



DOI: 10.5137/1019-5149.JTN.17839-16.1

Received: 01.04.2016 / Accepted: 25.05.2016

Published Online: 22.08.2016

Original Investigation

# Vascular Variations Associated with Intracranial Aneurysms

Metin ORAKDOGEN<sup>1</sup>, Selin TURAL EMON<sup>1</sup>, Hakan SOMAY<sup>1</sup>, Taner ENGIN<sup>1</sup>, Merih IS<sup>1</sup>, Tayfun HAKAN<sup>2,3</sup>

<sup>1</sup>Haydarpasa Numune Teaching and Research Hospital, Neurosurgery Clinic, Istanbul, Turkey

<sup>2</sup>Kolan International Hospital, Neurosurgery Clinic, Istanbul, Turkey

<sup>3</sup>Okan University, Vocational School of Health Services, Istanbul, Turkey

Parts of this study were presented in abstract/oral presentation form at the 29<sup>th</sup> Annual Scientific Congress of Turkish Neurosurgical Society, Antalya, Turkey, April, 17-21, 2015.

## ABSTRACT

**AIM:** To investigate the vascular variations in patients with intracranial aneurysm in circle of Willis.

**MATERIAL and METHODS:** We used the data on 128 consecutive intracranial aneurysm cases. Cerebral angiography images were analyzed retrospectively. Arteries were grouped as anterior cerebral arterial system (ACS), posterior cerebral arterial system (PCS) and middle cerebral arterial system (MCS) for grouping vascular variations. Lateralization, being single/multiple, gender; and also any connection with accompanying aneurysms' number, localization, dimension, whether bleeding/incidental aneurysm has been inspected.

**RESULTS:** Variations were demonstrated in 57.8% of the cases. The most common variation was A1 variation (34.4%). The rate of variations was 36.7%, 24.2% and 10.2% respectively in ACS, PCS and MCS. MCS variations were significantly higher in males. Anterior communicating artery (ACoA) aneurysm observance rates were significantly higher and posterior communicating artery (PCoA) aneurysm and middle cerebral artery (MCA) aneurysm observance rates were significantly lower when compared to 'no ACS variation detected' cases. In 'PCS variation detected' cases, PCoA aneurysm observance rates and coexistence of multiple variations were significantly higher.

**CONCLUSION:** The rate of vascular variations in patients with aneurysms was 57.8%. Arterial hypoplasia and aplasia were the most common variations. ACS was the most common region that variations were located in; they were mostly detected on the right side. Coexistence of ACoA aneurysm was higher than PCoA and MCA aneurysms. In the PCS variations group, PCoA aneurysms were the most common aneurysms that accompanying the variation and multiple variations were more common than in the other two groups. The variations in MCS were most common in males.

**KEYWORDS:** Aplasia, Cerebral aneurysm, Vascular variation, Circle of Willis, Hypoplasia, Microsurgical anatomy

## INTRODUCTION

The carotid and vertebrobasilar systems are connected to each other by a polygonal anastomosis channel system that is called 'circulus arteriosus' at the base of the brain. Although Thomas Willis made the first attempt to attribute a function to this anatomy that he described in 1664; his description of the brain became accepted as definitive, appearing in the *Bibliotheca Anatomica* of 1774-1777 for

the first time as the famous 'circle of Willis' in the eighteenth century (25).

Classically, a symmetrical and complete Willis pattern accounts for only 30-50% of individuals in the population (1,8,10,27). The arteries constituting it may show different variations depending on their hypoplasia, aplasia and fenestration, duplication, trifurcation. These variations may play a considerable role in the development of an aneurysm,



Corresponding author: Tayfun HAKAN

E-mail: tayfunhakan@yahoo.com

arteriovenous malformation or cerebrovascular occlusive disease by changing the blood-flow pattern and increasing hemodynamic stress (3,4,7,12,13,15,23,26,29). There are some reports that have investigated the relationship between variations and aneurysm localization in cadaveric (12,20,28) and clinical studies (14,18,22,31).

The aim of this study was to reveal the normal pattern and variation rates in a series of patients operated for intracranial aneurysms and show these variations' gender, localization, lateralization, multiplicity features besides their relationship with aneurysms in several locations, whether bleeding or incidentally diagnosed.

## ■ MATERIAL and METHODS

The study was carried out in a total of 128 consecutive aneurysm cases operated at Haydarpaşa Numune Teaching and Research Hospital between the years 2008 and 2014. Cerebral digital subtraction angiography (DSA) images of each patient and the detailed reports written by neuroradiologists were analyzed retrospectively by two neurosurgeons who practiced neurovascular surgery.

Associated vascular variations of the anterior cerebral, posterior cerebral and middle cerebral arterial system were grouped and studied morphologically:

- 1) Anterior cerebral artery (ACA) and its branches were assumed as the anterior cerebral arterial system (ACS)
- 2) Vertebral artery and its branches were assumed as the posterior cerebral arterial system (PCS)
- 3) Middle cerebral artery (MCA) and its branches were assumed as the middle cerebral arterial system (MCS).

Vascular variations such as hypoplasia, aplasia (absence), duplication, fenestration, trifurcation were noted and lateralization, single or multiple, gender associations and number of aneurysms, localization, diameter, incidental or bleeding aneurysm coexistence with these vascular variations were searched for.

A variation of the circle of Willis was regarded as congenital abnormalities (5,22). Arteries with external diameter less than 1 mm and communicating arteries smaller than 0.5 mm were accepted as "hypoplastic" and the absence of the artery as "aplastic" (1,6,20,28). The posterior cerebral artery (PCA) segment of Willis polygon was defined as "fetal type" and "adult type" according to its size.

When visualized P1 on DSA had smaller size than ipsilateral posterior communicating artery (PCoA) or totally absent, it was accepted as fetal-type origin of PCA; and a P1 segment had the same size as or larger size than PCoA was defined as adult type origin of PCA (15).

