

# Origins of the middle meningeal artery and its probable embryological mechanism – A review

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## Abstract

The middle meningeal artery is traditionally described by the human anatomy books as having its origin in the first portion of the maxillary artery. However, more detailed studies have shown that there are numerous variations on this arterial segment with considerable clinical importance. Therefore, the aim of this study was to perform a wide review about this aspect analyzing scientific articles and textbooks. Thus, this review shall be useful for clinicians, surgeons and academics that manipulate and keep interest for this particular anatomical site.

**Keywords:** middle meningeal artery, anatomic variation, embryology.

## 1 Introduction

According to Williams, Warwick, Dyson et al. (1975), the middle meningeal artery (MMA) passes between the sphenomandibular ligament, the lateral pterygoid and the two roots of the auriculotemporal nerve penetrating the floor of the middle cranial fossa through the foramen spinosum. Travels laterally through a ridge crest in the middle fossa, grooving and bending on the greater wing of sphenoid, where at a variable point, is divided in frontal and parietal branches (GARDNER, GRAY and O'RAHILLY, 1988).

As described by Moore, Dalley and Agur (2011), the frontal branch can be located in a bony canal, particularly fragile in the skull fractures; this channel may be only one groove. After this branch crosses the channel, it divides in branches that go to the dura mater and the internal surface of the skull (WILLIAMS, WARWICK, DYSON et al., 1975).

The MMA, or its branches, and other large intracranial extracerebral vessels have been implicated in the pathophysiology of migraine by theories suggesting neurogenic inflammation or cranial vasodilatation, or both, as explanations for the pain of migraine (HOSKIN, ZAGAMI and GOADSBY, 1999; SYED, KOIDE, BRAAS et al., 2012). In this context, some authors (USTÜN, BÜYÜKMUMCU, SEKER et al., 2004; USTÜN, BÜYÜKMUMCU, ULKU et al., 2006) have described that detailed knowledge about the morphological organization of the MMA may assist in procedures like bypass.

According to Psillakis, Zanini, Mélega et al. (1987), in patients who suffer side-impact head in temporoparietal region, there is always the possibility of rupture of some branches of the MMA. This type of patient can reach well at the hospital and in few hours show neurological signs of

epidural hematoma. For this reason, one should pay much attention to trauma in this region.

Therefore, in injuries of the MMA, it is important be aware of the variations of its branches. Ligature or clipping of the MMA for bleeding after injury will be totally or partially insufficient in many of the described cases of mentioned variations (KLISOVIĆ, ŠIKIĆ and KRMPOTIĆ-NEMANIĆ, 1993). Moreover, according to Bruner and Sherkat (2008) information about possible vascular asymmetries between the right and left sides in the organization of the MMA are still unknown and should be elucidated.

Given the clinical importance of variations in the MMA in head injuries and their treatment, we decided to perform a wide review about the variations in origin of this arterial segment, both in scientific articles and textbooks.

## 2 Materials and Methods

To perform this study were consulted papers published in English and available on *PubMed* and *ScienceDirect* databases. The search was conducted using terms such as “middle meningeal artery”, “anatomical variation” and “origin”, associated or not. Human anatomy textbooks were also consulted in this review.

## 3 Results and Discussion

Some variations in anatomical origin of the MMA are known and well documented (LASJAUNIAS, MORET, MANELFE et al. 1977; MANJUANATH, 2001; SHAH and HURST, 2007). Thus, several anomalies of this artery have been reported (ROYLE and MOTSON, 1973; SEEGER and HEMMER,

1976; TANOYATA, MAEHARA, NODA et al., 1987; MANJUANATH, 2001), and embryologically studied to improve the knowledge of possible anatomic variations (PADGET, 1948).

As described by Liu and Rhoton (2001), the complex embryological development of the MMA may cause numerous variations of origins, and this development may result in anomalies not only of origin, but also in other important variations (KURUVILLA, AGUWA, LEE et al., 2011).

At the 4th-5th week of gestation, the MMA begins as a dorsal branch of the stapedia artery, which arises from the hyoid artery derived from the second branchial arch. After passing through the ring of stapes, it divides into two main branches: the maxillofacial, which leaves the cranial cavity through the foramen spinosum, and the supraorbital branch that supply the orbit and the intracranial segment of the MMA anteriorly (SEEGER and HEMMER, 1976; SHAH and HURST, 2007). At the 7th-8th week of gestation, the stapedia artery involutes and the remnants become the tympanic branches of the MMA, which retains communication with the supraorbital and maxillofacial divisions. Thus, the distal portion of the internal maxillary artery forms and communication with the intracranial components of the stapedia system is established (MANJUANATH, 2001; SHAH and HURST, 2007). The branches of the normal adult MMA include a supraorbital branch to the orbit, as well as smaller branches to the trigeminal ganglion, the petrosal branch, and the superior tympanic artery (SHAH and HURST, 2007).

In addition, a recent report of the MMA origin from the cavernous portion of the internal carotid artery indicated that communication with the normal intracranial MMA branches occurred by coursing around the trigeminal ganglion, again suggesting a potential contribution of branches in the region of the trigeminal ganglion to embryologic anastomosis formation (KAWAI, YOSHINAGA, KOIZUMI et al., 2006).

Rarely, the MMA may arise as a branch of the persistent stapedia artery. The persistent stapedia artery, usually a branch of the petrous portion of the internal carotid artery, enters the tympanic cavity through its floor and traverses the obturator foramen of the stapes. It is enclosed in a bony canal for a short distance and passes through the facial canal to emerge into the middle cranial fossa under the dura to give off the MMA (ALTMANN, 1947; MANJUANATH, 2001).

