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Evaluation of the Distance of the V3 Segments of the Vertebral Artery to the C1 Lateral Mass and C2 Pedicle on the Dominant and Non-Dominant Sides: A Cadaver Study

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ABSTRACT

Objective: Aim of this study is investigation of the risk of vertebral artery injury on the dominant and non-dominant vertebral artery sides at the craniocervical junction on cadavers.

Methods: A total of five cadavers and 10 vertebral arteries injected with red latex were studied. Dissection was performed on all of the cadavers. The study also involved CT scans obtained from all of the cadaver specimens. Distance of C1 lateral mass medial wall to the V3 segment of the vertebral artery, distance of C1 lateral mass lateral wall to the V3 segment of the vertebral artery, distance of C2 pedicle medial wall to the V3 segment of the vertebral artery, and distance of C2 pedicle lateral wall to the V3 segment of the vertebral artery were measured and statistically analyzed.

Results: There was no statistically significant difference between anatomical measurements on cadavers and on CT scan measurements. The data in the study demonstrated that the non-dominant (hypoplastic) vertebral artery follows a much closer course to the pedicle and the lateral mass, compared to the dominant artery.

Conclusion: In conclusion, it has been shown that the vertebral artery may be easily injured during surgical procedures due to the anatomical proximity of the pedicle and lateral mass and the screws' entry points being much closer on the non-dominant side.

Keywords: Vertebral Artery, Injury, Dominant, Non-dominant, Cadaver, Craniocervical Junction

1. INTRODUCTION

The unique anatomy of the atlantoaxial region makes surgical interventions challenging in this region. The vertebral artery to run through the C1-2 region varies from other cervical regions and may be subject to injury during surgical procedures. Surgical procedures performed in this region are due to cervical fractures-dislocations, spine and spinal cord tumors, congenital anomalies and degenerative diseases. Injuries may occur through direct contact with surgical instruments used during surgical procedures.

The vertebral artery injury (VAI) has been published that be as high as 8.2% during C1-2 region surgery. Transarticular screws are found to violate the C2 vertebral artery 9.5%, and pedicle screws are found to violate the C2 vertebral artery 8 % in several studies [1] [2]. Additionally high riding vertebral artery increases the injury rate during surgery [2].

VAI may cause a decrease in blood supply to the vertebrobasilar system, resulting in infarcts in the brainstem and cerebellum, and may result in death. Injuries may occur while drilling the entry point in the vertebra and during the placement of the screw. The screw may injure the vertebral artery or it may completely occlude it.

Aim of this study is investigation of the risk of VAI on the dominant and hypoplastic vertebral artery sides of cadavers during surgical procedures involving C1-2 at the craniocervical junction together with measurements performed on computed tomography (CT) scans of the cadaver specimens.

2. METHODS

2.1. Study Permissions and Ethical Statement

The study was conducted at Marmara University Neurological Sciences Institute. Ethical approval form was obtained

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from the Marmara University Faculty of Medicine Ethics Committee.

2.2. Study Design

A total of five cadavers and 10 vertebral arteries injected with red latex were studied.

Dissection was performed on all of the cadavers with midline skin incision extending from the occiput to the level of the C3 vertebra at the nuchal line. Muscles on both sides are dissected in the cervical region by proceeding from the nuchal ligament toward the midline. The muscles from the posterior elements of the vertebrae and suboccipital triangle were dissected bilaterally as a single layer of skin.

The Vertebral Groove and transverse process were revealed by performing a lateral dissection from the C1 Posterior arch. The V3 segment of the vertebral artery was exposed from where the artery exits from the C1 transverse process to the vertebral groove. The C2 lamina and the Transverse foramen were dissected and exposed. The site of the vertebral artery exit from the transverse process was determined and the artery was exposed by fine dissection. In the study, it was detected at the C1-2 level of the vertebral arteries on both sides. Dominant and hypoplastic vertebral artery were identified. Distance of C1 lateral mass medial wall to the vertebral artery (A), distance of C1 lateral mass medial wall to the vertebral artery (B), distance of C2 pedicle medial wall to the vertebral artery (C), and distance of C2 pedicle lateral wall to the vertebral artery (D) were measured and statistically analyzed (Figure 1).

