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ANATOMIC VARIATIONS

Trifurcated external carotid artery and complete gamma-loop of its maxillary branch

Mugurel Constantin Rusu[1] · Nicoleta Măru[1] · Petrinel Mugurel Rădoi[2,3] · Dănuţ Dincă[4]

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Abstract

The external carotid artery (ECA) normally bifurcates terminally with the superficial temporal artery (STA) and the maxillary artery (MA). From the horizontally coursing, mandibular segment of the MA leaves the middle meningeal artery (MMA). We hereby report a previously unknown anatomic possibility, incidentally found during an angio-CT scan in an adult female patient. Unilaterally, the ECA was terminally trifurcated, sending off the MA, STA, and MMA. On that side, the mandibular segment of the MA had a gamma-loop and the contralateral one had a U-loop; both these loops were inferior to the lateral pterygoid muscle, closely approaching the respective lingula of the mandible. These findings are relevant during surgery of the parotid gland and infratemporal fossa, approaches of the MMA, and inferior alveolar nerve blocks. The modified origin of the MMA could be explained by an altered development of the primitive stapedial artery.

Keywords Carotid artery · Middle meningeal artery · Maxillary artery · Anatomic variation · Mandible · CT

Abbreviations

ECA	External carotid artery
HSA	Hyostapedial artery
ICA	Internal carotid artery
MA	Maxillary artery
MMA	Middle meningeal artery
SA	Stapedial artery
STA	Superficial temporal artery

✉ Nicoleta Măru
nicoleta.maru@umfcd.ro

Mugurel Constantin Rusu
anatomon@gmail.com

Petrinel Mugurel Rădoi
muguradoi@yahoo.com

Dănuţ Dincă
danut_dinca2000@yahoo.com

1 Division of Anatomy, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, 8 Eroilor Sanitari Blvd, 050474 Bucharest, Romania

2 Faculty of General Medicine, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

3 National Institute of Neurology and Neurovascular Diseases, Bucharest, Romania

4 Department II of Surgical Clinical Divisions, Faculty of Medicine, "Ovidius" University, Constanţa, Romania

Introduction

The external carotid artery (ECA) usually terminates by two branches, the maxillary artery (MA) and the superficial temporal artery (STA). There were not described any different possibilities of terminal branching of ECA, except the possible ECA origin of the transverse facial artery [10]. The middle meningeal artery normally arises from the mandibular segment of the MA. The MMA is referred to as the largest branch of the MA [1], vascularising the meninges and the bony framework of middle cranial fossa. The spasm of MMA is one of the main players in the etiology of migraine [1].

Other origins of the MMA were designated as rare, and include different segments of the internal carotid artery (ICA), the basilar artery, the superior and, respectively, posterior inferior cerebellar arteries, the third part of the maxillary artery, the ophthalmic artery, the lacrimal artery, the ascending pharyngeal artery, and the persistent stapedial artery [1, 4, 5, 7, 10].

We report here rare anatomic variations, which include the unilateral origin of the MMA as a terminal branch of the trifurcation of the ECA, and arterial loops (gamma- and U-shaped) of the mandibular segments of the MAs.

Case report

A 69-year-old female diagnosed with subarachnoid hemorrhage was admitted to the neurosurgical department of the National Institute of Neurology and Neurovascular Diseases for further diagnosis and treatment. A brain cerebral tomographic angiogram (CTA) demonstrated a 4 mm saccular aneurysm located at the left middle cerebral artery bifurcation, along with parietal microcalcification and stenosis in the supraclinoidian segments of both internal carotid arteries. 50 ml iodine radiocontrast agent (Ultravist 370 mg/ml) was injected into the right brachial vein of a 75 kg female, with 4 ml/s flow, followed by 20 ml saline medium. The CTA was performed with a 32-slice scanner (Siemens Multislice Perspective Scanner), using a 0.6 mm collimation and reconstruction of 0.75 mm thickness with 50% overlap for multiplanar, MIP, and 3D volume rendering technique (3D-VRT). The case was documented using the OsiriX Lite software and its 3D Volume Rendering application.

On axial slices we observed the bilaterally different terminations of the ECAs, the left one being bifurcated into the MA and the STA, but the right one being trifurcated (Fig. 1). The trifurcation of the right ECA was medial to the posterior border of the mandible neck, and from it, there were leaving the MA, the STA, and the MMA (Fig. 1).