### Statistical Analyses

The Number Cruncher Statistical System (NCSS) 2007 & Power Analysis and Sample Size (PASS) 2008 Statistical Software (Utah, USA) programs have been used for statistical analysis. The Mann-Whitney U test was used for descriptive

statistical methods (Mean, Standard Deviation, Median, Frequency, Rate, Minimum, Maximum) and in comparing quantitative data that did not show a normal range/distribution. The Pearson Chi-Square test, Fisher's Exact test and Yates Continuity Correction test (Yates corrected Chi-Square) were used for comparing qualitative data. Significance at a level of  $p < 0.01$  and  $p < 0.05$  was obtained.

## ■ RESULTS

The study was carried out on a total of 128 consecutive patients with intracranial aneurysms. The numbers of incidental and bleeding cases were 17.2% ( $n=22$ ) and 82.8% ( $n=106$ ), respectively. The patients included 55 (43%) men and 73 (57%) women who ranged in age from 16 to 81 years (mean= $52.35 \pm 12.38$  years). Among all cases, 95 (74.2%) had single aneurysm and 33 (25.8%) had multiple aneurysms.

Vascular variations were demonstrated in 57.8% ( $n=74$ ) of the cases. Variations were single in 40.6% ( $n=52$ ) of the cases. There were 2 variations in 18 cases and 3 variations in 4 cases.

### Gender

The differences between variation observance rates ( $p=0.426$ ;  $p > 0.05$ ) and variation number rates ( $p=0.083$ ;  $p > 0.05$ ) by gender were not statistically significant. However, MCS variation observance rates were significantly higher in males than females ( $p=0.031$ ;  $p < 0.05$ ) (Table I).

### ACS Variations

ACS variation was the most frequent occurrence for 36.7% ( $n=47$ ) of the cases. The most common variation was A1 variation with 44 (34.4%) cases: 33 had hypoplasia and 11 aplasia. Others were anterior communicating artery (ACoA) fenestration, bilateral pericallosal hypoplasia, and left callosomarginal aplasia. Thirty-one of these cases had single and 16 had multiple variations. The variations were right-sided in 30 (68.2 %) cases and left-sided in 14 (31.8%) (Figure 1A-D).

Right-side ACS variations were twice as frequent as those on the left side; 62.8% of A1 hypoplasia-aplasia variations were on the right side and 31.8% were on the left side. A1 variations were hypoplasia in 33 cases and aplasia in 11 cases.

The ACS variation rate and ACoA aneurysm coexistence were significantly higher ( $p=0.001$ ;  $p < 0.01$ ) (Table II). Apart from 5 internal carotid artery (ICA) bifurcation aneurysms, there were an additional 6 ICA aneurysms. Three of them were ophthalmic aneurysms, 1 was a superior hypophyseal aneurysm, 1 was a paraclinoid aneurysm and 1 was an ICA wall aneurysm. In these cases, the variation rates were significantly lower ( $p=0.005$ ;  $p < 0.01$ ).

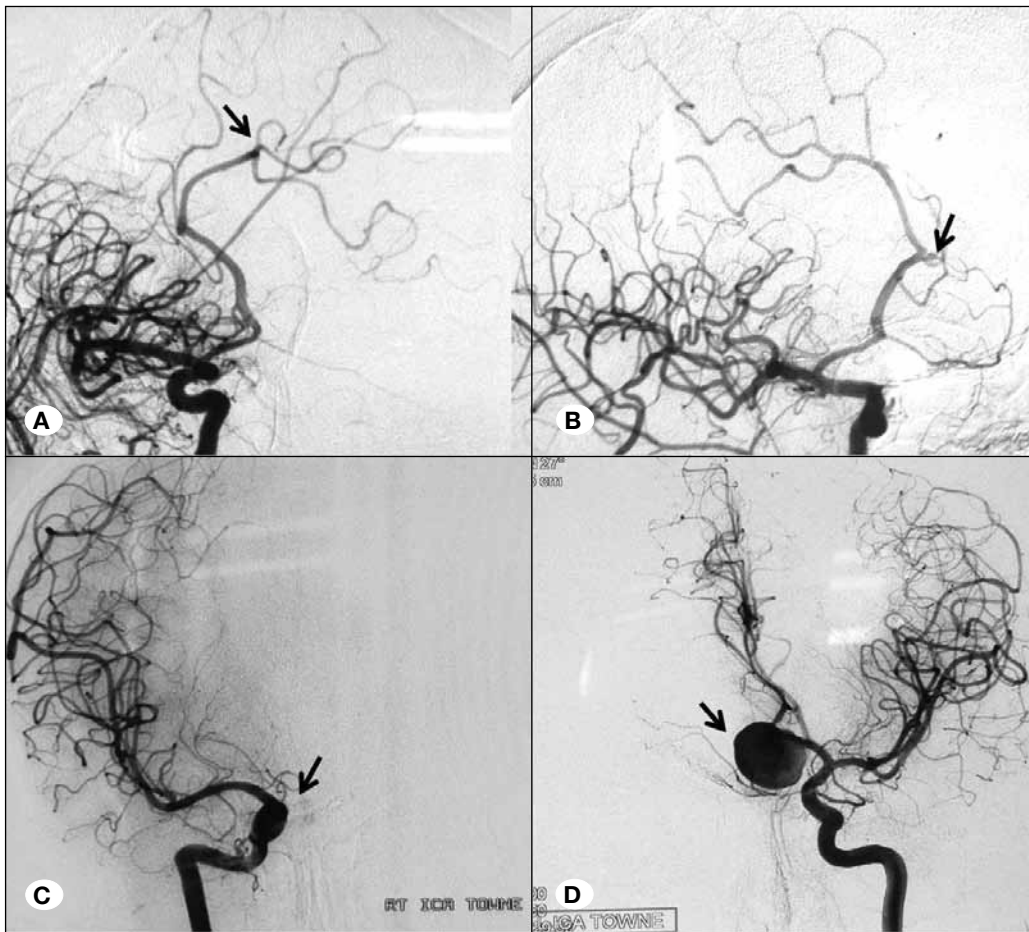
### PCS Variations

PCS variation was observed in 31 (24.2%) cases with 14 single and 17 multiple variations. P1 hypoplasia/aplasia was the most common variation with 28 (21.9%) cases. In this group, 2 hypoplasia and 1 aplasia were detected in vertebral arteries. The variations were right-sided in 12 (38.7%) cases, left-sided

