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ORIGINAL ARTICLE

A new variant ligament of the atlantooccipital joint: the lateral oblique atlantooccipital ligament

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Abstract

Purpose During routine dissection of the anterior craniocervical junction (CCJ), a variant ligament just anterior to the articular capsule of the atlantooccipital joint was observed. To our knowledge, no literature has previously described this ligament. Therefore, the aim of this study was to clarify the anatomy, incidence, and biomechanics of this undescribed structure of the anterior atlantooccipital joint.

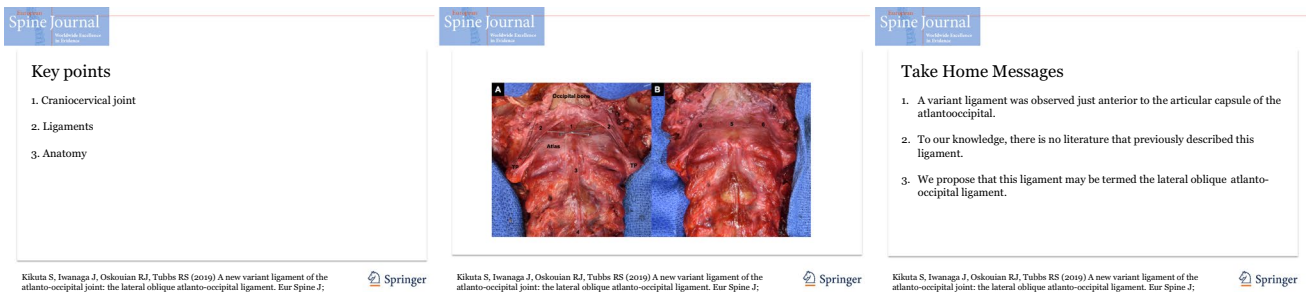
Methods Twenty-six sides from 13 fresh-frozen adult cadavers were used for this study and the morphology of the variant ligament examined. When present, its length, width, thickness, and the angle from the midline of the CCJ were measured.

Results The variant ligament identified, when present, is distinct and located anterior to the atlantooccipital joint capsule traveling between the occipital bone and the transverse process of the atlas. The ligament was found on 12 of 26 sides (46.2%). The mean length of the ligament was 32.0 ± 5.5 mm. The ligament became taut with contralateral lateral flexion and the ipsilateral rotation of the atlantooccipital joint.

Conclusions We propose that this ligament may be termed the lateral oblique atlantooccipital ligament. To date, this structure has not been described in any textbooks or reports in the extant medical literature. Although its function is not clear, based on its course and connections, it might function as a secondary stabilizer of the atlantooccipital joint. As the stability of the craniocervical junction is of paramount importance, knowledge of normal and variant anatomical structures in this region is important for the surgeon treating patients with pathology of this region.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.



Keywords Craniocervical joint · Ligaments · Anatomy · Cadaver · Cervical vertebra · Skull base

Introduction

The craniocervical junction (CCJ) consists of the occipital bone, atlas, axis, and associated ligaments and membranes [1, 2]. The CCJ includes the atlantooccipital and lateral and median atlantoaxial joints, and is related to various cranial

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nerves and the spinomedullary junction [3–5]. This junction between the upper cervical spine and skull base allows for complicated movements such as the rotation, flexion, and extension of the neck, while its ligaments protect regional neurovascular structures [4–8]. The transverse and alar ligaments, which are the most significant ligaments, have been well studied [9–13]. Other ligaments, such as the apical, accessory atlantoaxial, Barkow's, and lateral atlantooccipital ligaments have been studied less so.

During the routine dissection of the CCJ, we observed a thin but distinct ligament superficial to the capsule of the atlantooccipital joint. Therefore, to better elucidate this structure, the present anatomical study was performed using fresh-frozen cadavers.

Materials and methods

Twenty-six sides from thirteen fresh-frozen adult cadavers (12 Caucasian and 1 Asian, five males and eight females) were dissected for this study. The age at death ranged from 57 to 101 years with a mean of 81.7 ± 12.6 years. In the supine position with the neck hyperextended, the prevertebral tissues were removed. The longus capitis and rectus capitis anterior on both sides covering the occiput and atlas were removed, and the anterior surface of the atlantooccipital joint was observed. When the ligament, which we termed the lateral oblique atlantooccipital ligament (LOAOL), was identified, its length, width (proximal, middle, and distal parts), and thickness were measured using a microcaliper (Mitutoyo, Kanagawa, Japan). Additionally, the angle of the LOAOL from the midline of the CCJ was measured with a goniometer. No gross disease or signs of previous surgery to the area dissected were observed in any specimen.

