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ABSTRACT

Background: The goal of the study was to provide relevant data about the location and prevalence of the OA-VA anastomosis in patients without visible occlusive disease, as well as to thoroughly discuss the clinical significance of these anastomotic channels. Furthermore, the morphometric properties of the OA and its branches were also analyzed.

Materials and methods: A retrospective study was carried out to indicate anatomical variations, their prevalence, and morphometrical data on the OA and its branches. The study was performed on 55 randomly selected computed tomography angiographies (CTA) of the head and neck region. Each CTA result was analyzed bilaterally. Thus, 110 results were originally assessed.

Results: The OA median maximal diameter was demonstrated at 4.85 mm (LQ: 4.11; UQ: 5.53) and the median maximal diameter of VA at 3.60 mm (LQ: 2.79; UQ: 4.38). The distances between OA and its branches were also measured giving a median result of 21.73, 30.29, 60.84, 34.88, 18.02, 55.16 mm for the LSCMB, USCMB, MeB, MaB, and DB respectively. The median distance between OA and its first anastomosis was set to be 51.15 mm (LQ: 37.20; UQ: 60.10). Moreover, a set of additional measurements was carried out in order to create a 3-dimensional anatomical heat-map of the occurrence of the OA-VA anastomosis.

Conclusions: Knowledge about the anatomy of the OA-VA anastomosis might be of immense importance to avoid potentially fatal complications during embolization of the OA and its branches.

Key words: occipital artery, anastomosis, anatomy, vertebral artery

INTRODUCTION

The occipital artery (OA) arises slightly above the level of the hyoid bone or facial artery, from the posterior side of the external carotid artery (ECA) [13]. It courses posteromedially and parallel to the attachment of the posterior belly of the digastric muscle in the occipital groove in the temporal bone. During its course, it gives off numerous branches. The upper and lower sternocleidomastoid branches are considered the main branches of the OA. However, other inconstant branches also arise from the OA, such as the auricular branch or the mastoid branch [12].

The amount of data concerning the prevalence of the occipital-vertebral (OA-VA) anastomosis is scarce in the available literature. The said anastomotic channel was first extensively described by Schechter in 1964 [16]. In the study, 1000 cerebral angiograms were analyzed and the anastomosis was observed eight times. Another study regarding this topic was conducted by Alvernia et al. on six cadaveric heads [2]. Microscopic anastomoses between the OA and the VA were present in 11 out of 12 hemispheres.

Knowledge about the OA-VA anastomosis is of immense importance during endovascular procedures. Vascular and neoplastic processes fed by the OA or its branches are embolized with increasing frequency due to the advancements in endovascular techniques and increased knowledge of the vascular anatomy. However, these procedures are associated with potentially disastrous complications, such as posterior circulation stroke [2, 17]. Understanding the variable anatomy of the OA and its branches might be of great importance when performing revascularization procedures, such as the occipital artery-posterior inferior cerebellar artery (OA-PICA) bypass. The OA has been described as a great donor vessel for the revascularization of the posterior fossa due to its satisfactory length, caliber match, and close proximity to the intracranial arteries in that region [3].

The goal of the study was to provide relevant data about the location and prevalence of the OA-VA anastomosis in patients without visible occlusive disease, as well as to thoroughly discuss the clinical significance of these anastomotic channels. Furthermore, the morphometric properties of the OA and its branches were also analyzed. It is hoped that the present study can help physicians who perform endovascular and neurovascular procedures associated with the OA.

MATERIALS AND METHODS

Bioethical Committee

The research protocol was submitted for assessment and approved by the Bioethical Committee of the Jagiellonian University, Cracow, Poland (1072.6120.51.2022). Further stages of the study were carried out in accordance with the approved guidelines.

Study Group

A retrospective study was carried out to indicate anatomical variations, their prevalence, and morphometrical data on the OA and its branches. The study was performed on 55 randomly selected computed tomography angiographies (CTA) of the head and neck region. The CTAs were analyzed in the Department of Radiology of Jagiellonian University Medical College, Cracow, Poland in May 2022. Each CTA result was analyzed bilaterally. Thus, 110 results were originally assessed. Exclusion criterias were established as follows: (1) head or/and neck trauma affecting the course of OA or/and its initial branches, (2) artifacts significantly preventing precise and accurate imaging or/and measurements, (3) unintelligible and low quality images and (4) significant deficit of filling the whole arterial system with contrast. Defects that met exclusion criteria but considered only one side of the CTA without affecting the clearance of the contralateral side, did not disqualify the entire CTA but only the damaged side. Finally, a total of 88 sides were analyzed. Of the excluded, the majority (n=14) was eliminated due to significant artifacts. The other 8 were low quality.

