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Anomalous meningeal branches of the ophthalmic artery feeding meningiomas of the brain convexity

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Summary: Many anomalies may involve the ophthalmic and middle meningeal arteries, because of the close relationship of their development. The system of the ophthalmic artery may supply the dural convexity by the middle meningeal artery of ophthalmic origin, the anterior branch of the middle meningeal artery or an accessory meningeal artery. The development and the anatomic arrangement of these anomalous vessels are discussed. Three cases of meningiomas of the brain convexity supplied by anomalous meningeal arteries arising from the ophthalmic artery are described. In one case internal carotid angiography showed an anomalous anterior branch of the middle meningeal artery arising from the ophthalmic artery, whereas the maxillary artery provided only the posterior branch of the middle meningeal artery. In two cases the middle meningeal artery system was normal, but the ophthalmic artery provided an accessory meningeal artery supplying the meningioma. Whereas an ophthalmic origin of the middle meningeal artery is rather common, the angiographic finding of an accessory meningeal artery or an anterior branch of the middle meningeal artery arising from the ophthalmic arterial system is exceptional. The preoperative embolization of dural lesions supplied by anomalous meningeal vessels of ophthalmic origin is dangerous because of the risk of embolization into the ophthalmic circle.

Branches méningées anormales de l'artère ophtalmique alimentant les méningiomes de la convexité

Résumé : Un grand nombre d'anomalies touche les aa. ophtalmique et méningée moyenne en raison de leurs liens embryologiques. Le système de l'a. ophtalmique peut vasculariser la dure-mère de la convexité lorsqu'elle donne naissance à l'a. méningée moyenne ou à sa branche antérieure, ou à l'a. méningée accessoire. Le développement et la disposition anatomique de ces anomalies vasculaires sont discutés. Trois cas de méningiomes de la convexité, alimentés par des aa. méningées provenant de l'a. ophtalmique, sont décrits. Dans un cas, l'opacification de l'a. carotide interne montrait que la branche antérieure de l'a. méningée moyenne provenait de l'a. ophtalmique ; l'a. maxillaire ne donnait alors que sa branche postérieure et l'a. méningée moyenne. Dans deux cas, le système de l'a. méningée moyenne était normal, mais l'a. ophtalmique donnait une a. méningée accessoire vascularisant le méningiome. Alors que l'origine ophtalmique de l'a. méningée moyenne est relativement commune, la naissance à partir de l'a. ophtalmique de l'a. méningée accessoire ou de la branche antérieure de l'a. méningée moyenne est exceptionnellement décrite en angiographie. L'embolisation pré-opératoire des lésions durales alimentées par les vaisseaux méningés anormaux provenant de l'a. ophtalmique est dangereuse en raison des risques oculaires.

Key words: Middle meningeal artery — Accessory meningeal artery — Ophthalmic artery — Cerebral arterial anomaly

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The development of the ophthalmic and middle meningeal aa. shows a fundamental relationship with the development of the embryonic system of the stapedial a. [13]. For this reason, anomalies of vascularization of the orbit and dural covering of the brain convexity are strictly correla-

Table 1. Data on 3 cases of meningiomas of the brain convexity supplied by anomalous meningeal branches of the ophthalmic a.

Cases	Age - sex	Location of the meningioma	Findings on selective external carotid angiography	Findings on selective internal carotid angiography
1	48 M	Right frontal convexity	Posterior branch of the MMA arising from the maxillary a., no vascular tumor stain	Tumoral vascularization from the anterior branch of the MMA arising from the OA
2	52 F	Left frontal convexity	Normal aspect of the MMA, no vascular tumor stain	Tumoral vascularization from an accessory meningeal a. arising from the O.A.
3	29 F	Right parasagittal-falx region (middle third)	Normal aspect of the MMA, no vascular tumor stain	Tumoral vascularization from an accessory meningeal a. arising from the OA

MMA; middle meningeal a; *OA,* ophthalmic a.

ted [3, 10]. The middle meningeal a. arising from the ophthalmic a. is the commonest of these anomalies. On the other hand, the isolated origin of the anterior branch of the middle meningeal a. from the ophthalmic a. or the presence of an accessory meningeal a. of ophthalmic origin are quite rare. We report three cases of meningiomas of the anterior convexity supplied by anomalous meningeal aa. of ophthalmic origin (anterior branch of the middle meningeal a. in one case and accessory meningeal a. in two). The embryologic origin and radiologic implications of these anomalies are discussed.

