



Twig-like middle cerebral artery or Moya Moya: Report of two cases and literature review

Jeanne Le Bars¹✉, Julien Boucherit², Nicolas Lassalle¹,
Clément Tracol¹, Maud Guillen¹

¹CHU Pontchaillou, Neurovascular Unit, 35000 Rennes, France

²CHU Pontchaillou, Interventional neuroradiology Unit, 35000 Rennes, France

✉ Corresponding author:
jeanne.lbg@gmail.com

<https://doi.org/10.53480/emerg-neurol.082e>

Received: 9 November 2023

Accepted: 17 June 2024

Published: 12 July 2024

Referees:
Nesrine Kouki
Zakaria Mamadou

Background. Several anomalies of the middle cerebral artery have been described in humans. Since the early 2000s, an anatomical variant called “twig-like middle cerebral artery” has been described. It is defined as the replacement of the M1 segment by a plexiform network of vessels. Pathophysiology, clinical and radiological modalities of detection and follow-up are still unclear, although it may have clinical consequences.

Methods. We present two cases of patients with twig-like middle cerebral artery hospitalised in the neurovascular unit in Rennes - Pontchaillou University Hospital between July 2022 and February 2023. We then carried out a literature review of cases of twig-like MCA in order to better define the clinical and imaging characteristics of this disorder.

Results. Bleeding complications are the most frequent, often related to the rupture of an aneurysm. Complications are treated according to the usual procedure for stroke and cerebral haemorrhage. This entity is often misdiagnosed as Moya-Moya disease.

Conclusion. Twig-like MCA is an emerging diagnosis which can lead to ischemic and hemorrhagic complications. The etiological, therapeutic and follow-up management remains unclear and further longitudinal studies are needed to improve patients' care.

Keywords: twig-like, Moya-Moya, middle cerebral artery, aneurysm

Citation:

Jeanne Le Bars, Julien Boucherit,
Nicolas Lassalle, Clément Tracol,
Maud Guillen, Emerg Neurol
2024;1:1
<https://doi.org/10.53480/emerg-neurol.082e>



Artère cérébrale moyenne *twig-like* ou Moya Moya : étude de deux cas et revue de la littérature

Contexte. Plusieurs anomalies de l'artère cérébrale moyenne ont été décrites chez l'homme. Depuis le début des années 2000, une variante anatomique appelée *artère cérébrale moyenne en forme de brindille* a été décrite. Elle est définie comme le remplacement du segment M1 par un réseau plexiforme de vaisseaux. La physiopathologie, les modalités cliniques et radiologiques de diagnostic et de suivi ne sont pas encore claires, bien qu'une telle anomalie puisse avoir des conséquences cliniques.

Méthodes. Nous présentons deux cas de patients présentant une artère cérébrale moyenne *twig-like* hospitalisés dans l'unité neurovasculaire du CHU de Rennes - Pontchaillou entre juillet 2022 et février 2023. Nous avons ensuite réalisé une revue de la littérature des cas d'artère cérébrale moyenne *twig-like* afin de mieux définir les caractéristiques cliniques et d'imagerie de cette malformation.

Résultats. Les complications hémorragiques sont les plus fréquentes, souvent liées à la rupture d'un anévrisme. Les complications sont traitées selon la procédure habituelle pour les accidents vasculaires cérébraux et les hémorragies cérébrales. Cette entité est souvent diagnostiquée à tort comme une maladie de Moya-Moya.

Conclusion. L'artère cérébrale moyenne *twig-like* est un diagnostic émergent à risque de complications ischémiques et hémorragiques. La prise en charge étiologique, thérapeutique et de suivi reste floue et d'autres études longitudinales sont nécessaires pour améliorer la prise en charge des patients.

Mots clés : artère cérébrale moyenne *twig-like*, Moya-Moya, artère cérébrale moyenne, anévrisme

1. Introduction

Twig-like Middle Cerebral Artery (MCA) is a congenital anomaly of the MCA described as a replacement of the M1 segment by a plexiform network of small vessels. This anomaly is also known as aplastic MCA, unfused MCA or rete mirabile. The physiopathology is still unclear but it is thought to arise from an aberration in embryonic development [1–3]. MCA and anterior cerebral artery (ACA) are normally formed by the coalescence of a network of small vessels. In twig-like MCA, these vessels do not fuse or do so incompletely and the M1 trunk is therefore replaced by a network of small vessels called twigs. It should also be noted that some authors believe that the network appears as a substitute network after a segmental steno-occlusal change in proximal M1, and that it evolves on its own as the individual grows but retains a plexiform appearance.

Twig-like MCA is an uncommon anomaly with a frequency reported in the literature between 0.1 and 1.17% [4–7]. However, it is a diagnosis that is becoming increasingly frequent with the development of imaging techniques. Most of the cases reported are from Asian countries and especially from Japan. In Europe, this vascular anomaly is still little known, and rarely diagnosed. Though, twig-like MCA disrupts cerebral haemodynamics and may lead to multiple symptoms and complications (headache, aneurysm, intracranial haemorrhage, ischemic stroke...). As a result of this lack of knowledge, there is likely to be an underdiagnosis and a lack of treatment recommendations. The main differential diagnosis remains Moya-Moya disease (MMD) although it has different anatomical features.

Hence, twig-Like MCA can have severe clinical consequences and deserves appropriate monitoring and therapeutic management. In this article, we propose 2 cases of twig-like MCA and a review of the literature in order to update the latest epidemiological data and clinical characteristics of this entity.

2. Cases presentations

We identified two cases of twig-like MCA during the period January 2022 and December 2023, in our neurovascular unit in Pontchaillou Hospital, Rennes. We then conducted a review of the literature based on the PRISMA criteria (Figure 3).

2.1. Case 1

A 17-year-old female has been experiencing daily headaches for the past 3 years. She had a history of headaches during childhood which resolved with the use of corrective eyewear. A brain magnetic resonance imaging (MRI) performed when she was 4 years old was reported as normal at that time. She is not undergoing any treatment or using contraception. Her current headaches are daily and non-lateralised. They have a pulsatile character and are relieved by isolating herself in a quiet and dark room, suggesting migraine-like symptoms. There is no familial history of headaches or neurological symptoms.

Due to the recurrence of headaches during adolescence, she sought consultation with the neurologist, leading to a new MRI.

The MRI has initially been described with arterial anomalies, including dysplastic stenosis of the termination of the left internal carotid artery (ICA) and of the M1 segment of the left MCA with a developed arteriolar collaterality aspect. There was no vascular accident sequelae or sign of hypoperfusion.

These findings were suggestive of MMD. She was then hospitalised for an etiological and prognostic assessment.

The clinical examination at entry was normal and did not reveal any neurological deficit. The patient only described her usual migraines. Exhaustive biological check-up and lumbar puncture returned without any significant abnormalities.