Results Acquisition

All head and neck CTA were performed on a 128-slice scanner CT (Philips Ingenuity CT, Philips Healthcare). The main CT imaging parameters were as follows:

collimation/increment: 0.625/0.3 mm; tube current: 120 mAs; field of view: 210 mm; matrix size: 512 × 512.

All of the patients received intravenous administration of contrast material at a dose of 1 mL/kg (standard dose). A non-ionic contrast medium (CM) containing 350 mg of iodine per mL was used (Jowersol 741mg/mL, Optiray®, Guerbet, France). CT data acquisition was triggered using a real-time bolus-tracking technique (Philips Healthcare) with the region of interest (ROI) placed in the ascending aorta. The CM was intravenously injected using a power injector at a flow rate of 5 mL/s, which was immediately followed by injecting 40 mL of saline solution at the same flow rate. Following injection of CM and saline, image acquisition was automatically started with a 2s delay when the attenuation trigger value reached a threshold of 120 Hounsfield units (HU). Scanning was performed in the caudocranial direction, while the CTA examination was started at the level of the aortic arch up to the circle of Willis.

The CTAs were analyzed on a dedicated workstation in the Anatomical Department of Jagiellonian University Medical College, Cracow, Poland. To ensure the highest possible quality of the visualizations and measurements and minimize potential bias, Materialise Mimics Medical version 22.0 software (Materialise NV, Leuven, Belgium) software was used. 3-dimensional (3D) reconstructions of each scan were developed, employing a set of settings, severally adjusted to each scan. Due to the nature of the contrast study, the cut-off level was set at the lower limit of normal, oscillating in the range of 25-80 HU. The range was individually adjusted to each TT after a visual investigation.

Evaluation and Measurements

At the starting point of each calculating part, the authors ensured that OA, its branches, and close anatomical area were fully visualized. Moreover, each branch of OA was identified by following its course. The direction of the OA and a set of its branches with their arrangement were evaluated and descriptively noted. A set of measurements was enrolled by two independent researchers separately. The measurements executed on each OA are as follows: (1) OA's maximal diameter at its origin and at its ending, (2) OA's ostial area at its beginning and its ending. Additionally, all branches and anastomosis of each OA were identified and noted. Afterward, a set of measurements regarding the distances between each branch and/or anastomosis were enrolled. The ostial area and maximal diameter of each OA branch have been taken. Furthermore, the distance between OA and each branch was measured. Additionally, each OA was evaluated by respecting its course, its branches, and their pattern. The mean value has been established after obtaining the results of the research.

Ethical approval

The research protocol was submitted for assessment and approved by the Bioethical Committee of the Jagiellonian University, Cracow, Poland (1072.6120.51.2022). Further stages of the study were carried out in accordance with the approved guidelines.

Ethical concern

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The material used for this research was obtained from a body donation program.

Statistical analysis

Statistical analysis was performed with STATISTICA v13.1 (StatSoft Inc., Tulsa, OK, USA). The frequency and percentages presented qualitative features. The Shapiro-Wilk test was being used to establish the normal distribution. . Quantitative characteristics were presented by medians and upper and lower quartiles (UQ, LQ), as well as means and standard deviation (SD), depending on the verified normality of the data. Statistical significance was defined as $p < 0.05$. U Mann-Whitney and Wilcoxon signed-rank tests were used to establish potential differences between groups. Spearman's rank correlation coefficient was used to determine possible correlations between the parameters.

RESULTS

A total of 88 OAs of 44 patients were analyzed. Of these, 32 were from women (36.4%) and 56 from men (63.6%) in age from 17 to 82 years old (mean age: 48 years old, SD: 17.95). One of the criteriums included in the study was the presence and absence of the occipital artery branches; Lower Sternocleidomastoid (LSCMB), Upper Sternocleidomastoid (USCMB), Meningeal(MeB), Mastoid (MaB), Auricular (AB), and Descending (DB) as well as the potential appearances of the anastomosis. LSCM branch was present in 11 of the cases (12.5%), USCM in 12 of the cases (13.6%), MeB in 9 of the cases (10.2%), MaB in 4 of the cases (4.5%), AB in 6 of the cases (6.8%), and DB in 44 of the cases (50.0%). Anastomoses were established in 11 Occipital arteries (12.5%). The detailed results are presented in Table 1. Illustration of the branches of the OA can be found on Figure 1. Illustration of a sample anastomosis of the OA can be found on Figure 2.

The OA median maximal diameter was demonstrated at 4.85 mm (LQ: 4.11; UQ: 5.53) and the median maximal diameter of VA at 3.60 mm (LQ: 2.79; UQ: 4.38). The distances between OA and its branches were also measured giving a median result of 21.73, 30.29, 60.84, 34.88, 18.02, 55.16 mm for the LSCMB, USCMB, MeB, MaB, and DB respectively. The median distance between OA and its first anastomosis was set to be 51.15 mm (LQ: 37.20; UQ: 60.10). All the above-mentioned results and more detailed results are presented in Table 2.

