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Clinical study

Neuroangiography patterns of the middle cerebral artery: Study of 554 cerebral angiography results

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1. Introduction

The middle cerebral artery (MCA) is the largest and most complex of cerebral arteries because the cerebral neocortex is significantly developed in humans [1,2]. The MCA covers a large part of the cerebral hemispheres; therefore, it is exposed during surgical intervention in that area. Aspects of the cerebral branches tend to vary, and different branching patterns can be described. In the past, surgical interest in the MCA has been directed at avoiding damage to its branches during surgery performed within its territory. Microsurgical techniques have made reconstruction and bypass to the MCA, surgical approaches to MCA aneurysms and resection of arteriovenous malformations (AVMs) related to MCA branches common procedures in vascular neurosurgery [2].

The vascular territory of the MCA includes some of the most eloquent cortical areas for motor and sensory functions. That territory encompasses the receptive and expressive components of language, abstract thought and other faculties of higher cognitive functioning. Moreover, the perforating branches of the proximal MCA supply the basal ganglia and important descending and corticospinal tracts [3]. Anatomical variations of the MCA have to be recognised when planning interventions in order to avoid damage or occlusion of the perforating vessels that arise from the MCA and to assess their contribution to the perfusion of the deep MCA territory [4].

Descriptions of the origins and possible common trunks of the MCA branches are still lacking in the literature. While bifurcation and trifurcation types of MCA branching are usually described, most studies fail to mention the different subtypes. Moreover, there is still some confusion about the criteria used to determine the different branching subtypes. Thus, the present study aimed to review the neuroangiography patterns of the MCA.

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2. Patients and methods

2.1. Patients and neuroangiography data

Data were retrieved from the Neuroangiography Center of Dr Soetomo Academic Medical Center Hospital database, which includes all the neurosurgery patients who underwent cerebral angiography during the 2014–2018 period. We identified data from 578 consecutive cerebral angiographies. We excluded the results from 24 cases because of a lack of adequate MCA angiographies (n = 12), broken data (n = 4) and the lack of data on MCA patterns (posterior circulation data only) (n = 8). The remaining 554 cerebral angiography results from 300 patients had adequate MCA angiography patterns. The use of cerebral angiography in our hospital began in 2014; since then, it has been the imaging modality used for many of the neurosurgical cases at our institution. Each patient's neuroangiography images were stored in the database in the Digital Imaging and Communications in Medicine (DICOM) data format. The DICOM data were reviewed using DICOM reader software (Horos™) (measurement was done using the length calculation feature in the software) and analysed with IBM SPSS® software using descriptive statistics.

2.2. Nomenclature

The MCAs were identified in each patient and classified. The length of the main trunk was classified as short (3–12 mm), medium (13–22 mm) or long (23–40 mm). If branching occurs within 5 mm from the MCA origin, it is referred to as early branching [5].

The MCAs were grouped into 11 branching patterns: (1) monofurcation, (2) tetrafurcation, (3) pseudotetrafurcation, (4) medial bifurcation, (5) lateral bifurcation, (6) medial pesudobifurcation, (7) lateral pseudobifurcation, (8) true trifurcation, (9) pseudotrifurcation, (10) proximal trifurcation and (11) distal trifurcation (Fig. 1) [6].

