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Intracavernous branches of the internal carotid artery (ICA)

Comprehensive review of their variations

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Summary. Since we started to work in the lateral sellar region (in 1973), a large volume of angiographic material has provided us with exceptional variations that added to the anatomic facts obtained from our dissections. At present, these anatomic facts remain, but the way we look at them and the way we use them for endovascular treatments, has created a need for a different type of approach and understanding.

In this report, we present a flexible anatomical view of the intracavernous branches of the internal carotid artery and a scheme to understand and predict the anatomical variations of these collaterals. Four embryonic vessels play an important role in the variations of the arterial supply to the lateral cavernous region : the dorsal ophthalmic artery, the stapedial artery, the trigeminal artery and the primitive maxillary artery. In general each of them partially regresses leaving behind a remnant. However there is a spectrum from their persistence to incomplete regression, resulting in variations of the supply to their distal territories. The term "meningohypophyseal" should be abandoned because it is misleading and improperly used.

Complete agenesis is known for a long time; in case of segmental agenesis of the ICA each of the embryonic vessels presented above may represent an alternate route to bypass the agenesis. The ICA is not a direct feeding artery but a succession of independant segments which can be the site of various anomalies. An embryonic transdural circle can be individualized; it is constituted by the trigeminal arteries posteriorly, the ICA siphon anteriorly, the transsellar anastomosis and internal maxillary artery connections. Although regressions usually occur in this embryonic transdural circle, its derivatives congenital and acquired arterial pathologies. It also constitutes the key system in determining the arterial variations of the perisellar region.

Offprint requests : P Lasjaunias

Collatérales intra-caverneuses de la carotide interne : synthèse de leurs variations

Résumé. Depuis que nous avons commencé notre travail, sur la région latéro-sellaire (en 1973), une grande quantité d'angiographies sélectives de variations vasculaires est venue compléter le matériel anatomique que nous avions obtenu à partir des dissections. Aujourd'hui les faits anatomiques observés restent, mais la façon dont nous les regardons et la manière dont nous les utilisons pour nos traitements endovasculaires nécessitent une vision et une présentation différente de ces variétés.

Dans cet article, nous proposons une vision anatomique « flexible » des branches intra-caverneuses de la carotide interne à partir d'un schéma générique permettant de comprendre et de prédire les variations de ces collatérales. 4 vaisseaux embryonnaires jouent un rôle clé dans le déterminisme des variations artérielles de cette région : l'artère ophtalmique dorsale, l'artère stapédienne, l'artère trijéminée et l'artère maxillaire primitive. En général, chacune d'entre elles régresse partiellement, laissant derrière elle un reliquat artériel. En fait, il existe toute une gamme possible, entre la persistance du vaisseau embryonnaire et le reliquat; chacun de ces intermédiaires, crée une variation dans le territoire de vascularisation de ces artères. Ainsi le terme de tronc méningo-hypophysaire devrait être abandonné car il est source de confusion et utilisé la plupart du temps de façon anatomiquement impropre.

De même, l'agénésie complète de la carotide interne est connue depuis longtemps; mais en cas d'agénésie incomplète de la carotide interne chacun des vaisseaux embryonnaires présentés ci-dessus constitue une voie de suppléance, court-circuitant le segment agénatique. La carotide interne ne doit pas être considérée comme une artère nourricière proprement dite mais comme une succession de segments indépendants pouvant être le siège d'anomalies multiples mais spécifiques. Enfin, on peut donc décrire, un cercle embryonnaire trans-dural constitué par les artères trijéminées en arrière, les siphons carotidiens en avant, l'anastomose trans-sellaire sur la ligne médiane et les anastomoses maxillaires internes en dehors. Bien que chacun des éléments de ce cercle embryonnaire régresse au cours du développement, ces reliquats constituent en pratique des voies accessoires fournissant la circulation collatérale efficace aussi bien dans les anomalies congénitales qu'acquises du tronc artériel carotidien interne. Ce cercle artériel embryonnaire constitue le système clé du déterminisme des variétés artérielles de la région péri-sellaire, ses variétés sont indépendantes de celles du cercle de Willis.