All quantitative measurements were presented as the mean ± SD. One-way analysis of variance was applied to compare data with Scheffé's post hoc test and Fisher's exact test. Statistical significance configured at $P < 0.05$. No approval by our ethical committee was needed as this was a cadaveric study. The study was conducted according to the requirements of the Declaration of Helsinki (64th WMA General Assembly, Fortaleza, Brazil, October 2013).

Results

The LOAOL was identified on 12 sides (46.2%) in seven specimens, derived from three males and four females (Table 1). Of these, two specimens had the ligament unilaterally. When present, the LOAOL was located as a distinct structure just deep to the rectus capitis anterior (Fig. 1) and superficial to the joint capsule and anterior atlantooccipital membrane (AAOM). This structure always ran obliquely between the occipital bone and the transverse process of the atlas (Fig. 2). The ligament attached to the basilar part of the occipital bone widely and tapered distally at its attachment onto the transverse process of the atlas. The mean length of the LOAOL was 32.0 ± 5.5 mm (range 25.9–43.3 mm). The mean width of the LOAOL was 14.7 ± 1.9 mm (range 11.6–16.9 mm) at its proximal part, 10.2 ± 3.2 mm (range 4.7–14.8 mm) at its middle part, and 9.0 ± 2.3 mm (range from 4.0 to 11.2 mm) at its distal part, respectively. The thickness of the LOAOL was 0.3 ± 0.1 mm (range from 0.2 to 0.4 mm). This ligament traveled diagonally at an angle of 29°–44° (mean 36.8° ± 5.0) from the midline. There was no significant difference between the right and left sides for all measurements (Table 2). With lateral flexion, the contralateral LOAOL became taut. With ipsilateral rotation of the atlantooccipital joint, the ligament also became taut. Flexion of the CCJ resulted in the LOAOL becoming lax, while hyperextension made the ligament taut.

Table 1 Incidence of the LOAOL

	Specimens ($n = 13$) (%)	Sides ($n = 26$) (%)
Presence	7 (53.8)	12 (46.2)
Bilaterally	5 (38.5)	10 (38.5)
Unilaterally	2 (15.4)	2 (7.7)
Right	1 (7.7)	1 (3.8)
Left	1 (7.7)	1 (3.8)

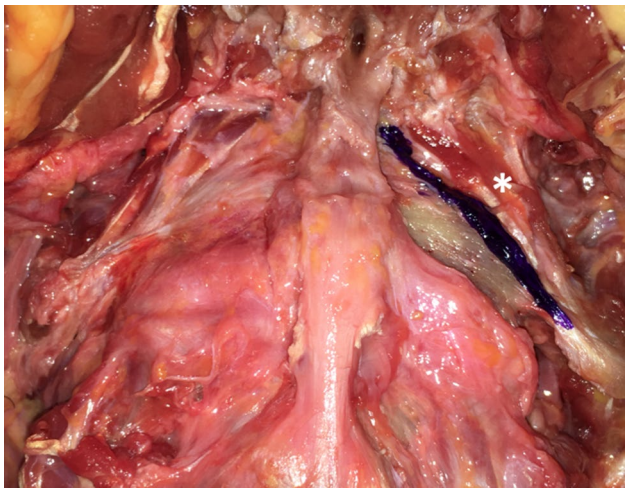

Fig. 1 Anterior view of the anterior craniocervical junction in a cadaver. The LOAOL (highlighted with the purple color) is located deep to the rectus capitis anterior (asterisk). Note the rectus capitis anterior is slightly moved laterally to show the ligament. LOAOL, lateral oblique atlantooccipital ligament