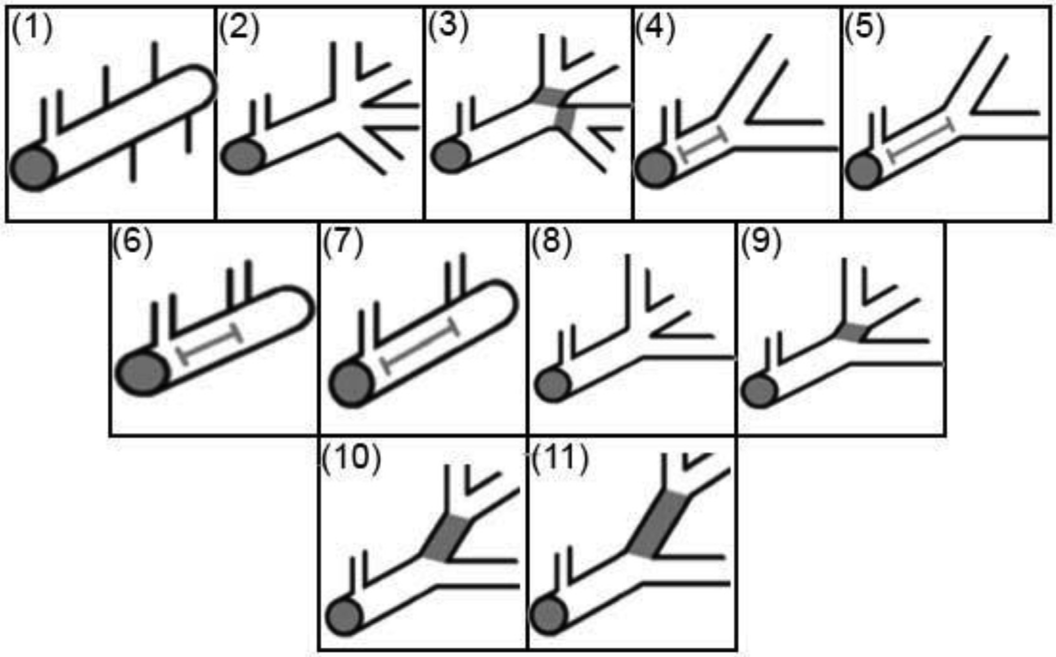

Fig. 1. The 11 different branching patterns of MCAs.

Table 1
Baseline variables of cerebral angiography results.

Variables	Total (n = 300), n (%)	Remarks
Age, y.o		Mean ± SD = 37.3 ± 17.3
<18	48 (16%)	
≥18	252 (84%)	
Sex		
Male	125 (41.7%)	
Female	175 (58.3%)	
Diagnosis		
Aneurysm	53 (17.6%)	
AVM	39 (13%)	
Stenosis/infarct	13 (4.3%)	
CCF	31 (10.3%)	
Stroke ICH	16 (5.3%)	
Trauma	8 (2.7%)	
dAVF	6 (2%)	
Moya-moya disease	4 (1.3%)	
Thrombosis	2 (0.7%)	
Other	2 (0.7%)	Parkinson with cerebellar degeneration, Cerebellar atrophy
Unknown	34 (11.3%)	
Side	(n = 554)	
Right	286 (51.6%)	
Left	268 (48.4%)	

Table 2
The MCA patterns from cerebral angiography results.

Variables	Total (n = 554), n (%)	Remarks
Diameter, mm		Mean ± SD = 2.39 ± 0.49
Length, mm		Mean ± SD = 15.56 ± 7.75
Length Type		
Short (3–12 mm)	225 (40.6%)	
Medium (13–22 mm)	220 (39.7%)	
Long (23–40 mm)	109 (19.7%)	
Early Branching (≤5 mm)		
Yes	33 (6%)	
No	521 (94%)	
Branching Pattern		
Monofurcation	0 (0%)	
Tetrafurcation	4 (0.7%)	
Pseudotetrafurcation	4 (0.7%)	
Medial bifurcation	255 (46%)	
Lateral bifurcation	67 (12.1%)	
Medial pseudotrifurcation	14 (2.5%)	
Lateral pseudotrifurcation	4 (0.7%)	
True trifurcation	52 (9.4%)	
Pseudotrifurcation	27 (4.9%)	
Proximal trifurcation	69 (12.5%)	
Distal trifurcation	58 (10.5%)	

3. Results

3.1. Demographics

From the baseline variables (Table 1), the mean age of the subjects was 37.3 years. Most of the subjects (252 subjects; 84%) were adults (≥18 years old). The male-to-female ratio was 5:7 (41.7%:58.3%). Aneurysm was the most frequent diagnosis (53 results, 17.6%), followed by AVM (39 results, 13%), carotid-cavernous fistula (CCF) (31 results, 10.3%), stroke intracerebral haemorrhage (ICH) (16 results, 5.3%), stenosis/infarct (13 results, 4.3%), traumatic brain injury (TBI) (8 results, 2.7%), dural arteriovenous fistula (DAVF) (6 results, 2%), Moyamoya disease (4 results, 1.3%), sinus thrombosis (2 results, 0.7%) and other (2 results, 0.7%, including Parkinson's with cerebellar degeneration and cerebellar atrophy). Unfortunately, the diagnoses from 34 results (11.3%) were not included in the database, so they were not available. According to the side of the MCAs, the right-to-left ratio is nearly equal (51.6%: 48.4%).

