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Case Report

Middle meningeal artery arising from the petrous internal carotid artery: Outcome of unusual stapedial artery regression

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ABSTRACT

Background: The internal and external carotid arterial systems are generally separate regarding branching patterns. However, these two systems do form collateral circulations with their terminal parts. On rare occasions, branches that belong to one arterial system may arise from the other.

Case Description: We present a rare variant of a middle meningeal artery, generally derived from the external carotid artery, arising from the internal carotid artery and entering the floor of the middle cranial fossa by traveling through a small unnamed foramen. This anatomy and embryology and other variants of the middle meningeal and petrous carotid systems are discussed.

Conclusion: Embryologically, this variant anatomy signifies an atypical regression of the distal stapedial artery and its connection to the external carotid artery. Surgeons who operate on the skull base, vascular interventionalists, and radiologists should be aware of this potential anatomical variation of the skull base.

Keywords: Anatomy, Artery, Carotid, Meninges, Temporal bone

INTRODUCTION

The middle meningeal artery typically originates from the maxillary artery, a branch of the external carotid artery, within the infratemporal fossa. It then passes superiorly behind the mandibular nerve to enter the middle cranial fossa through the foramen spinosum.[24] As the artery courses along the floor of the middle cranial fossa, it bifurcates into anterior and posterior branches that ascend along the internal surface of the calvaria, supplying adjacent bone and dura mater.[4,24] The middle meningeal vein and a meningeal branch of V3 of the trigeminal nerve, the nervus spinosus, accompany the vessel.[25] The middle meningeal artery is a landmark at the base of the skull for various skull base approaches.[20] Clinically, the vessel can be injured, resulting in epidural hematoma. It frequently provides blood supply to cranial meningiomas, and traumatic arteriovenous fistulas involving this artery have been reported.[4,9] The artery is also utilized for ablation procedures in patients with chronic subdural hematomas.[11]

Anatomical variations of the middle meningeal artery may encompass its origin, branches, and potential anastomoses.[4] This artery may be absent or replaced by branches of the ophthalmic or lacrimal artery.[19,24] The ectopic origin of the artery from the ophthalmic artery is well documented.[24] Extremely rare origins of the middle meningeal artery include origins from the basilar artery, posterior inferior cerebellar artery, cervical, cavernous, and supraclinoid parts of the internal carotid artery (ICA), the occipital artery, and the ascending pharyngeal artery.[4,12,13,15] This broad range and variety of origins of the middle meningeal artery underscores the complexity of its embryogenesis. Here, we report an unusual origin of the middle meningeal artery from the petrous part of the ICA in a cadaveric specimen and discuss the embryological basis of the observed variant.

CASE REPORT

During the routine dissection of a 78-year-old male cadaver, an unusual source of the middle meningeal artery was noted. The variation was found on the left side only, and no other intracranial variations were noted. The donor died from pneumonia. The dura mater was cut circumferentially after removing the calvaria with a bone saw. The brain was removed. Laterally, the distribution of the middle meningeal artery was typical. However, medially, the vessel's origin was from the petrous portion of the ICA [Figure 1]. The artery entered the floor of the middle cranial fossa from the petrous part of the ICA by traveling through a small unnamed foramen. The left foramen spinosum was absent in its typical position posterolateral to the foramen ovale. The vessel size was comparable to the normally arising middle meningeal artery.

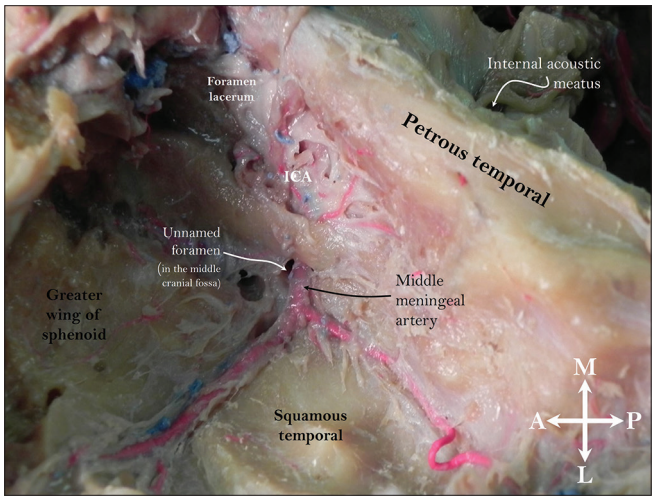

Figure 1: Left middle cranial fossa illustrating the arterial variant identified in this case report. Note the petrous internal carotid artery giving rise to the middle meningeal artery. Observe the unnamed foramen at the skull base that the artery uses to gain access from the petrous carotid artery to the floor of the middle cranial fossa. ICA: Internal carotid artery.