**Table I:** Variation Rates according to Gender

		Gender		p
		Male n (%)	Female n (%)	
Variation	No	21 (38.2)	33 (45.2)	<sup>a</sup> 0.426
	Yes	34 (61.8)	40 (54.8)	
Number of variation (n=74)	Single variation	20 (58.8)	32 (80.0)	<sup>b</sup> 0.083
	Multiple variation	14 (41.2)	8 (20.0)	
ACS variation	No	13 (38.2)	15 (37.5)	<sup>b</sup> 1.000
	Yes	21 (61.8)	25 (62.5)	
PCS variation	No	21 (61.8)	22 (55.0)	<sup>b</sup> 0.725
	Yes	13 (38.2)	18 (45.0)	
MCS variation	No	24 (70.6)	37 (92.5)	<sup>b</sup> 0.031*
	Yes	10 (29.4)	3 (7.5)	

<sup>a</sup>Pearson chi square test, <sup>b</sup>Yates Continuity Correction, \*p<0.05.

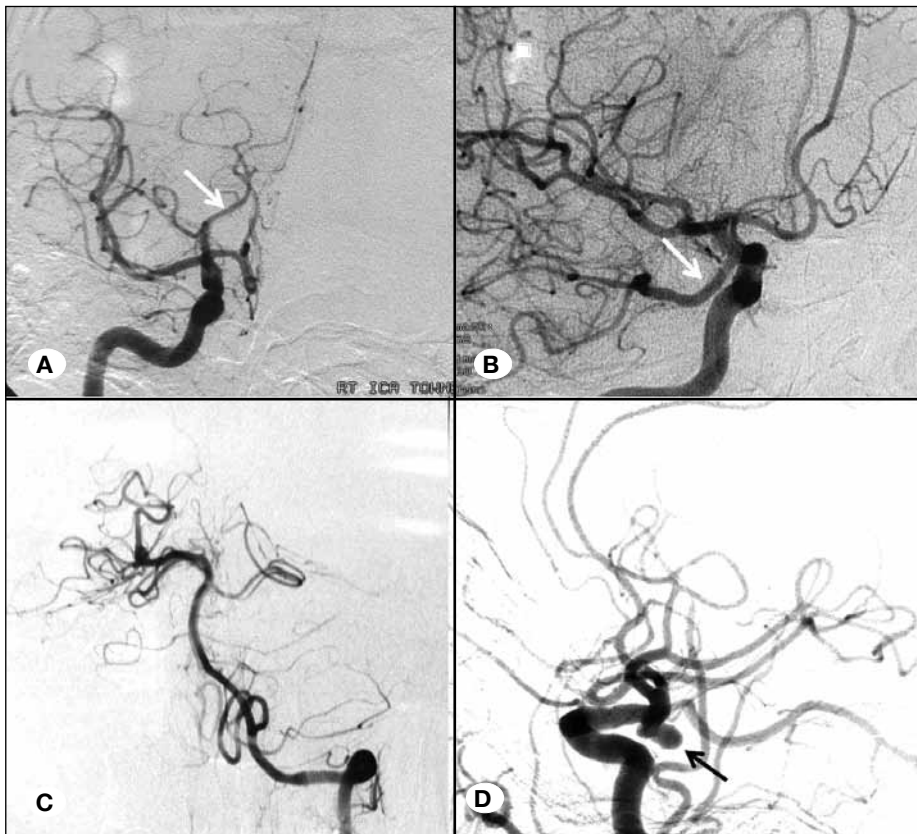


**Figure 1:** DSA examination showing examples of ACS variations. **A)** Pericallosal hypoplasia. **B)** Distal anterior cerebral artery (DACA) aneurysm in the DSA examination of the same patient. **C)** Right A1 aplasia. **D)** ACoA aneurysm that fills from left carotid system.

**Table II:** Aneurysm Rates according to ACS Variation Presence

		ACS variation		p
		No	Yes	
		n (%)	n (%)	
ACoA	No	64 (79.0)	13 (27.7)	<sup>a</sup> 0.001**
	Yes	17 (21.0)	34 (72.3)	
PCoA	No	62 (76.5)	44 (93.6)	<sup>a</sup> 0.026*
	Yes	19 (23.5)	3 (6.4)	
MCA	No	40 (49.4)	34 (72.3)	<sup>a</sup> 0.019*
	Yes	41 (50.6)	13 (27.7)	
ICA bifurcation	No	74 (91.4)	44 (93.6)	<sup>b</sup> 0.745
	Yes	7 (8.6)	3 (6.4)	
AChoA	No	77 (95.1)	45 (95.7)	<sup>b</sup> 1.000
	Yes	4 (4.9)	2 (4.3)	
ICA	No	75 (92.6)	47 (100.0)	<sup>b</sup> 0.085
	Yes	6 (7.4)	0 (0.0)	
DACA	No	75 (92.6)	46 (97.9)	<sup>b</sup> 0.422
	Yes	6 (7.4)	1 (2.1)	

<sup>a</sup>Yates Continuity Correction, <sup>b</sup>Fisher's Exact Test, \* $p < 0.05$ , \*\* $p < 0.01$ .



**Figure 2:** DSA examination showing examples of PCS variations. **A)** Fetal circulation in AP projection (white arrow). **B)** Fetal circulation in lateral projection (white arrow). **C)** AP projections showing P1 aplasia. **D)** Accompanying PCoA aneurysm in the same patient.

in 13 (42%) cases and bilateral in 6 (19.3%) cases (Figure 2A-D). PCS variation rate and PCoA aneurysm coexistence were significantly higher ( $p=0,023$ ;  $p<0.05$ ) (Table III).