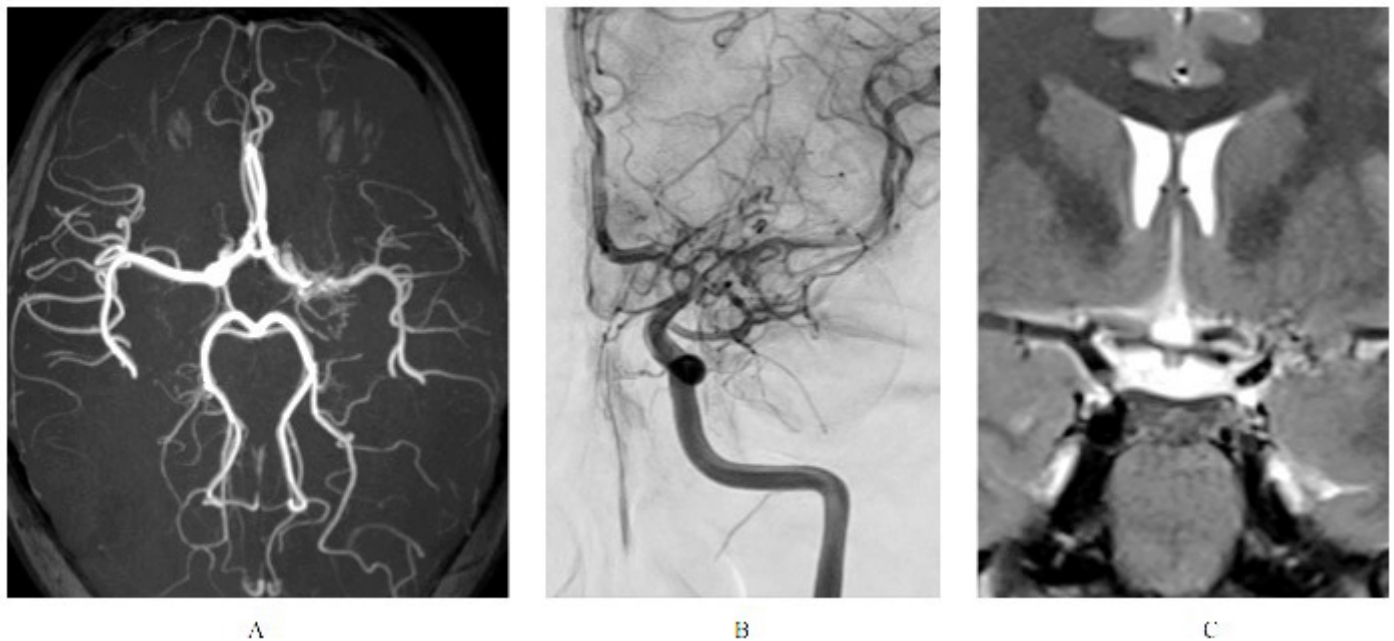


Figure 1. Iconography of the first case report : A. Axial brain MRA TOF. B. Cerebral angiography. C. Coronal Brain MRA T2. Both showing aplasia of proximal M1 replaced by a plexiform network.

Brain magnetic resonance angiography (MRA) revealed an aplasia of the left MCA in its M1 portion, replaced by a plexiform network of collaterals (Figure 1). This imaging also showed duplication of the left A1 segment and fenestration of the right A2 segment, along with anomalies of the middle cerebral artery.

The arteriography demonstrated aplasia of the proximal M1 segment replaced by a plexiform network, without abnormal distal vascularization with M2 branches of normal calibre and modal appearance (Figure 1). There was no evidence of smoke curl or stenosis of the carotid termination or the origin of the left A1. The rest of the arterial vessels were normal, with no intracranial aneurysms, significant stenosis or calibre irregularities. The arteriography findings suggested a congenital malformation of the twig-like type, and there were no arteriographic arguments supporting MMD. The review of the MRI performed when she was 4 years old effectively confirmed the presence of the plexiform network at that age, and it has remained unchanged since then.

A Diamox Brain perfusion Single Photon Emission Computed Tomography (SPECT) showed no abnormalities in cerebral perfusion, especially in the territory of the left middle cerebral artery.

2.2. Case 2

A 42-year-old male was admitted to the hospital in July 2022 due to the sudden onset of vertigo and headaches followed by left hemiparesis. He had no medical history apart from type 1 diabetes and an occasional drug use. Upon admission to the emergency room, he was lethargic with a Glasgow Coma Scale (GCS) score of 10 with left hemiparesis, hemianesthesia and facial paralysis.

A Computed Tomography (CT) scan revealed right fronto-temporal parenchymal haematoma associated with a subarachnoid haemorrhage (SAH). The injected sequences suggested a Moya-Moya type vascular anomaly with a plexiform network of vessels at the M1 segment of the right MCA (Figure 2).

Arteriography confirmed the presence of a plexiform network of vessels in place of the M1 segment of the right MCA with an approximately 50% stenosis of the origin of an M2 branch of the left sylvian artery (Figure 2). Initially, these anomalies were thought to represent an incomplete form of MMD. However, upon careful review of the images, the diagnosis was revised to twig like MCA.

Exhaustive clinical and biological investigations did not reveal any abnormalities that could fit into a secondary form of MMD.

Complementary brain MRA showed a hypoplastic appearance of the right ICA, which divided into numerous small vessels at its termination, creating a rete mirabile aspect. Additionally, there was a duplication of the A1 segment of the right ACA and early bifurcation of the right MCA. No signs of ischaemic sequelae, microbleeds, cavernomas, or aneurysm were seen.

A Diamox Brain perfusion SPECT conducted after the hospitalisation showed no abnormalities in cerebral perfusion. A follow-up brain MRA at 3 months confirmed the rete mirabile like appearance consistent with Twig-Like MCA (Figure 2). Clinically, after a period of rehabilitation, the patient's clinical condition significantly improved. At the 3-month follow-up visit, the patient was able to walk and perform activities of daily living independently. He still had left hemicorporal hypoesthesia with some neuropathic pain. He had not yet returned to work due to significant fatigue but had resumed physical activity at the gym.