DISCUSSION

The ICA comprises cervical, petrous, cavernous, and supraclinoid segments.[5] The petrous segment extends from the opening of the carotid canal in the skull base to the posterior edge of the foramen lacerum. The vertical subsegment transitions into the horizontal subsegment through the genu of the petrous ICA, which forms a 90° bend in the vessel.[5] Postganglionic sympathetic fibers continue to travel with the ICA. A venous plexus also surrounds the petrous part of the ICA.[7] Branches from this part of the ICA include a periosteal branch, the caroticotympanic artery, and the vidian artery.[22] Variant branches of this part of the ICA include a persistent stapedial or otic artery.[23]

Variations

Variations of the middle meningeal artery should be known to the neurosurgeon and those who interpret cranium imaging. Several arterial variants of this vessel have been reported.[3] For example, the vessel may be absent in about 3% of the population.[3,4,24] Bergman *et al.* stated that the middle meningeal artery enters the skull through the foramen spinosum in 99% of cases, but if this foramen is absent, the vessel will enter through the foramen ovale, which is the foramen that normally transmits the accessory meningeal artery.[3] This latter branch either arises from the middle meningeal artery (50%) or directly from the maxillary artery below the skull base.[3,24] The anterior division of the middle meningeal artery can give rise to a medial branch, which may anastomose with the ophthalmic artery after passing through the superior orbital fissure or a small foramen in the greater wing of the sphenoid.[24] In cases where the middle meningeal artery is absent, it may be substituted by branches originating from the lacrimal or ophthalmic arteries.[24] In approximately 2% of individuals, the communicating branch of the middle meningeal artery may join the lacrimal artery, effectively replacing the entire ophthalmic artery.[24] Early division of the middle meningeal artery into an anterior and posterior division may result in duplication of the foramen spinosum.[6]

Omeis *et al.* reported a patient with multiple intracranial vascular anomalies, including left temporal lobe cavernoma and cavernous angioma.[17] In this case, the left middle meningeal artery originated from the petrous portion of the ICA, the foramen spinosum was absent, and the ophthalmic artery arose from the cavernous ICA. There was an accessory middle cerebral artery on the left side. A persistent stapedial artery may also arise from the petrous segment of the ICA. It typically enters the middle ear, traverses between the crura

of the stapes, courses through the facial canal, exits through the facial hiatus, proceeds in the epidural space over the floor of the middle cranial fossa, and eventually becomes the middle meningeal artery.[1,16,24] The persistent stapedial artery has been reported in two out of 8000 middle ear surgeries.[10] Among the two anatomical variants of the persistent stapedial artery, one is known as the persistent hyoid stapedial artery, supplied by an enlarged caroticotympanic artery, a remnant of the embryonic hyoid artery stem. It emerges from the petrous portion of the ICA through the caroticotympanic canaliculus.[14] The other variant, the persistent pharyngo-stapedial artery, is supplied by an enlarged inferior tympanic artery originating from the ascending pharyngeal artery or cervical ICA. It traverses through the inferior tympanic canaliculus into the middle ear, where it forms an anastomosis with the embryonic hyoid artery.[2,14] Rodesch *et al*. reported a case of a hyoid stapedial artery originating from the petrous ICA, coursing within the middle ear and middle cranial fossa, giving off the middle meningeal artery, and then exiting the skull through the foramen spinosum to become the maxillary artery.[18] Notably, the middle meningeal artery can arise from different segments of the ICA, indicating that the vestiges of the stapedial artery may not always traverse the tympanic cavity, as seen in our case.

Embryology

Tandler's seminal work offers profound insights into the intricate embryonic development of the cranial arterial system [Figure 2].[21] In a 17-mm embryo at stage 19 of His, the ICA gives rise to the stapedial artery within the tympanic cavity, penetrating the stapes shortly after its origin. The stapedial artery rapidly bifurcates into two primary branches. The upper branch is known as the supraorbital ramus. The lower branch descends posterior to the mandibular nerve and forms an anastomosis with the external carotid artery. At this point of anastomosis, it further bifurcates, with one of its branches, the infraorbital ramus, running laterally to the mandibular nerve, ultimately destined to become the maxillary artery. In the 19-mm embryo, the anastomosis between the stapedial artery and the external carotid artery exhibits an increase in caliber. In the 23-mm embryo (stage 21 of His), the proximal trunk of the stapedial artery regresses, resulting in the stapedial artery appearing as a slender structure originating from the ICA and extending to the region between the limbs of the stapes. Beyond this point, the stapedial artery completely disappears. The remaining distal portion of the stapedial artery then becomes continuous with the supraorbital ramus, eventually developing into the middle