To evaluate the sexual dimorphism in the morphometry and anatomical features of the OA results in each category were separated for each sex. There were no statistically significant differences ($p > 0.05$) in any of the studied groups. Detailed results concerning sex are gathered in Table 3.

Additionally, potential differences in the dimensions regarding the patients' side of the OA were analyzed. There were no statistically significant differences between measurements on the left and the right side. On the left, mean values of 4.79, 3.84, 75.08 mm (OA Maximal Diameter, VA Maximal Diameter, OA Length respectively), and on the right; 4.94, 3.51, 72.72 were established.

Moreover, possible correlations between the age of the patient and each dimension were analyzed. The statistically significant associations between OA length and (1) Distance between OA and USCMB ($R=0.59$; $p=0.04$), (2) Distance between OA and MeB ($R= 0.90$; $p=0.001$), (3) Distance between OA and the DB ($R=0.75$; $p=0.00$) were obtained. The statistically significant correlation between the distance between OA and USCMB and the distance between OA and the DB was obtained. No association between age and any of the OAs morphology was found. The R values obtained in the correlation analysis between the groups can be found in Table 4.

Moreover, a set of additional measurements was carried out in order to create a 3-dimensional anatomical heat-map of the occurrence of the anastomosis of the OA. In order to create the heat-map, three points on each of the CTAs were localized: (1) internal occipital protuberance; (2) angle of the mandibula, and (3) condylar process. Out of those points, two triangles (on both sides) were established on each CTA. Furthermore, using geometrical transformations in order to maintain standardization of the results, the positions of the anastomosis were applied to the illustrations. The heat maps are presented in Figure 3.

DISCUSSION

Mannie M. Schechter was the first to extensively describe the prevalence of the OA-VA anastomosis in 1964 [16]. In the study, 1000 consecutive cerebral angiograms were reviewed, and the anastomosis was observed 8 times. However, in two of these patients, occlusive disease was present in the cervical portion of the vertebral arteries. These anastomotic channels can form as a result of disturbances in the hemodynamic balance between the external carotid and vertebral systems, such as in cases of stenotic disease. However, these anastomoses can also occur in the absence of occlusive disease. Alvernia et al. conducted a microanatomical study about the OA and the OA-VA anastomosis in the absence of occlusive disease [2]. In the study, anastomotic vessels were observed in 11 out of the 12 specimens (91%), and they were characterized into three types. The most common type consisted of an anastomosis between the OA and the posterior radicular artery of the vertebral artery which was related to the dorsal root of C2.

Angiographically, these anastomotic channels are oftentimes not well visible because of their small caliber. The anastomoses may enlarge and become more functionally important under certain hemodynamic conditions. Therefore, in order to gather reliable data about the prevalence of the OA-VA anastomosis, cases where the patient suffered from visible occlusive disease were excluded. The result of the present study shows that the OA forms an anastomosis with another artery in 12.5% of the cases. The most common branch involved in the OA-VA anastomosis was the descending branch of the OA (45.5%); however, the USCM branch was also involved in this anastomosis (27.3%). Interestingly, the OA formed an anastomosis with the deep cervical artery, which is the branch of the costocervical trunk, in 27.3% of the cases (Figure 4). The deep cervical artery may have a variable origin, originating either from the costocervical trunk or directly from the subclavian artery [4, 5, 14]. Nevertheless, these results show that the OA can form anastomoses between both the vertebral but also the subclavian systems. Our results show a higher prevalence of the OA-VA anastomoses than what Schechter presented [16], possibly because of the advancements in angiographic imaging. Alvernia et al. presented a much higher frequency of the occurrence of the anastomotic channels, however, the said study was a microanatomical one, and the small vessel caliber of the vessels forming the anastomosis would not be visible on CTA [2]. Their small size can also raise questions about whether these microscopical anastomoses are as clinically significant as the ones that are well visible on CTA.

The OA-VA anastomotic channels are important to take into consideration because they can provide an additional route for the delivery of thrombolytic drugs in extreme cases of occlusive disease [2, 9]. Alvernia et al. discussed a case where a patient with bilaterally occluded vertebral arteries and acute basilar artery syndrome could be treated because of the presence of the OA-VA anastomosis [2]. Re-establishment of flow through the basilar artery was possible due to subselective catheterization of the OA, which reconstituted the VA that it formed an anastomosis with. Subsequently, the thrombolytic agent could be delivered through the VA to the occluded basilar artery [2].

