Classification of the Ophthalmic Artery that Arises from the Middle
Meningeal Artery in Japanese Adults

By

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Summary: In a study of Japanese adults, we found that the orbital branch (OB) passing through the superior orbital fissure frequently anastomosed with the lacrimal artery or the ophthalmic artery (12/20). However, the OB passing through the meningo-orbital foramen (mof) only associationaly anastomosed with branches of the ophthalmic artery (4/79). Furthermore, the OB in the orbit, excluding the lacrimal gland as previously reported. We examined 116 cases in which the OB passed through the mof in 129 adult Japanese cadavers (45.0% in 258 sides). The OB passing through the mof was always distributed to the periorbital region and the area that it supplied was limited to the periorbita in about half of those cases. In another half of the cases (58/116), the area supplied included the lacrimal gland.

The ophthalmic artery in the orbital branch arising from the middle meningeal artery has been described previously (Zuckerkandl, 1876; Meyer, 1887; Lang and Wachsmuth, 1979; Hollinshead, 1982). Moreover, the orbital branch (OB) has been considered to be an important source of blood for the orbital contents and named the accessory ophthalmic artery by Gillian (1961). The course of the OB is, however, controversial, it has been proposed to pass exclusively through the superior orbital fissure (Duke-Elder and Wyber, 1961; Doxanas and Anderson, 1984) or mainly through the meningo-orbital foramen (mof: Fig. 1; Kopsch, 1955; Lasjaunias, 1981; Ducasse et al., 1985). In this present study, we examined the course passing through the mof, of the ophthalmic artery branch in the orbit and classified the course into four types according to the area supplied. The extent of supply by the ophthalmic artery reveals an important problem in the surgical treatment of the base of orbit.

Materials and Methods

We examined 258 sides of 129 adult Japanese cadavers (74 males and 55 females) to determine the course of the orbital branch and the nerve of the supply to the orbital area from the middle meningeal artery, passing through the mof. In 75 of 129 cadavers, polyvinyl acetate was injected from the common carotid artery in order to allow us to identify the small twigs that extended through the superior orbital fissure. In preliminary observations, initially, the whole brain was removed and the dura mater was carefully removed with forceps from the inner surface of the anterior cranial fossa to the middle cranial fossa. After treatment, we found the OB of the middle meningeal artery if it was located at the roof of the orbit. If present such branches were carefully dissected out and recorded photographically and by drawing each case.

Results

Types of entry of the orbital branch of the ophthalmic artery arising from the middle meningeal artery into the orbit (Fig. 2).

Seventy-five injected cadavers (150 sides) were examined. The orbital branch (OB) of the middle
The orbital branch passing through the meningo-orbital foramen.

The OB was often observed passing through the mof (45.0%, 116 of 258 cases). In such cases, the OB issued from the frontal branch of the middle meningeal artery beneath the posterior edge of the lesser wing of the sphenoidal bone. The mof was usually located at the sphenofrontal suture or the frontal bone or the greater wing of the sphenoidal bone in the apex of the orbit within a range of 10–20 mm lateral to the sof, as shown in Figure 1. The average length of the so-called Hyrtl canal (Lasjaunias, 1981) was 5–10 mm. The canal ran almost straight in the dorsi-ventral direction and was found near the sof. In other cases, the canal was located almost at the anterior part of the frontal bone, at a distance from the sof. This tortuous canal was about 20 mm in length. The OB passing through the mof always supplied the inferior and lateral part of the periorbita. The distribution of the OB was classified into four types and the incidence of each was as follows (Fig. 4 and Table 1): type 1, the area supplied by the OB was limited to the periorbita (46.6%, 54 of 116 cases); type 2, the OB supplied the lacrimal gland in the absence of the usual lacrimal artery (32.8%, 38 of 116 cases); type 3, the OB mainly supplied the lacrimal gland together with the usual lacrimal artery (17.2%, 20 of 116 cases); Type 4, the OB anastomosed with the ophthalmic artery or the lacrimal artery at the base of the orbit (3.4%, 4 of 116 cases). Details of each type are described below.