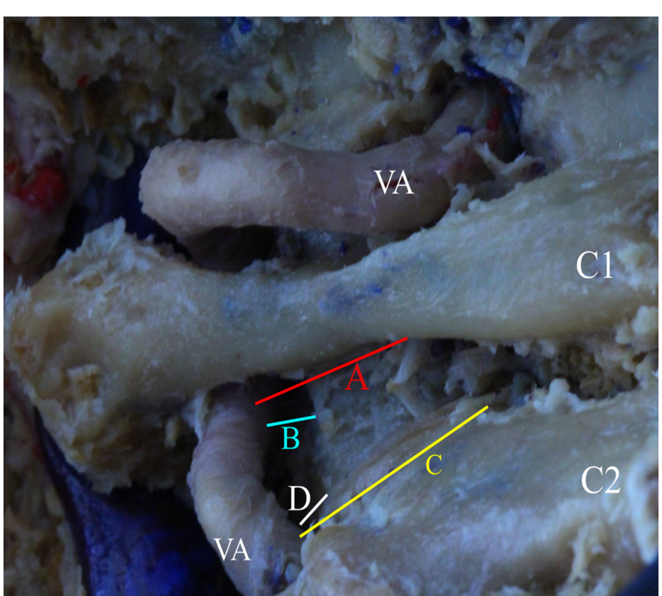

Figure 1. *The distances of C1 lateral mass and C2 pedicle to the vertebral artery.*

A-Red line: Distance of C1 lateral mass medial wall to vertebral artery, B-Blue line: Distance of C1 lateral mass lateral wall to vertebral artery, C-yellow line: Distance of C2 pedicle medial wall to vertebral artery, D-White line: Distance of C2 pedicle lateral wall to vertebral artery, VA: vertebral artery.

2.3. Radiology

The study also involved CT scans obtained from all of the cadaver specimens. The vertebral artery's distance to the medial wall of lateral mass and medial wall of pedicule were measured in the CT scans and statistically investigated (Figure 2, Table 1).

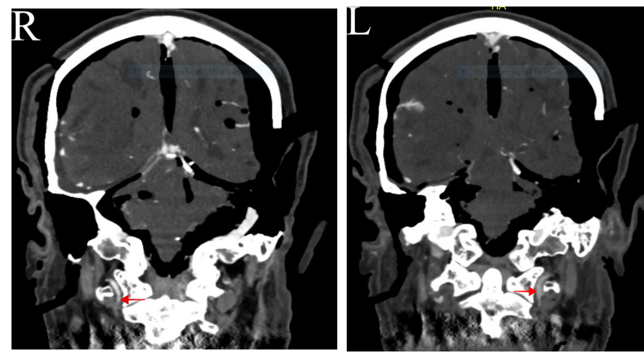

Figure 2. *CT image sample of a cadaver. Red arrow shows the vertebral artery. R:Right, L:Left.*

3. RESULTS

Dissections were performed on all of the cadaver specimens. Anatomical distances were physically measured on the cadavers, in addition to the CT scan measurements of the same specimens (Figure1, 2; Table 1). The results of the anatomical properties of C1, C2 and VA measurements of all cadavers are demonstrated in the Table 1.

3.1. Statistical Analysis Results

GraphPad Prism version 10.0.0 for MacOS (GraphPad Software, Boston, Massachusetts USA) was used in statistical analyses. The means and the standard deviations were calculated for parameters based on the measurements on the left and the right, respectively (Table 1). A paired samples t-test was used to compare the cadaver and CT scan measurements. A *p*-value < 0.05 was considered statistically significant (Table 2).

The mean distance of the C1 lateral mass medial wall to the vertebral artery (A) on the right side was 15.32 ± 1.12 mm on cadavers and 15.42 ± 1.23 on the CT scans. The same mean distance on the left side was 15.36 ± 0.5683 on the cadavers and 15.42 ± 0.497 on the CT scans (Figure 1 and 2).

The C1 lateral mass lateral wall distance to vertebral artery (B) on the right side was 1.12 ± 0.21 mm on cadavers and 1.22 ± 0.24 on CT scans. Whereas it was 1.62 ± 0.44 on the left side of cadavers and 1.82 ± 0.58 on CT scans (Figure 1 and 2).

The C2 pedicle medial wall distance to the vertebral artery (C) on the right side was 14.12 ± 0.64 mm on cadavers and 14.08 ± 0.66 on CT scans. It was 14.94 ± 1.17 on the left side of cadavers and 15.08 ± 1.27on CT scans (Figure 1 and 2).