3.2. Patterns of MCAs

Based on the MCA pattern results (Table 2), the mean diameter of the MCA (M1) was 2.39 mm; the mean length was 15.56 mm. Based on the classification for the length of the main trunk, most of the MCAs were short (225 results, 40.6%) (Fig. 2). Medium MCAs (Fig. 3) and long MCAs (Fig. 4) were seen in 220 results (39.7%) and 109 results (19.7%), respectively. Early branching was only found in

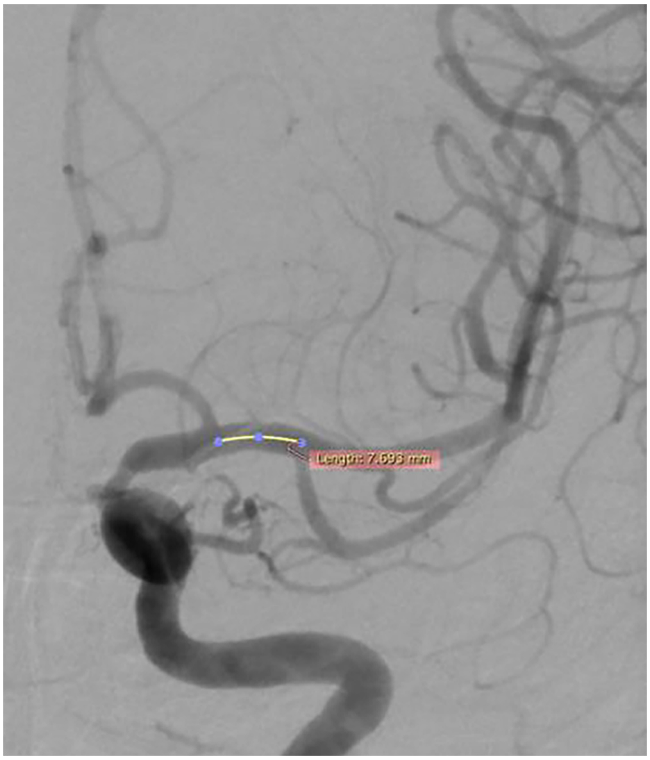

Fig. 2. Short segment.

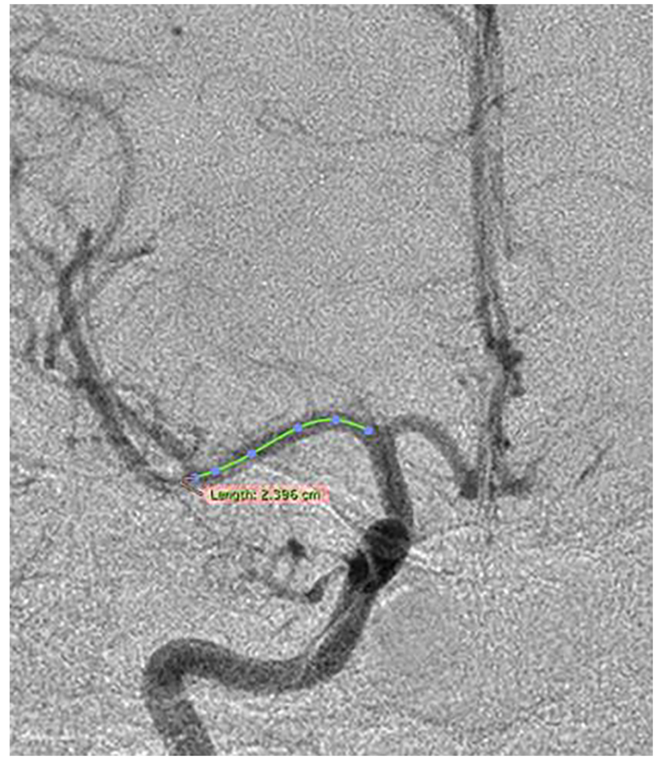

Fig. 4. Long segment.

Fig. 3. Medium segment.

