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Magnetic Resonance Angiographic Study of the Anatomical Variations of the Anterior Communicating Artery Complex in a Turkish Population

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ABSTRACT

AIM: To provide a definition of arterial anomalies in the anterior communicating artery complex (ACoAC), determine their prevalence and investigate their relationship with aneurysms.

MATERIAL and METHODS: The three-dimensional time-of-flight magnetic resonance angiography images of 1,857 adult patients who presented to our hospital between January 2020 and September 2022 were evaluated retrospectively. The images of 1,537 cases were subsequently classified according to their ACoAC anatomical variants. The patients were further grouped as those with no pathology, those with ACoAC aneurysms and those with pathologies other than ACoAC, and the relationship between the ACoAC anatomical variants of each group was investigated using statistical methods. Rare variants such as trifurcations of the A2 segments, single A2 segments, fenestrations of the A1 segment and double AComAs were evaluated in separate groups.

RESULTS: The results of the classification of the 1,537 cases revealed the classical anatomical variant in 39.2% of the cases without ACoAC pathologies and 53.3% of the cases with ACoAC aneurysms. There was no significant difference between the sexes in terms of variant distribution (p=0.09), and no significant relationship between the presence of ACoAC aneurysms and sex (p=0.5).

CONCLUSION: ACoAC anatomical variants of the cerebral arterial system were detected in 60% of the cases. The most common anterior circulation (AC) vascular variants (VV) were A1 segment hypoplasia and aplasia. No clear relationship was found between intracranial aneurysms and anatomical variation.

KEYWORDS: Anterior cerebral artery, Anterior communicating artery, Vascular variation, Aneurysm, Magnetic resonance imaging

INTRODUCTION

The cerebral arterial circulation system (CACS) is an anastomosis located at the base of the brain, and is known as the Circle of Willis. The CACS configuration is not symmetrical in 54.8% of the general population (10), although CACS variations, especially those of the polygon of Willis, are very common (18). The most common variations are hypoplastic and absent arteries or the presence of multiple arteries (18). Different variations to the original anatomical morphology have been identified in cadaver studies, and defined as the persistence of an embryonic pattern (10). Advances in imaging techniques have led to the more frequent identification of normal variations and abnormalities in cerebral arteries (18).

Several classification systems have been devised to describe the anterior communicating artery complex (ACoAC) in the anatomical variants of CACS. The ACoAC comprises an anterior communicating artery (AComA) and two anterior cerebral arteries (ACAs), which in turn consist of an A1 segment (A1S) (from the internal carotid artery (ICA) to the AComA), an A2 segment (A2S) (extending from the AComA), and an A3, or pericallosal, segment (18). These variations typically include AC, which is the most common location of intracranial aneurysms (IA) (14). Variants are not abnormalities, but should

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rather be considered as anatomical variations (AV). There are marked differences in the distribution of variants between different populations (5). It has been reported that differences in familial and sexual tendencies, as well as between ethnic and racial groups, may be effective in variations (10).

Some anatomical variants pave the way for the development of IA in AC (5). The AV of CACS have been reported to be associated with such cerebrovascular diseases as ischemic stroke and decreased calibration of the ipsilateral ICA (10) and their radiological identification is of clinical importance in terms of occlusive events and treatment planning (11).

The present study provides a description of arterial anomalies, and investigates the prevalence of ACoAC in a Turkish population. After depicted depicting the variations radiologically, whether any of the detected variants are associated with aneurysms or any other pathology is investigated.

MATERIAL and METHODS

This study was conducted according to the ethical standards of the institutional review board (Ankara Diskapı Yıldırım Beyazıt Educational and Research Hospital, 06.06.2022/139/35).

The anatomical variations in ACoAC were investigated from three-dimensional time-of-flight magnetic resonance angiographies (3D-TOF-MRA), and classified based on the most common anterior circulation variants (Figure 1) (5).

All the patients were evaluated with a 1.5 T magnetic resonance device (Philips Achieva; Philips Healthcare, Amsterdam, The Netherlands). The patients were scanned in the supine position with a multi-channel high-density neurovascular coil. Compressed reformatted MRA images were examined in the transverse plane after obtaining routine 3D-TOF sequences using the SPGR method using the following parameters: repetition/echo time, 25/6.9 ms; flip angle, 20°; number of excitations, 1; field of view, 160; matrix, 400x229; and section thickness, 1.6 mm, and the resulting imaging data were transferred to a Philips workstation. Multi-planar volume reconstruction images were obtained in the coronal plane from the raw image sections using the maximum intensity projection technique.

