

Superficial anterior atlanto-occipital ligament: Anatomy of a forgotten structure with relevance to craniocervical stability

ABSTRACT

Introduction: The superficial anterior atlanto-occipital ligament (SAAOL) is a narrowband located anterior to the anterior atlanto-occipital membrane. Nearly forgotten, it has not been well described in older anatomical textbooks and is missing in the current anatomical literature. As all of the binding structures of the craniocervical junction (CCJ) are important in maintaining stability, this study aims to clarify the anatomy and potential function of the SAAOL.

Materials and Methods: The CCJ from ten fresh-frozen cadavers was studied. These specimens were derived from three males and seven females, and the age at death ranged from 57 to 91 years (mean, 79.8 years). The length, width, and thickness of the SAAOL were measured. In five specimens, the force to failure was recorded.

Results: The SAAOL was found between the anterior tubercle of the atlas and the occiput and located as central thick fibers in front of the anterior atlanto-occipital membrane in 9 (90%) specimens. In one specimen, the vertical band to the occipital bone did not attach to the anterior tubercle of the atlas, but extended to the anterior aspect of the axis. The mean length, width, and thickness of the SAAOL were 19.8, 6.2, and 0.6 mm, respectively. The force to failure for the ligament was 38.8 N.

Conclusion: The SAAOL was a constant structure of the anterior atlanto-occipital joint. This ligament seems to be a secondary stabilizer of the CCJ by limiting the extension of CCJ. Knowledge of this ligament may help in further understanding of craniocervical stability.

Keywords: Anatomy, cadaver, cervical vertebra, craniocervical joint, ligaments

INTRODUCTION

The craniocervical junction (CCJ) includes occiput, atlas, axis, and specialized ligaments and membranes.^[1] The CCJ is the most flexible joint of the spine.^[2,3] Knowledge of its anatomy and biomechanics is vital to succeed in the diagnosis and treatment of the various pathological conditions in the CCJ.^[4] The ligaments of the CCJ, especially the transverse and alar ligaments, have been well studied.^[5-9] By contrast, there is a rarely discussed and nearly forgotten ligament on the CCJ, the superficial anterior atlanto-occipital ligament (SAAOL).^[10] The ligament is described in antiquated anatomical texts as running vertically anterior to the anterior atlanto-occipital membrane (AAOM) (synonym for the anterior atlanto-occipital ligament).^[10-12] The SAAOL is poorly understood, and to date,

no study has focused on its anatomy and potential function. Therefore, the present study aims to clarify the anatomy

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and biomechanical function of the SAAOL using fresh-frozen cadavers.

MATERIALS AND METHODS

The CCJs from nine fresh-frozen Caucasian cadavers and one Asian cadaver were used for this study. These specimens were derived from three males and seven females, and the age of the cadavers at death ranged from 57 to 91 years (mean, 79.8 years). With the cadavers in the supine position and the necks extended, the mandibles and prevertebral tissues were removed. The prevertebral muscles including the longus capitis, longus cervicis, and rectus capitis anterior were removed, and the ligaments between the basilar part of the occipital bone and atlas were observed. When the SAAOL was identified, its length, width, and thickness were measured. All measurements were performed using a microcaliper (Mitutoyo, Kanagawa, Japan) with a resolution of 0.01 mm and an accuracy value of ± 0.025 mm.

After the measurements, the occiput and C1 and C2 vertebrae were transected *en bloc* in five specimens, and ligaments and membranes, except the SAAOL and its bony attachment, were removed. Sequentially, the anterior arch of the atlas was grabbed with the bony clamps in the midline to pull the ligament vertically [Figure 1]. In five specimens, the tensile force (N) was recorded using a tensile testing machine (M2-200, Mark-10 Corporation, Copiague, New York, USA).

No obvious pathological changes or signs of previous surgery in the areas were found in any specimen. The study was conducted in accordance with the requirements of the Declaration of Helsinki (64th WMA General Assembly, Fortaleza, Brazil, October 2013).

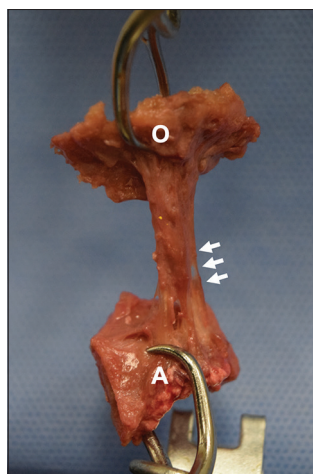


Figure 1: Photograph of failure for the SAAOL (white arrows). The anterior tubercle of the atlas (A) and the basilar base of the occipital bone (O) held with bone clamps with vertical traction applied. The tensile force (N) was recorded as the force at failure of the ligament

RESULTS

In all specimens, the SAAOL was observed traveling between the basilar part of the occipital bone and the anterior tubercle of the atlas. In all specimens, the ligament ran anterior to the AAOM. The SAAOL was identified in 9 (90%) specimens, uniting the basilar part of the occipital bone and the anterior tubercle of the atlas [Figure 2]. However, in 1 (10%) specimen, the vertical band ascending to the basilar part of the occipital bone did not attach to the anterior tubercle of the atlas, but continued to the anterior aspect of the axis. This single ligament variant of the SAAOL we termed the superficial anterior occipito-axial ligament (SAOAL). The SAAOL and SAOAL were slightly wider at the attachment onto the basilar part of the occipital bone and narrower at the attachment onto the atlas ($n = 9$) or axis ($n = 1$). The mean length of the SAAOL was 19.8 ± 4.0 mm (range, 15.1–24.7 mm). The mean width and thickness of the SAAOL were 6.2 ± 1.6 mm (range, 3.8–9.5 mm) and 0.6 ± 0.1 mm (range, 0.5–0.8 mm), respectively. The peak force (N) at failure for the ligament was 38.8 ± 9.7 N (range, 30–57 N). With manual hyperextension of the CCJ, the SAAOL became taut, and with hyperflexion, the ligament became lax [Figure 3]. With the intentional removal of the SAAOL and SAOAL, the degree of flexion and rotation of the CCJ did not change significantly.

