

Original Article

The Vertebral Artery Convergence to the Cervical Spine in the Elderly

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Abstract

Background: In the older population, tortuosity of the vertebral artery (VA), uncovertebral joint (UVJ) osteoarthritis, and abnormal vertebral alignment may alter the normal anatomy.**Aim:** We aimed to determine the anatomical variations and relationships between the cervical segment of the VA and the cervical spine with regard to ageing.**Materials and methods:** In this retrospective cross-sectional study, the computed tomography angiography scans of 110 subjects were reviewed. Any variations in the VA, UVJ degeneration were identified. The distance between the VA and uncinat process (UP) was measured electronically. The distance between the VA and UP were compared according to the age group (group A < 45, group B = 45-65, and group C > 65 years old).**Results:** With regard to the transverse foramen, 7.2% of the cases had entering abnormalities of the VA, while in one case (0.83%), the right VA had an exiting abnormality (exiting from the C2 instead of the C1). UVJ degeneration was found to be significantly higher in the older age group ($p < 0.05$). Furthermore, at the C4-C7 levels, the distances between the VA and UP were significantly smaller in the older age group ($p < 0.01$).**Conclusions:** The VA-UP distance has been shown to decrease due to increasing UVJ osteoarthritis in the elderly. The convergence of the VA toward the spine occurs at the most mobile segment of the cervical spine, and this anatomical alteration may predispose temporary and/or permanent vertebral artery occlusion clinically, and be dangerous during cervical spine surgery.

Key words:

aging, computed tomography, angiography, spine, osteoarthritis, vertebral artery

INTRODUCTION

Anatomically the vertebral artery (VA) is divided into four segments: The V1 segment exits from the subclavian artery, following a short soft tissue course enter the C6 transverse foramen (TF). The V2 segment course cranially and vertically through the transverse processes of the C6 to C2. Then it ascends to C2, make a wide loop between C2 and C1 (V3 segment). The V4 segment is intracranial segment,

after penetrating dura mater both VA unite as basilar artery. Vertebral artery (VA) pathologies cause serious complications in the hindbrain since it is the main blood supplier to that area.¹⁻⁴ Normally, the second segment of the VA (V2) is relatively straight, and is usually located in the extra-foraminal area.⁵ Both arteriosclerosis and progressive degenerative changes in the neighbouring cervical vertebrae in aging individuals can affect the V2. For example, the osteophytes projecting from the uncovertebral joints (UVJ) can

permanently or intermittently compress the VA and cause neurological symptoms according to the posture.⁶ Uncinate process (UP) osteophytes can occur in the C3-C7 vertebrae, but are more frequently found at the C5-C6 and C6-C7 levels, and the lateral widening of the UP causes entrapment of the spinal nerves in the intervertebral foramen. When the shelf-like enlargement lies in the opposite direction, it may project into the transverse foramen (TF). The osteophytes originating from the anterior side of the UP may cause an indentation of the VA medially; however, the osteophytes projecting from the posterior side of the UP may result in stiffness in the neck and limitations in movement.⁷ Computed tomography angiography (CTA) is a unique imaging method used to display the arteries together with the bones. Moreover, the increasing use of the CTA has led to the evaluation of VA variations and their relationships to the cervical vertebral structures. This study was designed to demonstrate the age-related morphological changes of the cervical spine and its V2 relationships in CTA studies. In the first part of the study, we concluded that the incidence of VA tortuosity increases with age, and was found to occur at a rate of 73% after 65 years of age.⁸ Overall, the size of the transverse foramen was found to be larger in the older subjects, which could be explained by the VAs tortuosity. In the second part of the study, the alterations in the distance between the V2 segments and the neighbouring cervical vertebrae due to ageing were researched. Although it is generally known that spondylosis and/or atherosclerosis may induce vertebrobasillary insufficiency in elderly but there is still not any reported radiological study yet. Variations in the VA have also been presented in the current manuscript.