The images of 1,857 patients who underwent a 3D-TOF brain MRA in the radiology clinic between January 2020 and September 2022 were evaluated retrospectively and randomly using the hospital Picture Archiving and Communication System (PACS). Excluded from the study were 225 patients due to poor imaging quality (n=35), aged over 65 years (n=178), artifacts preventing imaging analysis (n=6) (history of brain tumor, trauma or surgery), cerebral arterial circulation preventing the classification of ACoAC variants, and vascular anomalies (n=6). A further 95 patients with rare abnormalities (double AComA, trifurcation of the A2 segment, fenestration of the A1 segment and single A2) that were not defined in the applied classification were grouped separately. The study was thus conducted with a total of 1,537 patients aged between 18 and 65 years who met the classification criteria, whose anatomical variants were subsequently classified and numbered 1–7 (Figure 2). All the 3D-TOF brain MRA scans included in the study were evaluated independently by two neuroradiologists with 10 years of experience.

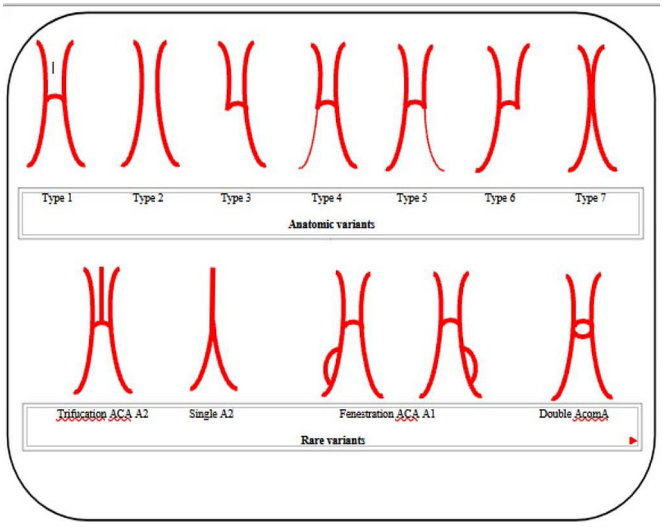

Figure 1: Schematic drawing of ACoAC anatomical variants: type 1, typical configuration; type 2, aplastic AComA; type 3, right A1 aplasia; type 4, right A1 hypoplasia; type 5, left A1 hypoplasia; type 6, left A1 aplasia; type 7, the common body of ACA with an X-shaped or no AComA; and rare anomalies not classified among these variants (trifurcation of ACA A2, single A2, fenestration of ACA A1, and double AComA).

The patients were divided into three groups: Group 1 with no ACoAC pathology, Group 2 with ACoAC aneurysms, and Group 3 with any non-ACoAC vascular pathology affecting cerebral arterial circulation, such as stenosis of the carotid artery.

Statistical Analysis

All the data analyses were performed using IBM SPSS Statistics (Version 24.0. Armonk, NY: IBM Corp.). The data distribution was tested for normality with a Shapiro-Wilk test. Continuous variables were presented as mean±standard deviation with range (minimum-maximum) values, while categorical variables were reported as percentages and frequencies. The prevalence of each variant was compared between sexes using Fisher's exact test. A p value of <0.05 was considered statistically significant.

RESULTS

A total of 1,537 patients were included in the study, of which 901 (58.6%) were female and 636 (41.4%) were male. There were 95 cases with rare abnormalities, including trifurcation of the A2 segment (n=61), single A2 (n=21), fenestration of the A1 segment (n=8) and double AComA (n=5) (Figure 3). Group 1 contained 1,464 patients; Group 2, 15 patients; and Group 3, 58 patients. The most common variant in all groups was Type 1 (Table I).

