess the integrity of DAAL after ex vivo surgery was performed to verify the existence of differences in mechanical properties between the surgery and intact groups. Eight specimens from the 18 surgically approached cadavers were selected for the uniaxial tension test of the DAAL. All stabilizing structures, except the DAAL, were removed from the tested specimens. The cranial and caudal ends of C1 and C2 were fixed in a self-polymerizing acrylic resin (Vertex trayplast; Vertex-Dental) in stainless molds, respectively, to avoid the resin from applying to the DAAL and its bony attachment. The atlas was fixed on the upper jig, and the axis on the lower jig. **(Figure 2)**. Subsequently, the molds were connected to a universal material test machine (WL2100C; Withlab). The atlas-embedded portion was mounted onto the actuator and the load cell. The tension load was applied in a craniocaudal direction at a constant speed of 1 mm/s until the ligament ruptured.[29] A load cell recorded the applied force, and a displacement sensor measured the linear displacement values. A connected computer recorded the displacement until rupture and ultimate strength.

Statistical analysis

A priori power analysis using statistical software (G*Power V3.1.9.4) was performed to estimate the number of cadavers required for the study. A sample size of 6 dogs was calculated based on: $\alpha = 0.05$, power = 0.8, and estimated effect size ($d = 1.4634567$) when using the mean and SD variation of the ultimate force of DAAL in a pilot study of 6 dogs. The final sample size was 8 dogs, applying a 20% expected dropout. Data were analyzed using available software (SPSS, version 26.0; IBM Corp). Additionally, the Shapiro-Wilk test was used to determine if continuous values followed a normal distribution. The Mann-Whitney *U* test was used to compare the ultimate strength across the surgically approached and control groups. Furthermore, an independent *t* test was performed to evaluate the differences between the 2 groups regarding displacement. For the statistical test, values of $P < .05$ were considered statistically significant.

Clinical cases

In this study, 2 dogs with AA bands were included with owner permission. The 2 dogs were both Pomeranians and included the following: dog 1, 5 years old, castrated male, 3.5 kg; and dog 2, 5 years

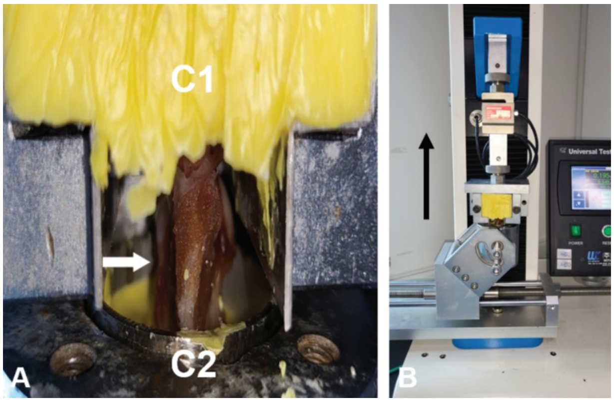

Figure 2—Images of biomechanical test construct used in evaluating the mechanical properties of the dorsal atlantoaxial ligament during the cadaveric portion of the study described in Figure 1. A—Biomechanical test is performed using a self-drafted jig with self-polymerizing acrylic resin for fixation of specimens. The atlas is fixed on the upper jig, and the axis is fixed on the bottom jig. The dorsal atlantoaxial ligament (arrow) is visible between the jigs. B—Overview of the setup showing the test being operated in a craniocaudal direction (arrow) by vertically pulling up the embedded specimen. Simultaneously, the connected computer records the load and displacement.

