Experimental Study on the Atlanto-axial Joint and Related Structures with Regional Anatomy and Medical Imaging

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ABSTRACT

Objective: *To evaluate the anatomy and medical imaging characteristics in a study observing the atlanto-axial joint (AAJ) and related structures.*
Methods: *Eight cadaveric specimens of the AAJ segment were studied with both anatomical and imaging methods. The vertebral arteries of the AAJ segment (VA-A), the first and second cervical nerves (CN1, CN2) and synovial fold (SF) of the AAJ were observed and measured.*
Result: *After extending from the vertebral canal, the CN1 goes between the posterior arch of the atlas and VA-A, and the CN2 passes between the posterior arch of the atlas and axis, and is posterior to VA-A. Among the eight cases, six were found in the SF in the central anterior AAJ and five in lateral. The vertebral arteries of the AAJ segment go along the AAJ with four curves, of which the second and fourth are away from the bone structure of the AAJ. The distance from CN1, CN2 to VA-A and that from the second, fourth curve of VA-A to AAJ is 0.0–2.2 mm, 0.0–3.6 mm and 0.0–4.8 mm, 2.0–7.9 mm respectively. There is no significant difference between the measurements made anatomically and those by the imaging method ($p > 0.05$).*
Conclusion: *The anatomical method has advantages in observing the CN and SF, while the imaging method shows clearly and directly the VA-A and AAJ. Both are mutually complementary with consistent measurements. The combined use of the two provides a new way to study the complicated anatomy in this region.*

Keywords: Anatomy, atlanto-axial joint, medical imaging, relational structure

Estudio Experimental de la Articulación Atlanto-axial y las Estructuras Relacionadas con la Anatomía Regional y la Imagen Médica

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RESUMEN

Objetivo: *Evaluar las características del método anatómico y el uso de la imagen médica en un estudio de observación de la articulación atlanto-axial (AAA) y estructuras relacionadas.*
Métodos: *Se estudiaron ocho especimenes cadavéricos del segmento de la AAA tanto con métodos anatómicos como con métodos de imaginología médica. Las arterias vertebrales del segmento de AAA (AV-A), el primer y el segundo nervios cervicales (NC1, NC2) y los pliegues sinoviales (PS) fueron observados y medidos.*
Resultado: *Tras de extenderse desde el canal vertebral, el NC1 se extiende entre el arco posterior del atlas, y el NC2 pasa entre el arco posterior del atlas y el axis, y es posterior a las AV-A. Entre los ocho casos, se encontraron seis en los PS en la AAA anterior central, y cinco en la lateral. Las arterias vertebrales del segmento AAA van junto con la AAA con cuatro curvas, de las cuales la segunda y la cuarta están separadas de la estructura ósea de la AAA. La distancia del NC1 y NC2, a las AV-A, y la de la segunda y cuarta curvas de las AV-A a la AAA es 0.0–2.2 mm, 0.0-3.6 mm y 0.0-4.8 mm, 2.0–7.9*

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*mm respectivamente. No hay ninguna diferencia significativa entre las mediciones realizadas anatómicamente y las hechas mediante métodos de imaginología (*p *> 0.05).*

***Conclusión:** El método anatómico tiene ventajas al observar el NC y los PS, mientras que el método imaginológico muestra clara y directamente las AV-A y la AAA. Ambos son mutualmente complementarios con las mediciones. El uso combinado de los dos proporciona una nueva manera de estudiar la complicada anatomía de esta región.*

Palabras claves: Anatomía, articulación atlanto-axial, imagen médica, estructuras relacionales

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INTRODUCTION

The atlanto-axial joint (AAJ) and related structures connect the head and neck. They provide vital functions but the anatomy is complicated. Recently there has been a lot of reported studies on the AAJ and the vertebral artery (VA-A) at the AAJ (1−5). To our knowledge, a combination of anatomical and imaging methods to study the anatomy of AAJ, VA-A, the first and second cervical nerves (CN1, CN2), synovial fold (SF) and their relations has not been reported. In this study, we combined both methods to observe these structures on the specimens of cadaveric AAJ segments and hope to provide a detailed anatomy for clinical diagnosis and surgery.

SUBJECTS AND METHODS

Ascertaining the sample number: According to the principle of reproducibility, researchers set the probability of type I error at $\alpha = 0.05$, type II error at $\beta = 0.1$, the differentiating measurement at 0.5 mm, the standard deviation at 0.25 mm−0.5 mm and have the paired *t*-test. Calculating the experimental sample numbers or looking for the T table, 5−13 cases of the sample are demanded. In our study, eight cases of cadaveric specimens of AAJ were used.