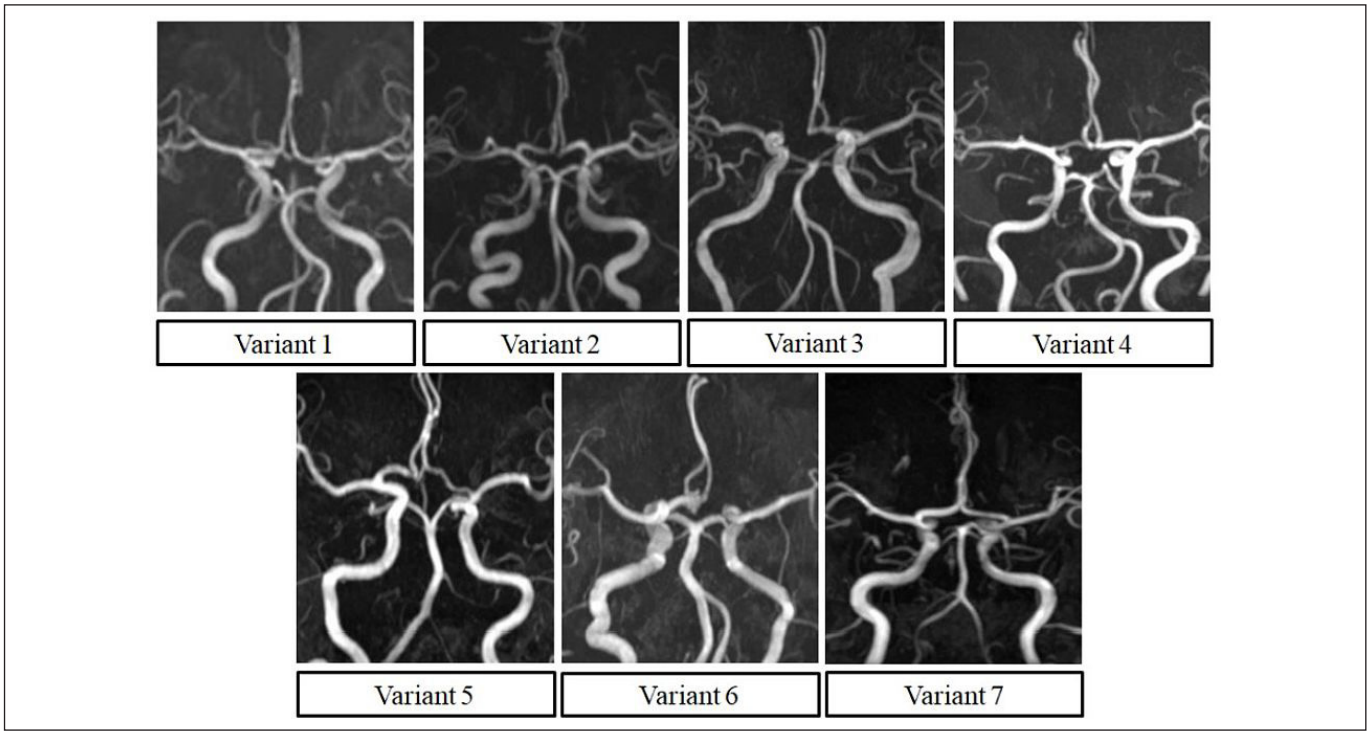

Figure 2: Anatomical variants of ACoAC classified according to types 1-7 on time-of-flight magnetic resonance images.

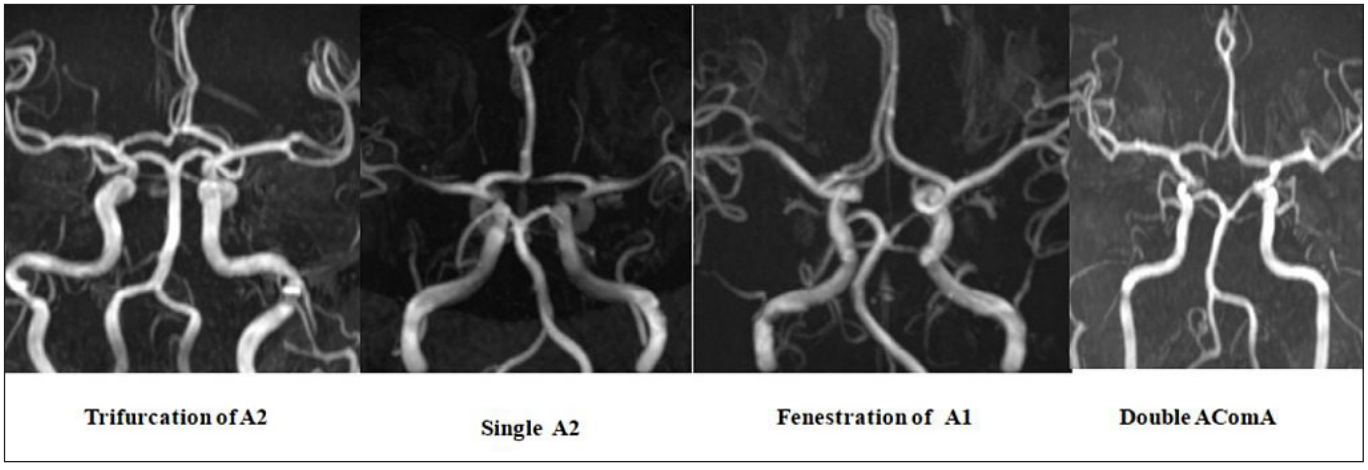

Figure 3: Time-of-flight magnetic resonance image of the of other rare variants.