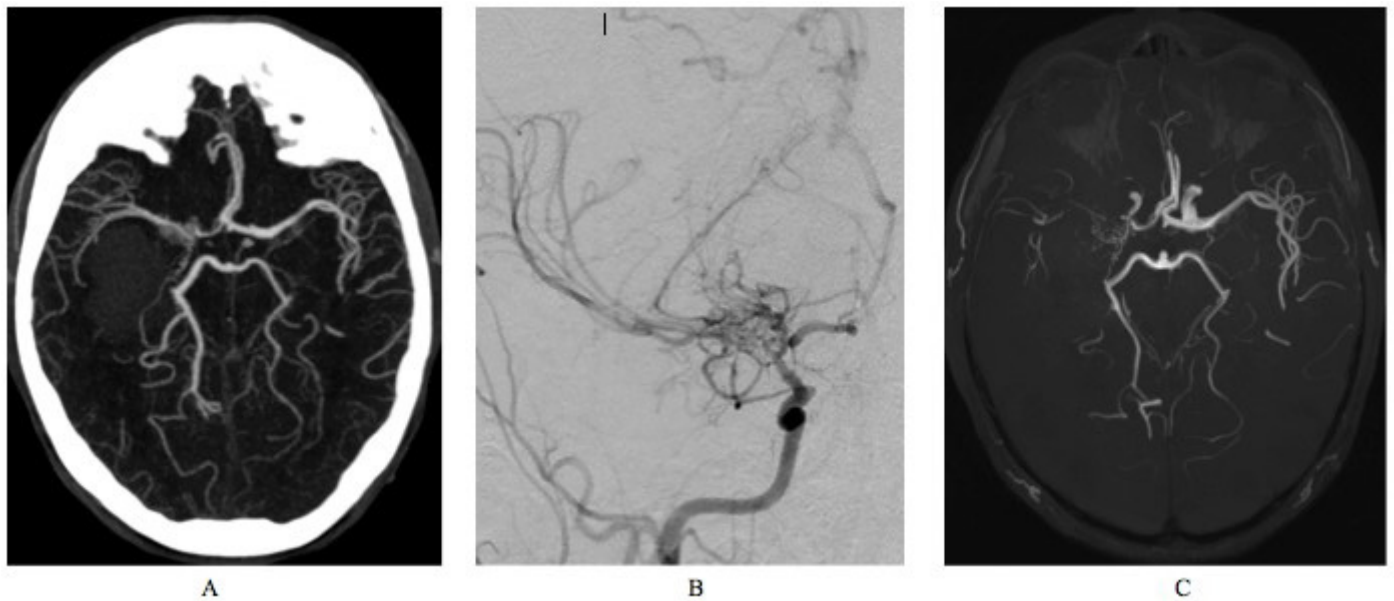


Figure 2. Iconography of the second case report : A. Initial axial CT scan. B. Cerebral angiography. C. 3 months-follow-up MRA. Showing aplasia of the right ICA terminus associated with a rete mirabile aspect.

3. Literature review

We conducted a search on PubMed to identify case reports of twig-like MCA using different keywords : “twig-like MCA”, “twiglike MCA”, “unfused MCA”, “aplastic MCA”, “MCA rete mirabile”, “rete MCA” from 2005 to 2023 excluding articles where demographic, clinical or radiological data were insufficiently detailed or missing. Based on our search criteria, we identified 32 reported cases of Twig-Like MCA, most of which were from Asian countries, particularly Japan (20 out of 32 cases *i.e.* 62,5% of the reported cases). Details of this literature review are available in Figure 3 and Table 1. Our review did not reveal a specific age preference for the discovery of this anomaly, as it was found in individuals ranging from 17 to 81 years. In terms of gender distribution, our review finds 17 women and 15 men.

Twig like MCA is rarely discovered incidentally, with only 3 patients in our cohort being asymptomatic at the time of initial management. The most common mode of diagnosis is a bleeding complication (20 out of 32 patients *i.e.* 62.5% of the patients), mostly subarachnoid haemorrhages (13 out of 32 patients *i.e.* 40.6%) but also intraparenchymal (10 out of 32 patients *i.e.* 31%) or intraventricular (5 out of 32 patients *i.e.* 15.6%) haemorrhages. Cerebral infarction was observed in only 4 cases (*i.e.* 12.5%).

Complementary examinations usually involve an initial CT scan followed by MRA, depending on the practice. However, angiography remains the best examination for the final diagnosis of twig-like MCA. Some authors have complemented the assessment with SPECT. It is important to note that 4 patients out of 32 were initially misdiagnosed with MMD.

Initial imaging does not always identify the plexiform network of vessels developed at the expense of the MCA (19 cases out of 32, *i.e.* 59%). This network is sometimes hindered by the complications that reveal it, particularly in cases of hematoma resulting from aneurysm rupture, where only the cessation of blood flow in the middle cerebral artery is

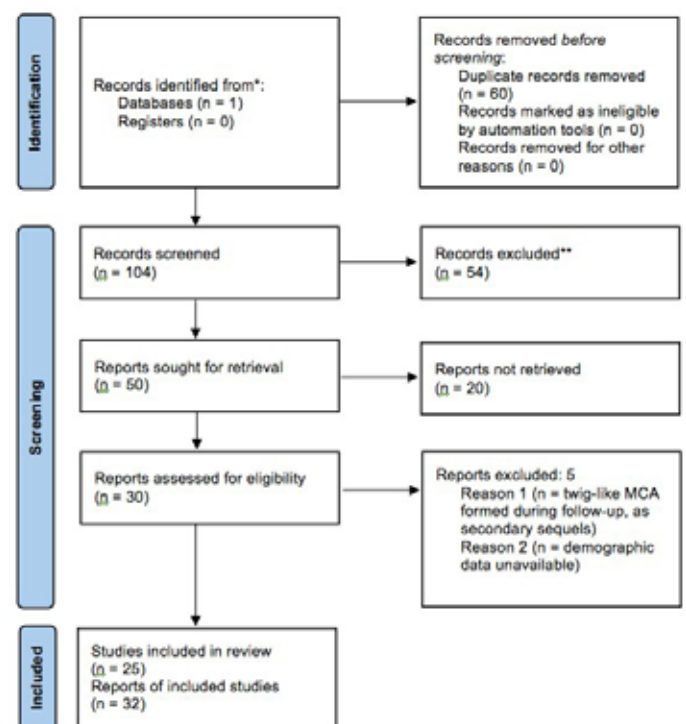


Figure 3. PRISMA diagram of our literature review.

observed. Twig-like MCA is frequently revealed by the aspect of MCA stenosis (22 cases out of 32, *i.e.* 69%), or MCA occlusion (8 cases out of 32, *i.e.* 25%). In rare cases (3 out of 32 cases, 9%), initial imaging reveals anomalies in the anterior cerebral artery. One case even reported an anomaly of the internal carotid artery. In 15 cases out of 32 (*i.e.* 47%), an aneurysm was identified on the initial imaging, mostly on the plexiform network (7 cases out of 32, *i.e.* 22%). In only 9 cases (*i.e.* 28%) was the diagnosis of twig like made on initial imaging. In the other 23 cases, the diagnosis was rectified as the investigations progressed.

Table 1. Demographic, clinical and radiological findings of 26 reported cases of twig-like MCA.