**MCS Variations**

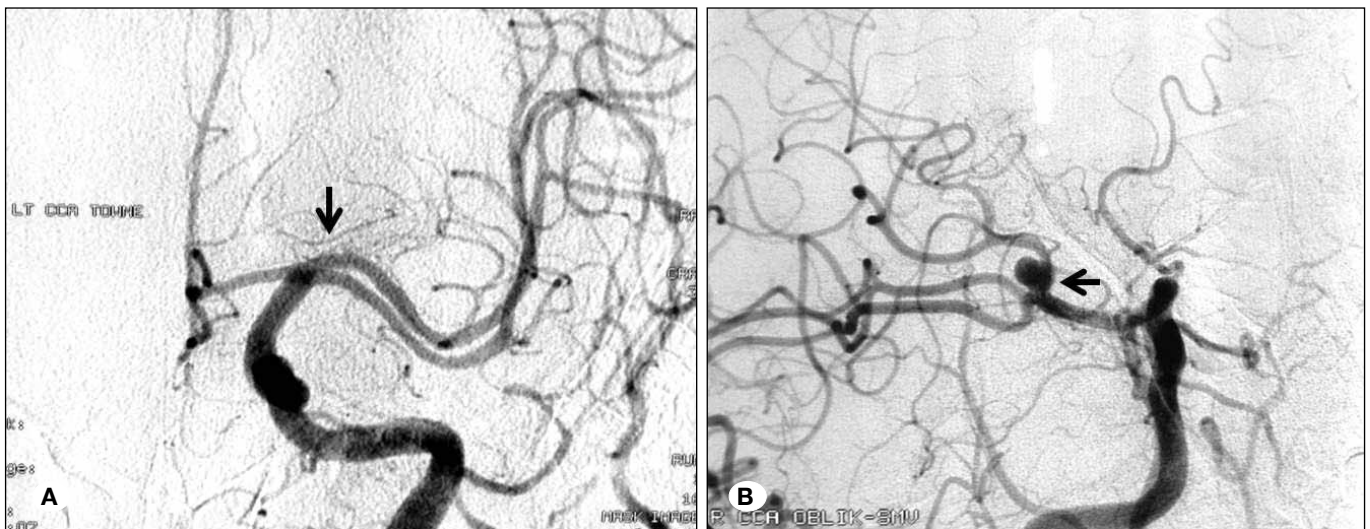
MCS variations were seen in 13 (10.2%) cases; 8 were single and 5 were multiple. One-sided or bilateral MCA trifurcation

was the most common variation with 9 (7%) cases. Others were MCA trifurcation and early bifurcation, early bifurcation, MCA duplication, and M2 superior trunk hypoplasia. The variations were right-sided in 4 (30.8%) cases, left-sided in 7 (53.8%) cases and bilateral in 2 (15.4%) cases (Figures 3A,B; 4A,B)

**Table III:** Aneurysm Rates according to PCS Variation Presence

		PCS variation		p
		No	Yes	
		n (%)	n (%)	
ACoA	No	60 (61.9)	17 (54.8)	<sup>a</sup> 0.628
	Yes	37 (38.1)	14 (45.2)	
PCoA	No	85 (87.6)	21 (67.7)	<sup>a</sup> 0.023*
	Yes	12 (12.4)	10 (32.3)	
MCA	No	53 (54.6)	21 (67.7)	<sup>a</sup> 0.281
	Yes	44 (45.4)	10 (32.3)	
ICA bifurcation	No	89 (91.8)	29 (93.5)	<sup>b</sup> 1.000
	Yes	8 (8.2)	2 (6.5)	
AChOA	No	93 (95.9)	29 (93.5)	<sup>b</sup> 0.632
	Yes	4 (4.1)	2 (6.5)	
ICA	No	91 (93.8)	31 (100.0)	<sup>b</sup> 0.335
	Yes	6 (6.2)	0 (0.0)	
DACA	No	90 (92.8)	31 (100.0)	<sup>b</sup> 0.194
	Yes	7 (7.2)	0 (0.0)	

<sup>a</sup>Yates Continuity Correction, <sup>b</sup>Fisher's Exact Test, \* $p<0,05$ .

