Surgical and Radiologic Anatomy (2021) 43:1947–1950
https://doi.org/10.1007/s00276-021-02765-y

ANATOMIC VARIATIONS

Type 2 persistent primitive olfactory artery associated with bilateral ophthalmic arteries arising from the middle meningeal arteries diagnosed by magnetic resonance angiography

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Received: 9 January 2021 / Accepted: 8 May 2021 / Published online: 13 May 2021

Abstract
Persistent primitive olfactory artery (PPOA) is a relatively rare variation of the proximal anterior cerebral artery (ACA). Traditionally, there are two types: Type 1 is a common type, which generally follows an anteroinferior course and which takes a hairpin turn before continuing to the A2 segment of the ACA. Type 2 is an extremely rare variation that continues to the anterior ethmoidal artery without a hairpin turn. Since Type 2 PPOAs are small in caliber, previously reported cases were found during anatomical dissection or were detected by catheter angiography. We herein report a case of Type 2 PPOA that was diagnosed by partial-maximum-intensity projection images of magnetic resonance angiography. This patient also had bilateral ophthalmic arteries arising from the middle meningeal artery. These two variations may be related to each other.

Keywords Anterior cerebral artery · Ethmoidal artery · Magnetic resonance angiography · Ophthalmic artery · Persistent primitive olfactory artery

Introduction

The primitive olfactory artery (POA) usually regresses during early gestation [9], but when it persists, an anomalous course of the anterior cerebral artery (ACA) forms, called persistent POA (PPOA) [2–8, 11–13]. Traditionally, there are two types of the PPOA. Type 1 PPOA is a common type characterized by an anteroinferior course of the ACA along the olfactory sulcus. It then makes a hairpin turn, and finally connects to the distal ACA. Type 2 PPOA is extremely rare. It is a tiny artery that connects to the anterior ethmoidal artery (AEA) without a hairpin turn. Recently, three other rare variations of PPOA have been reported. Type 3 connects to both the AEA and distal ACA with a hairpin turn [2]. Type 4 connects to the accessory middle cerebral artery with a hairpin turn [4, 5]. Type 5 connects to the distal ACA without a hairpin turn [12].

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Since Type 2 PPOAs are small in caliber, previously reported cases were found during anatomical dissection [7] or were detected by catheter angiography [1, 3, 11]. We herein report a case of Type 2 PPOA that was detected by magnetic resonance (MR) angiography. This patient also had bilateral ophthalmic arteries (OAs) arising from the middle meningeal artery (MMA), which is a relatively rare OA variation [14].

Case report

A 69-year-old woman with cerebellar infarctions after aortic arch replacement underwent cranial MR imaging and MR angiography using a 3-T MR system (Achieva 3.0 T TX Quasar Dual, Philips Medical Systems, Best, The Netherlands). MR angiography was obtained using a standard three-dimensional time-of-flight technique. The imaging parameters were as follows: repetition time, 23.0 s; echo time, 3.45 s; flip angle, 18°; field of view, 20×20 cm; and slice thickness, 0.55 mm.

MR imaging revealed multiple cerebellar infarctions. No lesions were seen in the anterior cranial fossa or ethmoid sinus (not shown). Maximum-intensity-projection (MIP) images of MR angiography showed no occlusion or

significant stenosis of the vertebrobasilar system. It was incidentally found that bilateral OAs were arising from the MMAs instead of the internal carotid arteries (ICAs) (Fig. 1). During careful observation of MR angiographic source images, the first author found a tiny anomalous artery in the anterior cranial fossa. Subsequently, partial MIP images of the midline anterior cranial fossa were created (Fig. 2). A tiny artery arose from the A1–A2 junction of the left ACA and took an anteroinferior course and connected to the AEA, indicating that this was a Type 2 PPOA.

The patient was treated conservatively, and the clinical course was uneventful. Neither computed tomography angiography nor catheter angiography was performed.

Discussion

According to Padget [9], the ACA begins to develop at the formation of a secondary branch of the POA at 5 weeks of gestation. The rostral division of the primitive ICA constitutes the POA, which terminates in the nasal fossa. The secondary branch of the POA is the medial olfactory artery, which constitutes the future ACA. If regression of the medial branch of the POA does not occur normally, an anomalous course of the ACA and/or connection to the AEA develops [6].

The PPOA is a well-known variation of the proximal ACA; its prevalence on MR angiography in Japan is 0.14% [13]. There is no sex or laterality predominance. Nozaki et al. [8] reported that there were two types of PPOA. Type 1 is the most common variation, it is typically observed on the midline anterior cranial fossa. The proximal ACA takes an anteroinferior course and connects to the normally positioned A2 segment with a hairpin turn. In contrast, Type 2 PPOAs are extremely rare and anastomose to the AEA at the lamina cribrosa without connection to the distal ACA; thus, the Type 2 PPOA does not form a hairpin turn and is usually small in caliber (Fig. 3). As described in "Introduction", three additional rare types of PPOA have recently been reported [2, 4, 12].