Material and methods

This series includes three cases of meningiomas of the brain convexity supplied by anomalous meningeal aa. of ophthalmic origin (Table 1). The patients were two women and one man, aged 48, 52 and 29 years respectively. Epileptic seizures (2 cases) and intracranial hypertension (one case) were the presenting clinical features. All three patients were investigated by computed tomography

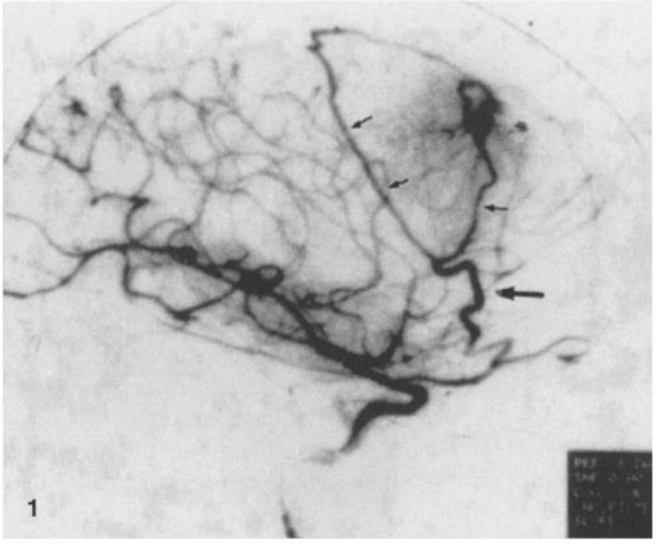

Fig. 1
Case 1. Selective right internal carotid angiography: anterior branch of the middle meningeal a. *(arrows)* arising from the ophthalmic a. and supplying a meningioma of the anterior convexity