MATERIALS AND METHODS

This study was approved by the Local Ethics Committee, and written informed consent was obtained from the patients. In total, 110 carotid-cerebral computed tomography angiography (CTA) studies done between October of 2011 and January of 2013 in our clinic were analyzed retrospec-

tively. Moreover, this dataset was previously used in another anatomical study.⁸ These patients were sent to our clinic with a preliminary diagnoses of cerebrovascular disease, carotid artery stenosis, or aneurysm indications. The demographic features of the subjects have been summarized in **Table 1**.

All of the patients were scanned using a 64 channel dual source CT (GE Discovery CT 750 HD). Previous to the scanning, a 20-22 gauge cannula was inserted into the right antecubital vein, and 50-65 ml of 300 mg/ml iodine contrast (iohexol), followed by 25-30 ml of saline were given at a rate of 3.5-5.7 ml/s by a power injector. A bolus tracking method was used, with 6 s of delay time, and the caudo-cranial direction scans were obtained with breath holding. The scanning parameters were: 25 cm field of view, 120 kVp with automatic tube current modulation, pitch = 1, and a 0.4 s gantry rotation time. The sections, starting from the arcus aortae through the vertex, were scanned in 6-10 s. The images were reconstructed using a standard algorithm, the 0.5 mm slice thicknesses were reconstructed with 0%-50% overlapping, and submillimetric slices were obtained.

IMAGE PROCESSING

The raw data were processed using Advantage Workstation Volume Share 5 (GE Healthcare), while the analyses of the images and measurements were done digitally. MIP, 3D volume rendering, and curved reformatted reconstructions were applied to the data.

ANALYSES OF THE IMAGES

The determinations of the pathologies and variations were done with the consensus of two radiologists. One observer performed the measurements. Any degenerative changes of the uncovertebral joints, including variations and acquired abnormalities of the VAs (atheroma, stenosis, and tortuosity), were recorded.

Since VA-UP relationship was more easily seen on the coronal plan, the measurements were done on the reformatted coronal images. The smallest distance between the UP and VA were measured electronically on both sides and

Table 1. Demography of the study groups

Groups	Gender						Age		
	Woman		Man		Total		mean \pm SD	min-max	median
	N	%	n	%	n	%			
<45 years old (Group A)	10	67	5	33	15	100	37.3 \pm 6.9	20-44	40
45-65 years old (Group B)	11	37	19	63	30	100	58.8 \pm 4.9	45-65	60
>65 years old (Group C)	24	49	25	51	49	100	76 \pm 7.8	66-96	74
Total	45	48	49	52	94	100	64.3 \pm 15.6	20-96	60

each level (**Fig. 1**). In those cases of severe UP osteoarthritis and/or associated scoliosis, in which the osteophytes were causing displacement of the VA, the distance between the UP and VA was defined as 0 mm (**Figs 2, 3**). Moreover, only the arterial lumen is opacified in a CTA image; however, there also exists an arterial wall, which is not visible on CT scans unless it is not surrounded by fat. Since the wall thickness of the VA is in the submillimetric range, which is below the sensitivity of a CT scan, the anatomical resolution was not evaluated.



Figure 1. Coronal MIP reformatted image. Measurement of VA-UP distance.