The aneurysms detected in Group 2 were as follows: AComA (n=10), right ACA A1 (n=1), right ACA A2 (n=1), left ACA A2 (n=1), right ACA A3 (n=1) and left ACA A3 (n=1) (Table II). Six (1.65%) aneurysms were detected in 364 patients with asymmetric precommunicating A1 variants (variants 3 to 6). Aneurysms were detected in nine (0.77%) of the 1,173 cases with symmetric variants (variants 1, 2, and 7) (Figure 4). The rates of all variants other than type 3 were statistically significantly higher in Group 1 than in the other groups, which was attributed to the higher number of patients in Group 1. Although there was a higher rate of variant 1 in Group 2 compared to Group 1, the difference was not statistically significant (SD) (Table III).

No SD was found between the sexes in terms of the distribution of variants (p=0.13), and there was no significant relationship between the presence of ACoAC aneurysms and sex in Group 2 (p=0.5).

DISCUSSION

In this retrospective study, arterial anatomical variations, their prevalence and the presence of other rare anatomical variations of ACoAC were defined in 1,857 patients using 3D-TOF-MRA.

Table I: Distribution of ACoAC Variants among the Three Groups

	Total (n)	Group 1 (n)	Group 2 (n)	Group 3 (n)
Type 1 variant	613	574	8	31
Type 2 variant	350	340	1	9
Type 3 variant	73	68	1	4
Type 4 variant	161	156	1	4
Type 5 variant	90	85	2	3
Type 6 variant	40	35	2	3
Type 7 variant	210	206	0	4
Total	1,537	1,464	15	58

ACoAC: *anterior communicating artery complex;* ***Group 1:*** *no ACoAC pathology;* ***Group 2:*** *ACoAC aneurysms;* ***Group 3:*** *non-ACoAC vascular pathology.*

Table II: Localization and Variant Distribution of ACoAC Aneurysms

ACoAC aneurysms	n (%) 15 (0.9%)
AComA	**10 (0.6)**
Type 1 variant	6
Type 3 variant	1
Type 5 variant	1
Type 6 variant	2
AComA	**5 (0.3 %)**
Right ACA A1 (type 4 variant)	1
Right ACA A2 (type 5 variant)	1
Left ACA A2 (type 1 variant)	1
Right ACA A3 (type 1 variant)	1
Left ACA A3 (type 2 variant)	1

ACoAC: *Anterior communicating artery complex;* ***ACA:*** *anterior cerebral artery;* ***AComA:*** *anterior communicating artery.*

Comparisons of different studies are difficult given the lack of a standardized classification approach to ACoAC variants. Following on from the common approach in literature (5), we used a classification that disregarded such rare variants as triple A2 segments, A1 or A2 segment fenestrations, infraoptic ACAs and precommunicating ACAs originating from the ophthalmic artery, and grouped the patients with these rare variants separately. MRA is a non-invasive and easily applied approach in patients without cerebrovascular diseases, and the patients included in the present study were all healthy individuals that were detected incidentally with aneurysms.

Absence or hypoplasia of the A1 segment (H-A1S) is one of the best-known variations of ACoAC. H-A1S is the most common variation of ACA, accounting for 9–31.2% of all cases in literature (4,12-14). In autopsy studies, H-A1S has been reported at a rate of 10%, and agenesis of the ACA A1S at a rate of 1–2% (4). In a study based on the results of computed tomography angiography (CTA), the rates of A1 segment hypoplasia and agenesis were determined as 7.25%