The importance of the OA-VA anastomosis was also highlighted by Milnerowicz et al. in a case study about a 20-year-old patient who underwent adenotonsillectomy [11]. The procedure itself went uncomplicated, however, the patient developed three episodes of significant bleeding from the left tonsillar bed. Therefore, the external carotid artery was ligated and the procedure had no complications. However, the patient came back with the same problem of recurrent bleeding. Selective arteriography of the left VA was performed and showed the presence of an OA-VA anastomosis with retrograde flow from the VA to the external carotid artery segment above the ligation. The trunk of the external carotid artery was then embolized through the anastomosis. Unfortunately, the patient became lethargic the next day. Subsequently, a head CT was performed and showed a hypodense area in the right thalamus corresponding to an ischemic stroke.

Furthermore, Takeuchi et. al stated that in patients who underwent external carotid artery ligation, the main collateral pathways to the external carotid artery were from the VA via the OA-VA anastomosis [18].

The morphological aspects of the OA were also analyzed in the present study. This knowledge can be of great use in procedures associated with this artery, such as the occipital artery-posterior inferior cerebellar artery (OA-PICA) bypass. The OA has been proven to be a reliable vessel for revascularization procedures of the posterior cranial fossa because of its satisfactory length, caliber match, and close proximity to the intracranial arteries in that region. The present study shows that the mean diameter of the OA at its origin was 4.90 mm in females and 4.82 mm in males. These results are considerably higher than the results of other studies concerning this topic [2, 7, 8, 10]. The data presented in the current meta-analysis can also be of great use when performing reconstructive flaps. Scalp defects in the temporal and parietal regions are usually repaired using island flaps which are normally supplied by the superficial temporal vessels [19]. Knowledge about the anatomy of the OA might also come in handy when performing the OA fascial flap for ear reconstruction [1, 6, 15].

Furthermore, the OA provides significant blood supply to the dura of the posterior fossa through transosseous and transforaminal branches. In the present study, we referred to them as the meningeal branch (present in 10.2% of the cases) and the mastoid branch (present in 4.5% of the cases). These branches provide vascularity to the wall of the venous sinuses in this region. The presence of the said branches would explain why the OA is a usual feeding artery of dural arteriovenous fistulas.

The present study undoubtedly has some limitations. Although the size of the study group used in the current paper is the largest among imaging studies concerning the morphology of the OA and the OA-VA anastomosis, larger population-based research is still warranted to discern the true prevalence of its variants. Additionally, radiological imaging only allows one to evaluate hemodynamically efficient arteries. Therefore, this can be a relatively big source of bias when assessing anatomical variations of the OA, and other arterial entities.

CONCLUSIONS

In this study, the morphometric properties and variations of the OA were presented. Furthermore, the anastomotic channels between the OA and the VA were analyzed and their potential clinical implications were discussed. Knowledge about the anatomy of the OA-VA anastomosis might be of immense importance to avoid potentially fatal complications during embolization of the OA and its branches.

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Conflict of interest: None declared

Abberviations List: OA - Occipital Artery; VA - Vertebral Artery; LSCMB - Lower Sternocleidomastoid Branch; USCMB - Upper Sternocleidomastoid Branch; MEB - Meningeal Branch; MAB - Mastoid Branch; AB - Auricular Branch; DB - Descending Branch

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Table 1. Qualitative results of the data analysis.

Category	N	Percentage

Patients' Sex		
Female	32	36.4%
Male	56	63.6%
Initial direction of the Occipital Artery		
Superior	32	76.2%
Posterior	8	19.0%
Interior	1	2.4%
Anterior	1	2.4%
Presence of the Lower Sternocleidomastoid branch		
Absent	77	87.5%
Present	11	12.5%
Presence of the Upper Sternocleidomastoid branch		
Absent	76	86.4%
Present	12	13.6%
Presence of the Meningeal branch		
Absent	79	89.8%
Present	9	10.2%
Presence of the Mastoid branch		
Absent	84	95.5%
Present	4	4.5%
Presence of the Auricular branch		
Absent	82	93.2%
Present	6	6.8%
Presence of the Descending branch		
Absent	44	50.0%
Present	44	50.0%
Presence of an Anastomosis		
Absent	77	87.5%
Present	11	12.5%
Type of an Anastomosis		
Descending branch of the occipital artery with vertebral artery	5	45.5%
Upper sternocleidomastoid branch of the occipital artery with vertebral artery	3	27.3%
Descending branch of the occipital artery with deep cervical artery	3	27.3%

Table 2. Results of the measurements.

