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Anatomical Imaging

Developed Collateral Networks between the Internal Carotid Artery and External Carotid Artery: Carotid Rete Mirabile

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Carotid rete mirabile (means wonderful net in Latin) (CRM) is a physiological network between the internal carotid artery (ICA) and external carotid artery (ECA) found in lower mammals such as dogs, cats, goats, oxeas, sheep, and pigs.[1,2] CRM is typically located around the cavernous portion of the ICA. CRM supplied by the branches of the ECA compensates for deficient intracranial blood supply and regulates heat and intracranial blood pressure.[1,2] Similar vascular networks between the ICA and ECA can be rarely developed as anastomotic collateral pathways following segmental dysplasia of the ICA in the human. Those anastomoses between the ICA and ECA resemble morphologically to a rete (net in Latin), and several authors call those anastomotic pathways as carotid rete although those pathological anastomotic collaterals are different from true physiological CRM in the lower mammals. Those carotid rete-like collaterals in the human result from the dysplasia of the ICA during the fetal stage. Herein, we present a case of these rare vascular networks supplying a segmental hypoplastic ICA via the ECA, which was visualized well on 3D volume-rendering reconstructed images. In this case presentation, we call those rete-like vascular collaterals CRM for convenience of explanation.

A 36-year-old man with a past intracerebral hemorrhagic episode underwent a follow-up angiography. The hypoplasia of the left ICA exiting from the foramen lacerum to the proximal to the bifurcation of the meningohypophyseal trunk (horizontal intracavernous segment, 5th segment defined by the classification of Lasjaunias) was disclosed. The left carotid canal was also hypoplastic. The left distal ICA was fed contralaterally by the right ICA[3] and ipsilaterally by the left ECA via developed vascular networks. The right twig-like anterior and middle cerebral arteries were also disclosed (**Fig. 1**). 3D reconstructed rotational digital cerebral angiography showed the anastomoses between the ECA and distal ICA. The arteries branching from the internal maxillary artery and ascending pharyngeal artery developed and passed through the superior orbital fissure, foramen ovale, foramen spinosum, carotid canal, jugular foramen, and hypoglossal canal, respectively. These arteries forming vascular networks among themselves entered the inferolateral trunk or meningohypophyseal trunk (**Fig. 2**). The anastomoses between the ICA and ECA formed CRM morphologically.

The exact pathogenesis of CRM in the human remains unclear. However, the residual carotid canal, which was observed in our case, can be considered as an evidence supporting that the segmental regression (not agenesis) of the ICA occurs,[4] and considering that the collateral flow of the distal ICA is supplied by the ECA, not by the carotid-basilar anastomosis, segmental regression of the ICA can occur in the late fetal stage (at least after five or six weeks of gestation). Thus, in the pathogenesis of CRM, the most accepted hypothesis is the late segmental regression of the ICA and development of rich collateral flow from the ECA.[1,4] In case that segmental agenesis of the cervical portion or cavernous portion of the ICA occurs, the ascending pharyngeal artery or internal maxillary artery branches can work intracranial