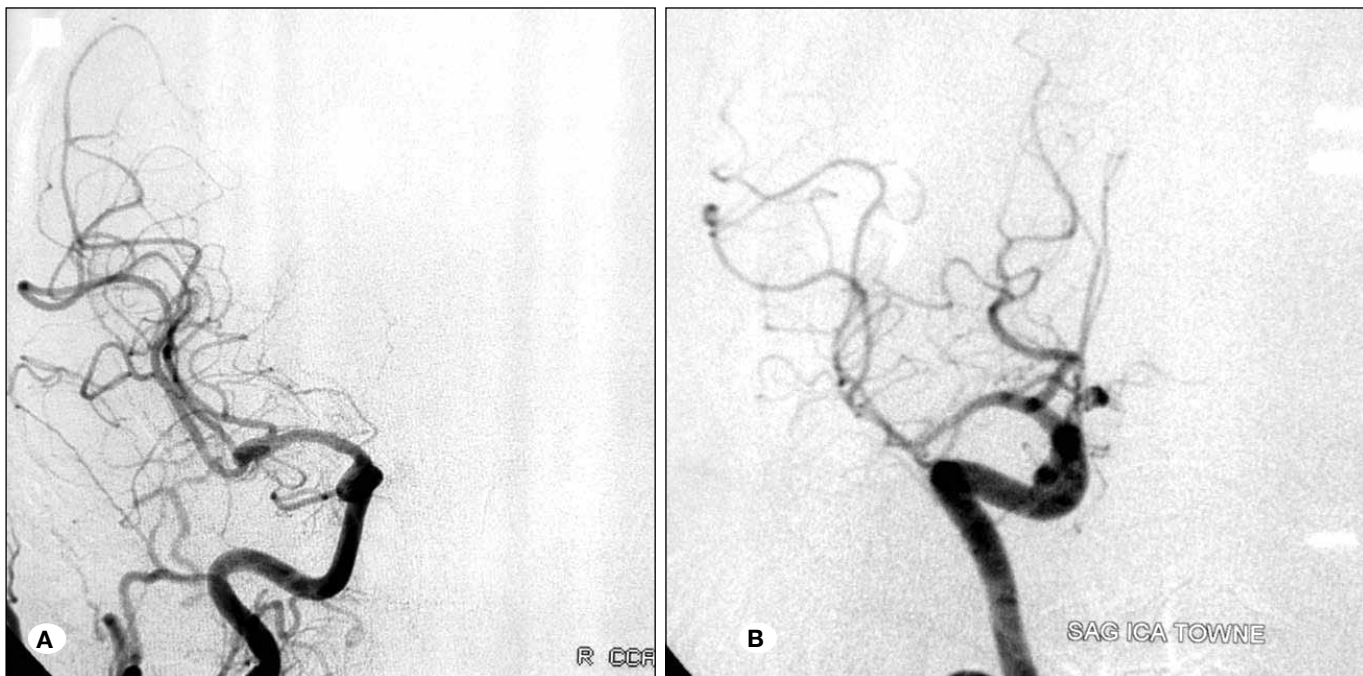


**Figure 3:** DSA examination showing examples of MCS variations. **A)** M1 duplication (black arrow). **B)** MCA aneurysm (black arrow) with trifurcation (right).

**Table IV:** Aneurysm Rates according to MCS Variation Presence

		MCS variation		p
		No	Yes	
		n (%)	n (%)	
ACoA	No	68 (59.1)	9 (69.2)	<sup>a</sup> 0.685
	Yes	47 (40.9)	4 (30.8)	
PCoA	No	93 (80.9)	13 (100.0)	<sup>b</sup> 0.123
	Yes	22 (19.1)	0 (0.0)	
MCA	No	69 (60.0)	5 (38.5)	<sup>a</sup> 0.232
	Yes	46 (40.0)	8 (61.5)	
ICA bifurcation	No	105 (91.3)	13 (100.0)	<sup>b</sup> 0.597
	Yes	10 (8.7)	0 (0.0)	
AChoA	No	109 (94.8)	13 (100.0)	<sup>b</sup> 1.000
	Yes	6 (5.2)	0 (0.0)	
ICA	No	109 (94.8)	13 (100.0)	<sup>b</sup> 1.000
	Yes	6 (5.2)	0 (0.0)	
DACA	No	109 (94.8)	12 (92.3)	<sup>b</sup> 0.536
	Yes	6 (5.2)	1 (7.7)	

<sup>a</sup>Yates Continuity Correction, <sup>b</sup>Fisher's Exact Test.



**Figure 4:** DSA examination showing examples of multiple variations. **A)** Right MCA trifurcation and A1 aplasia. **B)** Fetal circulation and A1 aplasia.

MCS variation rate and aneurysm coexistence showed no statistically significant difference in any localization (Table IV).

### Multiple Variations

The rates of single and multiple anomalies were 24% and 28%, respectively. There were two anomalies in 20% of the cases and more than two anomalies in 8% of the cases. Multiple variation rates were significantly higher in PCS cases ( $p=0.001$ ;  $p<0.01$ ) (Table V).

### Bleeding & Non-bleeding Aneurysm, Number and Localization of Aneurysm

The vascular variations were more common in bleeding aneurysms (61.3% versus 40.9%). The rate of multiple variations was also higher in bleeding aneurysms (18.9% versus 9.1%). There was no significant difference, either in variable rates ( $p=0.127$ ;  $p>0.05$ ) or in the number of variations ( $p=0.716$ ;  $p>0.05$ ), between bleeding/non-bleeding cases.

According to the aneurysm number, variation rates ( $p=0.291$ ;  $p>0.05$ ) and variation number rates ( $p=0.364$ ;  $p>0.05$ ) were not statistically significantly related.

In single aneurysm cases, there was no statistically significant difference between cases related with the aneurysm diameter ( $p=0.659$ ;  $p>0.05$ ).

There was no statistically significance between the aneurysm and number variation rates in any localization ( $p>0.05$ ). In single or multiple variation cases, there was no ICA aneurysm presence.

## DISCUSSION

### Incidence

In the present study, the overall rate of variations in the circle of Willis configuration with berry aneurysms was 57.8%. The rate of variations in series with accompanying intracranial aneurysms was between 40.7% and 97% (2,12,20,27,32,33). In a recent cadaveric study conducted on the Turkish population, adult configuration of the polygon was detected

in 87% (11). In cadaveric brains with unknown cause of death, Gunnal et al. (6) found gross morphological variations in 40% of the cases. Kapoor et al. (10) reported variations in 54.8% of 1000 medical autopsies. Qiu et al. (27) found the incidence of partial integrity and non-integrity as 70.17% and 17.59% respectively in 2,146 healthy subjects that were examined with magnetic resonance imaging (MRI) and magnetic resonance angiography (MRA).

### Variations

We found that the most common anomaly was hypoplasia in the Willis polygon, similar to other series (1,6,8,9,29). It was mostly seen in the A1 segment, followed by the P1 segment. Aplastic/hypoplastic A1 was also the most common variation in some reports (17,33). The incidence of hypoplastic and aplastic A1 segment of the anterior cerebral artery was reported as 36% by Kryzewski et al. (16). In an MRI study investigating anterior cerebral artery variations, the A1 segment aplasia rate was only 5.6% (36). The fenestration of the A1 and/or A2 segment was found to be 1.2%. Kovac et al. (13) reported that the patients had hypoplastic or congenital absence of A1 segment at a rate of 17.6% and 0.4%, respectively. Fetal origin of the posterior cerebral artery was found in 37% of the cases. In their series, Iqbal et al. (8) stated a hypoplasia in PCoA rate of 24% that was followed by hypoplasia in the P1, A1 and ACoA segments. Similarly, Karatas et al. (11) found hypoplasia most commonly in the PCoA. The hypoplasia of A1 was frequently associated with ACoA aneurysms and this is compatible with our results (26).

