The intracranial denticulate ligament: anatomical study with neurosurgical significance

Laboratory investigation

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Object. Knowledge of the detailed anatomy of the craniocervical junction is important to neurosurgeons. To the authors’ knowledge, no study has addressed the detailed anatomy of the intracranial (first) denticulate ligament and its intracranial course and relationships.

Methods. In 10 embalmed and 5 unembalmed adult cadavers, the authors performed posterior dissection of the craniocervical junction to expose the intracranial denticulate ligament. Rotation of the spinomedullary junction was documented before and after transection of unilateral ligaments.

Results. The first denticulate ligament was found on all but one left side and attached to the dura of the marginal sinus superior to the vertebral artery as it pierced the dura mater. The ligament always traveled between the vertebral artery and spinal accessory nerve. On 20% of sides, it also attached to the intracranial vertebral artery and, histologically, blended with its adventitia. In general, this ligament tended to be thicker laterally and was often cribiform in nature medially. The hypoglossal nerve was always superior to the ligament, which always concealed the ventral roots of the C-1 spinal nerve. The posterior spinal artery traveled posterior to this ligament on 93% of sides. On one left side, the ascending branch of the posterior spinal artery traveled anterior to the ligament and the descending branch traveled posterior to it. Following unilateral transection of the intracranial denticulate ligament, rotation of the spinomedullary junction was increased by approximately 25%.

Conclusions. Knowledge of the relationships of the first denticulate ligament may prove useful to the neurosurgeon during procedures at the craniocervical junction. (DOI: 10.3171/2010.9.JNS10883)

Key Words • anatomy • craniocervical junction • foramen magnum • vertebral artery • neurosurgery • dentate ligament

The denticulate (dentate) ligaments were first described and depicted by Johann Jacob Huber (1707–1778).12 These 20–21 paired ligaments are meningeal extensions that primarily attach the lateral cord to the internal aspect of the spinal dura mater.4 However, the most rostral of these meningeal specializations attaches intracranially (Fig. 1). At the foramen magnum, this intracranial or first (highest) denticulate ligament travels between the vertebral artery and the ventral rootlets of the C-1 spinal nerve anteriorly and the branches of the posterior spinal artery, spinal accessory nerve and if present, dorsal rootlets of C-1 posteriorly.2,13,17 Because this region is often encountered by the neurosurgeon and the intracranial denticulate ligament is surrounded by multiple important neurovascular structures, knowledge of its anatomical relationships is important.14,16 Therefore, the goal of the present study was to define the specific relationships, histological features, and attachments of the intracranial denticulate ligament.

Methods

Ten fresh and 5 embalmed adult cadavers (30 sides) underwent dissection of the craniocervical junction. Nine specimens were male and 6 were female, and the age range of the individuals at the time of death was 49–101 years (mean 75 years). In the prone position, the specimens underwent removal of the posterior musculature of the upper neck and occiput. We performed an intermastoid occipital craniectomy and then removed the posterior arch of C-1 using a high-speed drill and bone rongeurs. The dura mater was incised and retracted laterally while maintaining the arachnoid mater. Using a Zeiss surgical microscope, careful arachnoid dissection was performed and the dorsal roots of the C-1 spinal nerve and spinal accessory nerve were identified. The first denticulate ligament was found deep to these structures and followed intracranially to its point of attachment. This attachment site was carefully observed. We documented
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the relationships of regional neurovascular structures to this intracranial denticulate ligament and measurements of it. Rotation in the vertical axis was performed before and after transection of all left-sided intracranial denticulate ligaments to visualize any difference in motion of the spinomedullary junction. Last, samples of these ligaments were harvested and submitted for histological analysis.

Results

The intracranial denticulate ligament was found on all but one left side, and, in all specimens, was seen immediately superior to the vertebral artery as it pierced the posterior atlantooccipital membrane and dura mater (Fig. 2). On the single side with no ligament, the vertebral artery and spinal accessory nerve had an intimate relationship. On 6 sides (20%), the ligament was found to attach to the posterolateral aspect of the intracranial vertebral artery as it coursed to attach laterally. At this location, the vertebral artery pushed the intracranial denticulate ligament posteriorly with the ligament, acting as a sling on 10 sides (30%) (that is, the ligament was draped over the posterior aspect of the vertebral artery and did not assume its normal vertical course). Laterally, the ligament was found to attach at the level of the foramen magnum onto the outer layer of dura mater of the marginal sinus in all specimens and traveled between the vertebral artery and spinal accessory nerve. The medial broad aspect of the ligament arose along the spinomedullary junction. The mean length and width of this ligament was 10 and 8 mm, respectively. In general, this ligament tended to be thicker laterally and was often cribriform in nature medially. The hypoglossal nerve rootlets were always superior to the lateral attachment of the intracranial denticulate ligament. The ventral roots of the C-1 spinal nerve were seen on 14 sides (46.7%) and, when present, were always posterior to this ligament. Of the sides with dorsal rootlets of C-1, communications between it and the spinal accessory nerve were observed on 6 sides (43%). Two of these connections (33%) were noted to pierce the intracranial denticulate ligament as they traveled laterally. The posterior spinal artery with its branches traveled posterior to this ligament on 93% of sides and anterior to it on the remaining sides. On one left side, the ascending branch of the posterior spinal artery traveled anterior to the ligament and the descending branch traveled posterior to it. With unilateral transection of the ligaments, rotation of the spinomedullary junction was increased by approximately 25% in all specimens. Histologically, the ligament consisted of extensions of arachnoid and pia mater, and in the specimens with connections to the intracranial segment of the vertebral artery, this ligament blended with the adventitia of the vessel.