Case no.	Authors	Country	Year	Sex, Age	Symptoms	Radiological event	Initial diagnosis	Final diagnosis	Aneurysm	Aneurysm location	Treatment
1	Liu <i>et al.</i> [8]	Taiwan	2005	M, 44	Headache, nausea, vomiting, impaired consciousness	Intracranial haemorrhage	Vascular network between the bifurcation of ICA and insular segment of MCA	Twig like MCA	Yes	Plexiform network vessels	Surgical clipping
				F, 67	Impaired consciousness	Intracranial haemorrhage	Vascular network between the bifurcation of ICA and insular segment of MCA and stenosis of proximal A1	Twig like MCA	Yes	Plexiform network vessels	Surgical clipping
2	Cekirge <i>et al.</i> [3]	Turkey	2005	M, 32	Headaches	SAH and intraventricular haemorrhage	Embryonic unfused MCA with plexiform vascular network with ipsilateral ACA aneurysm	Left twig-like MCA	Yes	Left A1 segment in the ACA	Coil embolization carried out twice due to initial revascularisation
				M, 54	Vertigo	No haemorrhage nor cerebral infection	> 70% right carotid artery stenosis	Right twig-like MCA	Yes	Left ICA upraclinoid segment	
3	Akkan <i>et al.</i> [9]	Turkey	2015	M, 43	Epileptic seizure and head trauma	SAH	Right twig-like MCA	Same as initial	No		
				F, 37	Vertigo	No haemorrhage nor cerebral infection	Right twig-like MCA	Same as initial	No		
4	Uchiyama <i>et al.</i> [10]	Japan	2016	F, 52	Initially: sudden headache and temporary weakness in the right hand At 2 years: sudden headache and nausea followed by aphasia and weakness of the right extremities	Initially: no haemorrhage or cerebral infarction At 2 years: diffuse SAH and intracerebral haemorrhage in the left temporo parietal lobe	Severe stenosis in the left MCA	Twig like left MCA	No		
5	Inoue <i>et al.</i> [11]	Japan	2016	M, 55	Asymptomatic then, at 3 months, impaired consciousness	Initially asymptomatic 3 months later: Subcortical haemorrhage left frontotemporal and subdural hematoma	Left MCA occlusion	Twig like left MCA	No		Craniotomy and bypass surgery

Table 1. Continued.

Case no.	Authors	Country	Year	Sex, Age	Symptoms	Radiological event	Initial diagnosis	Final diagnosis	Aneurysm	Aneurysm location	Treatment
6	Tashiro <i>et al.</i> [12]	Japan	2016	F, 76	Sudden headache	SAH in the left sylvian fissure	Stenosis in the M1 segment of the MCA	Left twig-like MCA	No		
				F, 81	Sudden headache	SAH in the left temporal lobe	Pseudo-occlusion in the M1 segment of the MCA and stenosis of the M2 segment	Left twig-like MCA	No		
7	Lang <i>et al.</i> [13]	USA	2017	F, 54	Right hemiplegia, global aphasia, severe headache, vomiting, impaired consciousness	Diffuse SAH and intracerebral haemorrhage in the frontal lobe and sylvian fissure	Occlusion of the left MCA superior trunk and MCA aneurysm	Twig like left MCA concerning M2 segment	Yes	M2 segment of the left MCA	Craniectomy Surgical clipping
8	Seno <i>et al.</i> [2]	Japan	2017	F, 49	Sudden severe headache and impaired consciousness	SAH and intraventricular haemorrhage	Ruptured distal anterior choroidal artery aneurysm and right twig like MCA	Same as initial	Yes	Anterior choroidal artery	Craniotomy Surgical clipping Bypass surgery
9	Sakai <i>et al.</i> [14]	Japan	2018	F, 65	Initially: asymptomatic At 4 years: impaired consciousness	Initially: no haemorrhage or cerebral infarction At 4 years: intracerebral hematoma in the right frontal lobe and the caudate nucleus with intraventricular haemorrhage	Right twig like MCA with A1 aneurysm	Right twig like MCA with A1 aneurysm and ruptured de novo aneurysm on the twig like network	Yes	A1 segment of the ACA and multiples aneurysms of the plexiform network vessels	Coil embolization Surgical clipping and bypass surgery
10	Matsumaga <i>et al.</i> [15]	Japan	2018	F, 19	Transient left upper limb hemiparesis, dysesthesia, and headache for 8 years	No haemorrhage nor cerebral infection	Suspicion of unilateral MMD	Right twig-like MCA	No		Bypass surgery and encephalo-myosynangiosis
11	Miura <i>et al.</i> [16]	Japan	2018	M, 69	Sudden loss of consciousness	SAH	Occlusion of the left M1 segment, collateral arteries	Left twig like MCA and ruptured aneurysm in the collateral arteries from the left A1 to the left M2 segment	Yes	Plexiform network vessels	Surgical clipping

Table 1. Continued.

Case no.	Authors	Country	Year	Sex, Age	Symptoms	Radiological event	Initial diagnosis	Final diagnosis	Aneurysm	Aneurysm location	Treatment
12	Goto <i>et al.</i> [17]	Japan	2019	F, 36 (pregnant 14 weeks)	Sudden aphasia, right hemiparesis and impaired consciousness (GCS 14)	Left putaminal haemorrhage	Severe stenosis/occlusion of the left MCA	Twig like left MCA and unruptured aneurysm at the A1-A2 junction of the ACA	Yes	A1-A2 junction of the ACA	Surgical clipping
				F, 27 (pregnant 38 weeks)	Sudden headache, vomiting and impaired consciousness (GCS 6)	Intracranial haemorrhage in the left temporo-parietal lobe and intraventricular haemorrhage	Severe stenosis of the left MCA	Focal occlusion of the M1 segment of the left MCA and plexiform arterial network at the ipsilateral MCA trunk revealing twig like left MCA	No		
13	Shirokane <i>et al.</i> [18]	Japan	2020	F, 64	Sudden-onset headache	SAH in the left sylvian fissure	Bilateral aplastic or twiglike proximal MCA	Same as initial	No		Bypass surgery
14	Matsuo <i>et al.</i> [19]	Japan	2020	F, 17	Lethargic state with mild dysarthria and generalised tonic seizure in early post partum	Cortical SAH in the left frontoparietal convexity	SVCR and twig like left MCA	Same as initial	No		
15	Fukuyama <i>et al.</i> [20]	Japan	2020	F, 53	Headache and nausea	Diffuse SAH	Left twig like MCA and aneurysms in several fine arterioles	Same as initial	Yes	Fine arterioles of the plexiform network	Trapping of the aneurysms
16	Onoue <i>et al.</i> [7]	USA	2021	F, 26	Post-partum headache and generalised convulsion	Hemosiderin staining in the left parietal region likely from prior SAH	Chronic occlusion of the MCA	Left twig-like MCA	No		
				M, 25	Chronic headache with post-cotital exacerbation	No haemorrhage nor cerebral infection	MMD	Left twig-like MCA	No		
				M, 46	Left sided pulsatile tinnitus	No haemorrhage nor cerebral infection	Right MMD	Right twig-like MCA	No		

Table 1. Continued.