Key words : Internal carotid artery – Arterial variations – Agenesis – Cavernous sinus – Embryonic vessels

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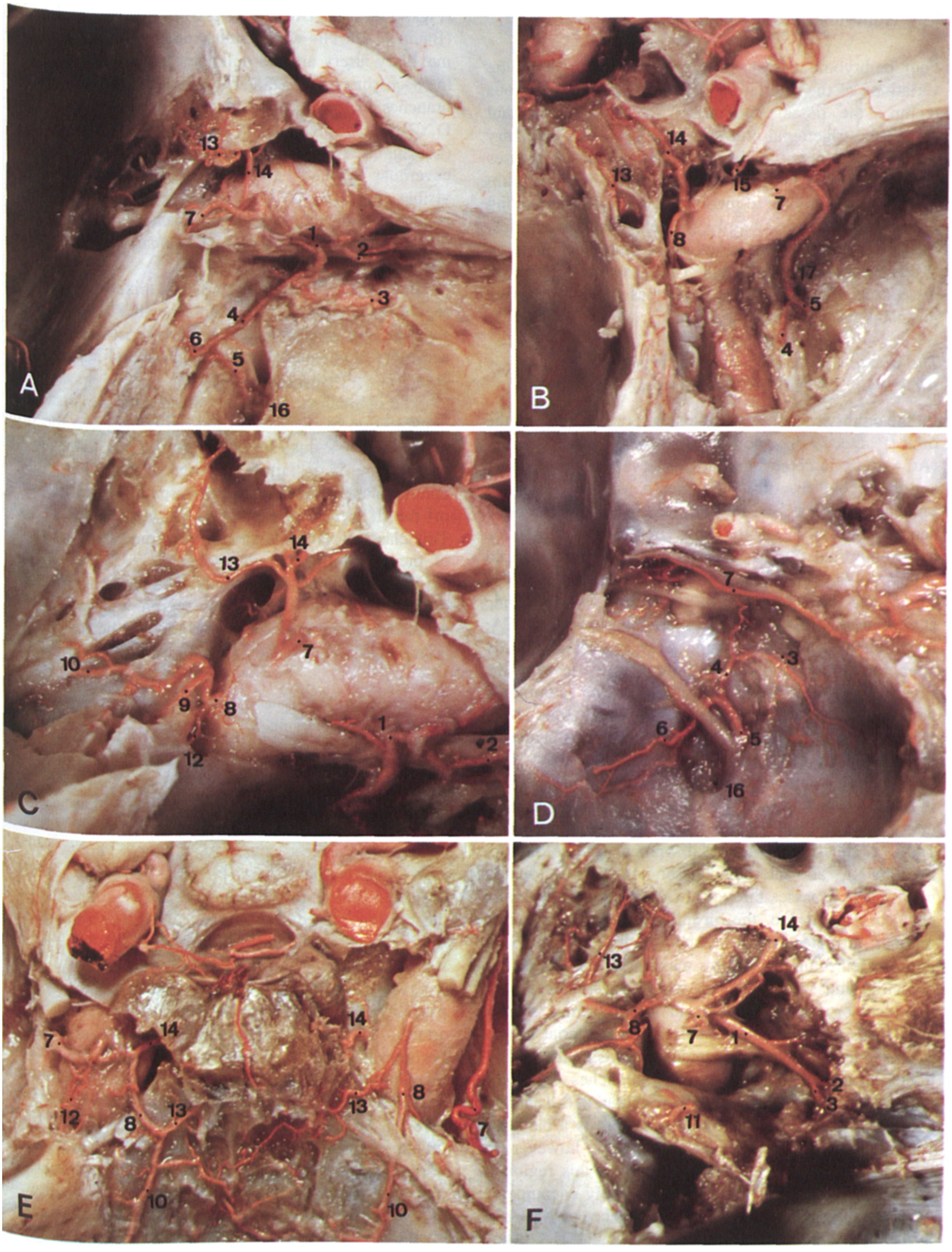
Anatomic (Francke 1982, Lang 1983, Lazorthes 1976, Santini 1974) and radioanatomic (Faure 1971, Manelfe 1972, Margolis 1969, Stattin 1961, Schnurer 1963, Wallace 1967) studies described in detail the most commonly found arterial branches in the cavernous region. Angiographic and anatomic reports on specific arterial variations at the base of the skull were first regrouped by Lie (1968). Modern anatomy now utilizes anatomical dissections, high quality angiographic material and a strong background in vascular embryology (Congdon 1922, Kier 1974, Padget 1948, Streeter 1918). Since we started to work in the lateral sellar region (in 1973), a large volume of angiographic material has provided us with exceptional variations that added to the anatomic facts obtained from our dissections. At present, these anatomic facts remain, but the way we look at them and the way we use them for endovascular treatments, has created a need for a different type of approach and understanding, that will be presented here. In our clinical practice, we have found that the vascular arrangements of patients who undergo angiographic procedures do not correspond exactly to the population on which traditional anatomical data was acquired.