In case reports is described the origin of the MMA from the ophthalmic artery and also the origin of the ophthalmic artery from the anastomosis with MMA, all these with important implications for the endovascular repair of lesions of the skull base (McLENNAN, ROSENBAUM and HAUGHTON, 1974; KLISOVIĆ, ŠIKIĆ and KRMPOTIĆ-NEMANIĆ, 1993; LIU and RHOTON, 2001). Moreover, ectopic sites of origin of the ophthalmic artery from the MMA are associated with visual complications of surgery directed along the sphenoidal wing or embolization of the MMA (HAYASHI, KUBO, TSUBOI et al., 2007).

Interesting information reported by Uchino, Saito, Takahashi et al. (2013) is that a persistent dorsal ophthalmic artery is a rare variation that originates from the cavernous segment of the internal carotid artery and enters the orbit

via the superior orbital fissure. Occasionally, the dorsal ophthalmic artery also arises from the MMA and enters the orbit via the superior orbital fissure.

Royle and Motson (1973) cited in their study the bilateral anomalous origin of the MMA from the lacrimal artery, and commented that it is very rare, but it has great importance. Altman (1947) reported the first case of origin of the MMA from the basilar artery. Similarly, Seeger and Hemmer (1976) described three patients with the first angiographic evidence of left MMA origin from the basilar artery. Shah and Hurst (2007) cited a case report in which the MMA also stems through the basilar artery.

Another more recent study (KUMAR and MISHRA, 2012) also described a rare variation of the left MMA originating from the basilar artery, detected incidentally during cerebral angiography. The right MMA was normal and an accessory meningeal artery arising from the maxillary artery was present on both the sides. The foramen spinosum on the variant side was absent. According to the same study, this abnormal origin of the MMA may be explained by the presence of a perineural arterial network in the region of the Gasserian ganglion, formed by branches of the developing basilar and stapedia arterial systems; the middle meningeal-basilar arterial channel opening up in the absence of a normally developing MMA.

Anomalous origin of the MMA from the lateral medullary segment of the cerebral artery posterior inferior was reported by Tanohata, Maehara, Noda et al. (1987), and has important clinical significance because the correct identification of this vessel by image exams is important in planning surgical interventions in the region of the skull base (KURUVILLA, AGUWA, LEE et al., 2011).

According to Chandler and Derezinski (1935), abnormalities in course and origin can occur when the foramen spinosum is not present, then the MMA enters the middle cranial fossa through the foramen ovale. It may still arise as a branch of the third part of maxillary artery (LOW, 1946). Several anomalies of the MMA are reported in the literature and include the origin from the stapedia artery (McLENNAN, ROSENBAUM and HAUGHTON, 1974), of the intracavernosal or extradural internal carotid artery portions (NEWTON and POTTS, 1974), and from the ascending pharyngeal artery (MORET, LASJAUNIAS, VIGNAUD et al., 1978).

Although we found a large number of quotes describing different variations of the MMA, our search in human anatomy textbooks showed that both in classical descriptions (ERHART, 1974, 1977, 1983; GUYTON, 1977; FRICK, LEONHARDT and STARCK, 1981; BRODAL, 1984; PSILLAKIS, ZANINI, MÉLEGA et al., 1987; GARDNER, GRAY and O'RAHILLY, 1988) and in more recent descriptions (COSENZA, 1990; FONSECA and WALKER, 1991; GOLDBERG, 1992; GUYTON, 1993; BURT, 1995; WILLIAMS, WARWICK, DYSON et al., 1995; CARNEIRO, 1997; MACHADO, 1998; MARTIN, 1998; ZIGMOND, 1999; COHEN, 2001; LENT, 2001; ROSENBAUER, ENGELHARDT, KOCH et al., 2001; BUTERA, 2003; D'ANGELO and FATTINI, 2003; FIGÚN and GARINO, 2003; CITOW and MacDONALD, 2004; GREENBERG, AMINOFF and SIMON, 2005; MADEIRA, 2010; MOORE, DALLEY and AGUR, 2011), the variation related to the MMA are not described in detail.

We believe that this lack of information is due to the fact that the human anatomy books for beginner students describe the body structures observed in most of people, approximately 70% (MOORE, DALLEY and AGUR, 2011). This can still be confirmed by Dângelo and Fattini (1983) and Shimizu, Hagiwara, Utsuki et al. (2008), which described the anatomical variations are substantially common but are rarely described in textbooks.

On the other hand, despite its clinical importance, recently some studies (MA, BAILLIE and STRINGER, 2012; DA SILVA, ELLWANGER, SILVA et al., 2013) showed in great details variations of the organization and distribution of MMA. Furthermore, although available in low quantity, these results provide baseline normal values for future studies aimed at further elucidating the functional and morphological pattern of the MMA (DA SILVA, ELLWANGER, SILVA et al., 2013).

#### 4 Conclusion

Our study provides essential information for the detailed knowledge about the anatomical variations of the origin of this important arterial segment. These variations are of clinical significance in fractures of the squamous and petrous parts of the temporal bones and in surgical interventions involving the nerve of the pterygoid canal and maxillary artery. Thus, this review shall be useful for clinicians, surgeons and academics that manipulate and keep particular interest for this anatomical site. Moreover, this work aims to provide a simple but multidisciplinary synthesis of the current knowledge concerning the morphogenesis, variation, and clinical significances of the MMA, and to help promoting future studies in this area.

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