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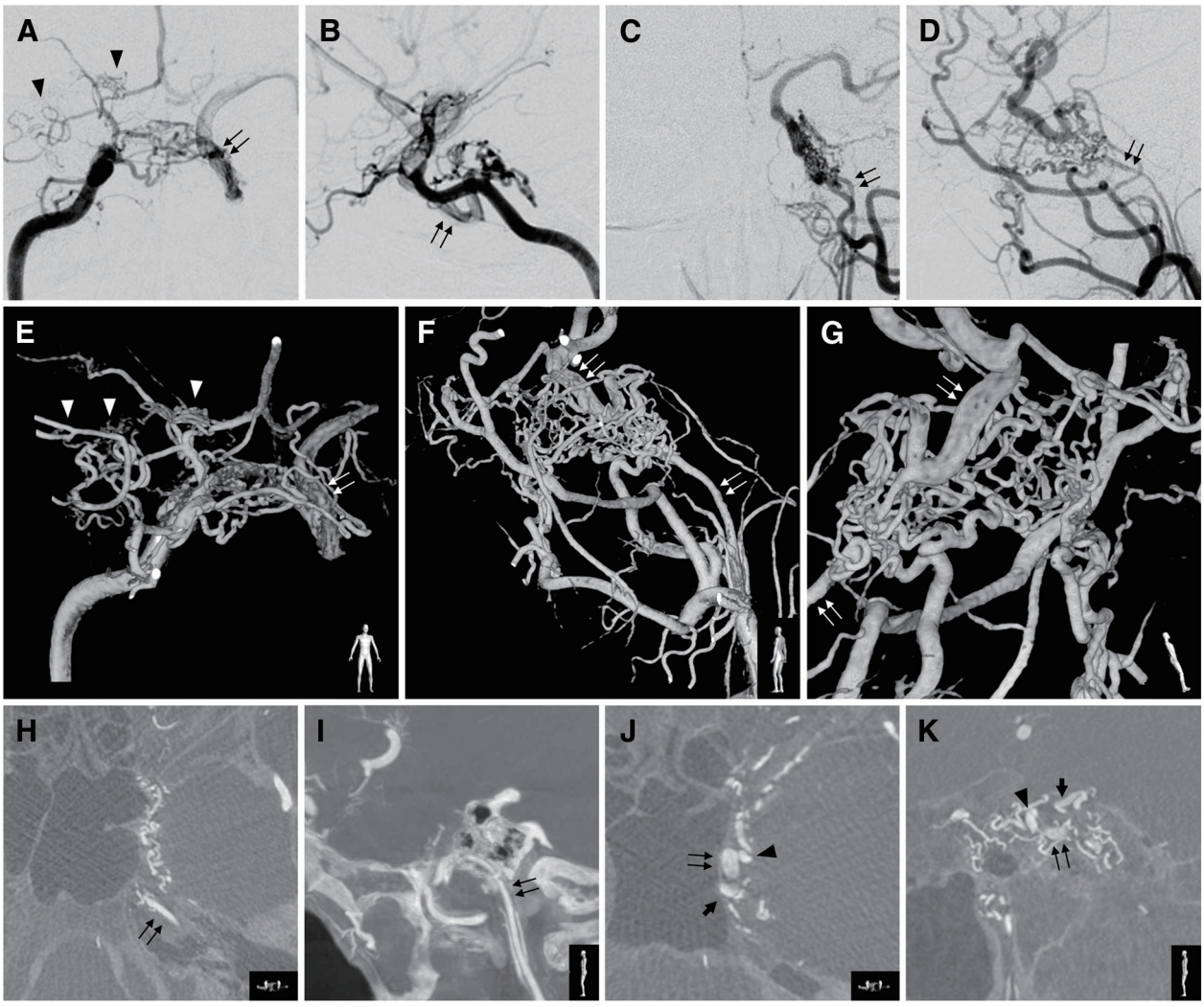

Fig. 1 Angiographical findings. The left ICA (double arrows) distal to the horizontal intracavenous segment was fed contralaterally through the anastomosis between the ICAs and ipsilaterally via the carotid rete. The right twig-like anterior and middle cerebral arteries (black arrowheads) were also disclosed (right internal carotid angiography: anteroposterior [**A**] and lateral projection [**B**], left common carotid angiography: anteroposterior [**C**] and lateral projection [**D**]). (**E**–**G**) The left ICA (double arrows) and right twig-like anterior and middle cerebral arteries (white arrowheads) were demonstrated (3-D volume-rendering reconstructed images of right internal carotid angiography [**E**],and those of left common carotid angiography [**F**, **G**]). (**H**–**K**: multiplanar reconstruction images) The left carotid canal was hypoplastic, but the ICA (double arrows) was observed. The left inferolateral trunk (black arrowheads) and meningohypophyseal trunk (black arrows) were both developed. The distal left ICA (double arrows) was anastomosed with the inferolateral trunk and meningohypophyseal trunk. ICA: internal carotid artery

arterial supply.[2] Development of the internal maxillary artery and ascending pharyngeal artery is considered an angiographical feature of CRM in the human. These developed arteries usually feed the cavernous portion of the ICA.[4,5] In our case, the artery of the foramen rotundum did not develop. However, the cavernous ICA was fed by the branches of the internal maxillary artery and ascending pharyngeal artery via the inferolateral trunk and meningohypophyseal trunk.

Bilateral CRM is described more frequently than unilateral CRM.[2] Typically, CRM is not accompanied by any abnormal vessels in the intradural circulation.[4] In our case, CRM was unilateral and accompanied by a twig-like right anterior and middle cerebral artery and a rare infundibular anastomosis.[3] These features seem unique in our case.

In a review article of Paschoal et al., CRM is often reported from Asian countries and can be found not only incidentally but also following neurological deficits, ischemic stroke, and subarachnoid hemorrhage.[2] This anomaly could have resulted in a hemorrhagic event. Coexistence of "carotid and vertebral rete mirabile" is also