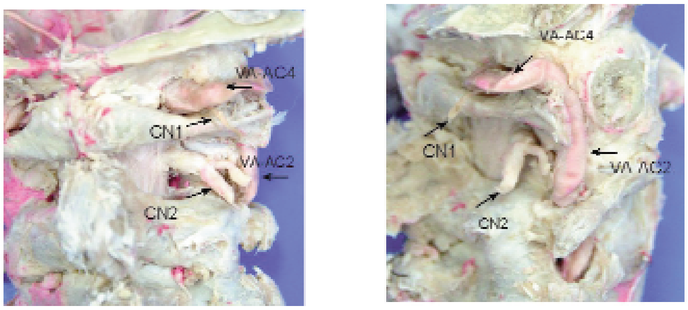
Marking and preparing specimen: Eight cadaveric specimens of the AAJ with the surrounding ligaments, VA-A, CN1 and CN2 were chosen. First, the VA was marked with the interventional guide wires or red latex liquid containing 30% Urografin. Then the AAJ specimens were fixed on the plank with non-metallic materials and epoxy resin (to avoid the artifacts of computed tomography (CT) and magnetic resonance imaging (MRI) scan) by drilling holes from the medial aspect of occipital bone to atlanto-occipital joint bilaterally and from the centrum and spinous process of the third or fourth cervical vertebrae to that of the second cervical vertebrae, respectively. Measurement tools included the vernier caliper, compass and dissecting instruments, *etc*.

Examination methods: The AAJ specimens were scanned with 64-multi-detector row spiral CT (64-MDCT, Light Speed VCT, GE Corporation, USA) with thickness of 0.625 mm, increment of 0.3 mm and pitch of 0.984. The scanning area covered the whole AAJ specimen. The AAJ specimen with water model (up to the weight to start the scanning) was scanned by 1.5T MRI (HD propeller, GE Corporation, USA) with cardiac coil. Parameters included the checking sequences of FIESTA, FOV of 14 cm × 14 cm, reverse angle of 73 degrees, TR = 4, TE = 1, FL = 60, NEX = 4, BW = 41.67, THK/SP = 2.0/-1.0; or the checking sequences of 3DSPGRE, FOV of 14 cm × 14 cm, TR = 10, TE = 5, NEC = 1, FL: 20, TI = 350, THK/SP = 1.4/-0.7, BW = 15.63. Parameters included the checking sequences of FIESTA, FOV of 14 cm × 14 cm, reverse angle of 73 degrees, TR = 4, TE = 1, FL = 60, NEX = 4, BW = 41.67, THK/SP = 2.0/-1.0; or the checking sequences of 3DSPGRE, FOV of 14 cm × 14 cm, TR = 10, TE = 5, NEC = 1, FL: 20, TI = 350, THK/SP = 1.4/-0.7 and BW = 15.63.

Imaging process and structures observation or measurement: Three-dimensional (3D) imaging was performed with data from CT or MRI on the workstation (Advantage workstation 4.2, GE Corporation, USA). Imaging methods were volume rendering (VR), maximum density projection (MIP) and multi-planar reformation (MPR). On these images, AAJ and related structures were observed and measured anatomically and with medical imaging, respectively. The contents include the size of SF, the features of VA and the distance between CN1, CN2, AAJ to VA-A. Statistical comparisons were made using paired *t*-test between the measurements made by anatomy and medical imaging; the *t* and *p*-values were calculated.

RESULTS

The anatomical method clearly demonstrated that the CN1 goes between the posterior arch of the atlas and VA-A, the CN2 between the posterior arch of the atlas and axis and behind the VA (Figs. 1, 2). In the course of the VA-A with four curves, there were two apparent curves away from the AAJ, one (VA-AC2) was on the side of AAJ space, the other (VA-AC4) on the posterior arch of the atlas. In the eight specimens, there were six cases with SF in the central anterior AAJ, five in the lateral AAJ (Fig. 3) and none in the posterior AAJ. The imaging method clearly and globally showed the course of the VA-A, adjacent ligaments, CN2 and the relations between the AAJ and VA-A (Figs. 4−6), whereas it could not clearly show the CN1 and SF. Anatomical and



Figs. 1−2: Lateral and posterior views observing the relations between VA-AC4 and CN1, VA-AC2 and CN.