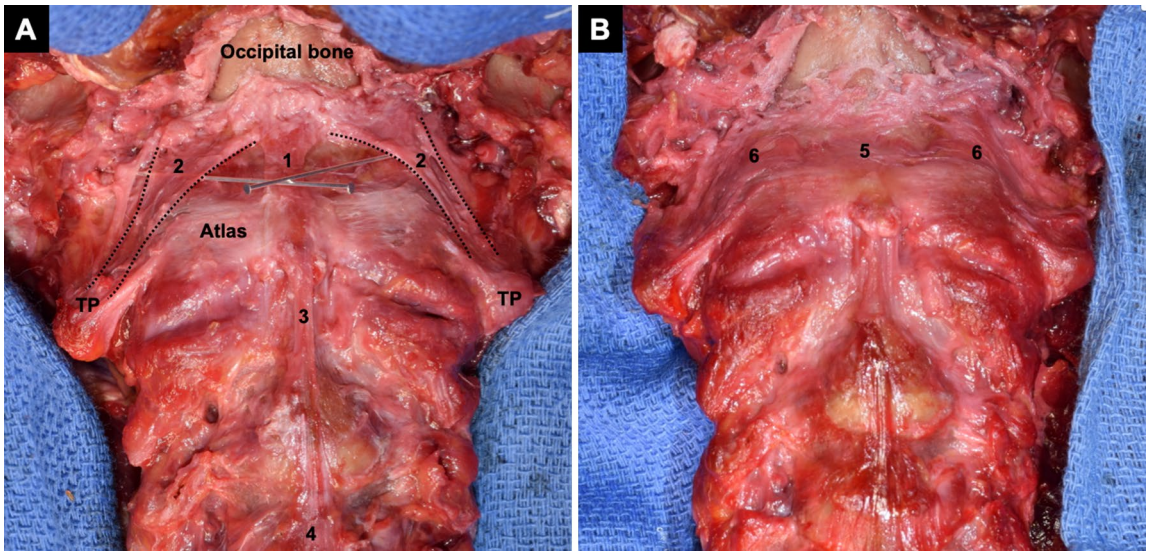

Fig. 2 Anterior view of the anterior craniocervical junction in a cadaver. **a** The LOAOL is highlighted with black dotted lines after removing the prevertebral muscles. **b** After removing the anterior longitudinal ligament between the occiput and atlas and LOAOL, the joint capsules and AAOM are seen. 1, Anterior longitudinal ligament between occiput and atlas; 2, lateral oblique atlantooccipital ligament (LOAOL); 3, anterior atlantoaxial ligament; 4, anterior longitudinal ligament; 5, anterior atlantooccipital membrane (AAOM); 6, joint capsules; TP, transverse process

Table 2 Results of measurement of the LOAOL

	Average (mm)	Range
Length	32.0 ± 5.5	25.9–43.3
Width		
Proximal	14.7 ± 1.9	11.6–16.9
Middle	10.2 ± 3.2	4.7–14.8
Distal	9.0 ± 2.3	4.0–11.2
Thickness	0.28 ± 0.1	0.2–0.4
Angle	36.8° ± 5.0	29°–44°

Discussion

Our study identified a variant ligament of the atlantooccipital joint, the lateral oblique atlantooccipital ligament (LOAOL). The ligament was constantly located anterior to the atlantooccipital joint capsule and traveled obliquely from the occiput to the transverse process of the atlas. This thin structure was occasionally identified unilaterally. The incidence of the LOAOL was 53.8% of all cadavers, and it may be a common variant in this region. The LOAOL has not been described previously probably due to the difficulty in dissecting the anterior craniocervical junction.

As seen in our anatomical study, the movements of the atlantooccipital joint might be slightly restricted by the LOAOL when it is present [4, 8, 14, 15]. When absent, other more standard ligaments such as the anterior atlantooccipital membrane (AAOM) and atlantooccipital capsular ligaments serve this purpose [4, 16, 17]. The AAOM runs from the anterior arch of the atlas to the basiocciput and resists extension [17, 18]. These anterior ligaments, including the LOAOL, when present, play a role as secondary stabilizers of the CCJ which may limit its movement and protect the CCJ from the injuries [18–21]. Knowledge of the detailed anatomy and potential anatomical variations of this region is important for those treating patients with injury to this area [22–26].

Conclusion

The present study identified a previously unreported variant ligament of the craniocervical junction. Further studies are now needed to clarify its function and clinical implications.

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Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

References

1. White AA 3rd, Panjabi MM (1978) The clinical biomechanics of the occipitoatlantoaxial complex. Orthop Clin North Am 9:867–878