Six years ago, our group attempted to understand and link these arterial variations that were sent to us or published in the literature (Lasjaunias 1980, 1986). In this report, we present a flexible anatomical view of the intracavernous branches of the internal carotid artery and a scheme to understand and predict the anatomical variations of these collaterals. The internal carotid (ICA) (arterial carotidis interna), external carotid (ECA) (arteria carotidis externa) and vertebral (VA) (arteria vertebralis) arteries all play a role in this region and their own variations creates additional complex variants that shall be presented.

Fig. 1
A, B, C, D, F Supero lateral view of the right cavernous sinus **E** Posterior view of the dorsum sellae **A** Classical arrangement with a complete ILT, and a meningo hypophyseal trunk **B** Accessory meningeal dominance to the supply of the region. The branch courses through the Vesale foramen. Incomplete "meningohypophyseal trunk" **C** Separate origin of the posterior group of intracavernous ICA branches. No "meningohypophyseal trunk" **C** Accessory meningeal dominance ot the supply of the region. The branch courses through the ovale foramen. Incomplete "meningohypophyseal trunk" **E** Meningo hypophyseal trunk on the left side, separate origin of the posterior group of intracavernous ICA branches on the right. **F** Common origin of the three remnants of the embryonic system of the region. Note the supracavernous course of the posteroinferior hypophyseal artery. No "meningohypophyseal trunk". Note from these dissections most of the possible origins of the marginal tentorial artery from the meningo hypophyseal trunk (**A, E**), the accessory meningeal artery (**B**), the posterior hypophyseal artery (**C**), the commun trunk (**F**), the intraorbital lacrymal artery (**D**) *1* ILT *2* Anteromedial branch *3* Artery of the foramen rotondum *4* Posterior branch *5* Accessory meningeal branch *6* Petrous branch *7* Marginal tentorial artery *8* Lateral clival artery *9* Basal tentorial artery *10* Anastomotic branch (with the ascending pharyngeal artery) *11* Artery of the Gasserian ganglion *12* Recurrent artery of the foramen lacerum *13* Medial clival artery *14* Posteroinferior hypophyseal artery *15* Capsular artery *16* Foramen ovale *17* Vesale foramen

A, B, C, D, F, vues supéro-latérales du sinus caverneux droit **E** vue postérieure du dos de la selle turcique **A** arrangement classique avec un tronc inféro-latéral complet et un tronc méningo-hypophysaire **B** dominance méningée accessoire à la vascularisation de la région, l'artère emprunte le tronc de Vésale. Trou méningo-hypophysaire incomplet **C** origine séparée des branches du groupe postérieur du siphon carotidien interne. Pas de tronc méningo-hypophysaire **D** dominance méningée accessoire à la vascularisation de la région; la branche emprunte le foramen ovale. Tronc méningo-hypophysaire incomplet **E** tronc méningo-hypophysaire du côté gauche, origine séparée des branches du groupe postérieur du siphon intra caverneux du côté droit **F** origine commune des trois reliquats des vaisseaux embryonnaires. Remarquer le trajet supra-carotidien de l'artère hypophysaire postéro-inférieure. Pas de tronc méningo-hypophysaire. Remarquer sur chacune de ces dissections, les origines possibles de l'artère du bord libre de la tente du cervelet, à partir du tronc méningo-hypophysaire (**A** et **E**) de l'artère méningée accessoire (**B**) de l'artère hypophysaire postéro-inférieure (**C**) du tronc commun (**F**) de l'artère lacrymale intra-orbitaire (**D**) *1* tronc inféro-latéral *2* branche antéro-médiane *3* artère du trou grand rond *4* branche postérieure *5* artère méningée accessoire *6* branche pétreuse *7* artère marginale tentorielle *8* artère latérale du clivus *9* artère tentorielle basale *10* rameau anastomotique *11* artère du ganglion de Gasser *12* artère récurrente du trou déchiré antérieur *13* artère médiane du clivus *14* artère hypophysaire postéro-inférieure *15* artère capsulaire *16* foramen ovale *17* foramen de Vesale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Key embryonic vessels and their derivatives

Four embryonic vessels play an important role in the variations of the arterial supply to the lateral cavernous region : the dorsal ophthalmic artery, the stapedial artery, the trigeminal artery and the primitive maxillary artery. In general each of them partially regresses leaving behind a remnant. However there is a spectrum from their persistence to incomplete regression, resulting in variations of the supply to their distal territories. These variations seem independant from the circle of Willis variations (Khodadad 1978) as seen either in dissections (Fawcett 1906, Lazorthes 1976) or during postnatal growth (Guerin 1976).