Category	**Median**	**LQ**	**HQ**	**Minimum**	**Maximum**	**Mean**	**SD**
Overall results							
OA Maximal Diameter	4.85	4.11	5.53	2.69	9.32	4.86	1.07
VA Maximal Diameter	3.60	2.79	4.38	2.05	6.03	3.67	0.97
Distance between OA and LSCMB	21.73	10.40	28.65	5.95	31.61	20.24	9.02
Distance between OA and USCMB	30.29	24.15	39.48	12.10	49.16	31.37	11.13

Distance between OA and MeB	60.84	53.23	67.62	32.93	78.73	60.15	13.00
Distance between OA and MaB	34.88	21.30	52.51	16.75	61.12	36.91	19.70
Distance between OA and AB	18.02	17.37	21.49	10.40	26.60	18.65	5.33
Distance between OA and the DB	55.16	48.59	59.96	24.22	88.89	55.01	11.92
Distance between OA and its first anastomosis	51.15	37.20	60.10	35.78	63.70	50.74	10.32

LQ — lower quartile; HQ — higher quartile; SD — standard deviation; OA — occipital artery; VA — vertebral artery; LSCMB — lower sternocleidomastoid branch; USCMB — upper sternocleidomastoid branch; MEB — meningeal branch; MAB — mastoid branch; AB — auricular branch; DB — descending branch

Table 3. Results of the measurements regarding sex

Category	**Sex**	**Median**	**LQ**	**HQ**	**Minimum**	**Maximum**	**Mean**	**SD**	**p-Value**
OA Maximal Diameter	Females	4.90	3.79	5.65	2.69	9.32	4.94	1.41	0.91
	Males	4.82	4.13	5.47	3.19	6.48	4.82	0.83	
VA Maximal Diameter	Females	3.74	2.67	4.43	2.05	6.03	3.75	1.19	0.98
	Males	3.58	2.93	4.38	2.32	5.67	3.63	0.82	
OA Length	Females	75.81	69.75	82.60	45.86	96.56	75.63	11.39	0.26
	Males	70.52	64.02	85.38	45.36	95.42	72.92	13.09	
Distance between OA and LSCMB	Females	29.23	21.73	31.61	21.73	31.61	27.52	5.16	0.08
	Males	17.07	10.22	25.46	5.95	28.65	17.51	8.79	
Distance between OA and USCMB	Females	32.06	28.09	49.16	28.09	49.16	36.44	11.20	0.48
	Males	28.52	21.26	37.32	12.10	45.70	29.68	11.23	

Distance between OA and MeB	Females	63.08	56.80	72.03	52.75	78.73	64.41	10.87	0.73
	Males	60.84	53.23	67.62	32.93	69.11	56.75	14.73	
Distance between OA and MaB	Females	61.12	61.12	61.12	61.12	61.12	61.12	—	—
	Males	25.85	16.75	43.90	16.75	43.90	28.83	13.82	
Distance between OA and AB	Females	—	—	—	—	—	—	—	—
	Males	18.02	17.37	21.49	10.40	26.60	18.65	5.33	
Distance between OA and the DB	Females	57.15	51.81	61.22	46.64	88.89	59.57	11.99	0.18
	Males	54.89	44.76	57.90	24.22	81.41	52.88	11.46	
Distance between OA and its first anastomosis	Females	54.51	51.01	60.79	50.87	63.70	55.90	6.13	0.32
	Males	48.76	36.81	60.10	35.78	62.96	47.79	11.44	

LQ — lower quartile; HQ — higher quartile; SD — standard deviation; OA — occipital artery; VA — vertebral artery; LSCMB — lower sternocleidomastoid branch; USCMB — upper sternocleidomastoid branch; MEB — meningeal branch; MAB — mastoid branch; AB — auricular branch; DB — descending branch

Category	Age	OA Maximal Diameter	VA Maximal Diameter	OA Length	Distance between OA and LSCMB	Distance between OA and USCMB	Distance between OA and MeB	Distance between OA and MaB	Distance between OA and AB	Distance between OA and the DB	Distance between OA and its first anastomosis
Age	1.00	-0.21	0.15	-0.07	0.09	-0.54	-0.38	-0.40	-0.03	0.01	-0.48
OA Maximal Diameter	-0.21	1.00	0.10	0.02	0.16	0.18	0.01	0.60	-0.31	-0.08	0.24
VA Maximal Diameter	0.15	0.10	1.00	0.04	-0.18	0.16	-0.61	-0.40	-0.20	-0.07	0.32
OA Length	-0.07	0.02	0.04	1.00	0.16	0.59	0.90	0.80	0.80	0.75	0.58
Distance between OA and LSCMB	0.09	0.16	-0.18	0.16	1.00					0.30	
Distance between OA and USCMB	-0.54	0.18	0.16	0.59		1.00				0.88	
Distance between OA and MeB	-0.38	0.01	-0.61	0.90			1.00			0.50	
Distance between OA and MaB	-0.40	0.60	-0.40	0.80				1.00			
Distance between OA and AB	-0.03	-0.31	-0.20	0.80					1.00	0.40	
Distance between OA and the DB	0.01	-0.08	-0.07	0.75	0.30	0.88	0.50		0.40	1.00	
Distance between OA and its first anastomosis	-0.48	0.24	0.32	0.58							1.00