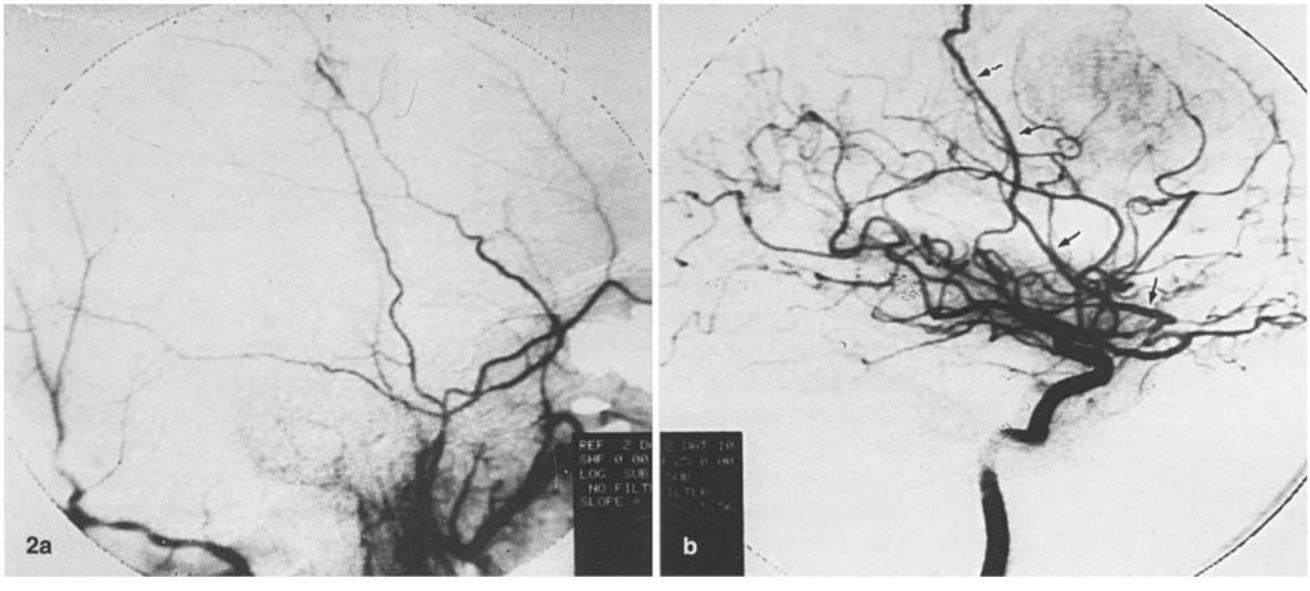

Fig. 2a, b
Case 2. **a** Selective angiogram of the left external carotid a. in *lateral view:* normal aspect of the middle meningeal a. (both anterior and posterior branches are present). **b** Selective angiogram of the left internal carotid a. in *lateral view:* accessory meningeal a. *(arrows)* arising from the ophthalmic a. with vascular tumor stain

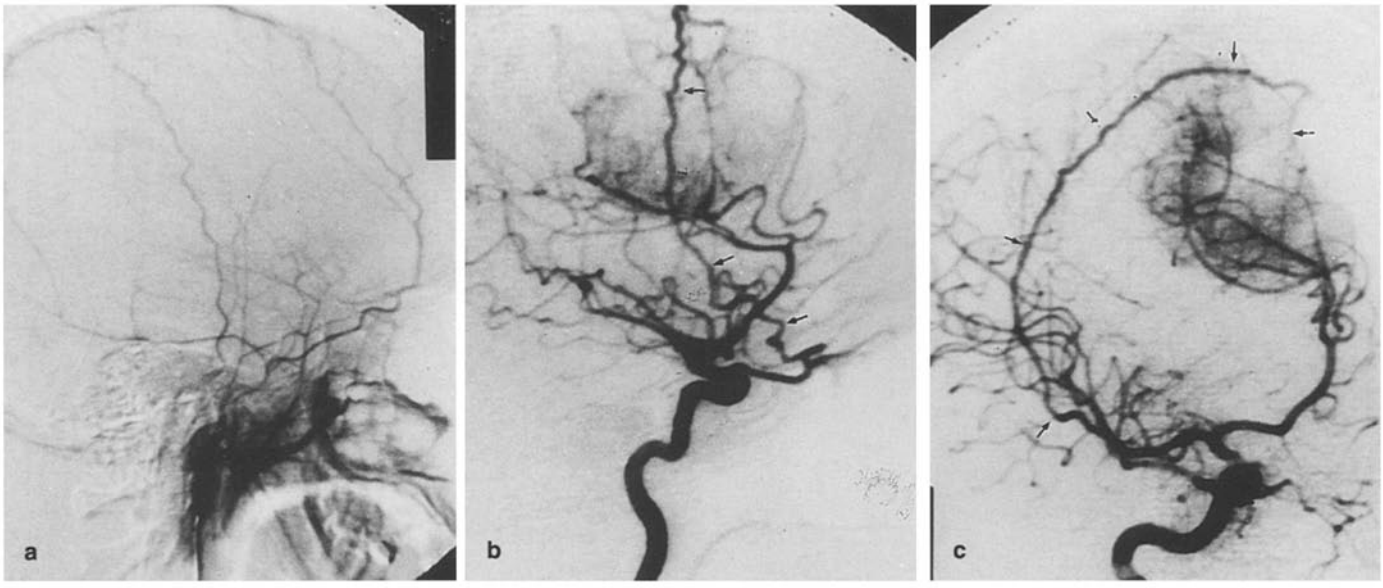

Fig. 3a-c
Case 3. **a** Selective angiogram of the right external carotid a. in *lateral view:* normal aspect of the middle meningeal a. with no visualisation of the tumor vascular stain. **b, c** Selective right internal carotid angiography in *lateral* **(b)** and *antero-posterior* **(c)** views: accessory meningeal a. *(arrows)* arising from the ophthalmic a. and supplying a meningioma of the middle parasagittal-falx region