The dorsal ophthalmic artery/Inferolateral trunk (ILT) (Ramus sinus cavernosi)

In the embryo, two anastomosing arteries supply the orbit (Padget 1948); one from the anterior cerebral artery (ACA) (arteria cerebri anterior), the ventral ophthalmic, and the second from the intra cavernous ICA, the dorsal ophthalmic artery. The former courses through the optic canal, whereas the latter joins the orbit through the superior orbital fissure. This is similar to the balanced supply to the orbit in the adult dog (Jewell 1952).

In the human embryo, the ventral ophthalmic anastomoses with the supra cavernous portion of ICA; its proximal segment from the ACA regresses. Shortly after, the dorsal ophthalmic involutes at the level of the superior orbital fissure. This leaves the commonly observed supracavernous origin of the ophthalmic artery (arteria ophtalmica) in the adult. Errors in this sequence of events lead to variations.

The infero lateral trunk (ILT) of the intracavernous ICA corresponds to the remnant of the dorsal ophthalmic artery (Lasjaunias 1977). It has four branches (Fig. 1A) : a superior or tentorial branch (ramus tentorii marginalis), an anteromedial branch (ramus ophtalmicus) which passes through the superior orbital fissure and corresponds to the primitive dorsal ophthalmic reliquat, an anterolateral branch which courses through the foramen rotundum (ramus maxillaris) and a posterior branch (ramus mandibularis) which anastomoses with the accessory middle meningeal artery (ramus meningeus accessoris). A balance exists in the arterial supply to the lateral cavernous region between these ILT branches and their anastomosing branches from the internal maxillary artery (arteria maxillaris) (Lasjaunias 1986). Early in the human embryo, there is a balanced contribution from both the ECA and ICA, however, in the human adult, a preferential supply to this region is established. The ICA dominance is usually encountered creating the pattern classically described where the horizontal segment gives off a prominant ILT trunk (Figs. 1A, 2A). However ECA dominance can be seen (Baumel 1961); when transcranial branches of the maxillary artery are the dominant supply to the region, the accessory meningeal artery gives off the 4 cavernous branches that correspond to the ILT territory (Fig. 1B, D, 2B). This variant is present in 20 % of cases (Lasjaunias 1977). There are no anastomoses with the cavernous ICA and no ILT arising from the siphon is visible (Fig. 1B, D). The accessory meningeal branch penetrates either through the foramen ovale (Fig. 1D) or the Vesale foramen (Fig. 1B) located more medial (Baumel 1961).

Intermediate forms exist where a mixed supply to the region occurs : the ILT from the ICA supplies the superior and anteromedial branches territories, and the accessory meningeal provides anterolateral and posterior branches.