Although we detected only one fenestration in this study, Suzuki et al. (34) reported 75% fenestration in 38 cases of ACA aneurysms in their surgical series. Two-dimensional images are thought to be unsuitable for detecting intracranial arterial fenestrations because of superimposition of vessels that may render their identification (17,34). In a recent study, including patients with subarachnoid hemorrhage, van Rooij et al. (39) found 24% fenestration by 3D rotational angiography. In a study with CT angiography, the fenestrations of middle cerebral artery M1 segment (0.2%), anterior communicating artery (0.4%), and anterior cerebral artery A1 segment (0.6%)

**Table V:** ACS, PCS and MCS Variation Rates according to the Number of Aneurysms

		Number of variations		p
		Single variation	Multiple variation	
		n (%)	n (%)	
ACS variation	No	21 (77.8)	6 (22.2)	*0.420
	Yes	31 (66.0)	16 (34.0)	
PCS variation	No	38 (88.4)	5 (11.6)	*0.001**
	Yes	14 (45.2)	17 (54.8)	
MCS variation	No	44 (72.1)	17 (27.9)	*0.510
	Yes	8 (61.5)	5 (38.5)	

\*Yates Continuity Correction, \*\*Fisher.

were also noted (13). Fenestration may be seen even in the A2 segment of the anterior cerebral artery (4).

Krayenbuhl and Yaşargil (15) reported vertebral artery fenestration or anomalous termination. Gunnal et al. (7) found morphological variations in termination in 17.64% of the cases. The prevalence of fenestrations of the intracranial VB system was reported to be between 1.17% and 2.77% (7,13,37).

We detected P1 hypoplasia/aplasia in 28% of the cases in the presented study. Iqbal et al.(8) reported a 10% variation rate for fetal PCA. Gunnal et al.(6) found that the most common variation rate was in the PCoA with 50%, followed by ACoA with 33.3%. Malamateniou et al. (21) stated that the most common variation was PCoA aplasia (30%) in the neonatal group. Saeki and Rhoton (30) reported that PCoA hypoplasia was unilateral in 26% of the cases and bilateral in 6% of the cases. The rate of a fetal configuration in which the PCA was arising predominantly from the carotid artery was 20% and 2% for unilaterally and bilaterally respectively. Yasargil (40) reported that the rate of the fetal type of circulation was 24.5% with much greater frequency on the right. Qiu et al. (27) demonstrated an incidence of 15.85% for P1 variation.

Gibo et al. (5) found that MCA anomalies are less common than the other anomalies consisting of duplicate or accessory MCA. They observed MCA trifurcation in 12% of the cases. This was similar to our study; MCA anomalies were the least common with 10.2% and, trifurcation was the most common variation with 7%.

#### Variation & Number, Localization of Aneurysm

Some specific aneurysms can be encountered together with some variations. Although ACA variations were seen commonly with ACoA aneurysms ( $p<0.01$ ) in this study, there was no variation in 6 ICA aneurysm cases and this was statistically significant ( $p<0.01$ ). A1 segment variations have been reported more frequently in ACoA aneurysm cases than in the control group (14,28). Suzuki et al. (34) reported 75% and Van Rooij et al. (39) reported 31% fenestration of ACoA that accompanied the aneurysm. In a study that investigated anatomic variations and recurrence rates of patients undergoing coil-embolization with aneurysms, A1 dominance on one side with ACoA aneurysms was found to be 73%. A1 dominant flow was shown to act in aneurysm formation, growth and instability after coil embolization treatment (35). Kryzewski et al. (16) suggested that A1 and A2 segment anomalies of the anterior cerebral artery may potentially be associated with aneurysm formation. Although the clinical significance of ACA variations is usually minor, an associated aneurysm is found relatively frequently (36).

Songsaeng et al. (31) reported more frequent ACoA, PCoA and BA aneurysm coincidence with A1 aplasia and fetal PCoA. Notably, asymmetrical A1 segment and asymmetrical basilar apex presence were associated with recurrence following coil embolization.

There was an inverse relation for PCoA and MCA aneurysms. In ACS variations, PCoA and MCA aneurysm coexistence ( $p<0.05$ ) was significantly lower than in cases without ACS

variation. There was no statistically significant difference between other aneurysm localizations and anterior system variation presence.

Macchi et al. (19) proposed that anatomic variation rates were higher in the left side, but we found a higher variation rate on the right side in the ACS group.

Stojanovic et al. (33) reported a Willis asymmetry prevalence of 64% in their series; in multiple aneurysms this rate increased to 75.7%. It was found to be 61.1% and 48.5% for accompanying single and multiple aneurysms respectively in the present study but there was no statistical significance. Mazighi et al. (22) reported that vascular anomalies were associated with aneurysm development and bleeding. Vascular anomalies were found in 88% of the patients with multiple intracranial aneurysms. The most common anomaly was the asymmetric caudal basilar fusion (43.2%) followed by variations of the anterior communicating artery (ACoA) complex (31.2%). The aneurysm bled proportionally more frequently when associated with the related vascular anomaly (22). Nurminen et al. (24) found major anatomic variations affecting cerebral arteries in 2% of the patients with giant intracranial aneurysms.

Willis variations were encountered frequently, particularly in ACoA and PCoA aneurysms (5,12,14,20). Asymmetrical A1 and ACoA aneurysms show this association, as well as asymmetrical PCoA and PCoA aneurysms. The association between variation and aneurysm localization supports the role of hemodynamic factors in the pathogenesis.

In several aneurysm cases, more than one variation can be observed (12). In our study, a single variation was observed in 40.6% of the cases; the rate was 17.2% for multiple variations. Multiple variations were 2 in number in 18 cases, and 3 in 4 cases.