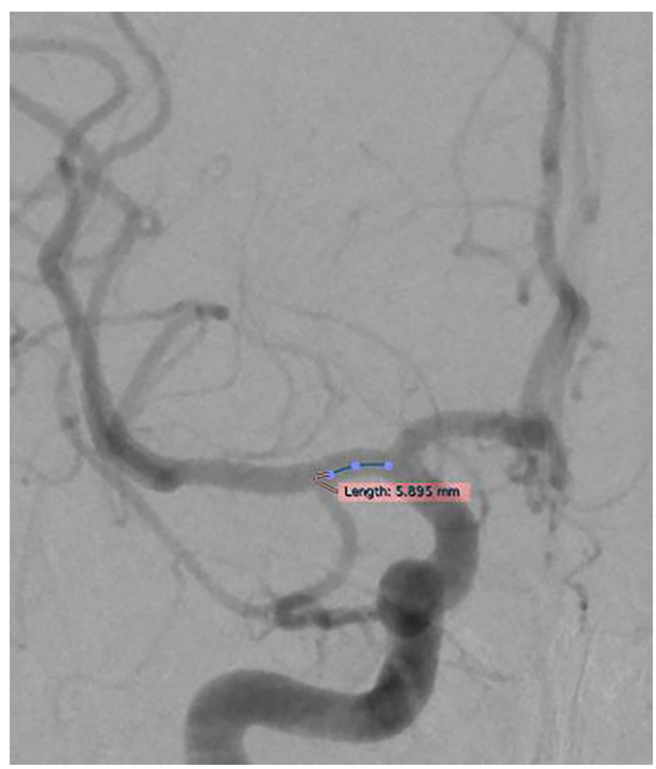

Fig. 5. Early branching.

33 of the results (6%) (Fig. 5). The most frequent branching pattern was medial bifurcation (255 results, 46%) (Fig. 6), followed by proximal trifurcation (69 results, 12.5%) (Fig. 7), lateral bifurcation (67 results, 12.1%) (Fig. 8), distal trifurcation (58 results, 10.5%) (Fig. 9), true trifurcation (52 results, 9.4%) (Fig. 10), pseudotrifurcation (27 results, 4.9%) (Fig. 11), medial pseudobifurcation (14 results, 2.5%) (Fig. 12), lateral pseudobifurcation (4 results, 0.7%) (Fig. 13), tetrafurcation (4 results, 0.7%) (Fig. 14) and pseudotetrafurcation (4 results, 0.7%) (Fig. 15). We did not find any monofurcation in this study.

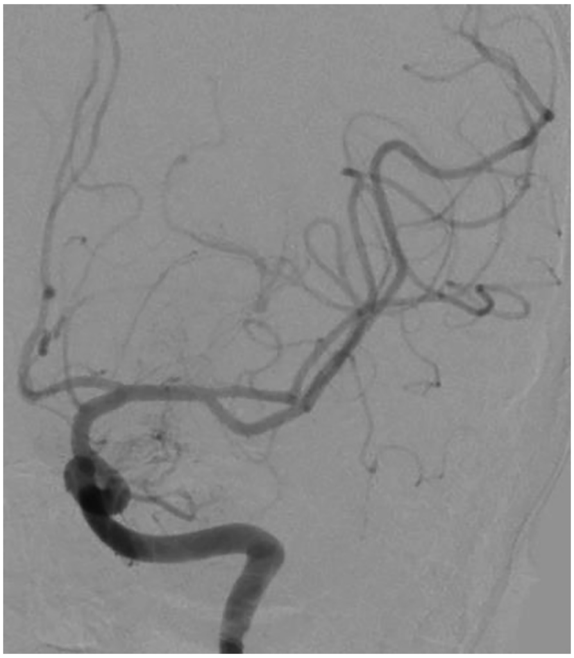

Fig. 6. Medial bifurcation.

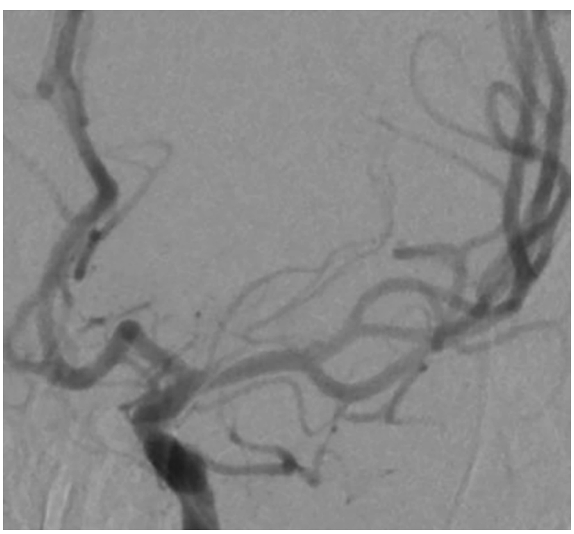

Fig. 7. Proximal trifurcation.