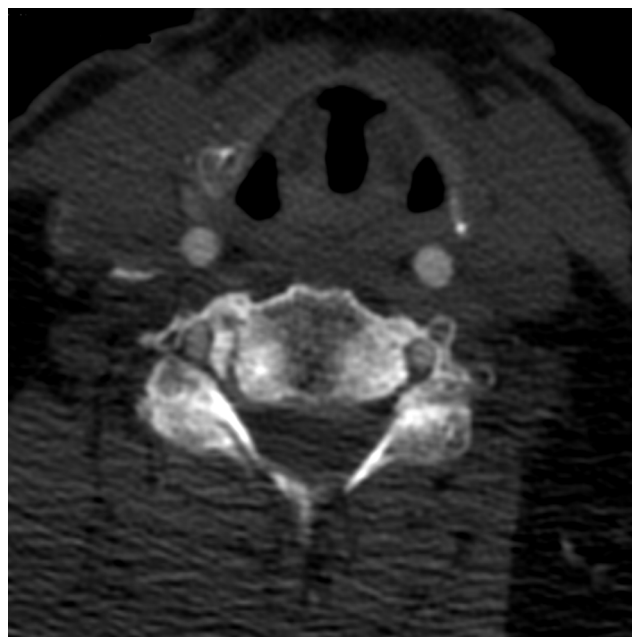


Figure 2. Axial section. Both VA entrapped by the osteophytes of the facet joints and uncinete process.

STATISTICAL ANALYSIS

The statistical analyses were done using the SPSS software (17.0.0; SPSS Inc., Chicago, IL, USA) adapted for Windows. Following the demographic analyses, the VA and concordant TF, VA/TF OR mean, standard deviation, minimum, and maximum values were determined at each level. Variances between the groups were determined by a one-way ANOVA. A value of $p < 0.05$ was accepted for statistical significance.



Figure 3. VA entrapment due to scoliosis and osteophytes.

RESULTS

Four VAs (3.6%) had arcus aorta origins, 6 VAs (5.4%) entered from the C5, and 1 bilateral entrance from the C4 was detected (1.8%). An entrance of the VA from the C6 was seen in 102 cases (92%). Moreover, there was right VA dominance in 25 (26%) cases, left VA dominance in 49 (49%) cases, and co-dominance in 24 (25%) cases, while a hypoplastic VA (an area $< 4 \text{ mm}^2$ was accepted) was seen in 3 cases. In one case, an exiting abnormality was detected: after exiting from the TF of the C2, the right VA entered into the vertebral canal from the C1-C2 interlaminar space (instead of passing through the transverse foramen of the C1), coursed cranially, reaching the foramen magnum, ex-

tending to the posterior fossa, and ending up as a posterior cerebellar artery (Figs 4-6). Those cases with severe stenosis (15 VAs) and/or dissection (1 VA) were excluded from the metric analysis.

In total, 94 cases were included in the metric analyses, and the mean age of those patients was 64.3 ± 15.6 years

(minimum: 20, maximum: 96). The cases were divided into 3 groups according to their ages: group A < 45 years old, group B 45-65 years old, and group C > 65 years old.

The incidences of scoliosis, kyphosis of the cervical spine, and degeneration of the UVJ are shown in Table 2. Overall, UVJ degeneration was the most significant finding



Figure 4. 3D volume rendering reconstruction image. After exiting TF at C2, right VA (black arrow) enters into the vertebral canal through C1-2. Normal course of the left VA is seen (blue arrow). * posterior arch of the Atlas.

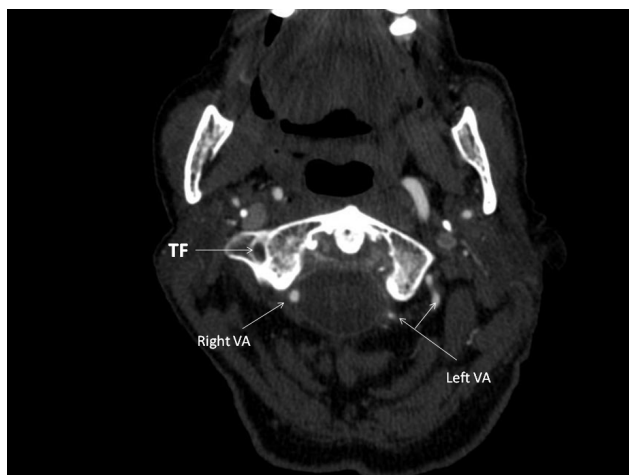


Figure 5. Maximum intensity projection image in coronal plane. Entrance of the right VA into the vertebral canal through C2-3 (white arrow).