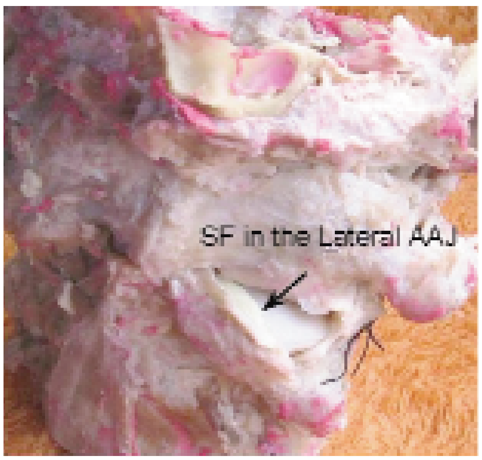


Fig. 3: Synovial fold in lateral AAJ.

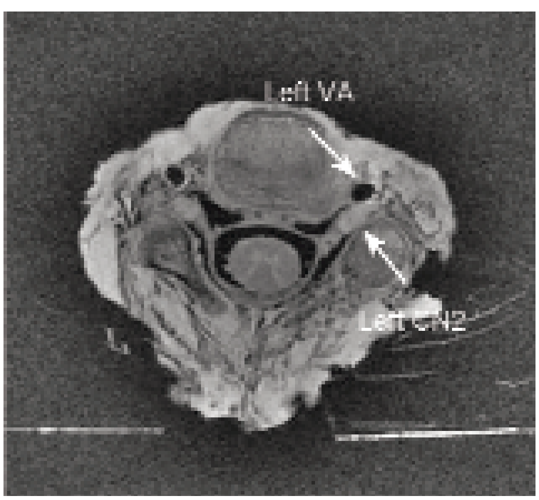


Fig. 4: MRI image showing the relation between VA and CN2.

imaging observations or measurements on the images and specimens were listed (Tables 1, 2). The distance from CN2 to VA-A, from VA-AC2 and VA-AC4 to AAJ was 0.0−3.6 mm, 0.0−4.8 mm and 2.0−7.9 mm, respectively. There was

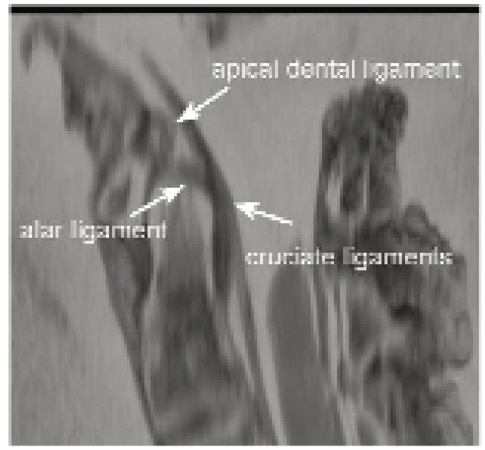


Fig. 5: MRI image showing the adjacent ligaments in the AAJ.

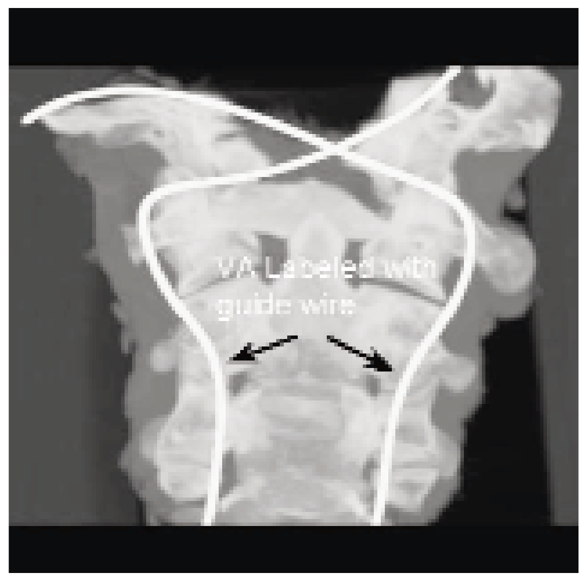


Fig. 6: CT 3D-image showing the course of VA marked by interventional guide wires.

no significant difference between the measurements anatomically and those by the imaging method ($p > 0.05$).