Table 1. Measurement of the Vertebral Artery with anatomical structures in cadaver and tomography

	Right								Left								D.S.
	A		B		C		D		A		B		C		D		
	Cad	*CT*	*Cad*	*CT*	*Cad*	*CT*	*Cad*	*CT*	*Cad*	*CT*	*Cad*	*CT*	*Cad*	*CT*	*Cad*	*CT*	
1	14,1	14	1,5	1,6	15	14,8	2,2	2,4	15	15,1	2	2,2	16	16,1	1,5	1,6	L
2	16,5	16,6	1	1,2	13,5	13,2	1	1,1	15,5	15,9	1	1,1	16	16,4	1,5	1,5	L
3	16,5	16,8	1,1	1,3	14,1	14,3	1	1	16,3	16	2,1	2,6	13,2	13,2	1	1,1	L
4	15	15,1	1	1	14,5	14,5	1	1	15	14,9	1,5	1,6	15	15	1	1	L
5	14,5	14,6	1	1	13,5	13,6	1	1	15	15,2	1,5	1,6	14,5	14,7	1	1	L
M	15,32	15,42	1,12	1,22	14,12	14,08	1,24	1,3	15,36	15,42	1,62	1,82	14,94	15,08	1,2	1,24	
SD	1,123	1,234	0,2168	0,249	0,6496	0,6611	0,5367	0,6164	0,5683	0,497	0,4438	0,5848	1,17	1,272	0,2739	0,2881	

A: Distance of C1 lateral mass medial wall to vertebral artery, B: Distance of C1 lateral mass lateral wall to vertebral artery, C: Distance of C2 pedicul;e medial wall to vertebral artery, D: Distance of C2 pedicule Lateral wall to vertebral artery, Cad: Cadaver, CT: Computed Tomography, M: mean, Sd: standard deviation, DS: Dominant Side

The pedicle lateral wall distance to vertebral artery (D) on the right side was 1.24 ± 0.53 mm on cadavers and 1.3 ± 0.61 on CT scans. It was 1.2 ± 0.27 on the left side of cadavers and 1.24 ± 0.28 on CT scans (Figure 1 and 2).

The dominant vertebral artery was on the left side in all cadavers. There was no statistically significant difference between anatomical measurements on cadavers and on CT scan measurements.

Statistical analyses demonstrated no statistical significance in all right and left side measurements between the cadaver and CT scan measurements. P values of the analyses are provided in table 2.

Table 2. *Statistical comparison of the measurements made on cadavers and the CT images*

	RIGHT	LEFT
Comparison "A" Cadaver/CT	*p=0,1890*	*p=0,6455*
Comparison "B" Cadaver/CT	*p=0,0890*	*p=0,0612*
Comparison "C" Cadaver/CT	*p=0,6885*	*p=0,2080*
Comparison "D" Cadaver/CT	*p=0,2080*	*p=0,1778*

The data in the study demonstrated that the hypoplastic vertebral artery follows a much closer course to the pedicle and the lateral mass, compared to the dominant artery.

4. DISCUSSION

The vertebral arteries originate as the first branches of the subclavian arteries. Commonly, a dominant vertebral artery with a contralateral hypoplastic vertebral artery is observed in the patients. The vertebral artery is divided into 4 segments according to the anatomical location. Vertebral arteries enter the transverse foramen throught the C6 vertebral level (V1 segments). V2 segment is from the transverse foramen of the C6 to the transverse foramen of the C2 vertebra. V3 segment is the portion from the transverse foramen of C2 to dura mater. Finally, V4 segment is described as the intradural or the intracranial segment. The neck is very mobile at the C2 and C1 levels, and V3 segment continues freely in this region between the C1 and C2 transverse foramina devoid of any bony relation. Additionally, it courses over the vertebral groove on the C1 posterior arc and enters through the dura and provides the posterior circulation of the brain. This region is exposed to an increased risk of arterial injuries due to its varying location and course in the VA C1-2 region compared to other cervical regions. However, it is not clear in the literature whether if there are crucial differences in the anatomical course of the dominant and hypoplastic vertebral arteries. The current study discusses the course of the vertebral artery V3 segment between C1-2 on the dominant and hypoplastic vertebral artery sides and its relationship with the spine. VAI is a serious problem that can lead to catastrophic complications. VAI may occur mostly after trauma, but it may also occur after iatrogenic interventions. Iatrogenic injuries can be seen in all anterior and posterior surgeries of the cervical region. However, the most commonly encountered region in means of iatrogenic injuries is the craniocervical region surgeries, especially C1-2 posterior intervention surgery. Posterior C1-2 surgeries may occur due to tumors of this region, posttraumatic fractures, and congenital anomalies. In such surgeries, it may be essential to dissect and isolate the vertebral artery during tumor resection or during an instrument placement to C1-C2 vertabrae and iatrogenic VAI may occur during these procedures. Drilling and instrumentation are the most common causes of injuries [3]. VAI has been reported 32.4 % in C1-C2 spine fixation, 11.7 % in posterior approaches, 9.5 % in C1-C2 transarticular screws and 8 % in pedicle screws and 5.4 % in laminectomies in the literature [1, 2, 4-6].