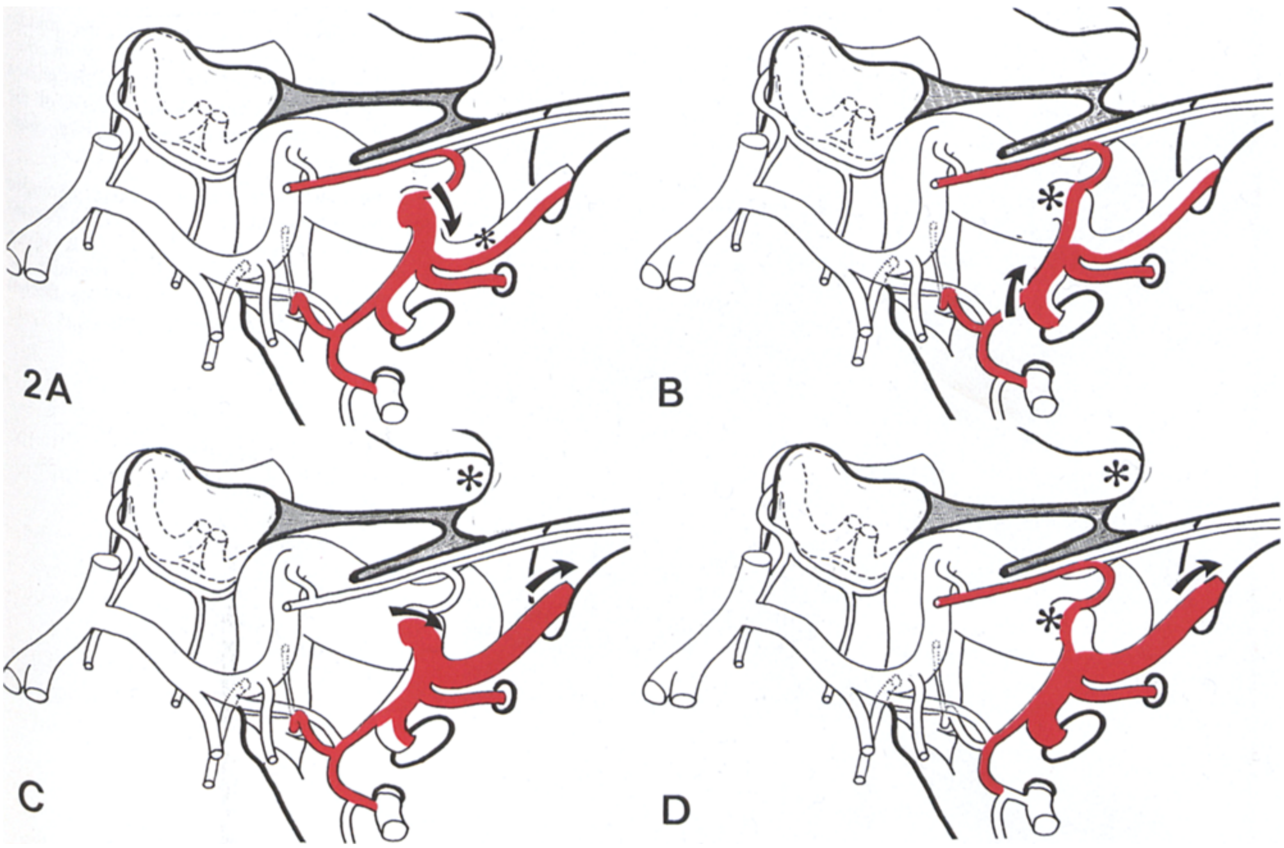
The ophthalmic artery can arise from the intracavernous portion of the ICA as the only supply to the orbit or be part of a dual supply (Figs. 2C, 3). This occurs when there is a failure of regression of the dorsal ophthalmic artery at the superior orbital fissure. It comes off the ILT, and correspond to its anteromedial branch. This classical variation should be named the persistence of the dorsal ophthalmic artery.

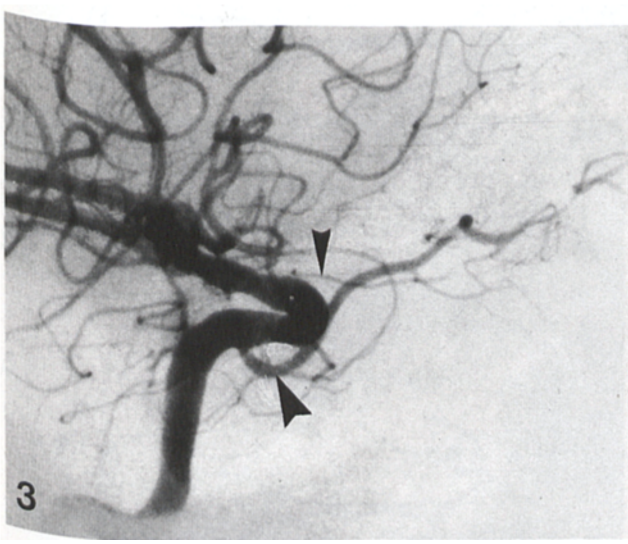
Persistence of the dorsal ophthalmic artery with dominance of the ECA to the region will produce the accessory meningeal artery origin of the ophthalmic artery (Lasjaunias 1986) (Fig. 2D).

The stapedial artery/Middle meningeal artery (arteria meningea media)

The stapedial artery is a tympanic collateral of the hyoid artery coming off the intra petrous ICA.

The stapedial artery enters the middle cranial fossa and divides into a supraorbital artery which remains endocranial and a maxillo-mandibular artery which leaves the cranial cavity through the future foramen spinosum (Altmann 1947, Fischer 1914). Extracranially, the ventral pharyngeal artery, future external carotid artery, annexes the maxillomandibular division of the stapedial artery (Padget 1948). Following this event, reversal of flow at the foramen spinosum occurs, which probably induces the intra tympanic regression of the artery. The previously called supraorbital division becomes the middle meningeal artery while the maxillomandibular one constitutes the main trunk of the internal maxillary artery. The maxillomandibular annexation and reversal of flow represents a key event in the future middle meningeal artery origin. If the transcranial portion regresses, with the tympanic one, the endocranial territory of the stapedial artery (middle meningeal) will be taken over by the nearest functional anastomotic channel. This accounts for the various sites of origin of