Case no.	Authors	Country	Year	Sex, Age	Symptoms	Radiological event	Initial diagnosis	Final diagnosis	Aneurysm	Aneurysm location	Treatment
17	Soejima <i>et al.</i> [21]	Japan	2021	M	Asymptomatic	No haemorrhage or cerebral infarction	Atherosclerotic M1 occlusion	Small unruptured aneurysms at the origin A1 of the anomalous collateral artery containing twig like networks and in the ACA	Yes	A1 origin	Surgical clipping and bypass surgery
18	Takarada <i>et al.</i> [22]	Japan	2021	F, 46	Sudden headache	Left intraventricular haemorrhage	Left MCA aneurysm and MCA trunk stenosis	Twig like left MCA harbouring multiple unruptured aneurysms on the MCA and the plexiform arterial network	Yes	MCA and plexiform network vessels	Bypass surgery
19	Serrano-Rubio <i>et al.</i> [23]	Mexico	2022	M, 43	Explosive right orbitofrontal headache and right hemiparesis	Right frontobasal hematoma with intraventricular disruption	Right MCA aneurysm (segment M1) and MCA stenosis	Unilateral right twig like MCA	Yes	M1 segment of the right MCA	Surgical clipping
20	Inoue <i>et al.</i> [24]	Japan	2022	M, 78	Right hemiparesis and aphasia	Acute cerebral infarction	Bilateral MCA occlusion referring to Moya-Moya disease (MMD)	Embolic occlusion of the unilateral MCA and contralateral T-MCA	No		
21	Watanabe <i>et al.</i> [25]	Japan	2022	M, 38	Severe headache and visual hallucinations, left hemianopia, confusion	Intracerebral haemorrhage from a ruptured aneurysm	Twig like MCA	Twig like MCA and aneurysm at nonbranching point of the twig-like vessel deep in the hematoma	Yes	Non branching point of twig like vessel	Surgical clipping
22	Takeda <i>et al.</i> [26]	Japan	2022	M, 62	Repetitive transient left hemiparesis episodes	No acute cerebral infarction but mild ischemic changes in white matter	Proximal occlusion of the right MCA and stenosis in the proximal portion of the left MCA	Right twig-like MCA and contralateral MCA stenosis	No		Bypass surgery and encephalo-myosynangiosis

Table 1. Continued.

Case no.	Authors	Country	Year	Sex, Age	Symptoms	Radiological event	Initial diagnosis	Final diagnosis	Aneurysm	Aneurysm location	Treatment
23	Hato <i>et al</i> [27]	Japan	2022	M, 40	Apraxia, numbness of the right little finger	Acute cerebral infarction in the left parietal lobe	Hypoplasia of the origin of the MCA and compensatory vascular formation	Left twig-like MCA	No		
24	Terakado <i>et al</i> [28]	Japan	2023	F, 77	Left hemiparesis	Right medial side of the anterior lobe infarction	Proximal right A2 occlusion and distal right A2 dissection	Right twig-like MCA with ipsilateral A2 dissection	No		
25	Zhang <i>et al</i> [29]	China	2023	M, 56	Acute headache	SAH	Right twig-like MCA and ruptured aneurysm at the origin of the accessory MCA	Same as initial	Yes	Origin of the accessory MCA	Endovascular coil embolization

The bleeding complications may occur spontaneously or due to the rupture of an intracerebral aneurysm. Among the patients, 15 out of 32 patients (*i.e.* 46.9%) had one or more aneurysms located on the ACA, the plexiform network composing the MCA, the accessory MCA or even on the anterior choroidal artery. Most aneurysms were managed by clipping. Several patients (7 out of 32 patients) underwent bypass surgery alone or in combination with endovascular treatment to restore proper cerebral hemodynamics by increasing the vascular supply distally to the twig-like network. Finally, two patients underwent encephalomyosynangiosis.

4. Discussion

Twig-like MCA remains an underdiagnosed condition in Europe, and patients often encounter an initial misdiagnosis due to its nonspecific clinical manifestations.

This literature review highlighted the small number of cases of this syndrome described, revealing either a lack of awareness of this syndrome or a low number of cases.

Our literature review suggests a slight female predominance of twig-like MCA, which has also been found in previous studies [4,5]. This female predominance is also found in MMD [4]. Larger studies would be beneficial to confirm this predominance and to investigate the influence of factors, particularly hormonal ones, in the development of twig-like MCA.

Clinically, patients with twig-like MCA may present with headaches, hemiparesis, aphasia, or impaired consciousness, which can evoke several other diagnoses. All of these symptoms are not specific to this disease and are more closely linked to the complications that arise. The radiological features of hematomas, aneurysms and ischemic strokes do not distinguish a twig-like abnormality from events related to other causes. Twig-like syndrome is rarely identified on initial imaging (just over half the cases in our review of the literature).

Twig-like MCA can be mistaken for various cerebral anomalies, including atherosclerosis, especially as patients with twig like often have cardiovascular risk factors [4]. However, the most common differential diagnosis is Moya-Moya disease [1,4,5,7,30], that consists in a progressive distal stenosis of the internal carotid artery extending to the proximal segments of the MCA and the ACA. This progressive stenosis induces the development of replacement vessels with a characteristic angiographic appearance of “smoke curls”, from which the Japanese name of Moya-Moya is derived. Therefore, twig-like MCA and MMD share similar angiographic features, leading up to 70% of initial misdiagnosis [4]. However, certain features can help to distinguish the two conditions (Table 2). Twig-like MCA is unilateral in the large majority of reported cases whereas MMD is commonly bilateral (30%). Furthermore, twig-like MCA usually spares the termination of the ICA and does not involve the posterior cerebral artery unlike MMD. However, there was one case in our review involving both MCAs, with an embolic occlusion of a MCA and a twig-like appearance of the contralateral MCA [24]. In our first clinical case, internal carotid artery dysplasia was described on initial imaging, but later refuted

Table 2. Clinical and radiological differences between Twig-like MCA and MMD.