Table 2. Anomalies of the ophthalmic and middle meningeal arteries

1. Ophthalmic a. arising from the middle meningeal a.
2. Separation of ocular branches of the ophthalmic a. from the extraocular intraorbital branches.
3. Double orbital vascularization from both ophthalmic and middle meningeal aa.
4. Middle meningeal a. arising from the ophthalmic a.
5. Anterior branch of middle meningeal a. arising from ophthalmic a.
6. Accessory meningeal a. arising from ophthalmic a.

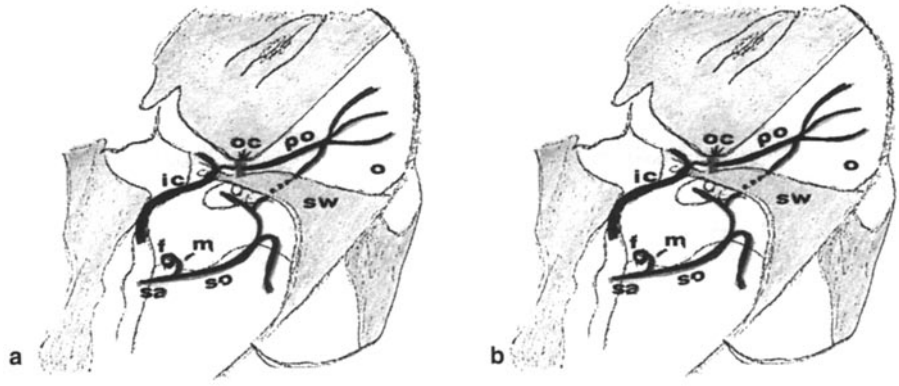

Fig. 4a, b
Schematic views of the skull base from above. **a** Embryologic arrangement of the system of the primitive ophthalmic and stapedial aa. The stapedial a. *(sa)* gives two intracranial branches: the maxillo-mandibular a. *(m)* exits through the foramen spinosum *(f)* and is annexed by the external carotid a.; the supraorbital a. *(so)* runs in the middle cranial fossa and gives a recurrent tentorial branch, a branch for the calvaria and another orbital branch that penetrates through the superior orbital fissure and anastomoses with the primitive ophthalmic a. *(po)*. **b** Definitive development of the ophthalmic and middle meningeal aa.: after involution of the proximal stapedial a., the maxillo-mandibular branch becomes the internal maxillary a.; its endocranial segment passes through the foramen spinosum and annexes the supraorbital a., which becomes the definitive middle meningeal a. *(mm)*, after involution of its connections with the definitive ophthalmic a. *(oa)*. *ic,* internal carotid a.; *oc,* optic canal.

and one also by magnetic resonance. The location of the meningioma was the frontal convexity in two cases and the right parasagittal-falx region in one. In all three cases an angiographic study of the tumor vascularization was performed by transfemoral catheterisation, with selective angiography of the external and internal carotid aa. homolateral to the tumor.

Results

The findings were as follows. In case 1, selective external carotid angiography showed opacification of the only posterior branch of the middle meningeal a. from the maxillary a., with no tumor vascularization; at selective internal carotid angiography, the tumor was supplied by the anterior branch of the middle meningeal a. arising from the ophthalmic a. (Fig. 1). In cases 2 and 3, selective external carotid angiography was negative, with a normal aspect of the middle meningeal a. and no visualisation of the tumor vascular stain (Figs. 2a, 3a). Selective internal carotid angiography showed vascularization of the meningioma from an accessory meningeal a.; it arose in