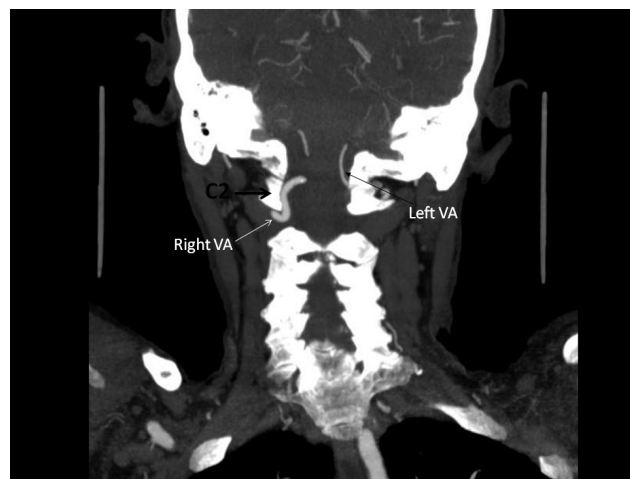


Figure 6. Axial section. Right TF of the C1 is empty (white arrow). Left VA course is normal (thin arrow).

in the older age groups, being present in 80% of group B and 96% of group C.

The distance between the VA and UP was evaluated in each of the age groups (Table 3). In group C, the distance was significantly low at the C7, C6, C5, and C4 levels ($p < 0.01$).

DISCUSSION

In the younger age group, the distance between the VA and UP was found to increase slightly from the C6 to the C3 vertebrae. The main reason for this is the normal anatomical enlargement of the vertebral bodies from the upper to the lower cervical spine. We found two cadaver studies in the literature which present similar conclusions. But it also should be considered that when compared with the limited cadavers studies, radiological anatomical studies help create quantitative analyses with larger and different age groups in vivo. In a study of 28 cadavers aged 41-78 years old,⁴ the mean distance between the upper corner of the UP to the VA was measured as 4.32 ± 0.84 mm (3.6-6.1 mm). These distances were found to decrease from the C3 to the C6 vertebrae, and the distance between the UP and VA was the shortest at the C4, and found to be the longest at the C6. One angiographic study in 12 cadavers⁹ revealed that the distances between the VA and UP were 1.8 mm at the C3, 2.4 mm at the C4, 2.5 mm at the C5, and 2.1 mm at the C6.

The VA to UP distance was found to be diminished in the older ages between the C6 and C4 levels, mostly at the

Table 2. Distribution of the study groups in terms of cervical scoliosis, kyphosis, uncovertebral joint (UVJ) degeneration and tortuosity of the VA

Absent		Group A n=15		Group B n=30		Group C n=49		p*
		absent	present	absent	present	absent	present	
Scoliosis	n	14/15 (93%)	1/15 (7%)	22/30 (73%)	8/30 (27%)	28/49 (57%)	21/49 (43%)	0.24
Kyphosis	n	12/15 (80%)	3/15 (20%)	22/30 (73%)	8/30 (27%)	33/49 (67%)	16/49 (33%)	0.6
UVJ degeneration	n	14/15 (93%)	1/15 (7%)	6/30 (20%)	24/30 (89%)	2/49 (4%)	47/49 (96%)	0.0*

*Pearson chi-square test

p<0.05 statistically significant

Table 3. The distance in mm between the VA and UP at each level in the study groups. The distance is significantly low at C7, C6, C5 and C4 levels in the group C (p<0.01)

		Group A (n=15)	Group B (n=30)	Group C (n=49)
C3	right (mm)	5.7	5	4.3
	left (mm)	5.1	4.6	4.6
C4	right (mm)	6.1	4.6	4.4
	left (mm)	6.2	5.1	4
C5	right (mm)	6.6	5.1	4
	left (mm)	6.1	5.2	3.9
C6	right (mm)	7	5.3	3.7
	left (mm)	7	4.4	4.1

