An indirect reduction technique for ventral stabilization of atlantoaxial instability in miniature breed dogs

F. Forterre1; N. Vizcaino Revés1; C. Stahl2; K. Gendron2; D. Spreng1
1Vetsuisse Faculty, University of Berne, Department of Clinical Veterinary Medicine, Small Animal Surgery, Berne, Switzerland; 2Vetsuisse Faculty, University of Berne, Department of Radiology, Small Animal Surgery, Berne, Switzerland

Introduction

Disruption of the atlantoaxial joint is an uncommon but potentially devastating cervical spinal condition in dogs. Although dogs of any breed or age can suffer traumatic atlantoaxial subluxation, the congenital or developmental form of atlantoaxial subluxation affects toy breed dogs. Irrespective of aetiology, atlantoaxial instability causes acute or chronic spinal cord compression (1, 2). The clinical signs that result may range from cervical pain to tetraplegia. In the worst cases, death may result from respiratory paralysis (3).

Although non-surgical methods of management have been described, surgical stabilization of the joint is usually advocated, especially if there are moderate to severe neurological deficits (1–5).

Materials and methods

The described technique was made to provide access to the spinal canal. Longitudinal distraction and realignment of C1-C2 were obtained by placing the tips of a Gelpi retractor in the two openings created. Overdistraction allowed removal of articular cartilage between C1-C2. Closing of the C1-C2 articular gap was finally achieved by applying lateral distraction with a second Gelpi retractor placed between the paired longus colli muscles. Fixation could then be performed without further stabilization.

Results

No intraoperative complications were observed. Recovery was uneventful.

Conclusions

The described technique offers good surgical visibility and permitted safe reduction of atlantoaxial subluxation.

Clinical relevance

By reducing manipulation and instrumentation necessary for reduction of atlantoaxial instability, the described technique may be advantageous in toy-breed dogs.

In most patients with congenital lesions, surgical therapy is indicated for permanent reduction and stabilization of the atlantoaxial joint to prevent vertebral movement and resulting spinal cord compression. Surgical treatment includes both dorsal and ventral stabilization techniques. Ventral surgical fixation of the atlantoaxial joint can be performed with screws inserted in lag fashion, plates, screws, threaded pins or Kirschner wires with or without additional support provided by polymethylmethacrylate (4–9). The ventral approach facilitates odontoidectomy and proper anatomic alignment, and promotes permanent fusion of the atlantoaxial joint (7).

The technical constraints associated with atlantoaxial stabilization, are mainly the limited bone available for implant purchase and the proximity of critical structures, which make this procedure challenging. Accurate reduction and implant placement are mandatory to ensure a satisfactory outcome (10). Interestingly, the greater part of the published literature deals with the complexity of the fixation, but to authors’ knowledge only a few scientific abstracts focus on the technique and the problems associated with reduction (11, 12). Furthermore, the small size of the anatomical structures, osseous or otherwise, makes both adequate reduction and fixation demanding. The instrumentation described for reduction, which include the AO small fragment forceps, Hohmann retractor, House curette, screws and orthopaedic wire, have to be held manually (2, 5, 13, 14). This may reduce the field of view as well as the working channel, and may not offer a stable reduction while placing implants. The main focus of the present study is to describe an indirect reduction method based on osseous and muscular distraction that allows easy reduction of atlantoaxial instability.
Materials and methods

Criteria for inclusion and data retrieval

Medical records of five dogs with atlantoaxial subluxation were reviewed. Dogs treated with ventral stabilization were included in the study if a radiographic diagnosis of atlantoaxial subluxation had been made and verified by computer tomography (CT) or magnetic resonance imaging (MRI), or a combination of both. In all dogs, reduction was achieved solely with two mini self-retaining Gelpi retractors. Information pertaining to signalment, duration of clinical signs, physical examination results, imaging findings and intra-operative and post-operative complications were reviewed. Postoperative assessment and outcome were determined by clinical examination. Owners were informed through a written consent form that the bone plate used for stabilization was a prototype.

Anaesthesia and diagnostic imaging

Anaesthesia and diagnostic imaging were performed as described in a previous study (15).