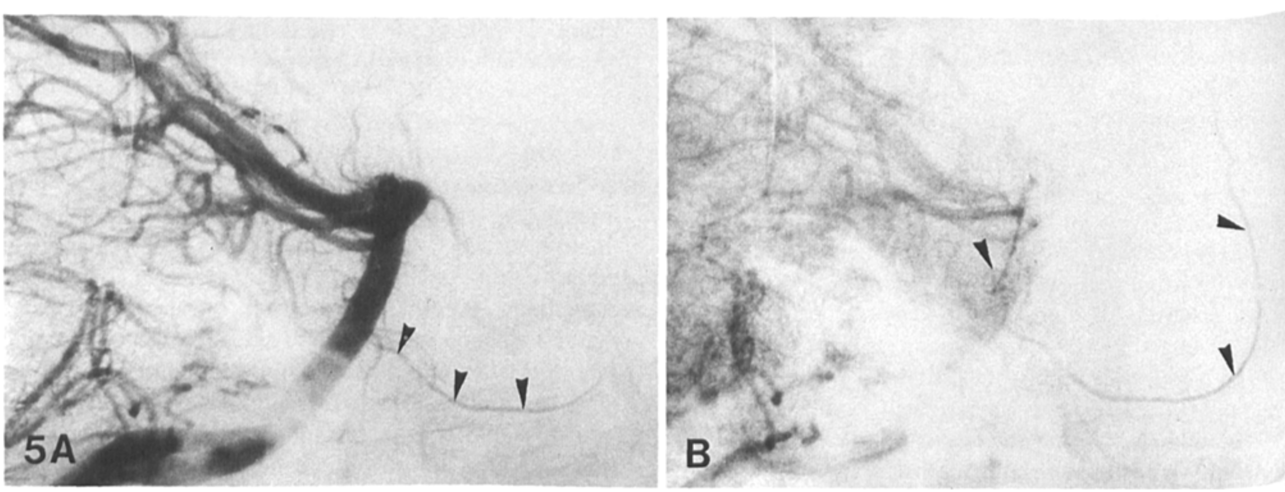




Figs. 2, 3

2 Schematic representation of the intracavernous ICA branches and their variants **A** ILT dominance **B** Accessory meningeal artery dominance **C** ILT origin of the ophthalmic artery (dorsal ophthalmic persistence) **D** Accessory meningeal artery origin of the ophthalmic artery **3** ICA angiogram. Persistence of the dorsal ophthalmic artery (large arrowhead). Note the small ventral ophthalmic remnant supplying the intracanalicular optic nerve (small arrowhead)

2 Schéma représentant les branches intra-caverneuses de la carotide interne et leurs variétés **A** dominance du tronc inféro-latéral **B** dominance de l'artère méningée accessoire **C** origine intra-caverneuse de l'artère ophtalmique **D** origine méningée accessoire de l'artère ophtalmique **3** Angiographie carotidienne interne avec persistance de l'artère ophtalmique dorsale (pointe de flèche) remarquer le petit reliquat de l'artère ophtalmique ventrale vascularisant la portion intra-canalaire du nerf optique (petite pointe de flèche)



Figs. 4, 5
4 ILT origin (curved arrow) of the middle meningeal artery (small arrowheads) (With courtesy of A Hasso) **5** Early (A) and late (B) phases of a vertebral angiogram. Basilar origin of the middle meningeal artery (arrowhead) *(With courtesy of J Seeger)*

4 Origine intra-caverneuse de l'artère méningée moyenne *(Cliché dû à l'obligeance de A Hasso)* **5** Temps précoce et tardif A et B d'une angiographie vertébrale. Origine basilaire de l'artère méningée moyenne (pointe de flèche) *(Cliché dû à l'obligeance de J Seeger)*

the middle meningeal artery (Lasjaunias 1986). Since ophthalmic origins will not be considered here, the next most frequent alternative origin is the intracavernous branches : both the ILT (Figs. 4, 7A) and the posterior group of intra cavernous ICA branches may be concerned. Partial persistence of the trigeminal artery provides a rare additional pathway : the basilar origin of the middle meningeal (Figs. 5, 7C) (Seeger 1976). Other origins of the middle meningeal artery include the carotid branch (ramus carotidus) of the ascending pharyngeal artery (arteria pharyngea ascendens) (Figs. 6, 7B), and the intra petrous ICA, with or without aberrant intra tympanic flow (Lasjaunias 1986).