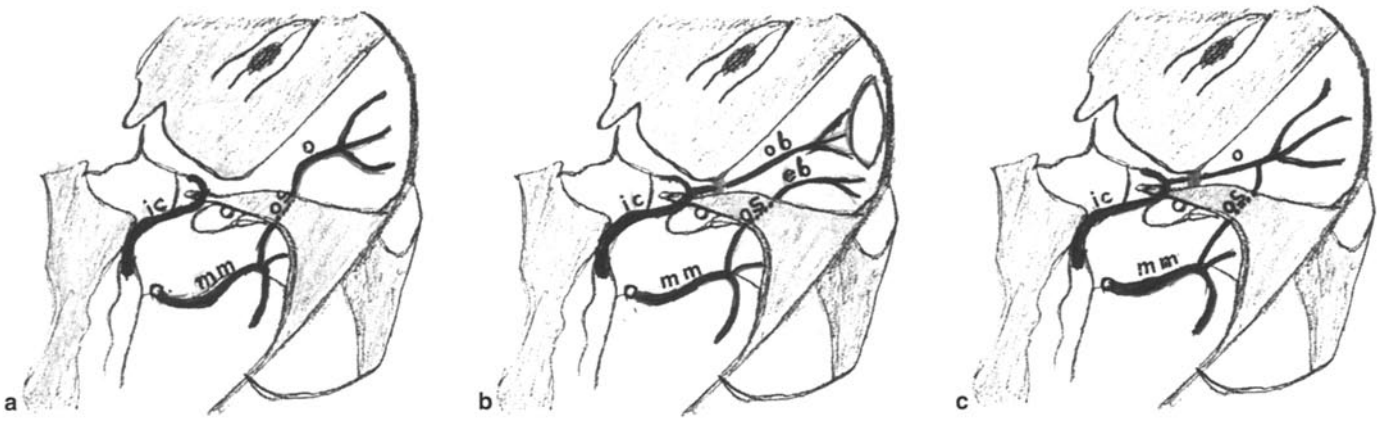

Fig. 5a-c
Schematic views of anomalies involving vascularization of the orbital structures from the middle meningeal a. **a** Ophthalmic a. *(o)* arising from the middle meningeal a. *(mm)*. **b** Separation of the ocular branches *(ob)*, filled by the ophthalmic a., from the extraocular branches *(eb)* filled by the middle meningeal a. *(mm)*, without anastomoses between the two systems. **c** The entire orbital circulation is filled at the same time by both the ophthalmic a. (o) and the middle meningeal a. *(mm)* (through the persistent retroorbital stapedial branches *(os)*