Surgical procedure

An area from the intermandibular space to the caudal cervical region, including the shoulder joints, was aseptically prepared. A ventral midline incision and a routine approach were made to the ventral aspects of the cervical (C) vertebrae C1 to C3 (16). The surgical dissection was carried further rostrally in order to expose the atlanto-occipital membrane and atlanto-occipital joint. Periosteal dissection of the longus colli muscles and the rectus capitis ventralis muscles was performed along the midline, separating them partially from their bony attachments, followed by their lateral retraction, thus exposing the median cervical region from the occipital bone to the cranial part of C3. Haemorrhage from the musculature was controlled with bipolar electrocautery before continuing the procedure. Two landmarks for the identification of the C1-C2 junction were determined. The cranial landmark was found by palpating the caudal borders of the wings of the atlas. By following them to the ventral midline, the second landmark, a sharp ventral prominence on the caudal aspect of C1, would be felt. This prominence corresponds to the ventral midline location of the C1-C2 interspace (17). A midline fenestration was performed at the intervertebral space C2-C3 and a narrow slot (3–4 mm deep) was created in the ventral cranial endplate of C3 to permit a greater purchase by one of the tips of the Gelpi retractor. The nucleus pulposus was partially removed with a small curette. The ventral margin of the foramen magnum was exposed. The atlanto-occipital membrane was incised along midline at the intercondylar incisure between the paired condyloid processes. This incision allowed visualization of the medial part of the occipital condyles and entry within the spinal canal in cases in which the tectorial membrane was injured. The tips of a mini self-retaining Gelpi retractor were carefully placed in the created openings, first at the atlanto-occipital junction and then at the level C2-C3. The cranial tip of the retractor was hooked to the occipital bone. Longitudinal distraction and realignment of C1-C2 were obtained by gently spreading apart the occipital bone and cranial part of C3. This manoeuvre distracted the C1-C2 joint, putting the joint capsule under tension and allowing its identification and excision with a number 11 scalpel blade. After removal of the joint capsule, overdistraction exerted with the Gelpi retractor permitted good visibility of the dens, the articular cartilage and the spinal cord (Fig. 1A). The articular cartilage of the atlas and axis was removed with a pneumatic drill and a 2 mm burr. The subchondral bone was exposed to allow fusion of the atlantoaxial joint (Fig. 1B). The overdistraction exerted by the Gelpi retractor was then relieved (Fig. 1C). At this point only a slight distraction was maintained, allowing the joint surfaces to move towards one another while preserving alignment between C1 and C2. Closure of the created atlantoaxial gap was finally achieved by exerting bilateral lateral distraction with a second mini self-retaining Gelpi retractor placed transversally between the paired longus colli muscles. The surgical wound was lavaged with lactated Ringer's solution. Before stabilization, a cancellous bone graft, harvested from the craniodorsal region of the proximal right humerus, was placed around and within the articular space. Without further stabilization, fixation with a prototype 1.5 mm butterfly locking plate was performed (15).

The sternothyroid muscle was reattached to the thyroid process. The bellies of the sternothyroid muscles and subdermal fat tissue were apposed with 1.5 metric polydioxanone, the subcutaneous tissues with 1.5 metric polydioxanone, and the skin with a 1.5 metric polypropylene.

Postoperative care and follow-up

Postoperative care and follow-up were performed as previously described (15).

Results

Five dogs (2 males, 3 females) met the inclusion criteria. There was one Chihuahua, two Maltese dogs, and two Yorkshire Terriers. The mean age at diagnosis was 3.1 years (range: 7 months – 6 years). Clinical signs on presentation included neck pain, tetraparesis and proprioceptive deficits.

Atlantoaxial subluxation was diagnosed radiographically. Computed tomography and MRI were additionally performed in all dogs. Ventral surgical stabilization with a locking plate was achieved after reduction of the subluxation using the above-described method in all patients. Reduction of the subluxation was confirmed in all patients by means of postoperative CT imaging. In two patients, anatomical position-
of the dens within the atlas was observed, and in the remaining three patients a slight dorsal deviation of the dens was seen after plate fixation. Only minor spinal cord contact was detected on the postoperative CT scans of these patients. In one dog screws penetrated the spinal canal. The screws (6 mm) were short enough not to impede the spinal cord. There were no complications observed during or immediately after surgery. Mean hospitalization time was five days. Dogs recovered uneventfully from anaesthesia and a soft neck bandage was applied for four weeks after surgery to prevent excessive flexion of the neck.