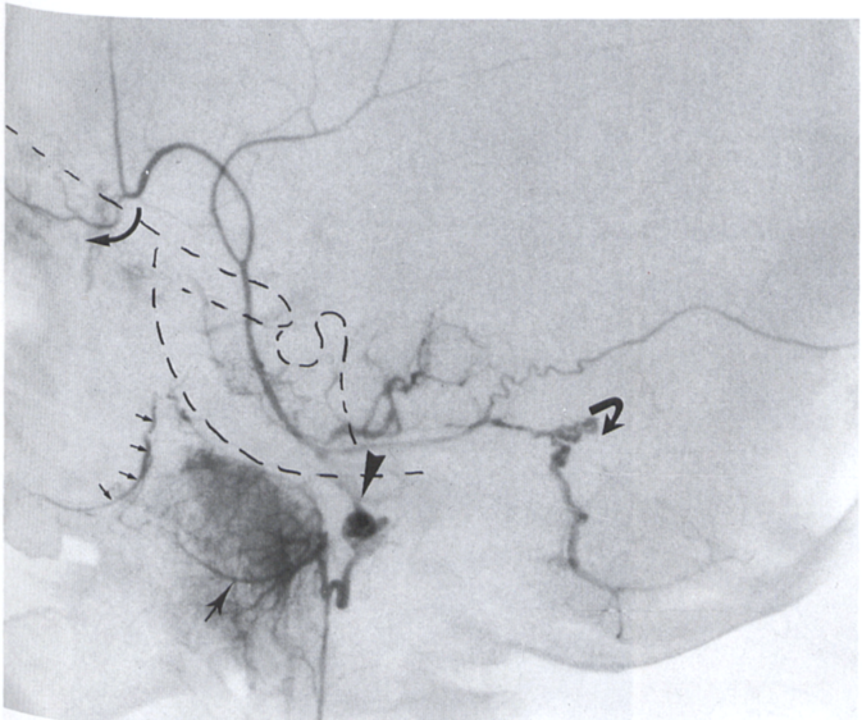
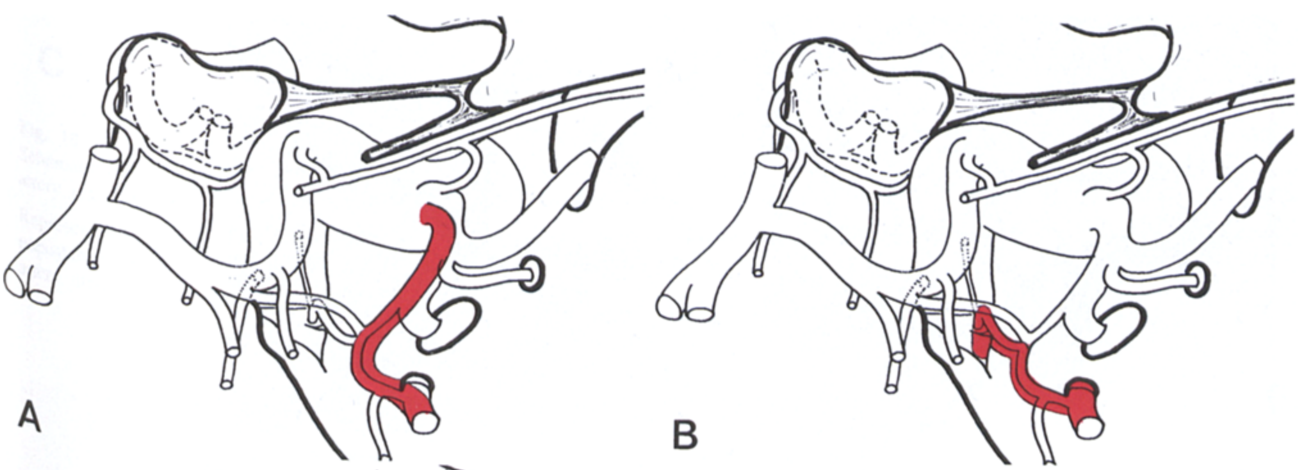


Fig. 6
Ascending pharyngeal artery (APA) origin of the middle meningeal artery (MMA) via the foramen lacerum (arrowhead). Note the typical APA territories : upper pharynx and solft palate (arrow), pterygoid anastomosis (small arrows); and the MMA supply of the supra tentorial dural covers, the posterior fossa (broken arrow) and the orbit (curved arrow) *(with courtesy of J Moret)*