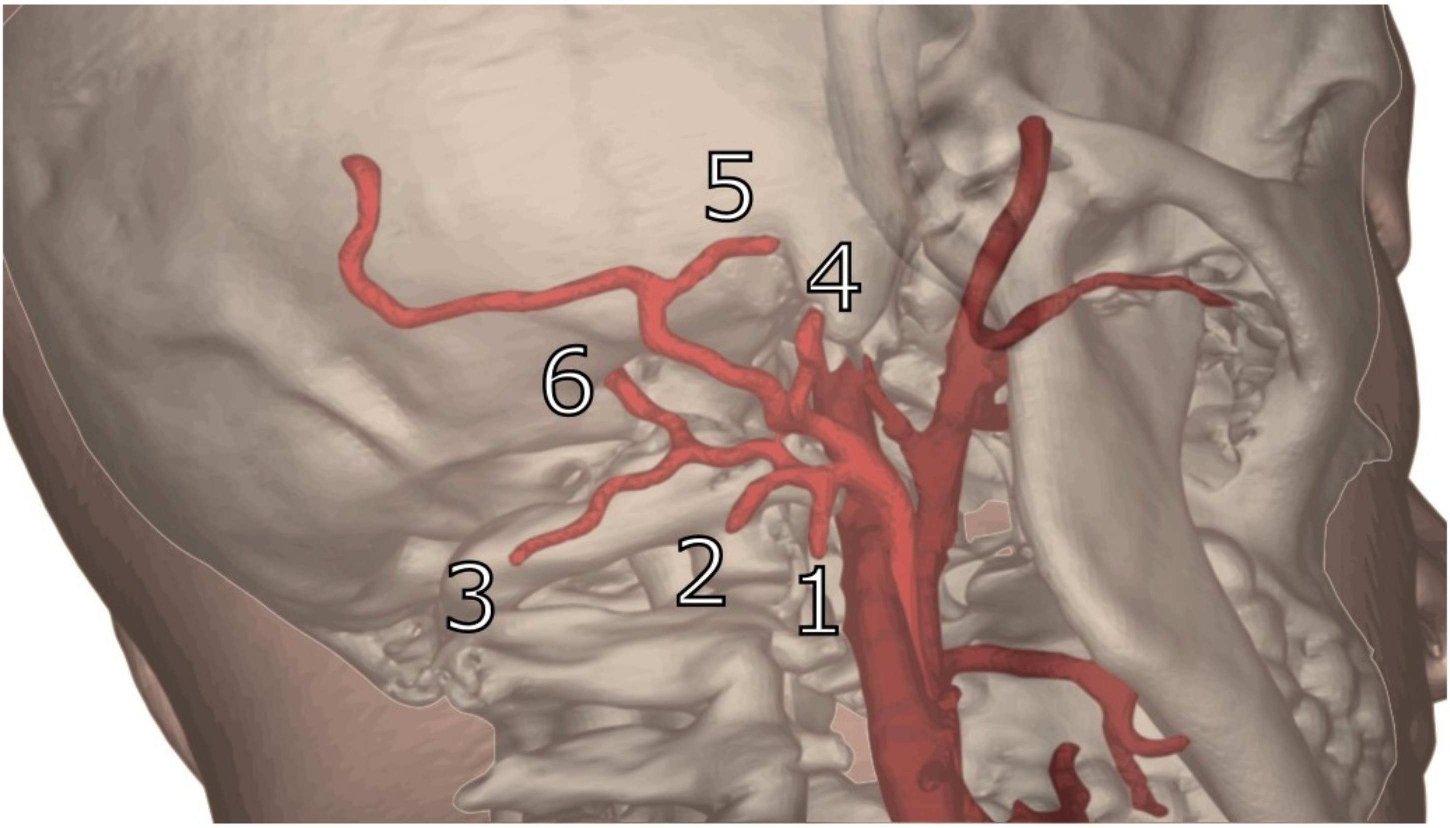
Table 4. Table gathers the R values obtained in the correlation analysis between categories. Highlighted in red are those in which the p value was smaller than 0.05; OA — occipital artery; VA — vertebral artery; LSCMB — lower sternocleidomastoid branch; USCMB — upper sternocleidomastoid branch; MEB — meningeal branch; MAB — mastoid branch; AB — auricular branch; DB — descending branch.

Figure 1. Occipital artery and its branches.

Figure 2. Sample anastomosis of the occipital artery.

Figure 3. Heat maps of the occurrence of the anastomosis of the occipital artery.