**Outcome**

Follow-up examinations were performed at the hospital in three cases, and by the referring veterinarian in the last two cases. Two dogs which were clinically normal at six months after surgery were lost to subsequent follow-up. The mean follow-up after surgery was 10.4 months. All five dogs showed a significant improvement of their neurological status. One dog had slight residual right-sided proprioceptive deficits (15 months after surgery) and four were without abnormal clinical signs (14, 9, 6 and 5 months postoperatively respectively). Three dogs had radiographic evaluation six weeks and six months after surgery. Except for loosening of an axial screw in one clinically normal dog, the position of the atlantoaxial joint and implants remained unchanged. Signs of osseous fusion of the atlantoaxial joint were not observed on the follow-up radiographic images. No visible complication nor recurrence of clinical signs were observed during the follow-up period. The owners were satisfied with the outcome in all five cases.

**Fig. 1** Surgical exposure of the atlantoaxial region in a Maltese dog with atlantoaxial instability. **A)** The cranial tip of the Gelpi retractor hooks the occipital bone in the intercondyloid fissure and the caudal tip is inserted in a small slot created in the cranial endplate of the third cervical (C3) vertebra after fenestration. Overdistraction between the occipital bone and C3 permits alignment of C1-C2 and opening of the atlantoaxial joint (small black arrows). The dens is also visible (large arrow). **B)** The articular cartilage of the atlantoaxial joint has been removed. A gap of 3-4 mm is present between the atlas and axis. **C)** Exerting overdistraction with the second mini self-retaining Gelpi retractor between the bellies of the longus colli muscles produces longitudinal tension within the muscles and closes the atlantoaxial joint gap while maintaining its ventral alignment (black arrows). **D)** Reducing overdistraction to a moderate degree maintains alignment between C1 and C2, but causes a slight dorsal tilting of the dens within the spinal canal.
Discussion

The surgical objectives for correction of atlantoaxial subluxation are to decompress the spinal cord and reduce and stabilize the atlantoaxial joint without causing morbidity or mortality (18, 19). The technique presented here leads to safe reduction of the atlantoaxial instability and good clinical results even if perfect anatomical reduction could not be achieved in each case.

An alternative to the ventral midline approach used by us is the right parasagittal approach to the atlantoaxial joint. This approach also provides good surgical exposure, requires less dissection and provides protection of vital structures during placement of fixation devices (17). Success of the surgical technique used for the treatment of atlantoaxial instability is ultimately dependent upon the ability to achieve a rigid and persistent fixation of the C1-C2 segment. This is only possible if adequate reduction of the subluxated atlantoaxial joint can be achieved. During reduction and implant placement, further care should be taken to avoid spinal cord damage and exacerbation of preoperative neurological deficits. Neurological deterioration following surgery is often temporary but in some cases may be permanent (20). In this regard, a thorough knowledge of the regional anatomy, and especially bone depth, is critical to avoid screw penetration into the spinal canal as was observed in one patient.

Particular attention should be given to dogs with chronic subluxation because they may have more permanent structural damage to the spinal cord than dogs with a shorter duration of clinical abnormalities. Therefore, there may be an increased susceptibility to trauma induced by surgical manipulation in dogs with chronic atlantoaxial subluxation, and the potential for long-term neurologic improvement may be limited (1). Furthermore, damage to the high cervical spinal cord or caudal brainstem may result in life-threatening respiratory impairment, contributing to the high perioperative mortality rate in dogs with atlantoaxial subluxation. Respiratory arrest during surgery and progressive respiratory distress or sudden death in the early postoperative period (fewer than 7 days) have been reported (4,6). In these cases the cause of death was probably due to the additional injury to the central nervous system from the surgical manipulations (4). Similar complications have also been reported after dorsal stabilization (6).