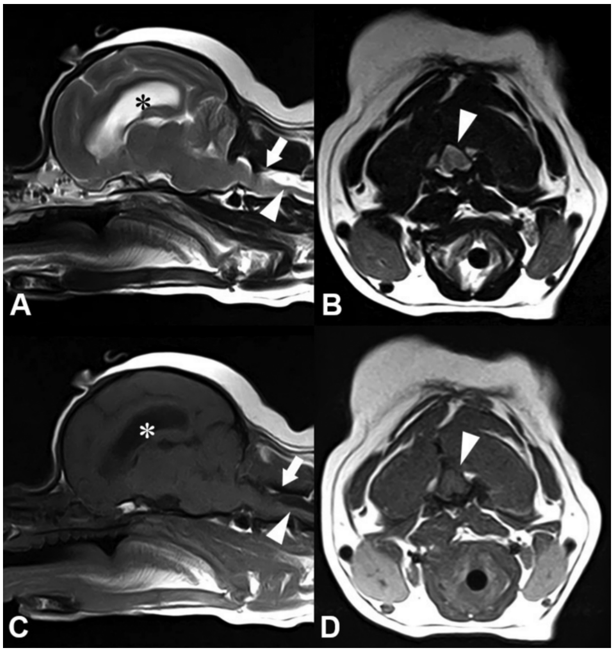

Figure 3—Sagittal (A) and transverse (B) T2-weighted and sagittal (C) and transverse (D) T1-weighted MRI images of the brain and cranial cervical spinal cord of a 5-year-old Pomeranian with a sudden-onset of ambulatory tetraparesis (dog 2) from the clinical portion of the study described in Figure 1. Notice the moderate ventriculomegaly (asterisk), mild herniation of cerebellar vermis, flattened caudal margin of the cerebellum, and dorsal compression (arrow) of the spinal cord. A syrinx (arrowhead) caudal to the atlantoaxial band is present. A collapsed subarachnoid space (arrowhead) is confirmed. B and D—Images obtained at the level of the atlantoaxial junction.

and 8 months old, intact female, 2.5 kg. Both dogs were referred for chronic neurologic signs as follows: dog 1 had chronic neck pain, intermittent hyperesthesia, phantom scratching, and lethargy; and dog 2 had an acute onset of ambulatory tetraparesis with chronic presentations like phantom scratching, wide-based stance, falling, and knuckling especially left forelimb. Furthermore, both dogs underwent neurologic examination and were graded on a modified Frankel scale that ranged from grade 0 to 5; grade 0, normal gait without neck pain; grade 1, normal gait with neck pain; grade 2, proprioceptive ataxia; grade 3, ambulatory tetraparesis; grade 4, nonambulatory tetraparesis; and grade 5, tetraplegia.[30,31] Dog 1 was assigned grade 1 and dog 2 was assigned grade 4. Suspicion of an AA band with concurrent CLM and syringomyelia (SM) in both dogs was identified using MRI **(Figure 3)**. Dorsal compressive lesion of the spinal cord at AA junction, malformation of occiput, and syrinx caudal to the lesion were confirmed in MRI. Additionally, mild multifocal disk protrusions (< 20% from intervertebral disk spaces C3-4 through C6-7) were found in both dogs. Ventriculomegaly was identified in dog 2. The dorsal compression index that indicates the severity of dorsal compression by the AA band was estimated as described in a previous study.[3] The measured values were 0.29 and 0.34 in dogs 1 and 2, respectively.[2,4] There was no difference in compression between the left and right sides in dog 1. A relationship between the clinical signs and lateralization of the lesion (more severe compression on the left side and clinical signs more visible on the left forelimb) was discovered in dog 2. The ventral compression index (VCI) is defined as the value estimated by dividing the ventral atlantodental interval by the dorsal atlantodental interval in the MRI images and can be used to diagnose AAI.[32] Both dogs had a VCI of 0.26 when their necks were extended (dog 1, 9.5°; dog 2, 18.9°), which was higher than the cutoff value (VCI, 0.16) in neck extension.

Both dogs underwent foramen magnum decompression (FMD) for CLM and AA band resection. Patient preparation and positioning were also conducted regularly.[28] First, FMD by craniectomy of the occiput and durotomy caudal to the cerebellum were performed to treat CLM.[28] The transforaminal approach was employed in both dogs. A visualization system was used to improve the visualization of the surgical field **(Figure 4)**.[33] Next, an incision on the dorsal AA membrane was made on the more compressed section. A 10-mm, 0° rigid laparoscope (autoclavable laparoscope; Stryker) was used and attached to a high-definition camera system (Stryker Endoscopy) when using the endoscopic system to magnify the surgical site. The scope was fixed using a mechanical endoscope holder (self-designed and crafted) to maintain its position. Additionally, the AA band was excised with a magnified surgical field using Castroviejo scissors, arthroscopic punch forceps, and microforceps. A thin layer of the fat autograft was positioned over the incision site of the dorsal AA membrane. Finally, a standard procedure for closure was performed. Clinical progress was assessed by

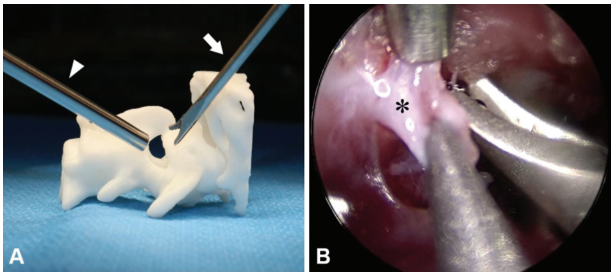

Figure 4—Image of a C1 through C2 vertebral column model with instrumentation (A) and an intraoperative endoscopic image (B) showing the visualization system used to improve the visualization of the surgical field for the transforaminal approach evaluated in the study described in Figure 1. A—The positioning of an endoscope (arrowhead) allows magnified visualization of the surgical site and arthroscopic punch forceps (arrow) used to excise the atlantoaxial band. B—The atlantoaxial band in dog 1 has thick white fibrotic tissue (asterisk) and is being excised with the use of arthroscopic punch forceps and Castroviejo scissors.

neurologic examination or phone calls during follow-up (every month until the last follow-up).