Twig-like MCA	Moya-Moya disease
Congenital replacement of the M1 segment by a plexiform network of small vessels called twig thought to arise from aberration in embryonic development	Spontaneous progressive steno occlusion of the distal ICA and proximal branches, with anormal collateral vessel for supplience
Clinical aspects :	
Stroke (58.6%) : hemorrhagic >> ischemic More likely to be asymptomatic	Stroke (86%) : ischemic > hemorrhagic Rarely asymptomatic (< 15% cases)
Radiological aspects :	
Unilateral involvement	Can be unilateral (30%) but mostly bilateral
Rare involvement in the ICA terminus	Constant ICA terminus involvement
No involvement of posterior cerebral artery or transdural anastomosis from the ECA	Possible PCA involvement and transdural anastomoses
Leptomeningeal anastomoses from the ACA and/or PCA [4,8]	Leptomeningeal anastomoses from the ACA and/or PCA
Twig like network join with the <i>in situ</i> MCA	Collateral vessels do not coalesce into a single main trunk
Frequent intracranial aneurysms (34.5%)	Occasional intracranial aneurysms (10.5%)
Frequent coexisting arterial anomalies (48.3%) concerning the MCA and ACA	Occasional coexisting arterial anomalies (12.3%)
No angiographic progression	Angiographic progression with progressive steno-occlusion and development of collateral vessels
Twig like network exists in parallel with the M1 segment of the MCA	Moya-Moya vessels are oriented perpendicular to the axis of the M1 segment of the MCA

on arteriography. The involvement of the internal carotid artery was also refuted *a posteriori* in one of the cases in our review [3]. These findings suggest the need for caution in the initial radiological interpretation, which may lead to a misdiagnosis between twig-like and MMD. In case of doubt, arteriography can rectify the diagnosis. Current knowledge therefore suggests that twig-like does not involve arteries other than the MCA and ACA, but imaging knowledge of this syndrome is still imperfect and remains to be improved.

The maintenance of adequate perfusion in twig-like MCA also explains why the transdural anastomoses from the ACE seen in MMD are not present. However, both conditions include leptomeningeal anastomoses from the ACA and/or PCA. Moreover, the plexiform vascular network develops parallel to the M1 segment of the MCA in twig like syndrome, while in MMD, the suppletive vessels are oriented perpendicular to the axis of M1 of the MCA.

The frequency of arterial anomalies associated with these two conditions appears to be different. Aneurysms, for example, can be seen in both syndromes but are more frequent in the twig-like MCA (35% vs 12% according to the literature) [4,7,31]. In fact, our literature review highlights that patients with a twig-like MCA are particularly at risk of developing intracranial aneurysms that may lead to bleeding complications. The increased frequency of aneurysms may partly explain the frequent haemorrhagic complications in the twig-like MCA while ischemic complications are most common in MMD [4]. However, some haemorrhagic complications seem to occur independently of aneurysm rupture, suggesting that certain aneurysms are incidentally discovered during an acute event unrelated to the aneurysm itself [17].

Moreover, in some patients with cerebral haemorrhage, no aneurysm was detected, suggesting that other mechanisms may explain the haemorrhagic complications, such as flow turbulence in the plexiform network and downstream vessels.

Twig-like MCA is also a cause of cerebral infarction [24,26–28], maybe due to hemodynamic stress in the plexiform network vessels, but it is rarer than in MMD.

The formation and rupture of aneurysms and their rupture in twig like MCA are probably related to hemodynamic stress and flow turbulence, which weaken the thin wall of the vessels forming the plexiform network [8,27]. Histological studies of aneurysms in twig like MCA have shown an internal elastic lamina (IEL) disruption and a thin aneurysmal wall [25]. The same histological findings are reported in patients with aneurysms and no history of twig-like MCA.

The increased risk of bleeding complications makes the diagnosis of twig like MCA important to prevent its potentially fatal consequences. Currently, there are no precise recommendation issued in Europe regarding the etiological and therapeutic management of this condition. Most of the time, the investigations carried out are similar to those performed in MMD, as the two conditions are often initially confused. Unlike MMD, which can be associated with systemic pathologies, twig-like primarily involves cerebral vascularization, and therefore, systemic investigations are not required.

The therapeutic management is not yet well-defined, except for the management of complications such as the rupture of aneurysms.

Contrary to aneurysms not related to twig-like MCA, where the endovascular embolization has a prominent place, the

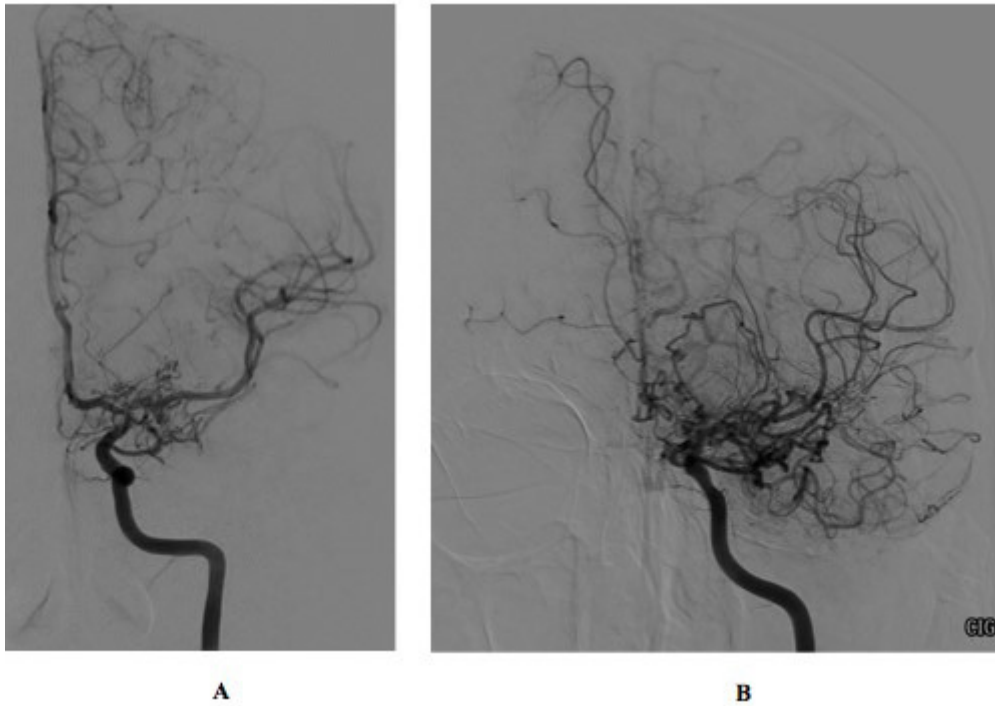


Figure 4. Imaging comparison. A. Twig-like MCA. B. Moya Moya disease.

complex network of small-calibre vessels constituting twig-like often poses limitations on the feasibility of endovascular treatment. As a result, clipping predominantly constitutes the approach, especially in the context of hemorrhagic events.