Table III: Rates of Each ACoAC Variant in Study Groups

	Total (%)	G1 (%)	G2 (%)	G3 (%)	p (G1 vs G2)	p (G1 vs G3)	p (G2 vs G3)
Type 1 (n=613)	39.9	39.2	53.3	53.4	**<0.001**	**<0.001**	1
Type 2 (n=350)	22.8	23.2	6.7	15.5	**0.029**	**<0.001**	1
Type 3 (n=73)	4.7	4.6	6.7	6.9	0.068	**<0.001**	1
Type 4 (n=161)	10.5	10.7	6.7	6.9	**0.031**	**<0.001**	1
Type 5 (n=90)	5.9	5.8	13.3	5.2	**0.002**	**<0.001**	1
Type 6 (n=40)	2.6	2.4	13.3	5.2	**0.013**	**0.001**	1
Type 7 (n=210)	13.7	14.1	0	6.9	0	**<0.001**	0
Total (n=1,537)							

Fischer's exact test. ***ACoAC:*** *Anterior communicating artery complex;* ***G1:*** *no ACoAC pathology;* ***G2:*** *ACoAC aneurysms;* ***G3:*** *non-ACoAC vascular pathology.*

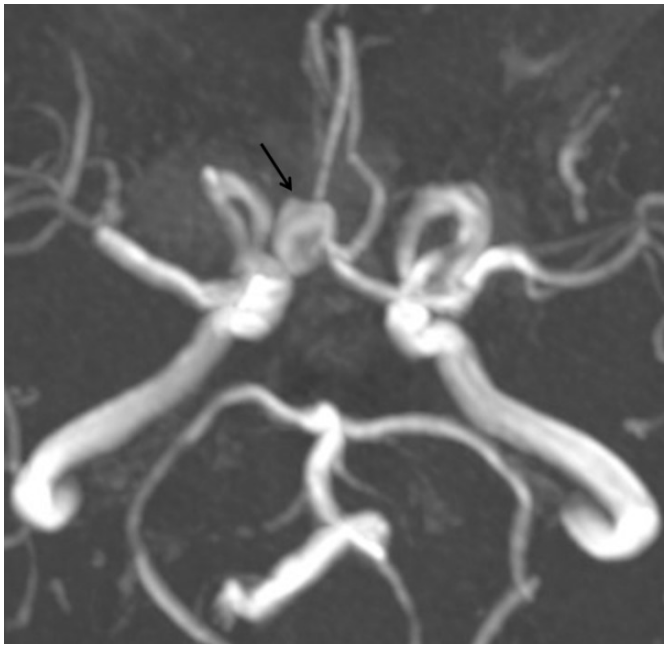

Figure 4: Time-of-flight magnetic resonance image of the most common variant (type 1) with an AComA aneurysm (black arrow).

and 4.59%, respectively (12). In the present study, (H-A1S) was identified in 16.30% of the patients and A1 segment agenesis in a further 7.35%. In literature, the prevalence of A1S fenestration has been reported to vary between 0 and 4% (7,12,13), which concurs with the findings of the present study (0.5%). A1 segment hypoplasia and agenesis are frequently associated with AComA aneurysms (15). In the absence or hypoplasia of the A1 segment, the contralateral ACA may supply some or all of the normal ACA irrigation through a large AComA (4), although in the presence of thromboembolic events, the risk of ischemia increases due to low collateral blood supply in these variants (2).

Some ACoAC variants may be associated with anomalies such as aneurysms. In a similar study in literature, variant 5 (left H-A1S) was identified at a higher rate in the group with ACoAC aneurysms than in the group without aneurysms (5). The authors reported that most of the aneurysms presented with ACoAC asymmetry (variants 3 to 6) (5), and an incidence of aneurysms of 3.4% in asymmetric precommunicating A1 variants (variants 3 to 6) and of 0.63% in symmetric variants (variants 1 and 2) (5). In the present study, aneurysms were detected at a rate of 1.65% in asymmetric precommunicating A1 variants and of 0.77% in symmetric variants. In the group with ACoAC aneurysms, however, variant 1 was found at a significantly higher rate, which was attributed to ethnic and racial differences.

In a previous study, A1 hypoplasia was reported in 16.7% of patients with complicated or uncomplicated aneurysms (2), while in another study, hypoplasia was reported to be the most common variant, and bilateral in 31.2% of patients (5). In our study, although H-A1S was the most common variant, it had a lower rate (16.3%). Variants involving the hypoplasia of the A1 segment are risk factors for aneurysm formation (11), and this supports the theory that hemodynamic stress facilitates the development of aneurysms in patients with asymmetric A1 configurations (5).