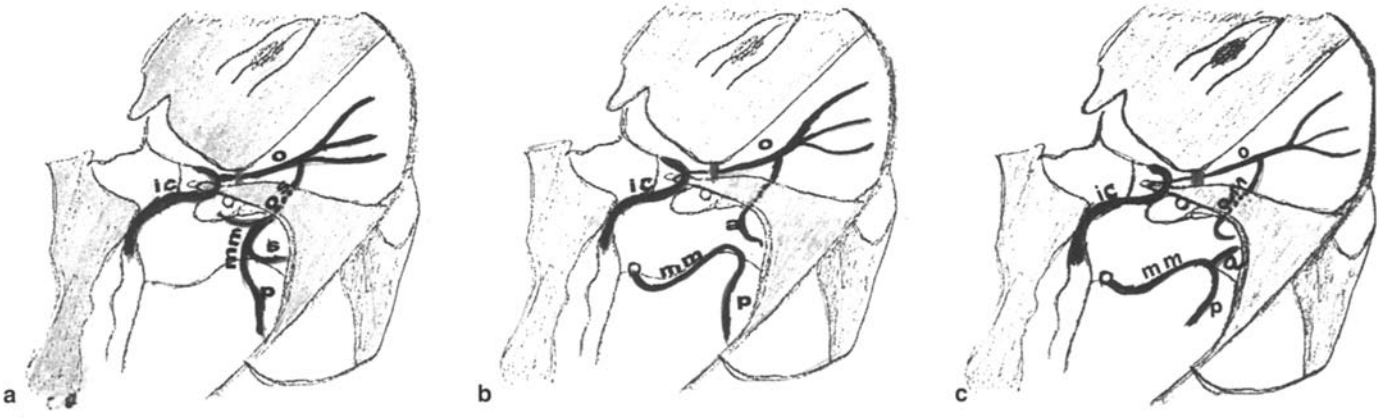

Fig. 6a-c
Schematic views of anomalies involving the vascularization of the dural convexity from the ophthalmic a. **a** Ophthalmic origin of the middle meningeal a. through the persistent proximal retroorbital stapedial branches *(os)*; the proximal segment of the middle meningeal a. and the foramen spinosum are absent. **b** Ophthalmic origin of the anterior branch of the middle meningeal a. *(a)* due to partial persistence of the retroorbital stapedial branches; the proximal segment of the middle meningeal a. is normal and fills the posterior branch *(p)*. **c** Ophthalmic origin of an accessory meningeal a. *(am)* supplying the anterior convexity, due to partial persistence of the retroorbital stapedial branches; the intracranial segment of the middle meningeal a. *(mm)* is normal and fills both its anterior *(a)* and posterior *(p)* branches, without connection with the accessory meningeal a.

both cases from the ophthalmic a. about 1.5 cm from its origin, ran postero-superiorly and then vertically along the frontal convexity up to the tumor site (Figs. 2b, 3b-c). At operation, the meningioma was easily removed in all three cases by standard craniotomy, with no particular problems related to their anomalous vascularization.

Discussion

The embryonic development of the middle meningeal a. results from morphologic changes in the stapedial arterial system and is closely related to the development of the system of the ophthalmic a. [3, 13, 20]. In the 20 mm embryo the stapedial a. (a branch of the hyoid a.) divides into two branches: a) the maxillo-mandibular division penetrates into the foramen spinosum and is annexed by the developing external carotid a., thus forming the definitive maxillary a. and the extracranial segment of the middle meningeal a.; b) the supraorbital division runs in the middle cranial fossa and reaches the supraorbital fissure, thus providing intraorbital and retroorbital branches which anastomose with the ophthalmic a. This supraorbital division forms the intracranial segment of the middle meningeal a. and the extraocular intraorbital aa. (Fig. 4). This close relationship between the development of the ophthalmic and middle meningeal aa. may account for the numerous anomalies involving these two arterial systems (Table 2). The partial or complete persistence of the intraorbital and retroorbital branches of the supraorbital a. explains both the dependence of the orbital vascularization on the middle meningeal a. and the variable participation of the ophthalmic a. in the vascularization of the dural convexity.

The vascularization of the orbital structures may depend partially or completely on the middle meningeal a. [4, 10] (Fig. 5)

The ophthalmic a. arising from the middle meningeal a. is a very rare anomaly [3, 8, 19], which results from complete assimilation of the primitive ophthalmic a. by the supraorbital stapedial division, with persistence of the retroorbital branches of the stapedial a. and involution of the proximal segment of the primitive ophthalmic a. (Fig. 5a). If the supraorbital stapedial branch persists but its embryonic anastomosis with the primitive ophthalmic a. is defective, an exceptional anomaly occurs where the ophthalmic a. supplies only the ocular globe and remains separate from the intraorbital extraocular branches (muscular and lacrimal) which are supplied by the middle meningeal a. [2, 3, 13] (Fig. 5b). If the supraorbital stapedial division persists and is anastomosed with the primitive ophthalmic a., the whole orbital circulation is supplied by both the definitive ophthalmic a. and the middle meningeal a. [6, 10] (Fig. 5c).

The vascularization of the dural convexity and related lesions, including meningiomas, may be provided by the system of the ophthalmic a. through three different anomalous meningeal vessels (Table 3 and Fig. 6)

1. The middle meningeal a. arising from the ophthalmic a. is the commonest of these anomalies with an incidence of about 0.5% in the angiographic material [1, 3, 5, 7, 9, 12, 15-18]. It results from two different embryologic processes (Fig. 6a): a) failure of the proximal intraorbital stapedial branches to involute, so that the intracranial segment of the middle meningeal a. remains in connection with the intraorbital stapedial branches; b) defective involution of the maxillo-mandibular division of the stapedial a., so that the extracranial segment of the middle meningeal a. is not formed. The anatomo-radiologic findings of this anomaly include: absence of the extracranial segment of the middle meningeal a. (from the maxillary a. to the intracranial segment); opacification of the entire territory of the middle meningeal a. (including the whole skull convexity) from the ophthalmic arterial system; absence of the foramen spinosum [11].