C5 and C6. C5-C6 is the most mobile segment of the cervical spine and gives rise to most degenerative changes. The incidence of VA tortuosity increases due to atherosclerosis in elderly.^{7,8} Both UP osteophytes and VA's tortuosity could result by decrease of the normal distance between the two structures. Clinically anatomical close location of the VA with regard to the cervical vertebral osteophytes may give rise to positional or transient vertigo and clinical cerebrovascular incidents in older patients.¹⁰⁻¹² Nowadays, the human's mean age has advanced to 75-80 years old in modern populations, increasing the incidence of rotational vertebral artery occlusion (RVAO), which is a clinical entity defined by recurrent attacks of paroxysmal vertigo, nystagmus, and syncope provoked by horizontal head rotation. Dynamic angiography demonstrates the compression of the VA during head rotation. The mechanical compression of the VA during head rotation might be caused by muscular and tendinous insertions, osteophytes, or degenerative changes resulting from cervical spondylosis. Our study suggests a possibility of susceptibility of the VA to compression by osteophytes and other degenerative changes of cervical spondylosis at the C2-C6 level. During head rotations toward the side of the osteophytes, the ipsilateral VA may

be compressed against the osteophytes, and the contralateral VA may be compressed at the foramina. Fibrous bands which have developed from the fibrous transformation of the neck muscles may also cause extrinsic compression of the VA, but they cannot be visualized easily using routine radiological methods.¹³ The CTA enables one to visualize VA narrowing, together with the osteophyte and/or bony deformation (scoliosis, alignment disorders) that is closest to the VA, and most likely to compress the VA during cervical movements.

Of clinical significance is the proximity of the UP to the VA creating a greater possibility of VA injury during cervical spine surgery. Technically, a VA injury may occur as a result of high speed burring during UVJ resection, during a foraminotomy, or during decompression for the reduction of locked facet joints. On the other hand, posterior cervical instrumentation surgeries using lateral mass or pedicle screws may injure the VA, resulting in severe complications.¹⁴ Even at the C7 level, where the VA is out of the TF and furthest from the spine, there is a risk of laceration during the intervention.⁹ Therefore, to prevent iatrogenic VA injuries, the course of the VA must be well defined before the surgery, specifically in older patients. An abnormal course or origin of the arteries is clinically important because it may result in an alteration of the hemodynamics, increase in the risks of stenosis and aneurysm, or iatrogenic injuries. Common VA abnormalities include exiting from the arcus aorta and at the V3 and V4 segments.^{15,16} Based on the literature, the incidence rate of exiting abnormalities (direct origin of the VA from the arcus aorta) has been reported to be 2.5%-8.3%,¹⁻³ and in our study it was 3.6%. In addition, the exiting of the right VA from the arcus has been reported to be 3%, but we did not encounter this abnormality in our study. Moreover, V2 abnormalities are relatively rare, and the entrance into the TF is generally at the C6 level, but it may enter more caudally or cephalically. We found 102 cases (92%) with C6 entrances, 4 cases (3.6 %) with left C5 entrances, 2 cases (1.8%) with right C5 entrances, 1 case (0.9%) with a bilateral C4 entrance, 1 case (0.9%) with a right C4 entrance, and 1 case (0.9%) with a right C7 entrance. In the literature, a C6 entrance was reported in 88%-94% of the cases, a C7 entrance in 0.3%-5.4%, a C5 entrance in 3.3%-7%, a C4 entrance in 0.5%-1.6%, and a C3 entrance in 0.1%-1%.^{2,3,17-19} These variations are not clinically important, with the exception of the risk of iatrogenic

VA lacerations. The abnormal entrance of the VA into the TF may be dangerous during the lateral cervical approach because the VA is not protected by the TP at the level of its entrance.² Since the VAs are not the primary focus of cervical spine imaging studies, possibly dangerous relationships must be considered before surgical procedures.