With our method, reduction can be achieved and maintained using two mini self-retaining Gelpi retractors, with minimal manipulation of the cervical spine or obscured visualization of the surgery field by handheld instruments. Most of the previously described methods lead to adequate reduction but necessitate manual retraction and reduction. In the authors’ experience, maintaining the reduction manually might be hazardous, as subluxation may reoccur during implant placement, potentially leading to misplacement of the implants or spinal cord trauma. A reduction technique similar to the one described herein has also been described by others (11, 12). The challenging phase of the reduction is the placement of the cranial tip of the retractor at the atlanto-occipital junction. The authors recommend the use of miniature self-retaining Gelpi retractors (length 9 cm) with short tips to perform distraction since their dimension are well suited to the small size of patients with atlantoaxial instability. Our technique of placing one of the tips of the Gelpi retractor though the opening created in the atlanto-occipital membrane and into the occipital bone is a slightly different to the method described by Boudrieau et al. (11, 12). They used a modified Gelpi retractor hooked under the cranial portion of the intercondylar incisure, necessitating a greater dissection for placement than that performed in the present study. The normal apical and alar ligaments as well as the thin ventral fibrous layer are missing in cases of atlantoaxial instability, but sufficient space is present at the atlanto-occipital junction to place the tip of a small retractor without risking iatrogenic spinal cord injury. There were no complications observed in our five cases associated with atlanto-occipital insertion of the Gelpi retractor. Further care should be taken not to injure the ventral occipital venous sinus when the atlanto-occipital membrane is incised. Should the venous sinus be pierced however, bleeding is usually minimal and without untoward consequences.

Insertion of the caudal tip of the spreader at C2-C3 can be done without specific problems, although fracture of the thin ventral cortical part of C3 could occur with superficial placement of the tip of the retractor, likely resulting in the loss of the reduction. A slot depth of 4 mm as described in the present study prevented this kind of complication. Fenestration of the C2-C3 intervertebral disc may also prevent later disc extrusion (21, 22). In the neck, the longus colli muscles arise from the transverse process of one vertebra to insert on the ventral surface of the vertebral body cranial to it (23). As a variation to the technique described by Boudrieau et al., where bony distraction is exerted by the first Gelpi retractor, we used a second Gelpi retractor placed transversally between the paired longus colli muscles to exert longitudinal traction on these muscles and indirectly through these muscular insertions left attached to the transverse processes of C2; this allows closure of the distracted atlantoaxial joint while maintaining ventral atlantoaxial alignment. However, relief of overdistraction led to a slight dorsal tilting of the dens without spinal cord impingement in three dogs. This finding might cause one to question the value of lateral muscular distraction exerted by the second Gelpi retractor for reduction of atlantoaxial instability. Moreover perfect anatomical reduction and restoration of normal canal diameter are not always necessary for resolution of pain and neurological deficits after treatment (8).

When considering stability, fixation of a distracted joint without bony contact may also be biomechanically problematic and may lead over time to implant loosening or breakage. To our knowledge, there have not been any biomechanical studies of reduction and stabilisation techniques of the canine atlantoaxial joint. Certainly lateral retraction of the longus colli muscles leads to increased soft-tissue trauma, although no signs of increased postoperative discomfort were observed in our patients. All dogs were treated uneventfully with a 1.5 mm butterfly locking plate as described in a previous study (15). For reasons unrelated to the implant design or function, the plate is not currently available.

In order to enhance atlantoaxial stabilization, it has been recommended to perform arthrodesis of the atlantoaxial joint by
removing the joint cartilage and performing a cancellous bone graft (8). The method we describe produced overdistraction of the C1–C2 space. In people, overdistraction has been reported to possibly lead to cervical nerve injury, vertebral artery injury, vertebral subluxation or even spinal cord injury (24). The magnitude of distraction tolerated by the canine cervical spine is unknown, but no deleterious effects were observed in a study where considerable distraction was performed to reduce cervical fractures and atlantoaxial subluxations (11, 12). Although it is a well established principle of arthrodesis that complete removal of articular cartilage offers the best chance of fusion, incomplete osseous union of the arthrodesis was evident on follow-up radiographs in our cases. It is unclear whether complete atlantoaxial arthrodesis is necessary for atlantoaxial stabilization (1, 8). Further studies will be needed to test this hypothesis.

Despite limitations inherent to this small case series, our findings suggest that return of a good neurological function should be expected after surgical intervention using this distraction method, even if the dens was slightly diverging from the floor of the atlas in some cases.

**Conflict of Interest**

None declared.

**References**