Type 1 (Fig. 5). After passing through the canal, the OB ran frontally to the periorbita of the upper wall of the orbit for 10–20 mm. The OB was then ramified into fine small twigs and supplied the periorbita, in the front of which the branch of the posterior ethmoidal artery and the deep temporal artery terminated.

Type 2 (Fig. 6). The supply to the periorbita was also observed, as in type 1. After ramification at the periorbita, the OB travel toward the lacrimal gland. Beyond the fronto-zygomatic suture area, the OB followed a tortuous or straight course along the lacrimal nerve. Some twigs supplied to orbital fat and the lateral rectus. The OB entered the lateral and inferior portion of the lacrimal gland. After supplying the lacrimal gland, the OB was often finally distributed to the upper eyelid (15.5%; 9 of 58 cases from type 2 and type 3).

Type 3 (Fig. 7). In this type, the lacrimal artery passed through the mof, as described in type 2 (the so-called meningo-lacrimal artery in Lasjaunias, 1981), and it was observed together with the usual lacrimal artery which extends from the ophthalmic artery.

Type 4 (Fig. 8). In 3 cases of this type, the OB anastomosed with the most proximal portion of the

Table 1. Classification of the orbital branch that passes through the meningo-orbital foramen

<table>
<thead>
<tr>
<th>Incidence of passage of the orbital branch passing through the foramen (in 258 sides)</th>
<th>45.0%</th>
<th>(N = 116 sides)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types</td>
<td></td>
<td>(Incidence in 116 cases of this branch)</td>
</tr>
<tr>
<td>1*</td>
<td>46.6%</td>
<td>(N = 54)</td>
</tr>
<tr>
<td>2</td>
<td>32.8%</td>
<td>(N = 38)</td>
</tr>
<tr>
<td>3</td>
<td>17.2%</td>
<td>(N = 20)</td>
</tr>
<tr>
<td>4</td>
<td>3.4%</td>
<td>(N = 4)</td>
</tr>
</tbody>
</table>

* Type 1. The area supplied is limited to the periorbita; type 2, supplying to the lacrimal gland without the usual lacrimal artery; type 3, supplying the lacrimal gland with the usual lacrimal artery; type 4, anastomosis with the ophthalmic or the lacrimal artery.
usual lacrimal artery immediately after the OB had passed through the mof. Moreover, in just one case of type 4, the OB passed through the mof to supply the lacrimal gland, the lateral rectus, superior rectus and levator palpebrae superioris muscles. Then the OB travelled along the frontal nerve towards the trochlea of the oblique superior muscle to become the supratrochlear artery that was distributed the frontal portion of the face. The artery running beneath the trochlea and supplying the face was also seen as a branch of the ophthalmic artery. A fine anastomosis was found between the OB and the ophthalmic artery under the rectus superior muscle in the posterior portion of the orbit.

We examined each type of blood supply to the orbital contents when the OB passed through the mof. The branching and distribution patterns of the ophthalmic artery showed, normal range of variation, except for those of the lacrimal artery.

Discussion

During our observations of 258 sides of cadavers of the Japanese adult, the OB passing through the mof was found in about half of cases (45.0%, 116/258). Moreover, in half of our cases, the OB that passed through the mof mainly supplied the lacrimal gland (58/116). In about half the cases (54/116), however, the area supplied in cases of type 1 was limited to the periorbital region. The OB passing through the sof was found in fewer cases (13.3%, 20/150 from type a and type c), although this branch was described by Lang and Wachsmuth (1979) and Hollinshead (1982). Our results cannot compared to previous reports about the OB which has not been examined including cases of type 1. However, Ducasse et al. (1985) reported that the OB passed through the mof and supplied the lacrimal gland (the meningo-lacrimal artery) in 28.5% of 70 cadavers of Caucasians examined. Recently, Lang and Kageyama (1990) reported that the meningo-lacrimal artery was found in 15.9% of 71 Caucasians cadavers. In both previous reports, the incidence corresponds closely to ours (22.5%, 58/258 from type 2 and type 3).