Table 3. Anatomo-radiologic features of anomalous meningeal vessels of ophthalmic arterial origin supplying lesions of the anterior brain convexity

Type of anomalous meningeal a.	Extracranial segment of the MMA (from the maxillary a.)	Anterior meningeal territory	Posterior meningeal territory	Foramen spinosum
MMA arising from the OA	Absent or hypoplasic	From the OA	From the OA	Absent
Anterior branch of MMA arising from the OA	Present	From the OA	From the MMA	Present
Accessory meningeal a. arising from the OA	Present	From the OA and MMA (without communication)	From the MMA	Present

MMA, middle meningeal a; *OA*, ophthalmic a.

2. An anterior branch of the middle meningeal a. arising from the ophthalmic a. is much more rare [3], although its true incidence has not been defined. Embryologically, the extracranial segment of the middle meningeal a. forms normally and unites with the intracranial segment, with only partial involution of the retroorbital stapedial branches. Consequently, the anterior branch of the middle meningeal a. (anterior skull convexity) fills from the ophthalmic a., whereas its posterior branch (posterior skull convexity) fills from the external circulation through the maxillary a. (Fig. 6b). The extracranial segment of the middle meningeal a. and the foramen spinosum are normal.

3. An accessory meningeal a. arising from the ophthalmic a. is rare. The meningeal territory of the anterior convexity and parasagittal region is supplied by two different sources: the anterior branch of the middle meningeal a. with normal origin and the accessory meningeal a. of ophthalmic a. origin; these two vascular territories are independent, as for other accessory aa. (Figs. 2, 3, 6c). The extracranial segment of the middle meningeal a. is normal and supplies the posterior skull convexity normally; the foramen spinosum is present. Embryologically, the supraorbital division of the stapedial a. forms the intracranial segment of the middle meningeal a. as usual; retroorbital stapedial branches develop as an accessory meningeal a. and lose their connection with the middle meningeal a. This may explain why the two vascular territories are independent (Fig. 6c).

The anatomo-radiologic features of anomalous meningeal branches of the brain convexity arising from the ophthalmic a. are rather typical. The intraorbital origin of these vessels usually occurs at the point where the ophthalmic a. curves around the optic n., near the origin of the posterior ethmoidal aa. Then, the anomalous meningeal a. travels upward through the superior orbital fissure to reach the cranial dura. Thus, the dural territory supplied by the meningeal vessel of ophthalmic arterial origin and the related meningeal lesions are opacified exclusively by injection of the internal carotid a., whereas external carotid angiography fails to visualise them.

The anterior branch of the middle meningeal a. and the accessory meningeal a. arising from the ophthalmic a. may be easily distinguished on the angiograms from the anterior meningeal a. (or a. of the falx), a normal branch of the anterior ethmoidal a. [14]. In fact, this normal vessel is almost at the midline in the antero-posterior angiograms, whereas in lateral angiograms it travels a few mm from the convexity. On the contrary, the anterior branch of the middle meningeal a. and the accessory meningeal a. of ophthalmic origin have a more lateral course, away from the midline, and do not reach the inner skull table.

Meningiomas of the brain convexity supplied by anomalous meningeal vessels of ophthalmic arterial origin may pose some problems concerning their possible preoperative endovascular treatment [10]. In fact, in these cases preoperative embolization is dangerous and should be avoided because of the risk of superselective catheterisation of the ophthalmic a. and migration of embolizing material into the ophthalmic circle with sudden visual deficits. On the other hand, the anomalous vascularization does not imply problems of bleeding control during surgery, as confirmed by our three cases.

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