A relationship has been identified between cerebral vascular variants and aneurysm formation (13). In a study evaluating the most common ACoAC variations in 128 cases of intracranial aneurysm, A1 hypoplasia was identified in 33 patients and A1 aplasia in 11 patients (17). In another study, AComA aneurysms were reported to be more prevalent in patients with variations in the A1 segment of ACAs (10). López-Sala et al. reported A1 segment hypoplasia to be the most common variant with a prevalence of 39.1% in patients with ACoAC aneurysms, but noted that although 60.9% of patients with ACoAC aneurysms had arterial variants, there was no statistically SD between patients with a normal vascular anatomy and those with variants (13). In another study, no significant difference in ACoAC vascular anatomy was reported between patients with and without cerebral aneurysms (19). In our study, we found no SD between the groups with and without ACoAC aneurysms in terms of the ACoAC variants.

Previous studies have reported that males have a more complete cerebral arterial circulation than women (12), while others indicate no SD in ACoAC between the sexes (5). In the present study, no SD was found in the distribution of variants according to the sexes.

Azygos ACA (AACA) is a vascular anomaly that is characterized by the formation of a single A2 segment in the midline as a result of the persistence of the embryonic median artery of the corpus callosum (CC). The dominant or bihemispheric A2 segment feeds both ACA irrigation areas, and a contralateral non-dominant hypoplastic A2 segment is observed (7, 11), and in both hemispheres, ACA is irrigated by a single A2 stem (4, 8). The reported frequency of the AACA variation varies between 0 and 10% (2). In the present study, the incidence of AACA variation was found to be 1.3%, which is consistent with literature. Occlusion of the dominant A2S may cause ischemia in both hemispheres (4). There is a relationship between this variant and aneurysm formation. AACA has greater blood flow than observed in a normal vascular irrigation area with an A2S on each side, leading to greater hemodynamic stress (HS), which is a predisposing factor for aneurysm formation (8). It has been suggested that arteries with aneurysms contain congenital defects in the tunica media, and that HS leads to the development and growth of aneurysms (2). In a previous study, the incidence of aneurysms in intracranial arteries was reported to be 12.28% in patients with AACA variations (2). The reported frequency of distal ACA aneurysms in AACA cases varies between 7.02 and 71% in different studies (2, 3, 6, 16). In our study, no aneurysm was observed in patients with AACA, which may be related to the limited number of cases, and this variation may be associated with arteriovenous malformations, some neuronal migration anomalies and holoprosencephaly (1). The vascular anomalies accompanying AACA have been identified as unilateral vertebral artery hypoplasia and H-A1S (2). Our cases were accompanied by vertebral artery hypoplasia and H-A1S on both sides, with no other additional anomalies detected in the brain.

The trifurcation of ACA or triple ACA refers to the presence of three A2s. The central or abnormal arterial branch originating from AComA is the median artery of the CC. The prevalence of ACA trifurcation is 2–13% (4). In the present study, this variation was seen at a rate of 3.7%.

Possible variants of AComA are absent, double, or fenestrated, and triple arteries (13). The absence of AComA is the most common atypical VV, with a reported incidence of 14% (9) and 19% (12). AComA agenesis was identified in 36.4% of the cases in the present study, although in literature the absolute absence of AComA has been reported to be lower, observed in 5% of surgical dissections (4). This discrepancy may be related to the misidentification of hypoplastic arteries as aplastic arteries due to the inability to visualize very small arteries in some studies (12).

Limitations

Our results were not confirmed by other imaging techniques or postmortem studies. CTA is often the first choice in patients presenting with an emergency ischemic or hemorrhagic stroke, and the rate of aneurysm detection is higher in this patient group. In our clinical practice, 3D-TOF-MRA is mostly routinely performed in outpatients, and aneurysms are detected incidentally. Based on the results of this study, therefore, we cannot definitively conclude that the presence of these variations is associated with an increased risk of stroke and necessitates imaging. To the best of our knowledge, however, this is by far the most comprehensive study to date evaluating ACoAC using 3D-TOF-MRA.

CONCLUSION

The typical ACoAC variant was detected in only 40% of the cases included in our study. We consider that the differences in the reported ACoAC variant rates are associated with ethnic differences. The most common AC vascular variants were H-A1S and aplasia of A1S. No clear relationship was identified between IA and AV in the present study.

AUTHORSHIP CONTRIBUTION

Study conception and design: HK

Data collection: HK, EKO

Analysis and interpretation of results: HK

Draft manuscript preparation: HK

Critical revision of the article: EKO

Other (study supervision, fundings, materials, etc...): HK

All authors (HK, EKO) reviewed the results and approved the final version of the manuscript.

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