Some teams also perform bypass surgery between the intra- and extracranial circulation inspired by the techniques used in the management of MMD. Precisely, one of those bypass surgeries, frequently used in MMD, encephalomyosynangiosis, can be performed in twig-like. This surgical technique, consisting of the transposition of the outer layer of the dura mater, a branch of the superficial temporal artery and the temporal muscle, aims to stimulate neoangiogenesis and to promote the development of cerebral anastomoses in order to re-establish an adequate flow in the cerebral hemisphere vascularised by the plexiform network. However, in the two cases we report, no hypoperfusion was found on MRI or SPECT. Thus, it is worth considering whether these examinations, usually performed in the investigation of MMD, should be systematic in the investigation of a twig like MCA. The management of follow-up is also poorly defined, varying from one centre to another and typically consists of clinical and imaging monitoring. The follow-up time varies from a few months to several years [11]. The imaging aspect appears stable during follow-up, with only one case of aneurysm progression reported [14]. Our cases confirm the stability of the imaging aspect, over one decade in the first case and over a few months in the second case. While most reported cases do not show progression, the case of progression aforementioned [14] underlines the need for follow-up, particularly radiological, to detect possible long-term complications.

In our cohort, no deaths were reported during follow-up. However, several patients required rehabilitation, and some still have neurological symptoms at the follow-up visit (e.g., mild cognitive impairment, aphasia, hemiparesis necessitating a cane...) such as our second case report.

Finally, echoing the female predominance of twig-like MCA found in the literature, two cases of haemorrhagic complications were reported during pregnancy [17] and one case of epilepsy and headache occurred in the post-partum context [7]. The small number of patients does not allow us to conclude that there is a link between the pregnancy context and hemodynamic consequences in patients with a twig-like anomaly. However, these cases suggest that close monitoring of patients with a known twig-like MCA should be implemented during pregnancy and confirm the need for larger studies to investigate the role of hormones in the occurrence of this syndrome and its complications.

In this context, our results must be qualified. Longitudinal studies on larger cohorts will be needed to confirm our analyses. There are also probably other distinctive features of the syndrome that are not known at this stage. The current development of research will make it easier to detect twig-like syndrome, create specific therapies, particularly before complications arise, and improve management of complications when they do occur. For the moment, in the absence of long-term studies or sufficiently large cohorts and regarding the frequent occurrence of complications, these patients should be treated with caution and offered regular follow-up.

5. Conclusion

Twig-like MCA is an uncommon congenital anomaly in Europe, with an emerging diagnosis in recent years. The main differential diagnosis remains Moya-Moya disease or stenotic-occlusive disease because of their close angiographic aspects. The complications differ, however, with haemorrhagic events being more frequent in twig like MCA. Hence, precise angiographic explorations are essential for accurate diagnosis. The screening, additional investigations and therapeutic management remains unclear and further studies

including a significant number of patients with long-term follow-up are needed to improve the management of this syndrome in the future. Longitudinal monitoring is also indicated to detect potential progressive complications of the twig-like.

Statements

Author Contribution Statement. All authors contributed equally to this work.

Declaration of Interest. The authors declare that they have no conflicts of interest.

Funding. None.

References

- Ota T, Komiyama M. Twig-like middle cerebral artery: Embryological persistence or secondary consequences? *Interv Neuroradiol J Peritherapeutic Neuroradiol Surg Proced Relat Neurosci*. 2021;27(4):584-7. <https://doi.org/10.1177/15910199211024077>
- Seno T, Kohno K, Tanaka H, Iwata S, Fukumoto S, Ichikawa H, *et al*. A Case of ruptured distal anterior choroidal artery aneurysm associated with a twig-like middle cerebral artery, treated with single-stage aneurysm clipping and STA-MCA double anastomoses in the acute phase. *No Shinkei Geka*. 2017;45(8):691-7. <https://doi.org/10.11477/mf.1436203576> [in Japanese]
- Cekirge HS, Peynircioglu B, Saatci I. Endovascular treatment of an "anterior cerebral artery" aneurysm in a patient with "embryonic unfused middle cerebral artery" anomaly: a case report. *Neuroradiology*. 2005;47(9):690-4. <https://doi.org/10.1007/s00234-005-1407-3>
- Goto Y, Nanto M, Oka H, Murakami N, Nakagawa T, Kimura S, *et al*. Radiological and clinical features of twig-like middle cerebral artery in comparison with moyamoya angiopathy: a multicenter retrospective study. *J Neurosurg*. 2022;137(6):1718-26. <https://doi.org/10.3171/2022.2.JNS212338>
- Seo BS, Lee YS, Lee HG, Lee JH, Ryu KY, Kang DG. Clinical and radiological features of patients with aplastic or twiglike middle cerebral arteries. *Neurosurgery*. 2012;70(6):1472. <https://doi.org/10.1227/NEU.0b013e318246a510>
- Lutz T, Mönnings P, Ayzenberg I, Lukas C. Twig-like middle cerebral artery: a seldom vessel anomaly of important relevance. *Clin Neuroradiol*. 2018;28(3):441-3. <https://doi.org/10.1007/s00062-017-0613-9>
- Onoue K, Nguyen TN, Mian A, Dasenbrock H, Bedi H, Abdalkader M. Twig-like middle cerebral arteries: Clinical and radiological findings. *Clin Imaging*. 2021;73:31-7. <https://doi.org/10.1016/j.clinimag.2020.11.049>
- Liu HM, Lai DM, Tu YK, Wang YH. Aneurysms in twig-like middle cerebral artery. *Cerebrovasc Dis Basel Switz*. 2005;20(1):1-5. <https://doi.org/10.1159/000086119>
- Akkan K, Ucar M, Kilic K, Celtikci E, Ilgit E, Onal B. Unfused or twig-like middle cerebral artery. *Eur J Radiol*. 2015;84(10):2013-8. <https://doi.org/10.1016/j.ejrad.2015.06.012>
- Uchiyama T, Okamoto H, Koguchi M, Tajima Y, Suzuyama K. A case of aplastic or twig-like middle cerebral artery presenting with an intracranial hemorrhage two years after a transient ischemic attack. *No Shinkei Geka*. 2016;44(2):143-8. <https://doi.org/10.11477/mf.1436203246> [in Japanese]
- Inoue A, Kohno K, Fukumoto S, Ichikawa H, Onoue S, Miyazaki H, *et al*. A case of ECA-MCA double anastomoses for hemorrhagic type of twig-like MCA. *No Shinkei Geka*. 2016;44(6):463-71. <https://doi.org/10.11477/mf.1436203312> [in Japanese]
- Tashiro R, Inoue T, Shibahara I, Ezura M, Uenohara H, Fujimura M, *et al*. Nonaneurysmal subarachnoid hemorrhage due to unfused or twiglike middle cerebral artery rupture: Two case reports. *J Stroke Cerebrovasc Dis Off J Natl Stroke Assoc*. 2016;25(6):e77-78. <https://doi.org/10.1016/j.jstrokecerebrovasdis.2016.03.029>
- Lang M, Moore NZ, Witek AM, Kshetry VR, Bain MD. Microsurgical repair of ruptured aneurysms associated with Moyamoya-pattern collateral vessels of the middle cerebral artery: A report of two cases. *World Neurosurg*. 2017;105:1042.e5-1042.e10. <https://doi.org/10.1016/j.wneu.2017.06.166>
- Sakai K, Hiu T, Fukuda Y, Ozono K, Honda K, Kawahara I, *et al*. A Rare case of a ruptured De Novo aneurysm arising from the twig-like networks of an anomalous collateral artery associated with hypoplasia of the M1 segment of the middle cerebral artery 4 years after the rupture of an A1 aneurysm at the origin of the collateral artery. *No Shinkei Geka*. 2018;46(8):713-22. <https://doi.org/10.11477/mf.1436203799> [in Japanese]
- Matsunaga Y, Izumo T, Morofuji Y, Horie N, Hayashi K, Matsuo T. Revascularization for aplastic or twiglike middle cerebral artery: A case report. *J Stroke Cerebrovasc Dis Off J Natl Stroke Assoc*. 2018;27(5):e78-9. <https://doi.org/10.1016/j.jstrokecerebrovasdis.2017.12.004>
- Miura S, Katsube T, Nakamizo S, Sakagami Y. A case of aplastic or twig-like middle cerebral artery with a ruptured aneurysm at an anomalous collateral artery. *Brain Nerve Shinkei Kenkyu No Shinpo*. 2018;70(9):1033-6. <https://doi.org/10.11477/mf.1416201125> [in Japanese]
- Goto Y, Oka H, Hiraizumi S, Okamoto T, Nishii S, Yamamoto H, *et al*. Aplastic or twig-like middle cerebral artery presenting with intracerebral hemorrhage during pregnancy: report of two cases. *World Neurosurg*. 2019;2:100018. <https://doi.org/10.1016/j.wnsx.2019.100018>
- Shirokane K, Tamaki T, Kim K, Morita A. Subarachnoid hemorrhage attributable to bilateral aplastic or twiglike middle cerebral artery. *World Neurosurg*. 2020;134:560-3. <https://doi.org/10.1016/j.wneu.2019.10.054>
- Matsuo A, Hiu T, Ito T, Moritsuka T, Honda K, Kawahara I, *et al*. Aplastic or twig-like middle cerebral artery with cortical subarachnoid hemorrhage and reversible cerebral vasoconstriction syndrome during the postpartum period in a juvenile female: A case report. *No Shinkei Geka*. 2020;48(5):435-44. <https://doi.org/10.11477/mf.1436204206> [in Japanese]
- Fukuyama R, Yamamura K, Murata H, Miyatake S, Matsumoto N, Abe H. Ruptured aneurysm of an aplastic or twig-like middle cerebral artery with ring finger protein 213 mutation: A case report. *No Shinkei Geka*. 2020;48(6):533-40. <https://doi.org/10.11477/mf.1436204224> [in Japanese]
- Soejima K, Hiu T, Shiozaki E, Ogawa Y, Ito T, Honda K, *et al*. Asymptomatic aplastic or twig-like middle cerebral artery associated with unruptured cerebral aneurysms at the origin (A1) of a collateral artery and the anterior communicating artery: A case report with multiple intracranial atherosclerotic stenoses. *Brain Nerve Shinkei Kenkyu No Shinpo*. 2021;73(4):379-88. <https://doi.org/10.11477/mf.1416201771> [in Japanese]
- Takarada A, Yanaka K, Onuma K, Nakamura K, Takahashi N, Ishikawa E. Aplastic or twig-like middle cerebral artery harboring unruptured cerebral aneurysms treated by clipping and bypass surgery: Illustrative case. *J Neurosurg*