Fig. 8. Lateral bifurcation.

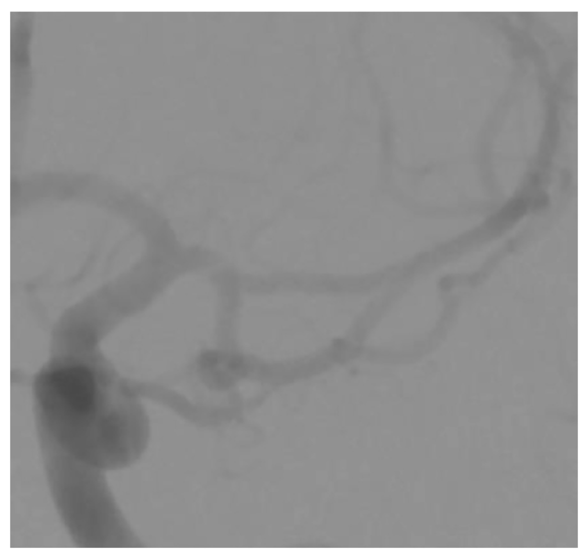

Fig. 9. Distal trifurcation.

3.3. Estimation in the population

Based on the MCA pattern results (Table 2), we estimated the mean diameter and the mean length of the MCAs in the study population (Table 3). The estimation of the MCA (M1) mean diameter in the population was 2.39–2.43 mm; the estimation of the mean length was 14.91–16.21 mm. A short MCA was estimated to occur in approximately 36.5–33.8% of the population, a medium MCA was estimated to occur in approximately 35.6%–43.9% of the population and a long MCA was estimated to occur in approximately 16.4%–23.2% of the population. The percentage early branching was estimated to be approximately 4.1%–8.3%.

The estimation of the MCA branching patterns in the population were as follows: monofurcation (0%–0.7%), tetrafurcation (0.2%–1.8%), pseudotetrafurcation (0.2%–1.8%), medial bifurcation (41.8%–50.3%), lateral bifurcation (9.5%–15.1%), medial pseudotrifurcation (1.4%–4.2%), lateral pseudotrifurcation (0.2%–1.8%), true trifurcation (7.1%–12.1%), pseudotrifurcation (3.2%–7%), proximal trifurcation (9.8%–15.5%) and distal trifurcation (8.0%–13.3%).

4. Discussion

In the present study, the mean diameter of the MCA (M1) was 2.39 ± 0.49 mm. This result was similar to the finding reported by Lasjaunias et al., which stated that the MCA diameter ranged from 2.4 mm to 4.6 mm [7]. In the present study, the length of the MCA (M1) was 15.56 ± 7.75 mm. This result is also similar to the findings reported by Harrigan et al., which stated that the average M1 segment is 16 mm long [8].

Fig. 10. True trifurcation.

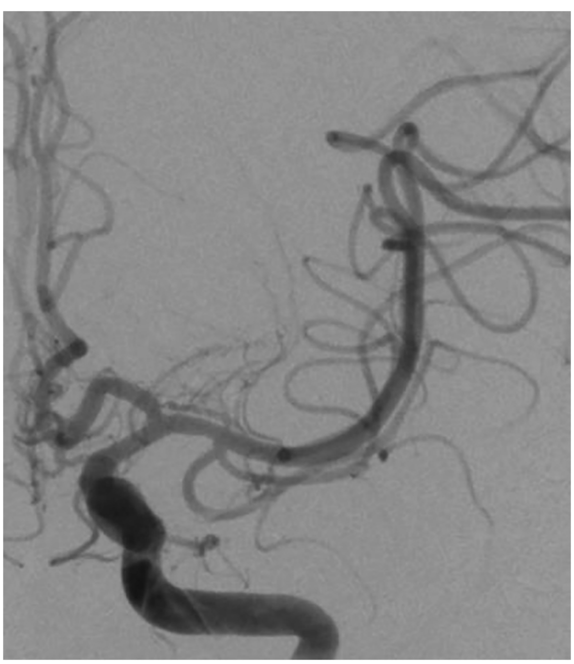

Fig. 11. Pseudotrifurcation.