DISCUSSION

Observing the AAJ, VA-A and relational structures is important for surgery. Anatomical and imaging methods have their own advantages, respectively. The anatomical method is important for observing the detailed anatomy of CN and SF, while the imaging method has the advantage of displaying the structure of the AAJ, VA-A and their spatial locations (5−8). The combination of the two methods can more clearly show these structures than either of them alone. This is a new study method in anatomy with good clinical applications. It helps in the understanding of the pathogenesis of related diseases and the search for valuable treatment. In

Table 1: Measurements of eight specimens by imaging and anatomical methods

Measurements	Imaging (mm)	Anatomical (mm)	*t*	*p*
Distance of CN1-VA-AC4	–	0.0−2.2	–	–
Distance of CN2-VA-AC2	0.0−3.5 (1.46 ± 1.22)	0.0−3.6 (1.56 ± 1.16)	0.442	0.665*
Distance of VAC4-AAJ	2.1−7.8 (4.56 ± 2.08)	2.0−7.9 (4.51 ± 2.06)	0.230	0.821*
Distance of VAC2-AAJ	0.0−4.8 (2.83 ± 1.34)	0.0−4.7 (2.83 ± 1.32)	0.000	1.000*
Size of SF in lateral AAJ	–	2.2−5.5	–	–
Size of SF in anterior AAJ	–	1.5−4.3	–	–

Note: "–" represent no measurement because of unclear displaying; * $p > 0.05$

Table 2: Comparison showing the structures with the imaging and anatomical methods

	Imaging		
Observations	**CT**	**MRI**	**Anatomical**
Distance of CN1-VA	unclear	less clear	more clear
Distance of CN -VA	Less clear	clear	more clear
Distance of VAC1-AAJ	more clear	clear	clear
Distance of VAC2-AAJ	more clear	clear	clear
Size of SF in AAJ	unclear	less clear	more clear
Joints paces of AAJ	more clear	clear	clear

addition, to clarify the 3D-relations between AAJ and VA or adjacent structures can enrich the contents of the regional anatomy, and improve the accuracy or safety of surgery (9−13).

Medical imaging can show the VA, atlas, axis and other structures respectively. Magnetic resonance imaging can show the ligaments, CN and joint capsule. Computed tomography 3D-imaging can show the course of the VA as clearly as digital subtraction angiography (DSA) does, and can show the bone structures of the atlas or axis as vividly as real bone specimens. In 3D-imaging, the VR technique is common and has been widely used in imaging diagnosis. Based on the techniques of separating, fusing, opacifying and false-colouring, VR can show independently or jointly the AAJ, VA-A, atlas and epistropheus in different colours or transparency, and display the superficial and deep structures simultaneously (8). At the same time, 3D-imaging can combine the technologies of the cutting, adding or deleting structure, and ensure the superior quality of the image. In addition, imaging data can be used repeatedly and 3D-images can be observed or analysed by different doctors. So the missed diagnosis and misdiagnosis can be avoided and high diagnostic accuracy can be ensured (7−9).

The anatomical method was superior to the imaging on observing the detailed anatomy of the AAJ, such as the size and shape of the SF, ligaments, CN *etc.* However, it did not show clearly the whole course of the VA and the relations to the AAJ. Its measurement accuracy may be affected by different researchers or measuring instruments. The imaging method was superior to the anatomical in showing the bony structure, the course of the VA-A and their correlation on three-dimensional views, and without overlap from the other structures. However, it distinguishes some detailed anatomy less clearly. The combination of the two methods will improve or increase the knowledge of the regional anatomy, as well as extend the basic study of medical imaging.

Combining both the anatomical and imaging methods will improve the ability to study the AAJ and adjacent structures since they are mutually complementary. Regional anatomy can observe the tiny structures, while imaging method with 2D- or 3D-imaging of CT or MRI can show not only their sectional anatomy, but also the whole and relations of the complex structures. Three dimensional-imaging can overcome draw-backs of structures overlapping and realize, individually, "non-invasive anatomy *in vivo*" for surgery. To our knowledge, combining both anatomical and imaging methods in studying the AAJ and adjacent structures has not been reported, but it will promote anatomical studies and provide a new approach to the basic research of medical imaging. Compared with regional anatomy, it has the following advantages: (1) displaying accurately the tiny anatomy and the whole relation about the deep and shallow structures, (2) observing the sectional anatomy and 3D anatomy *in vivo,* (3) providing thorough preoperative anatomical basis for interventional radiology and surgery (12, 13).