In previous reports, Type 2 PPOAs have been identified by anatomical dissection [7] or catheter angiography [1, 3, 11]. Recently, Rădoi et al. [10] reported a case of Type 2 PPOA using CT angiography. To the best of our knowledge, this is the first reported case of Type 2 PPOA diagnosed by MR angiography in the English language literature. Because of the low spatial resolution of MR angiography, tiny arteries like Type 2 PPOAs may not be visualized on routine MIP images. We could diagnose the Type 2 PPOA in our patient after obtaining partial MIP images. Careful observation of MR angiographic source images is important for the detection of arterial variations, and partial MIP images are useful for the identification of rare arterial variations.

Recently, Kamo et al. [3] reported that Type 2 PPOAs were frequently identified by selective catheter angiography in patients with moyamoya disease. In moyamoya disease, the terminal segment of the ICA is gradually occluded. Then, collateral circulation from the OA to the A2 segment of the ACA via the Type 2 PPOA may gradually develop. Tsutsumi et al. [11] reported a case of arteriovenous fistula of the anterior cranial fossa that was supplied by both Type 2 PPOA and AEA. Our patient had no pathological lesions in the midline anterior cranial fossa, including the ethmoid sinus.

In our patient, the bilateral OAs arose from the MMAs, not from the ICA. Prevalence of this OA variation on 3-T MR angiography is reported to be 1.45% per OA [14]. There is right-side predominance, and it can be seen bilaterally. Normally, the AEA is a relatively large branch of the OA. In our patient, the AEA was not supplied by the OA, rather, it was supplied by the Type 2 PPOA. There may be a relationship between the Type 2 PPOA and the bilateral OAs arising from the MMAs.

The clinical significance of a Type 2 PPOA is limited; however, recognition of the presence of this variation before performing midline anterior skull base surgery is important

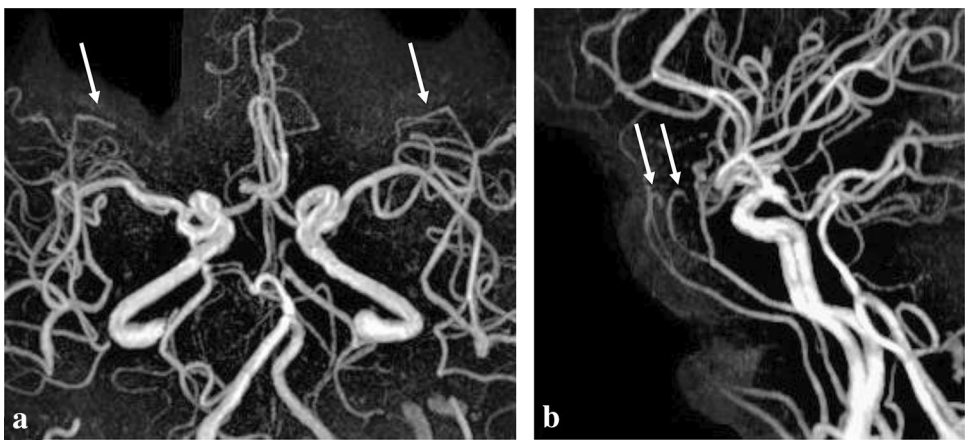

Fig. 1 Inferosuperior (**a**) and lateral (**b**) projections of cranial magnetic resonance (MR) angiography show bilateral ophthalmic arteries (OAs) arising from the middle meningeal arteries instead of the internal carotid arteries (ICAs) (arrows). No other arterial variations are recognized. The vertebrobasilar system is patent