VAI may cause a decrease in blood supply to the vertebrobasilar system, resulting in infarcts in the brainstem and cerebellum, and may result in death. VAI should be managed by intraoperative and postoperative methods. Intraoperative managements techniques are local control of hemorrhage, tamponade, packing with a hemostatic agent, electrocoagulation, direct repair and clipping, and ligation. Postoperative management of VAI are coil embolization, stenting and etc. .These procedures are performed to prevent vertebrobasilar ischemia and prevent cerebrovascular complications[7]. According to the literature, the general condition of patients after VAI occurence worsens in 13% of patients and is mortal in 8% of patients [3].

VAI may occur as a result of the screw being directed laterally or superiorly while trying to place the screw to the C1 lateral mass. While placing the C2 pedicle screw, medial movement of the screw may cause VAI. In patients with high-riding vertebral artery placement, there is a possibility of direct injury to the artery when placing a screw in the C2 pedicle. These two conditions have been discussed in detail in the literature and alternative surgical techniques have been suggested. At the C2 level, the lateral orientation of the screw may also cause VAI. If the C2 pedicle is narrow, the lateral orientation of the screw may also cause VAI. In craniocervical junction tumors, C1-2 bone tumors grow in the bone and push the vertebral artery laterally. In certain cases, the tumors may surround the vertebral artery. In all cases, the course of the vertebral artery at the C1-2 level and its proximity to anatomical structures must be well known. The course of the C2 Vertebral artery from where it exits the transverse foramen and where it enters the C1 transverse foramen should be essentially very well defined by the surgeons.

In the study, the examination of the medial wall of the C2 pedicle and the medial wall of the C1 lateral mass was taken as a guide by checking these anatomical structures during surgical interventions. Because these anatomical structures are used as guides for surgical applications in clinical practice. It is estimated how lateral the vertebral artery is away from these guide points during surgery. These guide points assist in finding the entry point of the C1 lateral mass screw and the entry point of the C2 pedicle screw. Additionally, while the C1 lateral mass screw is placed, lateral wall of the lateral mass is also controlled with the help of a nerve hook in some cases. While the C2 pedicle screw is placed, the lateral wall of the intersection of the pedicle and lamina may be controlled with a nerve hook. These markers were investigated in the current study since they are widely used checkpoints in clinical practice.

This study demonstrates that the proximity of the dominant and hypoplastic vertebral artery sides of the vertebral artery to the anatomical structures in the spine is variable. The side of the dominant vertebral artery must be checked in preoperative radiological examinations before the craniocervical junction surgical procedures. The reason for this is to avoid severe posterior system infarction that may occur due to possible injures to the dominant artery. However, it should not be forgotten that since the hypoplastic vertebral artery is very close to the pedicle and lateral mass, the risk of injury to the hypoplastic vertebral artery is higher on contrary to the common belief in the practice. But there is no any study about it in the litrature. This study demonstrates that there are differences between the distance of the vertebral artery to C2 pedicle and C1 lateral mass on the dominant and hypoplastic vertebral artery sides.

5. CONCLUSION

It was shown in the study that the vertebral artery on the hypoplastic side is very close to the lateral wall of the C2 pedicle and the C1 lateral mass. We found that the distances of the vertebral artery to the C2 pedicle and C1 lateral mass were greater on the dominant artery side. It is physiologically correct to pay more attention to avoid damaging the dominant vertebral artery, which is the main feeder of the posterior fossa. However, since the dominant vertebral artery is anatomically farther away from the surgical area, the probability of injury is lower than the hypoplastic side.

In conclusion, it has been shown that the vertebral artery may be easily injured during surgical procedures due to the anatomical proximity of the pedicle and lateral mass and the screws's entry points being much closer on the hypoplastic vertebral artery side.

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Design of the study: YG,UV,BT
Acquisition of data for the study: YG,UV,BT,EB
Analysis of data for the study: YG,UV,BT,EB
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