2. Debernardi A, D'Aliberti G, Talamonti G et al (2011) The craniovertebral junction area and the role of the ligaments and membranes. Neurosurg 68:291–301. https://doi.org/10.1227/NEU.0b013e3182011262
3. Menezes AH, Traynelis VC (2008) Anatomy and biomechanics of normal craniovertebral junction (a) and biomechanics of stabilization (b). Childs Nerv Syst 24:1091–1100. https://doi.org/10.1007/s00381-008-0606-8
4. Tubbs RS, Hallock JD, Radcliff V et al (2011) Ligaments of the craniocervical junction. J Neurosurg Spine 14:697–709. https://doi.org/10.3171/2011.1.SPINE10612
5. Offiah CE, Day E (2017) The craniocervical junction: embryology, anatomy, biomechanics and imaging in blunt trauma. Insights Imaging 8:29–47. https://doi.org/10.1007/s13244-016-0530-5
6. Selecki BR (1969) The effects of rotation of the atlas on the axis: experimental work. Med J Aust 1:1012–1015
7. Panjabi M, Dvorak J, Duranceau J et al (1988) Three-dimensional movements of the upper cervical spine. Spine 13:726–730
8. Wolfla CE (2006) Anatomical, biomechanical, and practical considerations in posterior occipitocervical instrumentation. Spine J. https://doi.org/10.1016/j.spinee.2006.09.001
9. Dvorak J, Panjabi MM (1987) Functional anatomy of the alar ligaments. Spine 12:183–189
10. Panjabi MM, Crisco JJ, Lydon C, Dvorak J (1998) The mechanical properties of human alar and transverse ligaments at slow and fast extension rates. Clin Biomech 13:112–120. https://doi.org/10.1016/S0268-0033(97)00053-3
11. Iwanaga J, Sardi J, Voin V et al (2017) Anatomy of alar ligament part I: morphometrics and variants. World Neurosurg 107:1001–1006. https://doi.org/10.1016/j.wneu.2017.07.187
12. Sardi JP, Iwanaga J, Schmidt C et al (2017) Anatomy of the alar ligament: part II: variations of its attachment onto the dens. World Neurosurg 107:1007–1011. https://doi.org/10.1016/j.wneu.2017.07.186
13. Iwanaga J, Sardi JP, Laws T et al (2017) Anatomy of alar ligament part III: biomechanical study. World Neurosurg 107:1012–1015. https://doi.org/10.1016/j.wneu.2017.07.188
14. Menezes AH, Ryken TC (1992) Craniovertebral abnormalities in down's syndrome. Pediatr Neurosurg 18:24–33. https://doi.org/10.1159/000120638
15. Steinmetz MP, Mroz TE, Benzel EC (2010) Craniovertebral junction: biomechanical considerations. Neurosurg 66:7–12. https://doi.org/10.1227/01.NEU.0000366109.85796.42
16. Morris H (1879) The anatomy of the joints of man. Blakiston, Philadelphia
17. Morris H (1921) Morris's human anatomy: a complete systematic treatise, 6th edn. Blakiston, Philadelphia
18. Crawford NR, Hurlbert RJ (2002) Anatomy and biomechanics of the craniocervical junction. Semin Neurosug 13:101–110
19. Chang YM, Kim G, Peri N, Papavassiliou E, Rojas R, Bhadelia RA (2017) Diagnostic utility of increased STIR signal in the posterior atlanto-occipital and atlantoaxial membrane complex on MRI in acute C1–C2 fracture. AJNR Am J Neuroradiol 38:1820–1825. https://doi.org/10.3174/ajnr.A5284
20. Bodon G, Kiraly K, Tunyogi-Csapo M et al (2018) Introducing the craniocervical Y-ligament. Surg Radiol Anat. https://doi.org/10.1007/s00276-018-2116-z
21. Štulík J, Hodasová G, Podhrásky M, Nesnídal P, Fojtík P, Naňka O (2018) Anatomy of the dens and its implications for fracture treatment: an anatomical and radiological study. Eur Spine J. https://doi.org/10.1007/s00586-018-5793-8
22. Oakes PC, Sardi JP, Iwanaga J et al (2017) Translation of Hecker's 1922 "the occipital–atlanto–axial ligament system": a study in comparative anatomy. Clin Anat 30:322–329. https://doi.org/10.1002/ca.22853
23. Sanchis-Gimeno JA, Perez-Bermejo M, Rios L et al (2017) Analysis of the relationship between the double transverse foramen and the possibility of developing clinical symptoms after whiplash. Clin Anat 30:761–766. https://doi.org/10.1002/ca.22897
24. Shoja MM, Ramdhan R, Jensen CJ et al (2018) Embryology of the craniocervical junction and posterior cranial fossa, part I: development of the upper vertebrae and skull. Clin Anat 31:466–487. https://doi.org/10.1002/ca.23049
25. Shoja MM, Ramdhan R, Jensen CJ et al (2018) Embryology of the craniocervical junction and posterior cranial fossa, part II: embryogenesis of the hindbrain. Clin Anat 31:488–500. https://doi.org/10.1002/ca.23048
26. Yoon SY, Moon HI, Lee SC et al (2018) Association between cervical lordotic curvature and cervical muscle cross-sectional area in patients with loss of cervical lordosis. Clin Anat 31:710–715. https://doi.org/10.1002/ca.23074

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