Case Lessons. 2021;2(9):CASE21360. <https://doi.org/10.3171/CASE21360>

23. Serrano-Rubio A, Ferrufino-Mejia BR, Balcázar-Padrón JC, Rodríguez-Rubio HA, Nathal E. Ruptured aneurysm associated with a twig-like middle cerebral artery: An illustrative case report. *Surg Neurol Int.* 2022;13:456. https://doi.org/10.25259/SNI_678_2022

24. Inoue H, Oomura M, Nishikawa Y, Mase M, Matsukawa N. Aplastic or twig-like middle cerebral artery and cardiogenic cerebral embolism mimicking moyamoya disease with RNF213 polymorphism: A case report. *Interv Neuroradiol J Peritherapeutic Neuroradiol Surg Proced Relat Neurosci.* 2022;28(6):634-8. <https://doi.org/10.1177/15910199211062016>

25. Watanabe N, Marushima A, Hino T, Minamimoto S, Sato M, Ito Y, *et al.* A ruptured aneurysm in aplastic or twig-like middle cerebral artery: A case report with histological investigation. *NMC Case Rep J.* 2022;9:7-12. <https://doi.org/10.2176/jns-nmc.2021-0276>

26. Takeda H, Yanaka K, Onuma K, Nakamura K, Ishii K, Ishikawa E. Aplastic or twiglike middle cerebral artery with contralateral middle cerebral artery stenosis showing transient ischemic attack: illustrative case. *J Neurosurg Case Lessons.* 2022;3(22):CASE22121. <https://doi.org/10.3171/CASE22121>

27. Hato T, Yamaguchi M, Sugiyama A, Aoki K, Fukuda H, Kohno M, *et al.* A case of cerebral infarction due to aplastic or twig-like middle cerebral artery after lung cancer surgery. *J Surg Case Rep.* 2022(9):rjac430. <https://doi.org/10.1093/jscr/rjac430>

28. Terakado T, Matsumaru Y, Ishikawa E. Anterior cerebral artery dissection for a patient with ipsilateral aplastic or twig-like middle cerebral artery: An illustrative case report. *Surg Neurol Int.* 2023;14:154. https://doi.org/10.25259/SNI_170_2023

29. Zhang L, Su H, Yu J. Case report: Endovascular coil embolization of an aneurysm at the origin of the accessory middle cerebral artery from the A1 segment as the collateral artery to twigs. *Front Neurol.* 2023;14:1078173. <https://doi.org/10.3389/fneur.2023.1078173>

30. Uchiyama N. Anomalies of the middle cerebral artery. *Neurol Med Chir (Tokyo).* 2017;57(6):261-6. <https://doi.org/10.2176/nmc.ra.2017-0043>

31. Viso R, Lylyk I, Albiña P, Lundquist J, Scrivano E, Lylyk P. Hemorrhagic events associated with unfused or twig-like configuration of the middle cerebral artery: A rare vascular anomaly with clinical relevance. *Interv Neuroradiol J Peritherapeutic Neuroradiol Surg Proced Relat Neurosci.* 2021;27(2):285-90. <https://doi.org/10.1177/1591019920970430>