Results

Ex vivo study

Six cadavers used in the pilot test were 2 Pomeranians and 4 mixed-breed dogs, all female, with a median body weight of 4.5 kg. Overall, the 26 cadavers comprised Cocker Spaniels (n = 7), Pomeranians (5), Maltese (4), mixed-breed dogs (4), Miniature Poodles (3), Japanese Spitz (2), and a Shih Tzu (1). There were 20 females and 6 males; the median body weight was 5.6 kg (range, 2.3 to 8.5 kg). On radiographic examination of the necks, instability of the AA joint or rupture of the DAAL was not observed.

During gross examination, no perforation of the DM after surgery was detected. Although subtotal excision of the LF in cadavers was confirmed, 1 specimen had some fibrous tissues still attached to the dorsal surface of the DM. The specimen could be assessed as excellent since the remaining area of LF was under 10%. During the ex vivo tension test, a DAAL rupture occurred in the middle part of the ligament rather than on the origin and insertion part, and an avulsion fracture could not be observed. The median ultimate strengths of the DAAL did not differ significantly (P = .645) between the surgery group (145.1 N; range, 102.3 to 392.3 N; IQR, 107.0 to 353.8 N; mean ± SD, 210.8 ± 124.8 N) and control group (153.7 N; range, 74.8 to 228.7 N; IQR, 109.9 to 209.8 N; mean ± SD, 156.4 ± 55.5 N). The mean displacements did not differ significantly (P = .855) between the surgery group (9.7 ± 1.8 mm; median 9.9 mm; range, 7.2 to 12.6 mm; IQR, 7.9 to 10.8 mm) and control group (9.9 ± 2.5 mm; median 9.2 mm; range, 6.7 to 15.3 mm; IQR, 9.2 to 10.8 mm).

Clinical cases

Decompression using the transforaminal approach and FMD were successfully performed in both patients. AA bands were confirmed as white fibrotic tissue located dorsally to DM **(Figure 4)**. There were no adhesions with the DM in dog 1 but some in dog 2. Moreover, major complications such as unintended durotomy, direct damage to the spinal cord, and major bleeding have not been reported intraoperatively. Hyperesthesia of the neck was reduced in dog 1 within the first month postoperatively. In contrast, the nonambulatory patient (dog 2) returned to ambulation within a week after surgery. Furthermore, at the last follow-up, dog 1 could ambulate normally without hyperesthesia of the neck and had no signs of lethargy (12 months after surgery), and dog 2 ambulated with mild ataxia but without knuckling or falling (7 months after surgery). However, it was difficult to determine which surgical procedure, decompression or FMD, mainly affected the improvement of the clinical signs. Both owners rejected follow-up MRI for economic reasons.

Discussion

This study described a novel transforaminal approach for AA band excision and evaluated the feasibility and safety of this procedure in dog cadavers and clinical cases. Interestingly, the transforaminal approach supported adequate and safe removal of the AA band, and no iatrogenic lesions in vital neural or vascular structures were observed. Biomechanically, this procedure did not significantly decrease the stability between C1 and C2. In clinical cases, both patients reached functional recovery within 1 month postoperatively and sustained this status until the last follow-up.

The DAAL plays a role in stabilizing the AA joint and regulates head rotation and flexion to limit over-rotation and -flexion.[12] Deformation or tear of the DAAL has been observed in patients with AAI and traumatic AA subluxation.[11,34,35] Therefore, sustaining the stability of the AA joint after surgery could be crucial during surgical decompression of the AA band caused by the risk of potential luxation after DAAL removal.[4,23] In a previously documented laminectomy approach, the DAAL was ablated during the procedure, and an absorbable suture material was placed between the epaxial muscles for dorsal stabilization.[4] Four of the 15 included cases needed revision surgery in this report, which supports the need for supplementary stabilization in such cases.[22] Therefore, the absorbable suture material possibly was not sufficiently strong to replace DAAL. In addition, postoperative scar adhesion after laminectomy has been reported to cause residual or new compression among exposed dural tissue or nerve roots in human medicine and postoperative relapse in veterinary medicine.[4,14,36,37] Notably, delayed union associated with the laminotomy flap has also been reported after laminotomy of the axis.[20] Therefore, to maintain joint stability after surgery, we designed a transforaminal approach to prevent damage to the DAAL and dorsal laminas of the vertebrae and verified the design concept using an ex vivo test. We resected the LF without affecting the spinal cord in this study, using an arthroscopic grasper. The tension test results between the surgical and intact groups showed that the ultimate strength (P = .645) and displacement (P = .855) of the technique did not affect the DAAL. Consequently, the transforaminal approach was believed to be a novel technique that could remove the AA band without damaging the DAAL or spinal cord.