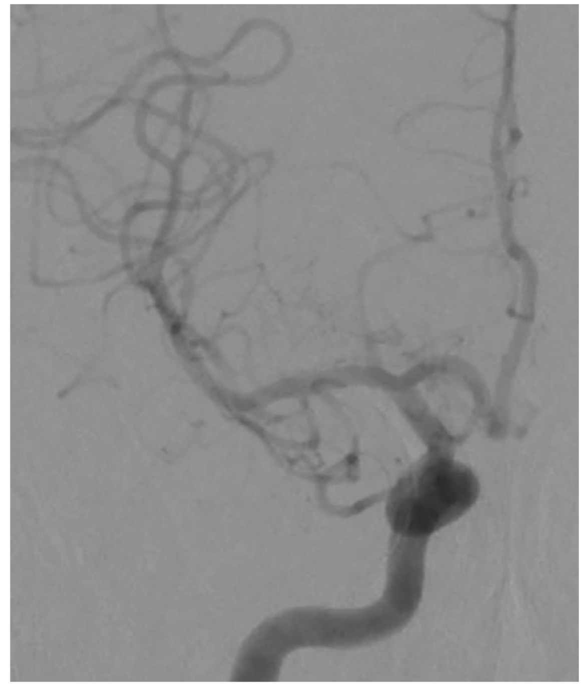

Fig. 12. Medial pseudobifurcation.

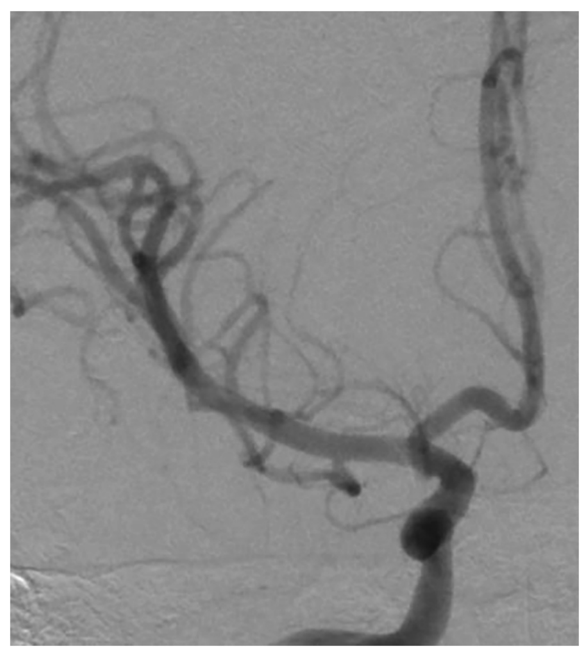

Fig. 13. Lateral pseudobifurcation.

Grellier et al. reported that the main trunk could be short (3–12 mm), medium (13–22 mm) or long (23–40 mm) [6]. To the best of our knowledge, the percentages associated with this classification have never been published. In the present study, short MCAs, medium MCAs and long MCAs were seen in 40.6%, 39.7% and 19.7% of the cases, respectively.

Most authors agree that branching within 5 mm is referred to as early branching. In a previous in the literature, early branching was reported to range from 2.7% to 11.3%; in the present study it was seen in 6% of the cases [6].

In this study, we refer to 11 different MCA patterns as classified by Cilliers et al. [6]. In the present study, medial bifurcation (46%) was the branching pattern that was most frequently found, followed by proximal trifurcation (12.5%), lateral bifurcation (12.1%), distal trifurcation (10.5%), true trifurcation (9.4%), pseudotrifurcation (4.9%), medial pseudobifurcation (2.5%), lateral pseudobifurcation (0.7%), tetrafurcation (0.7%) and pseudotetrafurcation (0.7%). No monofurcation was found in this study. To the best of our knowledge, no previous study has reported on the percentages of MCA patterns based on these 11 different patterns.