DISCUSSION

The CCJ has two joints, the atlanto-occipital and atlantoaxial joints, and includes important structures, for example, spinal cord, cranial nerves, and blood vessels.^[13,14] Different biomechanics of both joints enable the neck to rotate, flex, and extend.^[15-17] Both joints are composed of a complicated array of ligaments and membranes, which protect the neurovascular structures of this region.^[14] To date, these ligaments including some accessory ligaments

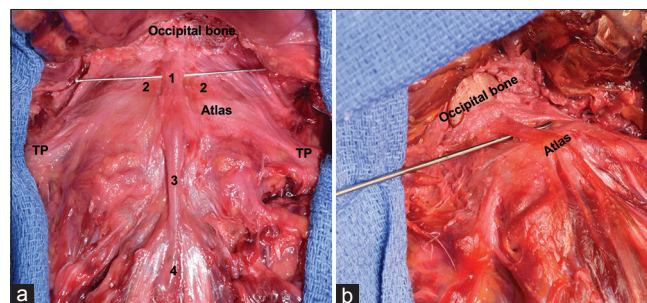


Figure 2: (a) Anterior view of the anterior craniocervical junction in a cadaver after removing the longus capitis, rectus capitis anterior, and longus colli muscles. (b) Lateral view shows the separated layers of each ligament. The superficial anterior atlanto-occipital ligament was located superficial to the anterior atlanto-occipital membrane. (1) SAAOL; (2) anterior atlanto-occipital membrane; (3) anterior atlanto-axial membrane; (4) anterior longitudinal ligament. TP – Transverse process of C1

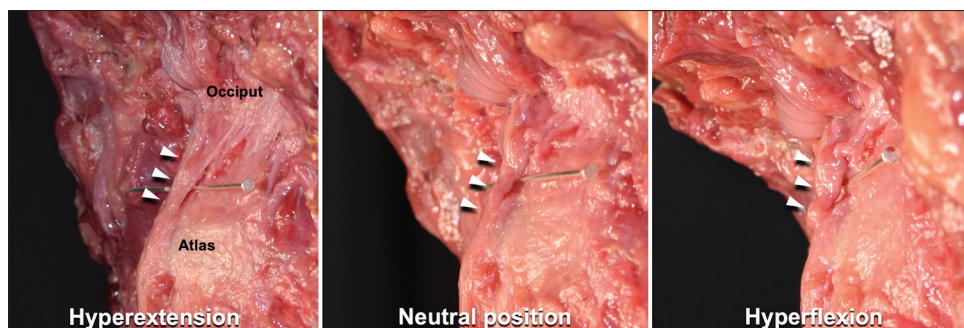


Figure 3: Lateral view (left) of the superficial anterior atlanto-occipital ligament with neck motion (hyperextension, neutral, and hyperflexion)

have been studied.^[5-9,14] However, the SAAOL has not been studied. Quain^[11] defined the SAAOL as a thick “accessory ligament” whose fibers reinforcing the AAOM. Testut^[18] described it as having a width of 5–6 mm. These previous descriptions regarding the SAAOL are consistent with our findings. In the present study, the SAAOL was made up of dense fibers in the midline and was anterior to the AAOM in all cases. In 90% of the specimens, the SAAOL connected the basilar part of the occipital bone and the anterior tubercle of the atlas; however, in 1 (10%) case, the ligament did not attach to the anterior tubercle of the atlas and appeared to be a direct continuation of the AAAL. We named this the SAOAL, which appears to be an anatomical variation of the SAAOL.

Morris^[10] described the SAAOL as a strong band that connects occipital bone to the atlas and that might limit extension of the neck. In the present study, the SAAOL became taut in extension of the neck, but after transection, excessive extension was not observed. These findings suggest that the SAAOL may act as an accessory ligament that reinforces the anterior atlanto-occipital joint with the capsular ligaments and AAOM. The tensile strength of the SAAOL was found to be 38.8 ± 9.7 N. Comparatively, the transverse and alar ligaments can resist approximately 350 and 200 N, respectively, before rupturing.^[9,19] Therefore, the SAAOL probably plays a supplemental role in maintaining stability of the CCJ. In conjunction with the capsular ligaments of the CCJ and AAOM, the SAAOL prevents hyperextension of the neck.^[10,14] A better understanding of the anatomy, variants, and function of the neck is important in helping diagnosis and treating various pathological conditions of the CCJ.^[20-25]

CONCLUSION

The SAAOL is a constant structure of the CCJ. Further experiments are required to elucidate further how the SAAOL is involved in pathological as well as normal conditions of the CCJ.

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Conflicts of interest

There are no conflicts of interest.

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