Fig. 1. Schematic drawing illustrating the relationships of the left intracranial denticulate ligament (lig). Note the relationship between the course of the vertebral artery and its branches and the spinal accessory nerve (n) and first cervical rootlets to this ligament. a = artery. Used with permission from Clarian Health.


**Discussion**

Lang\(^6\) has stated that in relation to the first denticulate ligament, the lowermost fibers of the spinal accessory nerve are farther dorsal than the upper ones. Linn et al.\(^9\) found that the spinal accessory nerve always crossed the vertebral artery dorsomedially. These authors further noted that in 76% of their MR imaging–examined cases that the vertebral artery at its dural entrance was in direct contact with the spinal accessory nerve.\(^9\) Treating patients for spasmodic torticollis, Nagata and colleagues\(^10\) found compression of the spinal accessory nerve between the dural perforation of the vertebral artery and dural attachment of the first denticulate ligament. Shima et al.\(^15\) reported a case of spasmodic torticollis in an adult patient in whom a cure was achieved by vascular decompression of the spinal accessory root without any nerve sectioning. 

The nerve compression was produced by the posterior inferior cerebellar artery and was released by transposing the artery from the nerve, using the divided intracranial denticulate ligament. The intracranial and upper cervical denticulate ligaments are important for isolating all contributions to the spinal accessory nerve during denervation procedures for spasmodic torticollis.\(^5,10\) The German anatomist Herbert von Luschka believed that turgescence of the vertebral artery may compress the hypoglossal nerve at this point, although based on our study the hypoglossal nerve was always superior to the most superior aspect of the intracranial denticulate ligament.\(^1\) If anything, the intracranial denticulate ligament may offer a protective barrier between the spinal accessory nerve and vertebral artery as demonstrated in our specimens in which the ligament was bowed posteriorly due to the posterior protrusion of the vertebral artery. In a cadaveric study, Nanda et al.\(^11\) found that the spinal accessory nerve passed posterior to the denticulate ligament in all but one specimen where the nerve was seen coursing anterior to this structure. De Oliveira et al.\(^2\) mentioned that the lateral aspect of the intracranial denticulate ligament may be adherent to the posterior spinal arteries and first cervical rootlets, making separation of these structures difficult. These authors went on to state that the “most rostral denticulate ligament” is attached to the intradural segment of the vertebral artery, implying that this is always the case.\(^2\) We found such an association in only 20% of sides and also noted that the ascending branch of the posterior spinal artery, on occasion, may travel anterior to the intracranial denticulate ligament. Rhoton\(^13\) has stated that the first denticulate ligament is often incorporated into the dural cuff around the vertebral artery at the site of dural penetration. Therefore, care should be taken in manipulating the intracranial denticulate ligament as its inadvertent traction may injure the vertebral artery or its branches.

Some authors have stated that while approaching aneurysms of the verteobasilar junction that following transection of the intracranial denticulate ligament, the medulla is allowed to more easily “fall away.”\(^12\) Similarly, Kashimura et al.\(^7\) have described a technique for exposing the verteobasilar junction with traction of the intracranial denticulate ligament via the far lateral suboccipital approach with partial condylar resection. The result of this method was that the medulla oblongata was lifted dorsally and slightly rotated via the denticulate ligament thus allowing a more superior or inferior approach. Rhoton\(^13\) has stated that sectioning the upper 2 denticulate ligaments allows greater access anterior to the spinal cord. Nanda and associates\(^11\) have stated that the intracranial denticulate ligament may need to be cut with far-lateral approaches to lesions of the foramen magnum. We found that unilateral sectioning of the intracranial denticulate ligament resulted in approximately 25 more degrees of rotation of the spinomedullary junction, which would allow better visualization of anteriorly located structures.

Pathologically, Jung et al.\(^6\) reported on a 72-year-old woman who presented with neck pain and tingling in the left arm. Via a midline suboccipital approach, the authors identified what was found to be a meningioma arising from the intracranial denticulate ligament. Of note, meningiomas arising anterior to the plane between the intracranial denticulate ligament and the lower cranial nerves are defined as ventral foramen magnum meningiomas.\(^6\)

In an earlier study of these ligaments, we found that the average tensile force of the cervical denticulate ligaments was 0.07 N and that such forces were greater in the cervical than the thoracic or lumbar regions.\(^18\) Developmentally, these ligaments in the upper cervical/cranial region have been implicated in the formation of the “knickung” or kinking of the spinomedullary junction as seen in patients with the Chiari malformation Type 2.\(^2\) This kinking is hypothesized to be caused by caudal displacement of a portion of the medulla held in relative immobility by the intracranial denticulate ligament.

**Conclusions**

The first denticulate ligament is likely to be encountered with approaches to the cranio cervical region. Detailed anatomical information regarding its morphology and neurovascular relationships may, therefore, assist the
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neurosurgeon during manipulation in this area, thereby maximizing surgical maneuvers and minimizing morbidity.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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