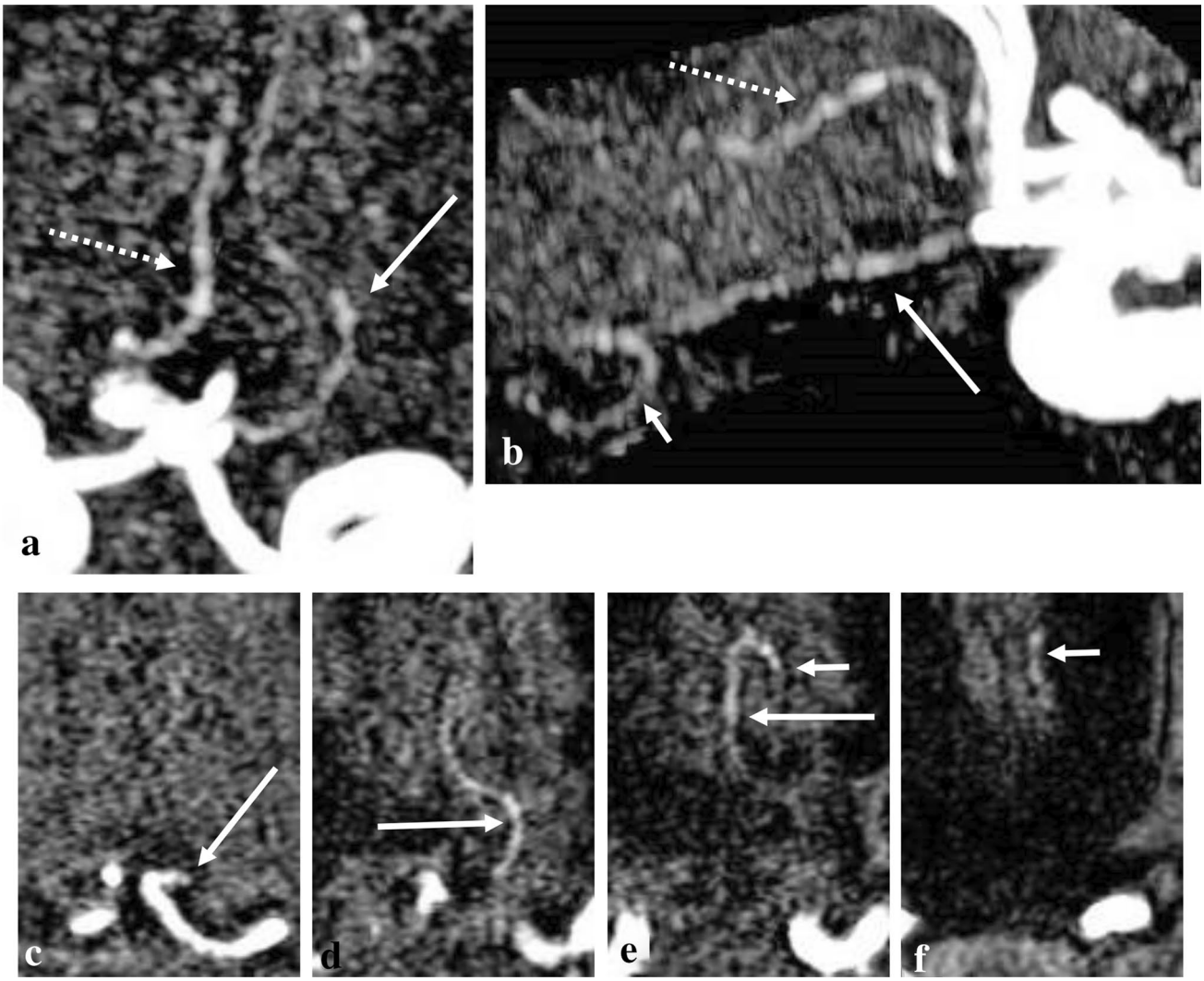

Fig. 2 Partial maximum-intensity-projection (MIP) images of the midline anterior cranial fossa in inferosuperior (**a**) and lateral (**b**) projections show a tiny artery arising from the A1–A2 junction of the left anterior cerebral artery (ACA) and taking an anteroinferior course (long arrows). This artery continues to the anterior ethmoidal artery (AEA) (short arrow), indicating that it is a type 2 persistent primitive olfactory artery (PPOA). Dotted arrows indicate the right fronto-orbital artery, the first cortical branch of the A2 segment of the ACA. No OAs arise from the ICAs. The source MR angiography images **c**–**f** demonstrate the entire course of the anomalous artery (long arrows) and the AEA (short arrows)

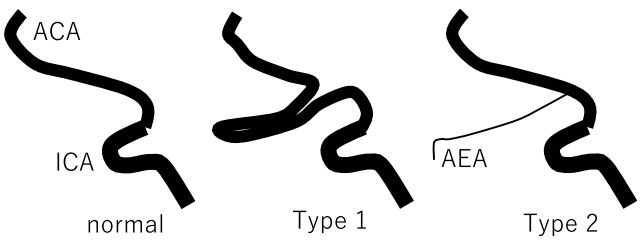

Fig. 3 A schematic illustration of the two main types of PPOA (left lateral projection). *ACA* anterior cerebral artery, *AEA* anterior ethmoidal artery, *ICA* internal cerebral artery (Modified from Reference [9])

for preventing complications. Furthermore, an OA variation arising from the MMA is dangerous during endovascular procedures involving the external carotid system.

Conclusions

We encountered a case of a Type 2 PPOA, a rare arterial variation of the midline anterior cranial fossa that was diagnosed by MR angiography. The importance of careful observation of MR angiographic source images and the usefulness of partial MIP images for making a correct diagnosis were

underscored. In the present case, bilateral OAs arose from the MMA. These two variations may be related.

Author contributions AU carried out the study design and drafted the manuscript. All the authors reviewed the manuscript critically, and have read and approved the final manuscript.

Declarations

Conflict of interest The authors declare that that they have no conflict of interest.

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