We further documented the arterial morphologies on the right (Fig. 2) and left sides on three-dimensional volume renderizations. The right MMA left the ECA directly, thus being longer than the opposite one; it coursed antero-supero-medially towards the foramen spinosum, initially in the interval between the mandible neck and the styloid process, then medially to the mandibular insertion of the lateral pterygoid muscle. The right MA initial segment was inferior to the respective MMA on the medial side of the mandible neck; it further continued inferiorly to the lateral pterygoid muscle and medially to the mandible ramus, where it described a complete gamma-loop with a descending horizontal arm and an ascending vertical one. That gamma-loop of the MA was postero-superior to the lingula of mandible. Then, the MA continued on the lateral side of the inferior head of the lateral pterygoid muscle, where it was sending off the anterior deep temporal artery. On the left side, the ECA was bifurcated terminally and the respective MA had a first ascending reversed U-loop on the medial side of the mandible neck, from which a short MMA left towards the

Fig. 1 Axial (**a**) and oblique-sagittal (**b**) slices depicting the terminal trifurcation of the right external carotid artery. 1. Ramus mandibulae; 2. caput mandibulae; 3. external carotid a.; 4. superficial temporal a.; 5. middle meningeal a.; 6. maxillary a.; 7. internal carotid arteries

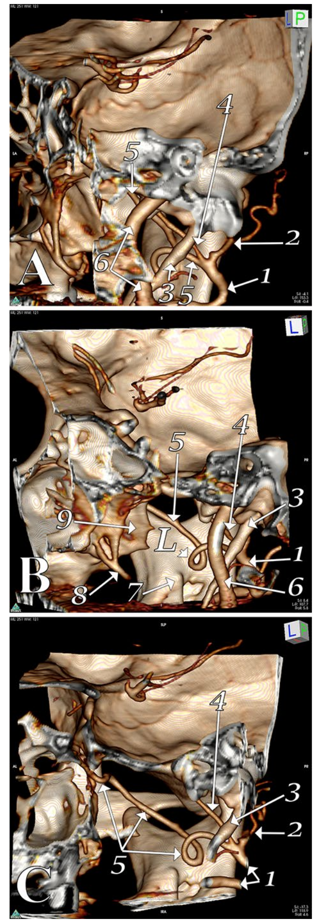

Fig. 2 Three-dimensional volume renderizations of the variant arterial anatomy on the right side. **a** Postero-medial view; **b** medial view; **c** infero-medial view. 1. External carotid a.; 2. superficial temporal a.; 3. styloid process of temporal bone; 4. middle meningeal a.; 5. maxillary a. (L: loop of maxillary a.); 6. internal carotid a.; 7. lingula mandibulae; 8. pterygoid hamulus; 9. lateral pterygoid plate

foramen spinosum. The second U-loop of the left MA was inferior to the lateral pterygoid muscle and it approached the respective lingula of mandible.

Discussion

During the developmental process of the cranial arteries, the primitive (embryonic) stapedial artery (SA) results from the dorsal remnants of the first aortic arch and coalesce with an outgrowth (the hyoid artery) from the second aortic arch. Thus forms the hyostapedial artery (HSA) that emerges from the primitive ICA [8]. The terminal stapedial segment of the HSA is divided into three branches, supraorbital (S), infraorbital (I), and mandibular (M), which course as satellites of the trigeminal nerve's three main divisions [8]. The maxillofacial (MF) division of the SA is the common trunk of origin of the infraorbital and mandibular branches [8]. The MF trunk was also designated as the maxillomandibular division of the SA [4]. The supraorbital division of the SA will send off the MMA [8]. Later, during the developmental process, atrophy of the HSA trunk will occur proximally to the stapes, while its distal branches, which belong to the primitive SA, will coalesce with the terminal end of the ECA outgrowth [8]. As a result, during its short life, the primitive SA shapes the stapes and transforms the MMA from an ICA branch into a branch of the external carotid system [2] which derives from the third aortic arch. Seemingly, the ECA origin of the MMA could be explained by a complete disappearance of the primitive SA trunk, which will determine the MMA and MF trunk to insert distinctively on the ECA outgrowth.