The anatomical and imaging methods can clearly show the AAJ and adjacent structures; they give an anatomical basis for diagnosing and treating related AAJ and VA disease. Anatomical research into the SF may provide an anatomical basis for the pathogenesis of the atlanto-axial dislocation (14). Three dimensional-imaging shows the course of the VA and any related variation. This can give solid support to the choice of treating methods and safety of operation; it has important significance in clinical medicine. There are many surgical treatment options for vertebro-basilar artery stenosis and occlusion, but it is very important to know the detailed anatomy of the VA and the relationship with adjacent structures before operation. This study clarified the value of anatomical and imaging methods in showing the AAJ and adjacent structures, their measurements are comparable to each other and have value in clinical application. Combination of two research methods will have a great effect on studying in complex anatomy and will become a new study direction in clinical anatomy (9−15).

REFERENCES

1. Tubbs RS, Shah NA, Sullivan BP, Marchase ND, Cohen-Gadol AA. Surgical anatomy and quantitation of the branches of the V2 and V3 segments of the vertebral artery. Laboratory investigation. J Neurosurg Spine 2009; **11:** 84−7.
2. Gupta T. Quantitative anatomy of vertebral artery groove on the posterior arch of atlas in relation to spinal surgical procedures. Surg Radiol Anat 2008; **30:** 239−42.
3. Cacciola F, Phalke U, Goel A. Vertebral artery in relationship to C1–C2 vertebrae: an anatomical study. Neurol India 2004; **52:** 178−84.
4. Duan SY, Lv SM, Ye F, Chen LB. Three-dimensional CT angiography study on the relations between the vertebral artery and atlantoaxial joint. Chin Med J 2009; **122:** 917−20.
5. Siclari F, Burger IM, Fasel JH, Gailloud P. Developmental anatomy of the distal vertebral artery in relationship to variants of the posterior and lateral spinal arterial systems. AJNR Am J Neuroradiol 2007; **28:** 1185−90.
6. Pfirrmann CW, Binkert CA, Zanetti M, Boos N, Hodler J. MR Morphology of Alar Ligaments and Occipitoatlantoaxial Joints: Study in 50 Asymptomatic Subjects. Radiology 2001; **218:** 133−7.
7. Hong JT, Lee SW, Son BC, Sung JH, Yang SH, Kim IS et al. Analysis of anatomical variations of bone and vascular structures around the posterior atlantal arch using three-dimensional computed tomography angiography. J Neurosurg Spine 2008; **8:** 230−6.
8. Duan SY, Lv SM, Ye F, Lin QC. Imaging anatomy and variation of vertebral artery and bone structure at craniocervical junction. European Spine Journal 2009; **18:** 1102−8.
9. Sylaja PN, Puetz V, Dzialowski I, Krol A, Hill MD, Demchuk AM et al. Prognostic value of CT angiography in patients with suspected vertebrobasilar ischemia. J Neuroimaging 2008; **18:** 46−9.
10. Hong JM, Chung CS, Bang OY, Yong SW, Joo IS, Huh K. Vertebral artery dominance contributes to basilar artery curvature and pri-vertebrobasilar junctional infarcts. J Neurol Neurosurg Psychiatry 2009; **80:** 1087−92.
11. Provenzale JM, Sarikaya B. Comparison of Test Performance Characteristics of MRI, MR Angiography, and CT Angiography in the Diagnosis of Carotid and Vertebral Artery Dissection: A Review of the Medical Literature. Am J Roentgenol 2009; **193:** 1167−74.
12. Coward LJ, McCabe DJ, Ederle J, Featherstone RL, Clifton A, Brown MM. Long-Term Outcome After Angioplasty and Stenting for Symptomatic Vertebral Artery Stenosis Compared With Medical Treatment in the Carotid And Vertebral Artery Transluminal Angioplasty Study (CAVATAS). Stroke 2007; **38:** 1526−30.
13. Yamazaki M, Okawa A, Hashimoto M, Aiba A, Someya Y, Koda M. Abnormal course of the vertebral artery at the craniovertebral junction in patients with Down syndrome visualized by three-dimensional CT angiography. Neuroradiology 2008; **50:** 485–90.
14. Inami S, Kaneoka K, Hayashi K, Ochiai N. Types of synovial fold in the cervical facet joint. J Orthop Science 2000; **5:** 475−80.
15. Sparacia G, Bencivinni F, Banco A, Sarno C, Bartolotta TV, Lagalla R et al. Imaging processing for CT angiography of the cervicocranial arteries: evaluation of reformatting technique. Radiol Med (Torino) 2007; **112:** 224−38.