The distribution of the OB passing through the mof varied among cases. The term "meningo-lacrimal artery" (Lasjaunias, 1981; Ducasse et al., 1985) cannot always apply to the OB that passes through the mof since the area is supplied often limited to the periorbita. Many previous reports, with the exception only of that of Diamond (1991), describe the meningo-lacrimal artery as supplying the periorbita as well as the lacrimal gland. We found that the OB passing through the mof anasto-

mosed with the lacrimal artery or the ophthalmic artery only rarely (type 4, 3.4%; 4 of 116 cases). However, the OB that passed through the sof frequently anastomosed with the proximal portion of the lacrimal artery or the ophthalmic artery (60.0%, 12/20 of type a and type c). Moreover, one of four cases of anastomosis showed a well-developed OB that passed through the mof, supplying to a large part of the orbital contents, as reported by Meyer (1887) and Hiura (1980). However, in the orbital artery (Adachi, 1928), the ophthalmic artery arising from the middle meningeal artery passes through the sof, not through the mof, in the Japanese (Adachi, 1928), in Negroes (Harvey and Howard, 1945) and in Caucasians (Zuckerkandle, 1876; Bansal, 1961). The differences in the frequencies of anastomosis and in courses of the orbital artery are summarized below.

It has been proposed that the OB is to derived from the anastomosis between the stapedial artery and the primary ophthalmic artery during development (Dilenge and Ascherl, 1980; Padget, 1948). However, the OB passing through the mof always supplied to the periorbital region but rarely anastomosed with the lacrimal artery or the ophthalmic artery. Moreover, the frontal branch of the middle meningeal artery, which extends the OB that passes through the mof, often runs in a canal in the frontal bone or the sphenoidal bone (Chandler and Derezinski, 1935). The canal is located close to the mof at the anterior base of the skull. The results suggest that most such cases are derived from a meningeal branch of the middle meningeal artery at an early developmental stage. In this study, the OB passing through the sof usually anastomosed with the lacrimal artery or the ophthalmic artery (12/20) and rarely supplied the periorbital region (2/20). Therefore, our observations seem to support the hypothesis that the OB passing through the sof originateds developmentally from the anastomosis between the stapedial and primary ophthalmic arteries.

The present study suggests that the OB passing through the mof might be clinically important as an accessory blood supply to the orbital contents. During reconstruction of the anterior base of the skull and the orbit after orbital base surgery (Price et al., 1988; Stiernberg et al., 1987), the OB passing through the mof can easily to be damaged and a large part of the blood supply to the orbital contents can be lost. Moreover, the OB passing through the mof is thought to become a main feeding artery of meningiomas in the anterior cranial fossa, as indicated by Kuru (1957).
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References

Explanation of Figures

Plate I

Fig. 1. The meningo-orbital foramen in the dry skull of a Japanese cadaver. A: Frontal view, B: Posterior view from the internal cranial base. The meningo-orbital foramina are located at the frontal bone (arrow), the spheno-frontal suture (small arrowhead) or the greater wing of the sphenoidal bone (large arrowhead). The corresponding foramen in the two views is indicated by the same symbol. Abbreviations: AC, anterior cranial fossa; F, hypophysial fossa; O, occipital bone.
Fig. 2. The middle meningeal artery travelling into the orbit on the right side. A. The orbital branch of the middle meningeal artery comes from the superior orbital fissure (type a): 4.7% (N = 7). B. Type b; the OB comes through the meningo-orbital foramen in directly: 44.0% (N = 66). C. Type c is a mixed case: 8.7% (N = 13). Abbreviations: sof, superior orbital fissure; mof, meningo-orbital foramen.
Fig. 3. The course and distribution of the OB passing through the superior orbital fissure. Examination of 20 cases of the OB passing through the superior orbital fissure (sof) (a case show in Fig. 2A and 2C). A. The branch anastomosis with the lacrimal artery or with the ophthalmic artery: 60.0% (N = 12), B. Supplying the lacrimal gland (Lacr) without the usual lacrimal artery: 25.0% (N = 5), C. Supplying an area limited to the periorbita: 10.0% (N = 2). Abbreviations: anas, anastomosis; po, twigs to periorbita.
Fig. 4. Classification of the types of course and distribution of the orbital branch that pass through the meningo-orbital foramen (mof) (116 cases in 258 sides: 45.0%). Viewed from the right side. A. Type 1, the area supplied is limited to the peri-orbita: 46.6% (N = 54); B. type 2, supplying the lacrimal gland (Lacr) without the usual lacrimal artery: 32.8% (N = 38); C. type 3, supplying to the lacrimal gland with the usual lacrimal artery: 17.2% (N = 20); D. type 4, anastomosis with the lacrimal artery or the ophthalmic artery: 3.4% (N = 4). Abbreviations: anas, anastomosis, po, twigs to peri-orbita
Plate V