#### Bleeding & Non-Bleeding Aneurysms

High Willis asymmetry rates in bleeding aneurysms confirm the relationship between hemodynamic disturbance due to asymmetric configuration and aneurysm formation and rupture (3,4,7,12,13,15,23,26,29,33). In bleeding ACoA aneurysms, Stojanovic et al. (33) reported that the asymmetry presence accounted for 72.7%; morphological changes were present in the A1 segment (44%) and mainly on the right side (60%).

Lazzaro et al. (18) found the Willis anomaly in 46.9% of bleeding aneurysms and 29.6% of non-bleeding (incidental) aneurysms, and proposed that aneurysm rupture rates were higher in the presence of a Willis anomaly. They stated that the Willis anomaly was more common in bleeding anterior and posterior communicating artery aneurysms than in non-bleeding aneurysms.

Van Rooij et al. (39) reported 31% fenestration of ACoA where an accompanying aneurysm caused SAH.

In the present study, compatible with Lazzaro et al. (18), variation presence was more common in bleeding aneurysm cases than in non-bleeding aneurysm cases at 61.3% and 40.9% respectively. The multiple variation rate was higher in bleeding aneurysms at 18.9% versus 9.1%. However, there



was no significant difference between bleeding/non-bleeding cases on statistical analysis, either in the variable rates ( $p=0.127$ ;  $p>0.05$ ) or in the number of variations ( $p=0.716$ ;  $p>0.05$ ).

### Gender Relationship

Van Overbeeke et al. (38) reported no significant frequency difference regarding gender or right-left side in the adult or fetal configuration in fetal and infant brains. They noted that variations occur as developmental modifications more than genetic factors. Malamateniou et al. (21) found that complete Willis variation rates were higher in preterm girls, and ACoA and P1 segment aplasia-hypoplasia was two times higher in term-born girls, whereas PCoA and A1 segment aplasia-hypoplasia were more frequent in preterm boys. In term-born infants, the fetal type of PCA is twice as frequent in the left side. In the present study, there was no difference in rates in the ACS and PCS groups considering the gender of cases, but MCA variation rates in males were significantly higher ( $p=0.031$ ;  $p<0.05$ ). In contrast, Krzyzewski et al. (16) reported that males had significantly higher prevalence of the typical ACoA complex.

The limitations of this study are as follows:

- The detected vascular variations in this study were all in patients who were subject to subarachnoid hemorrhage and/or cerebral aneurysm. These variations give no information about normal/healthy cases. Cadaveric studies may provide more accurate knowledge about natural anatomy, but the aim of this paper was to show the arterial variations in patients with an intracranial vascular insult.
- All the images are 2-dimensional, and 2-dimensional images may not be suitable for detecting intracranial arterial fenestrations.

### CONCLUSION

There was an association between aneurysm localization and vascular variations. In the present study, rate of variations in the circle of Willis configuration in patients with berry aneurysms was 57.8%. Arterial hypoplasia and aplasia were the most common vascular variations associated with intracranial aneurysms. ACS was the most common region that variations were located in; they were mostly detected on the right side. In the ACS variations group, coexistence of ACoA aneurysm was higher than with PCoA and MCA aneurysms. In the PCS variations group, PCoA aneurysms were the most common aneurysms that accompanied the variation. In the PCS variation group, multiple variations were more common than in the other two groups. The vascular variations in MCS were most common in males.

Knowledge/awareness of these variations would guide choosing and applying treatment modalities, and increase the success rate in managing the patients.

### REFERENCES

1. Alpers BJ, Berry RG, Paddison RM: Anatomical studies of the circle of Willis in normal brain. *Arch Neurol Psychiatry* 81: 409-418, 1959
2. Aydin IH, Takci E, Kadioglu HH, Tuzun Y, Kayaoglu CR, Barlas E: Vascular variations associated with anterior communicating artery aneurysms—an intraoperative study. *Minim Invasive Neurosurg* 40(1):17-21, 1997
3. Biondi A: Intracranial aneurysms associated with other lesions, disorders or anatomic variations. *Neuroimag Clin N Am* 16:467-482, 2006
4. Dimmick SJ, Faulder KC: Fenestrated anterior cerebral artery with associated arterial anomalies. Case reports and literature review. *Interv Neuroradiol* 14: 441-445, 2008
5. Gibo H, Carver CC, Rhoton AL Jr, Lenkey C, Mitchell RJ: Microsurgical anatomy of the middle cerebral artery. *J Neurosurg* 54(2):151-169, 1981
6. Gunnal SA, Farooqui MS, Wabale RN: Anatomical variations of the Circulus Arteriosus in cadaveric human brains. *Neurol Res Int* 2014:687281, 2014
7. Gunnal S, Farooqui M, Wabale R: Anatomical variability in the termination of the basilar artery in the human cadaveric brain. *Turk Neurosurg* 25(4):586-594, 2015
8. Iqbal S: A comprehensive study of the anatomical variations of the Circle of Willis in adult human brains. *J Clin Diagn Res* 7(11):2423-2427, 2013
9. Kamath S: Observations on the length and diameter of the vessels forming the circle of Willis. *J Anat* 133: 419-423, 1981
10. Kapoor K, Singh B, Dewan LI: Variations in the configuration of the circle of Willis. *Anat Sci Int* 83:96-106, 2008
11. Karatas A, Yilmaz H, Coban G, Koker M, Uz A: The Anatomy of Circulus Arteriosus Cerebri (Circle of Willis): A study in Turkish population. *Turk Neurosurg* 26(1):54-61, 2016
12. Kayembe KN, Sasahara M, Hazama F: Cerebral aneurysms and variations in the circle of Willis. *Stroke* 15:846-850, 1984
13. Kovač JD, Stanković A, Stanković D, Kovač B, Šaranović D: Intracranial arterial variations: A comprehensive evaluation using CT angiography. *Med Sci Monit* 20: 420-427, 2014
14. Krasny A, Nensa F, Sandalcioğlu IE, Görlicke SL, Wanke I, Gramsch C, Sirin S, Oezkan N, Sure U, Schlamann M: Association of aneurysms and variation of the A1 segment. *J Neurointerv Surg* 6 (3):178-183, 2014
15. Kraysenbuhl H, Yasargil M: Cerebral angiography. London: Butterworths, 1968: 72
16. Krzyzewski RM, Tomaszewska IM, Lorenc N, Kochana M, Goncerz G, Piotrowska WK, Walocha K, Urbanik A: Variations of the anterior communicating artery complex and occurrence of anterior communicating artery aneurysm: A2 segment. *Consideration Folia Medica Cracoviensia* 54:13-20, 2014
17. Krzyzewski RM, Tomaszewski KA, Kochana M, Kopeć M, Klimek-Piotrowska W, Walocha JA: A rare anatomical variant: Median anterior cerebral artery fenestration associated with an azygous infra-optic anterior cerebral artery. *Surg Radiol Anat* 37(1):81-86, 2015