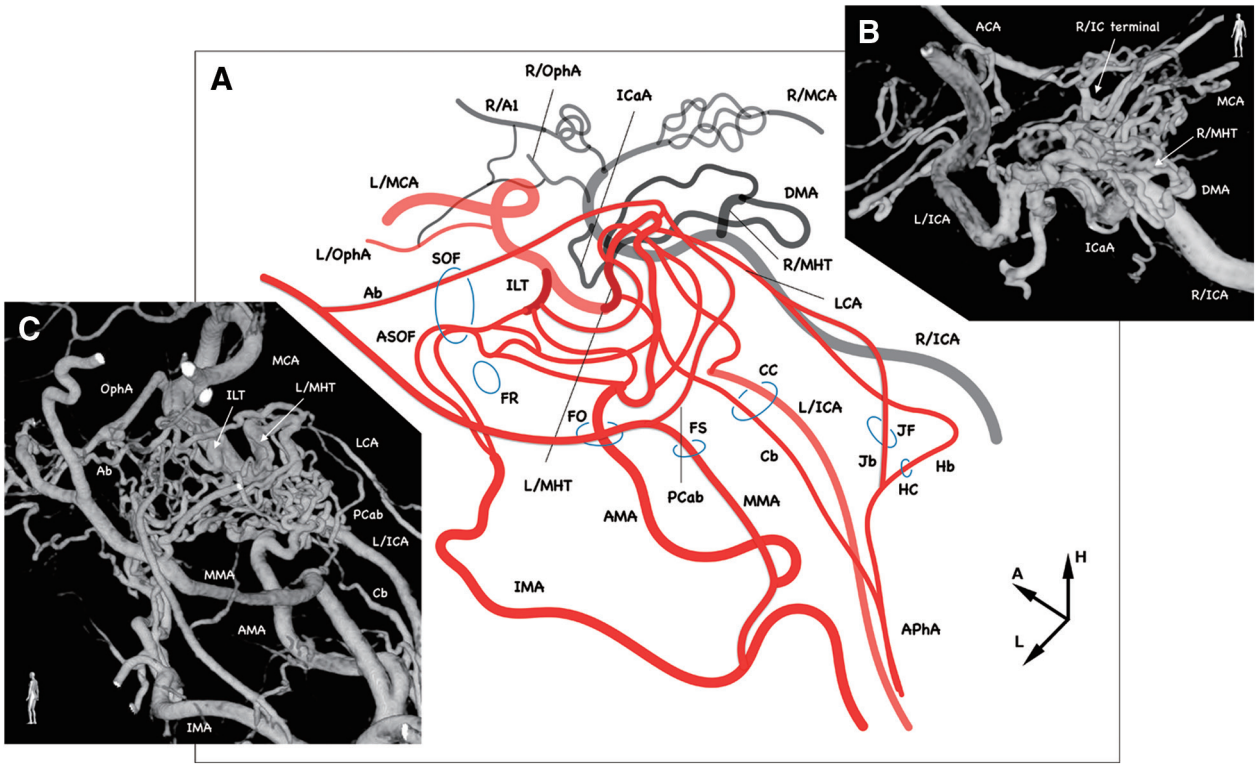

Fig. 2 Vascular network of the bilateral carotid arteries and left carotid rete. (**A**) The schema demonstrates the anastomoses of carotid rete. In this case, carotid rete consists of the branches through the superior orbital fissure, foramen ovale, foramen spinosum, carotid canal, jugular foramen, and hypoglossal canal. (**B**) Postero-oblique view of 3D volume-rendering reconstructed images of the right internal carotid angiography. (**C**) Postero-oblique view of 3D volume-rendering reconstructed images of the left common carotid angiography. A: anterior; A1: A1 portion of the anterior cerebral artery; Ab: anterior branch of the middle meningeal artery; AMA: accessory meningeal artery; AphA: ascending pharyngeal artery; ASOF: artery of the superior orbital fissure; Cb: carotid branch of the AphA; CC: carotid canal; DMA: dorsal meningeal artery; FO: foramen ovale; FR: foramen rotundum; FS: foramen spinosum; H: head; Hb: hypoglossal branch of the AphA; HC: hypoglossal canal; ICA: internal carotid artery; ICaA: inferior capsular artery; ILT: inferolateral trunk; IMA: internal maxillary artery; Jb: jugular branch of the AphA; JF: jugular foramen; L: left; LCA: lateral clival artery; MCA: middle cerebral artery; MHT: meningohypophyseal trunk; MMA: middle meningeal artery; OphA: ophthalmic artery; PCab: posterior cavernous sinus branch of the middle meningeal artery; R: right; SOF: superior orbital fissure

described.[2] Coexistence of multiple vascular anomalies including CRM may result from genetic conditions in individual cases.

Though CRM is a rare vascular anomaly, this collateral network can contribute to analyze the potential anastomoses between the ICA and ECA (the so-called dangerous anastomosis in endovascular surgery) that generally regresses during the normal development. Due to the recent development of 3D volume-rendering reconstructed images, we can evaluate the anastomoses between the ICA and ECA in detail.

Disclosure Statement

The authors have no conflicts of interest concerning this study.

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