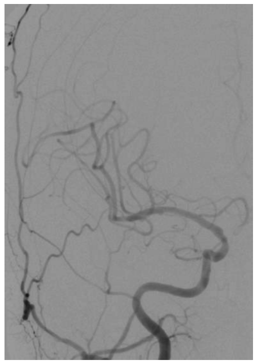

Fig. 14. Tetrafurcation.

Fig. 15. Pseudotetrafurcation.

Table 3
Estimation of the MCA patterns in the population.

Variables	Total (n = 554), n (%)	95% CI
Diameter, mm	Mean ± SD = 2.39 ± 0.49	2.34–2.43
Length, mm	Mean ± SD = 15.56 ± 7.75	14.91–16.21
Length Type		
Short (3–12 mm)	225 (40.6%)	36.5%–44.8%
Medium (13–22 mm)	220 (39.7%)	35.6%–43.9%
Long (23–40 mm)	109 (19.7%)	16.4%–23.2%
Early Branching (≤5 mm)		
Yes	33 (6%)	4.1%–8.3%
No	521 (94%)	91.7%–95.9%
Branching Pattern		
Monofurcation	0 (0%)	0%–0.7%
Tetrafurcation	4 (0.7%)	0.2%–1.8%
Pseudotetrafurcation	4 (0.7%)	0.2%–1.8%
Medial bifurcation	255 (46%)	41.8%–50.3%
Lateral bifurcation	67 (12.1%)	9.5%–15.1%
Medial pseudotrifurcation	14 (2.5%)	1.4%–4.2%
Lateral pseudotrifurcation	4 (0.7%)	0.2%–1.8%
True trifurcation	52 (9.4%)	7.1%–12.1%
Pseudotrifurcation	27 (4.9%)	3.2%–7%
Proximal trifurcation	69 (12.5%)	9.8%–15.5%
Distal trifurcation	58 (10.5%)	8.0%–13.3%

Table 4
The percentage of monofurcation, bifurcation, trifurcation, and tetrafurcation, with its average [7].

Authors	Monofurcation	Bifurcation	Trifurcation	Tetrafurcation
Jain (1964) [8]	0%	90%	10%	0%
Grellier (1978) [9]	17.5%	71.1%	11.4%	0%
Gibo (1981) [10]	0%	78%	12%	10%
Umansky (1984) [11]	5.7%	64.3%	28.6%	1.4%
Antunes (1985) [12]	0%	89.2%	10.8%	0%
Umansky (1985) [13]	0%	70.6%	20.6%	8.8%
Umansky (1988) [14]	3.8%	66.3%	26%	3.8%
Anderhuber (1990) [15]	0%	0%	7%	0%
Meneses (1997) [16]	7.1%	85.7%	7.1%	0%
Idowu (2002) [17]	6%	81%	13%	0%
Kulenovic (2003) [18]	0%	70%	30%	0%
Tanriover (2003) [19]	0%	88%	12%	0%
Tanriover (2004) [20]	0%	88.4%	11.6%	0%
Pai (2005) [21]	0%	80%	0%	0%
Vuillier (2008) [22]	17%	73%	9%	0%
Nowinski (2009) [23]	0%	78%	12%	0%
Ogeng'o (2011 [24]	6.3%	82.3%	10.8%	0.7%
Sadatomo (2013) [25]	0%	92.7%	7.3%	0%
Average	3.5%	74.9%	13.2%	1.3%

If we re-classified these patterns into monofurcation, bifurcation, trifurcation and tetrafurcation, the percentages for these patterns would be 0%, 61.3%, 37.3% and 1.4%, respectively. As seen in Table 2, these results can be compared to the results reported in previous studies [6]. Monofurcation was seen, on average, in 3.5% cases (ranging from 0% to 17.5%), bifurcation was seen, on average, in 74.9% cases (ranging from 0% to 92.7%), trifurcation was seen, on average, in 13.2% cases (ranging from 0% to 30%) and tetrafurcation was seen, on average, in 1.3% cases (ranging from 0% to 8.8%) (Table 4).

5. Conclusion

Anatomical variations of the MCA have to be recognised when planning surgical and endovascular interventions. Studying the neuroangiography patterns of MCAs may help to plan an optimal treatment strategy.

Disclosure of interest

The authors declare that they have no competing interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jocn.2019.07.054.

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