18. Lazzaro MA, Ouyang B, Chen M: The role of circle of Willis anomalies in cerebral aneurysm rupture. *J Neurointerv Surg* 4(1): 22-26, 2012
19. Macchi C, Lova RM, Miniati B, Gulisano M, Pratesi C, Conti AA, Gensini GF: The circle of Willis in healthy older persons. *J Cardiovasc Surg (Torino)* 43: 887-890, 2002
20. Mackenzie JM: The anatomy of aneurysm-bearing circles of Willis. *Clin Neuropathol* 10(4):187-189, 1991
21. Malamateniou C, Adams ME, Srinivasan L, Allsop JM, Counsell SJ, Cowan FM, Hajnal JV, Rutherford MA: The anatomic variations of the Circle of Willis in preterm-at-term and term-born infants: An MR angiography study at 3T. *Am J Neuroradiol* 30:1955-1962, 2009
22. Mazighi M, Porter PJ, Rodesch G, Alvarez H, Aghakhani N, Lasjaunias P: Vascular anomalies and the risk of multiple aneurysms development and bleeding. *Interv Neuroradiol* 8: 15-20, 2002
23. Nixon AM, Gunel M, Sumpio BE: The critical role of hemodynamics in the development of cerebral vascular disease. *J Neurosurg* 112:1240-1253, 2010
24. Nurminen V, Lehecka M, Chakrabarty A, Kivisaari R, Lehto H, Niemelä M, Hernesniemi J: Anatomy and morphology of giant aneurysms—angiographic study of 125 consecutive cases. *Acta Neurochir* 156:1–10, 2014
25. O'Connor JP: Thomas Willis and the background to Cerebri Anatomie. *J R Soc Med* 96(3): 139-143, 2003
26. Perlmutter D, Rhoton AL: Microsurgical anatomy of the anterior cerebral - anterior communicating - recurrent artery complex. *J Neurosurg* 45:259-472, 1976
27. Qiu C, Zhang Y, Xue C, Jiang S, Zhang W: MRA Study on variation of the Circle of Willis in healthy Chinese male adults. *Biomed Res Int* 2015:976340, 2015
28. Rhoton AL Jr: The supratentorial arteries. *Neurosurgery* 51 (4 Suppl): S53-120, 2002
29. Riggs HE, Rupp C: Variation in form of circle of Willis. The relation of the variations to collateral circulation: Anatomic analysis. *Arch Neurol* 8:8-14, 1963
30. Saeki N, Rhoton AL Jr: Microsurgical anatomy of the upper basilar artery and the posterior circle of Willis. *J Neurosurg* 46: 563–578, 1977
31. Songsaeng D, Geibprasert S, Willinsky R, Tymianski M, TerBrugge KG, Krings T: Impact of anatomical variations of the Circle of Willis on the incidence of aneurysms and their recurrence rate following endovascular treatment. *Clin Radiol* 65(11): 895-901, 2010
32. Stehbens WE: Etiology of intracranial berry aneurysms. *J Neurosurg* 70(6):823-831, 1989
33. Stojanović N, Stefanović I, Randjelović S, Mitić R, Bosnjaković P, Stojanov D: Presence of anatomical variations of the Circle of Willis in patients undergoing surgical treatment for ruptured intracranial aneurysms. *Vojnosanit Pregl* 66 (9):711-717, 2009
34. Suzuki M, Onuma T, Sakurai Y, Mizoi K, Ogawa A, Yoshimoto T: Aneurysms arising from the proximal (A1) segment of the anterior cerebral artery. A study of 38 cases. *J Neurosurg* 76(3):455-458, 1992
35. Tarulli E, Sneade M, Clarke A, Molyneux AJ, Fox AJ: Effects of circle of Willis anatomic variations on angiographic and clinical outcomes of coiled anterior communicating artery aneurysms. *Am J Neuroradiol* 35(8):1551-1555, 2014
36. Uchino A, Nomiyama K, Takase Y, Kudo S: Anterior cerebral artery variations detected by MR angiography. *Neuroradiology* 48: 647–652, 2006
37. Uchino A, Saito N, Okada Y, Kozawa E, Nishi N, Mizukoshi W, Inoue K, Nakajima R, Takahashi M: Fenestrations of the intracranial vertebrobasilar system diagnosed by MR angiography. *Neuroradiology* 54:445–450, 2012
38. van Overbeeke JJ, Hillen B, Tulleken CAF: A comparative study of the circle of Willis in fetal and adult life. The configuration of the posterior bifurcation of the posterior communicating artery. *J Anat* 176: 45-54, 1991
39. van Rooij SB, Bechan RS, Peluso JP, Sluzewski M, van Rooij WJ: Fenestrations of intracranial arteries. *AJNR Am J Neuroradiol* 36 (6):1167-1170, 2015
40. Yasargil MG: Microsurgical Anatomy of the Basal Cisterns and Vessels of the Brain, Diagnostic Studies, General Operative Techniques and Pathological Considerations of the Intracranial Aneurysms. *Microneurosurgery Vol: 1*, Stuttgart, New York:Thieme, 1984