An abnormal exit of the VA is extremely rare. Those reported cases are symptomatically characterized by long-standing suboccipital and posterior cervical neck pain, torticollis, arm pain, and dysesthesia, because the abnormal artery may compress the C2 root.²⁰ However, microvascular decompression of the nerve relieves the symptoms. The VA course, and its direct compression on the C2 dorsal rootlets against the cord are well demonstrated intraoperatively.^{10,11} Overall, the CTA is the best imaging modality for demonstrating the course of the VA with the neighbouring spine; therefore, in intractable occipital neuralgia cases, a CTA should be recommended before planning the surgical treatment. Unfortunately, the patient in our case could not be evaluated clinically because of her dementia. Some VA abnormalities can be asymptomatic, but they can also be symptomatic after minor trauma. Even loop formations of the VA may cause nerve root compression according to the anatomical location of the VA.⁵

The major limitation of this study was that the wall thickness of the VA could not be included in the measurements for two reasons. First, the CTA could only visualize the arterial lumen while contrast material passed through the lumen, and the arterial wall was not detectable unless it was not surrounded by macroscopic fat, which was not possible in all of the images. The second reason was that the wall thickness of the VA was in the submillimetric range, which was below the CTA scan's spatial resolution sensitivity. CT angiography is a perfect imaging method to display arteries together with the bones, and it cannot be replaced by other imaging methods that do not require radiation or contrast injection, such as ultrasonography or magnetic resonance imaging.

CONCLUSIONS

In the younger age group the distance between the VA-UP slightly increases from C6 to C3. In the elderly this distance decreases but mostly at the C6-C4 level which is the most mobile segment of the cervical spine. Changes of the normal anatomy are secondary to spondylosis and/or arterial tortuosity; even though the subject is asymptomatic. Therefore, the main purpose of this study was to reveal such alterations. Based on the principles of this study, a large number of patients in the study group is required to reveal age related changes of the VA, according to the cervical spine. Therefore, cadaveric studies would not provide a large enough group to conclude such changes, due to the limited number of cadavers.

This study shows that the VA distance decreases at the C4-C7 levels in the elderly because of enlarged UP osteo-

phytes. An anatomically close location may give rise to positional, transient vertigo and clinical cerebrovascular incidents, and may also increase the risk of iatrogenic VA lacerations during surgical interventions.

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Конвергенция позвоночной артерии к шейному отделу позвоночника у пожилых людей

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Введение: У более пожилой части населения сгибание позвоночной артерии (ПА), унковертебральный сустав (УВС), остеоартрит, аномальные позвонки могут привести к изменению нормальной анатомии.

Цель: Наша цель состояла в том, чтобы определить анатомические вариации и взаимосвязи между шейным сегментом ПА и шейным отделом позвоночника в ходе старения.

Материалы и методы: В этом ретроспективном исследовании настоящего состояния были изучены компьютерные томографические ангиографии у 110 пациентов. Были установлены все вариации ПА, дегенерация УВС. Расстояние между ПА и крючковидным отростком (КО) (uncinate process) измерялось электронным способом. Расстояние между ПА и КО было сопоставлено по возрастным группам (группа А < 45 лет, группа В = 45-65 лет и группа В > 65 лет).

Результаты: Что касается поперечной апертуры, в 7,2% случаев было отклонение на входе ПА, в то время как в одном случае (0,83%) правая ПА имел отклонение на выходе (выходя из С2 вместо из С1). Дегенерация УВС была значительно выше в группе более пожилых ($p < 0,05$). Кроме того, на уровне С4-С7 расстояние между ПА и КО было значительно меньшим в группе более пожилых ($p < 0,01$).

Выводы: Было доказано, что расстояние ПА - КО уменьшается из-за прогрессирования унковертебрального артроза у более пожилых. Конвергенция ПА к позвоночнику появляется в наиболее подвижном сегменте шейного отдела позвоночника, и эта анатомическая аномалия может predispose к временной или постоянной окклюзии позвоночной артерии клинически и представлять риск во время операции на шейном отделе позвоночника.