Fig. 5. The dissection of case of type 1: The orbital branch passes through the meningo-orbital foramen. Blue resin was injected from the common carotid artery. The orbital branch was cut at the meningo-orbital foramen portion as shown by an arrow. The area supplied in this artery was limited to the periorbita below the lateral part of the roof of the orbit (encompassed by a dotted line). The lacrimal artery is seen also visible below the periorbita (arrowheads). Abbreviations: oc, oculomotor nerve; oph, ophthalmic nerve; opt, optic nerve; pe, posterior ethmoidal artery; TM: temporalis muscle, UEL, upper eyelid; ZB, zygomatic bone.
Plate VI

Fig. 6. Dissection of a case of type 2 case from the right side. The orbital branch passes through the meningo-orbital foramen (large star). Photograph (A) and the corresponding line drawing (B). The branch supplies the lacrimal gland (LG) and the upper eyelid (UEL) without the usual lacrimal artery. Abbreviations: ae, anterior ethmoidal artery; f, frontal nerve; m, middle meningeal artery; oa, ophthalmic artery; opt, optic nerve; oph, ophthalmic nerve; sov, superior ophthalmic vein; LG, lacrimal gland; LPS, levator palpebræ superioris muscle; OS, obliquus superior muscle; RS, rectus superior muscle; TM, temporalis muscle; UEL, upper eyelid; ZB, zygomatic bone; Arrowheads, the orbital branch; small asterisks, branches to the rectus medialis muscle; small black stars, branches to the rectus inferior muscle; small white stars, branches to the rectus lateralis muscle.
Plate VII

Fig. 7. Dissection of case of type 3 case from the right side. The orbital branch passes through the meningo-orbital foramen. Photograph (A) and the corresponding line drawing (B). The branch supplies the lacrimal gland (LG) and the upper eyelid (UEL) with the usual lacrimal artery (pink in B). Arrowheads, the orbital branch, large star; meningo-orbital foramen (opened), a, anastomosis between the usual lacrimal artery and the middle meningeal artery (see Fig. 3A). Abbreviations: ae, anterior ethmoidal artery; f, frontal nerve; ic, internal carotid artery; ifo, infraorbital artery; m, middle meningeal artery; noi, nerve to the rectus inferior muscle; oa, ophthalmic artery; oph, ophthalmic nerve; opt, optic nerve; sov, superior ophthalmic vein; LPS, levator palpebrae superioris muscle; OI, obliquus inferior muscle; OS, obliquus superior muscle; RI, rectus inferior muscle; RL, rectus lateralis muscle; RM, rectus medialis muscle; RS, rectus superior muscle; Small white stars, branches to the rectus superior and levator palpebrae superioris muscles.
Fig. 8. Line drawing of a case of type 4 from the left side. The orbital branch (red) passes through the meningo-orbital foramen (large star). The branch supplies to the lacrimal Gland (LG), ocular muscles and the skin of the frontal region. The usual lacrimal artery is not found. Abbreviations: a, anastomosis between the ophthalmic artery and the type 4 orbital branch; ae, anterior ethmoidal artery; f, frontal nerve; ic, internal carotid artery; m, middle meningeal artery; oa, ophthalmic artery; opt, optic nerve; oph, ophthalmic nerve; sov, superior ophthalmic vein; LPS, levator palpebrae superioris muscle; OS, obliquus superior muscle; RS, rectus superior muscle.