Figure 4. Three types of occipital-verterbral arterial anastomosis; OA — occipital artery; ECA — external carotid artery; USCMB — upper sternocleidomastoid branch; DB — descending branch; AB — auricular branch; MaB — mastoid branch; MeB — meningeal branch; DCA — deep cervical artery.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4
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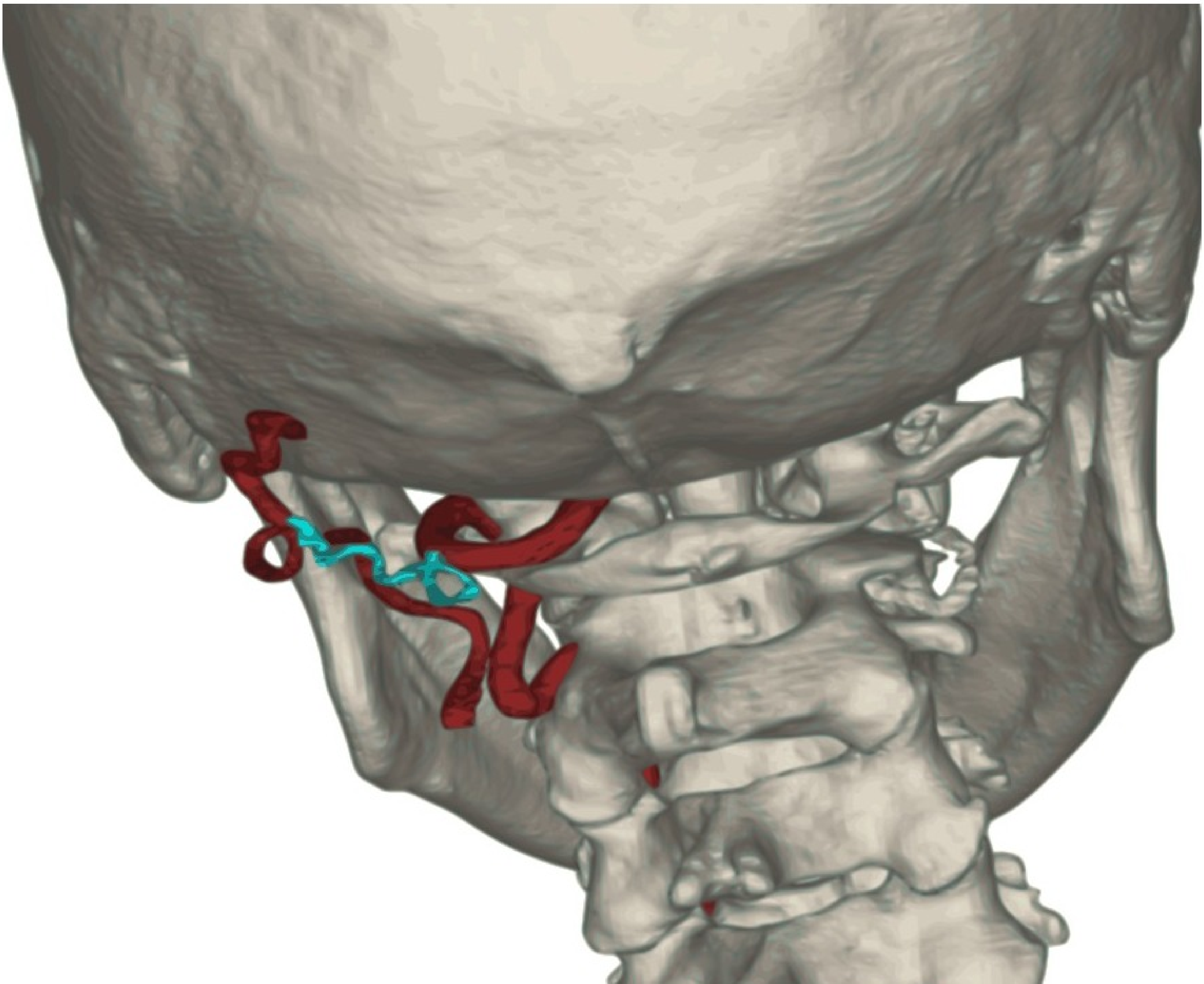