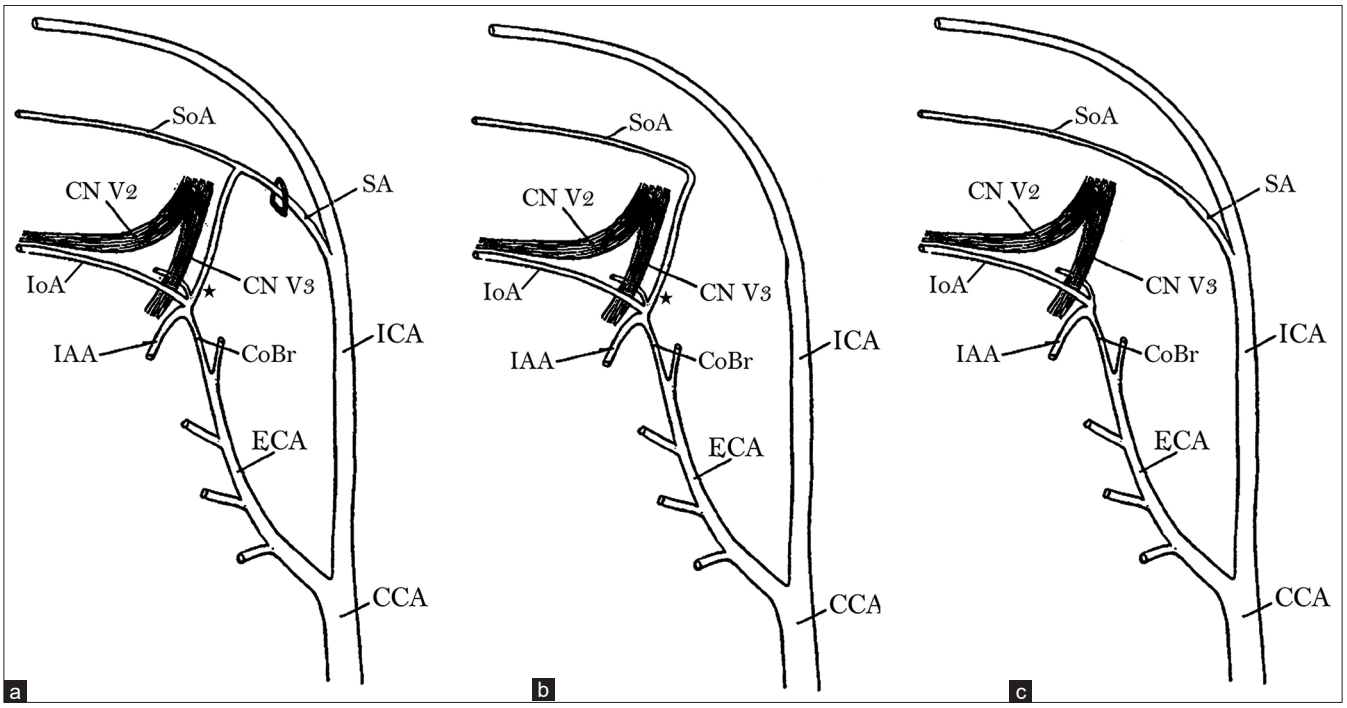

Figure 2: Embryogenesis of the middle meningeal artery and its variants. Stapedial artery and its communication (asterisk) with the external carotid artery in a 19-mm embryo (adopted from Tandler, 1902). (a) Shows an intact stapedial artery in an early developmental stage. (b) Shows typical regression of the proximal portion of the stapedial artery, leaving the SoA (the future middle meningeal artery) connected to the maxillary artery. (c) Shows atypical regression of the distal portion of the stapedial artery, leaving the SoA connected to the internal carotid artery. CCA: Common carotid artery; CoBr: Communicating branch; CN V2: Cranial nerve V2 (maxillary nerve); CN V3: Cranial nerve V3 (mandibular nerve); ECA: External carotid artery; IAA: Inferior alveolar artery; ICA: Internal carotid artery; IoA: Infraorbital artery; SA: Stapedial artery; SoA: Supraorbital artery.

meningeal artery. This newly formed middle meningeal artery maintains its connection with the infraorbital ramus, which is in the process of developing into the maxillary artery. Following this construct, the branches from the external carotid artery replace the usual distribution of the stapedial artery. If the connection with the external carotid artery fails to occur, the middle meningeal artery arises from the ophthalmic artery.[8] The stapedial artery may also persist. This vessel has also been associated with an aberrant ICA. The persistent stapedial artery typically enters the middle cranial fossa by the facial hiatus, which is the opening for the greater petrosal nerve and becomes the middle meningeal artery. In both of these cases, the foramen spinosum will be tiny or absent.

CONCLUSION

The present case highlights an exceedingly rare occurrence in which the middle meningeal artery originates from the petrous part of the ICA and enters the floor of the middle cranial fossa by traveling through a small unnamed foramen. Embryologically, this variant anatomy signifies an anomalous regression of the stapedial artery and its communicating branch to the external carotid artery. In typical development, the proximal portion of the stapedial artery regresses. While the supraorbital ramus of the stapedial artery gives rise to the middle meningeal artery, the remaining distal segment of the stapedial artery maintains its connection with the external carotid arterial system through the maxillary artery. However, in the observed case, this developmental pattern is reversed, whereby the distal portion of the stapedial artery, instead of the proximal portion, undergoes regression. This unique scenario results in the middle meningeal artery being directly connected to the ICA. Although uncommon, arterial variants described in this case report should be remembered by neurosurgeons who treat skull base lesions and radiologists who interpret imaging or perform minimally invasive procedures in this region.

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Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that they have used artificial intelligence (AI) technology for assisting in language editing of the manuscript only.

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