The AA joint has a complex anatomy.[26,27] It comprises the vertebral artery and vein that passes through the transverse foramen of the axis and the lateral vertebral foramen of the atlas, which is close to the neuroforamen. In addition, the second cervical nerve originates at the first intervertebral foramen.[26,27] Although we could obtain safe LF removal without visible damage to the DM in a cadaveric study, other obstacles might still be encountered when applying this approach in clinical cases. An additional risk of iatrogenic injury to the spinal cord or of achieving an incomplete resection of the AA band when adopting the transforaminal approach exists due to the shallow surgical site. Although the results of the cadaveric study demonstrated the feasibility and safety of the transforaminal approach in mid-sized dogs without magnification, considering that the AA band-predisposed breeds are primarily small-breed dogs and the anatomic circumstances, adopting a visualizing system such as an endoscope or surgical loupes might be helpful and almost compulsory in clinical cases. Therefore, we recommend using an endoscopic system in clinical cases to magnify the surgical site to ensure a safer surgery. In our cases using a laparoscope, no evidence of intraoperative damage to the vascular and neural tissues could be observed.

Furthermore, the presence of AA bands can be considerably linked with CLM in canines.[2] Previous studies[2,4,7,15] proposed that the synergetic effects of the AA band, CLM, and SM may induce neurologic signs. Theoretically, decompressing the AA junction with FMD in patients with an AA band, CLM, and SM could result in an improved outcome, compared to performing either AA band resection or FMD alone. Consequently, we established the coexistence of the AA band, CLM, and SM in both patients using MRI. Although the VCIs of the dogs were higher than the cut-off value (both VCIs, 0.26; cut-off value, 0.16), both patients were not diagnosed with a true AAI. Therefore, the transforaminal approach that could preserve DAAL and the stability of the AA joint without augmentation has been applied since a procedure that could increase instability should be avoided in patients with an AA band.[1–3,7,8] In addition, the patients recovered to satisfactory function without complications until the final follow-up.

The present study has some limitations. First, cadavers were not assessed for the AA band using MRI. We could not sample the cadavers with the AA band owing to increased time consumption and the requirement of a large number of cadavers, which was related to ethical issues. If LF is normal without enlargement and adhesions, it simplifies the procedure. Therefore, the excision of LF from cadaveric specimens could be different from that in a real patient. Second, the clinical interpretation of the clinical case was complex since the patients were diagnosed with the AA band and concurrent CLM. To the best of the authors' knowledge, there was no research regarding identifying the clinical relation induced by the AA band resection and FMD. In contrast to AA band patients, CLM and SM, even in severe forms, rarely induce tetraparesis in canine patients.[38] Therefore, the improvement observed in dog 2, which was nonambulatory before surgery, was primarily believed to be the result of the AA band resection. On top of this, a relationship between clinical signs and lateralization of the band lesion was observed in dog 2. Further clinical studies including a greater number of patients will be needed in the future to assess the clinical relevance of AA band excision. Third, the observers in the clinical cases were not blinded; therefore, the risk of bias was not excluded. Finally, a follow-up MRI was not performed for economic reasons, and we could not assess SM collapse and AA junction decompression. Consequently, additional follow-up is necessary to clarify these outcomes. Recurrence of neurologic signs was reported in 25% to 50% of cases following FMD in patients with CLM.[38] Therefore, follow-up with neurologic examination and MRI is believed to be useful when planning the treatment of these conditions.

The results of this ex vivo study and outcomes of clinical cases support the novel procedure for surgically managing the AA band in veterinary medicine. We verified that the new approach did not adversely affect the normal structures and the technique maintained normal anatomy providing safe and adequate AA band resection. Consequently, this new approach seems to present some advantages, compared to the existing procedures, to surgically treat AA band and opens the way for future clinical studies investigating this topic.

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YJJ, HBL, and YHR co-conceived the study, performed surgical procedures, data collection, interpretation of the results, surgical procedures, and manuscript preparation. JMJ, FF, and YHR reviewed the article critically and revised the manuscript. YJJ, HBL, JMJ, and YHR were actively involved in managing the cases. FF and YHR supervised the clinical management of the case. All authors contributed to preparation and final approval of the manuscript.

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