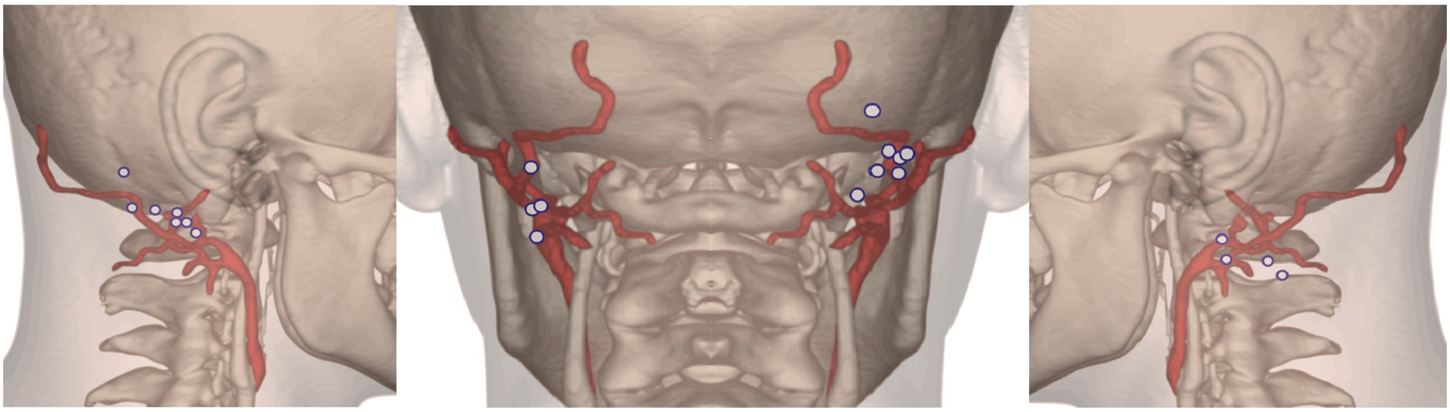

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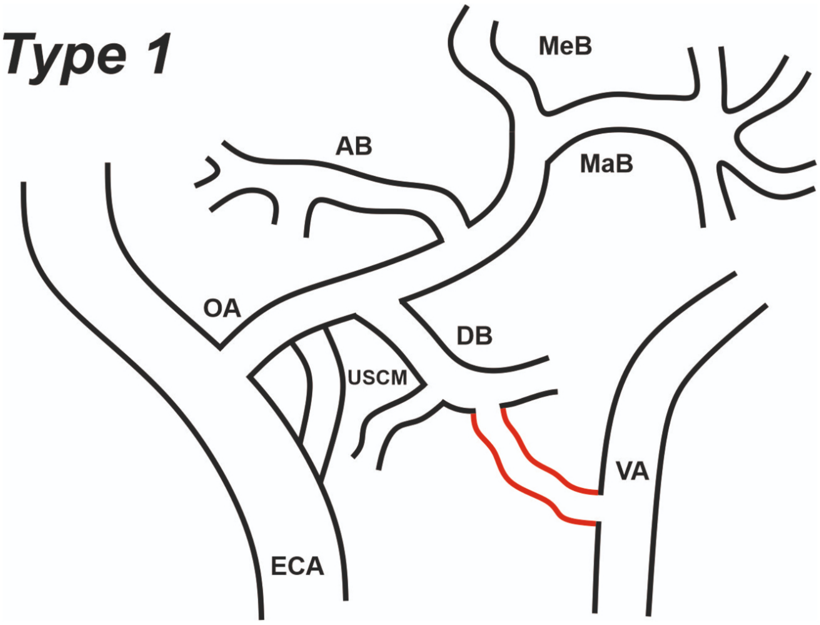

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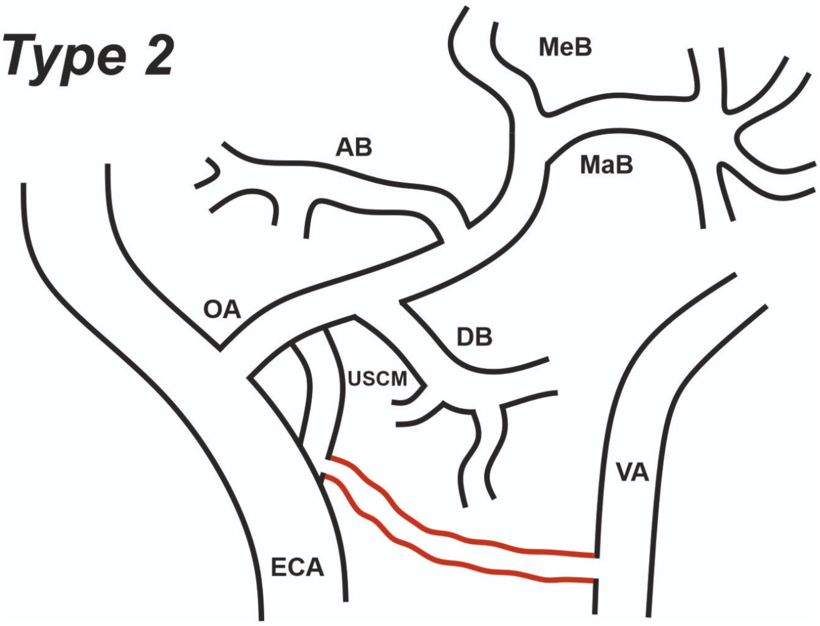

Type 3