In this regard, it is of interest to note here the observation of Maeda et al. that "the maxillary artery might be derived from a combination of both the external carotid and stapedial arteries" [6]. The STA origin of the MMA was observed in that study [6]. Thus, by taking into account the present findings and the previously reported variants [7], it could be reasonably speculated that the MMA origin could glide from the STA, via the endpoint of the ECA, towards the distal MA.

There are four known possibilities of ECA ending (Fig. 3): the common type I in which the ECA gives off the STA and MA, type II, with the transverse facial artery transforming the ECA bifurcation into a trifurcation, type III, when the MMA determines the trifurcation of ECA, and type IV, when the ECA continues as STA if the MA and facial artery left the ECA as maxillofacial trunk.

The knowledge of variations of the origin and course of the middle meningeal artery is of great importance in surgical and radiological practice. MMA pseudoaneurysms and arteriovenous fistulas, posttraumatic or iatrogenic in origin, may exhibit multiple draining pathways and are treated either surgically or by endovascular means. MMA embolization has been suggested as a method for treating refractory chronic subdural hematoma [3].

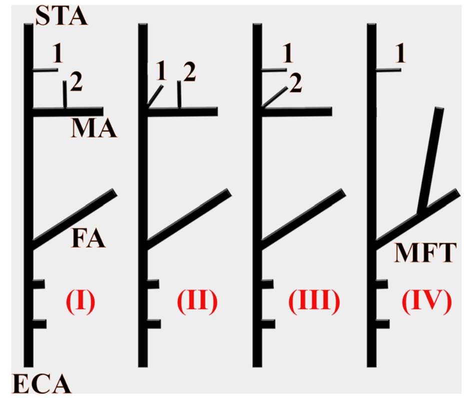

Fig. 3 Schematic drawings of the right external carotid artery (ECA) known possibilities of ending. Type I: bifurcated ECA, the superficial temporal artery (STA) further sends the transverse facial artery (1) and the maxillary artery (MA) gives off the middle meningeal artery (2). Type II: trifurcated ECA, with the transverse facial artery (1) leaving the angle of the STA and MA. Type III: trifurcated ECA, with the middle meningeal artery (2) leaving the angle of the STA and MA. Type IV: ECA continued as STA, when the MA and facial artery (FA) originate as maxillofacial trunk (MFT). Type III corresponds to the variant reported here

In what concerns the loops of the MA, it was noted that the anlage of the MA forms vascular rings around the branches of the developing mandibular nerve in the embryo, and afterward, either the superficial or deep halves of the rings disappear [9]. Seemingly, this was not the case of the right MA in this study, which presented persisting loops above the lingula of mandible. It is reasonable to speculate here that the gamma-loop of the MA persisted around the inferior alveolar nerve.

A comprehensive knowledge of variations of MA in the infratemporal fossa is of special relevance in oral maxillofacial surgeries, management of epistaxis, intractable neuralgias, or headaches. As usually described, the MA emerges from the antero-medial surface of the parotid gland to enter the infratemporal fossa; within the gland, the MA gives off the deep auricular artery and the anterior tympanic artery. Care must be taken to protect or tie off the maxillary artery during the resection of the condyle with the ramus and body of the mandible, or during parotid surgery. In this respect, the MMA giving rise to the ECA is an unexpected finding which could be damaged during the surgical procedures if not managed adequately.

The first, mandibular, segment of the MA is closely related to the mandible condyle, and thus, the internal fixation of the condyle or subcondylar fractures and various surgical procedures (temporomandibular joint arthroplasty, mandibular osteotomy) may determine intractable bleeding.

Loops of this segment of the MA, which we could not document elsewhere, increase the length of the arterial segment exposed to posttraumatic or surgical damage. Both loops of the MAs that we found, the gamma- and, respectively, U-loop, were immediately above the lingula of mandible. Such topography makes the MA vulnerable during the inferior alveolar nerve block in the pterygomandibular space, at the lingula (spine of Spix).

Author contributions MCR: protocol/project development, data analysis, documented specific literature, and approved the final version of manuscript. NM: data analysis, reviewed the manuscript, and contributed discussions. MPR: data collection and management, and manuscript writing. DD: data analysis, reviewed the manuscript, and contributed schema.

Compliance with ethical standards

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

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