Origine pharyngienne ascendante (APA) de l'artère méningée moyenne (MMA) par le trou déchiré antérieur (pointe de flèche). Noter les territoires typiques de l'artère pharyngienne ascendante : pharynx supérieur, palais mou. Anastomose ptérygoïdienne. Le territoire méningé moyen est également bien vu, y compris la fosse postérieure (flèche courbe) et l'orbite *(cliché du à l'obligeance de J Moret)*



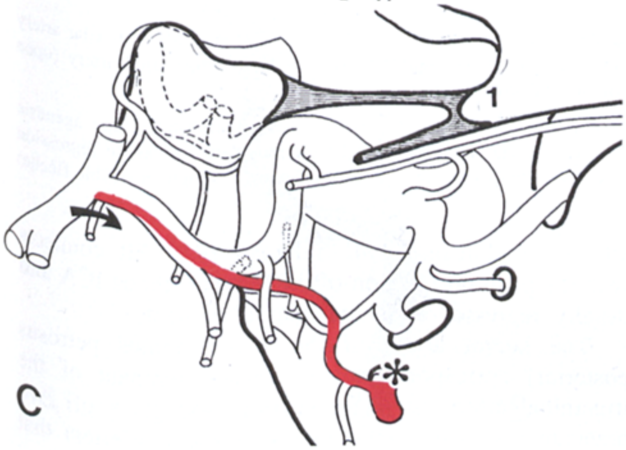
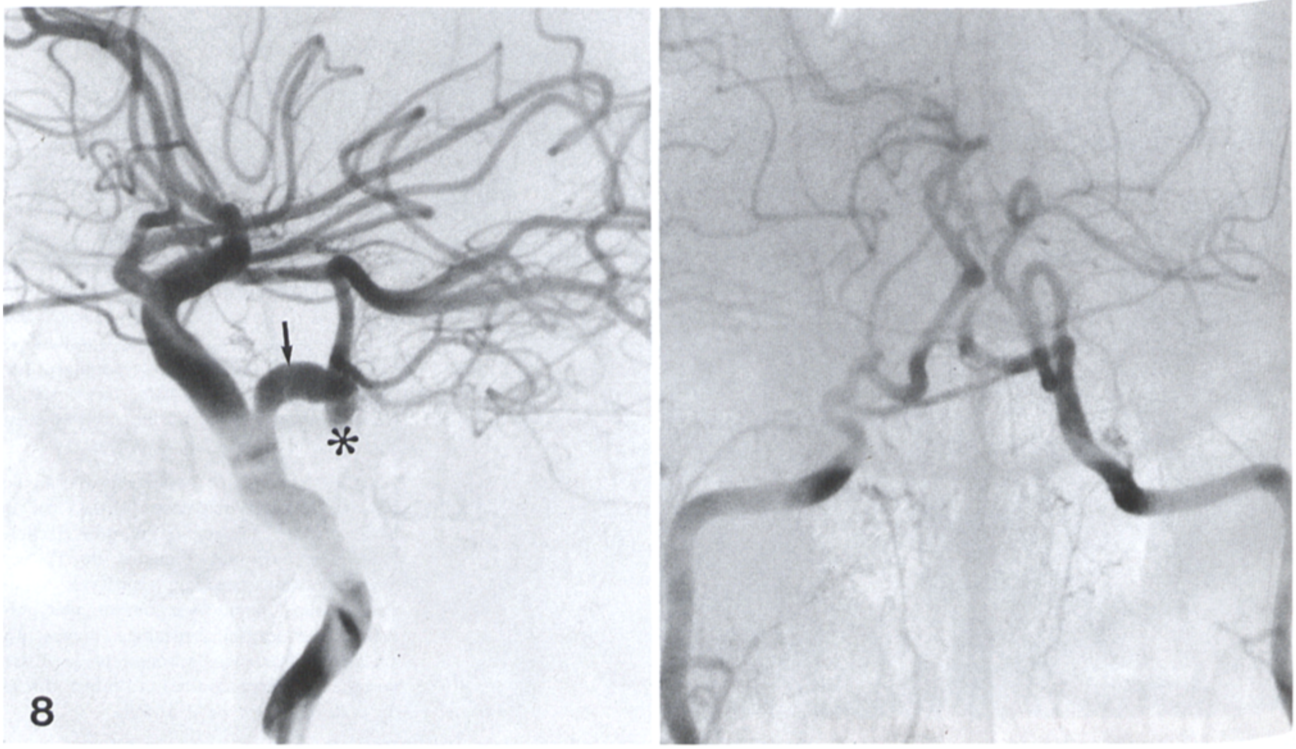
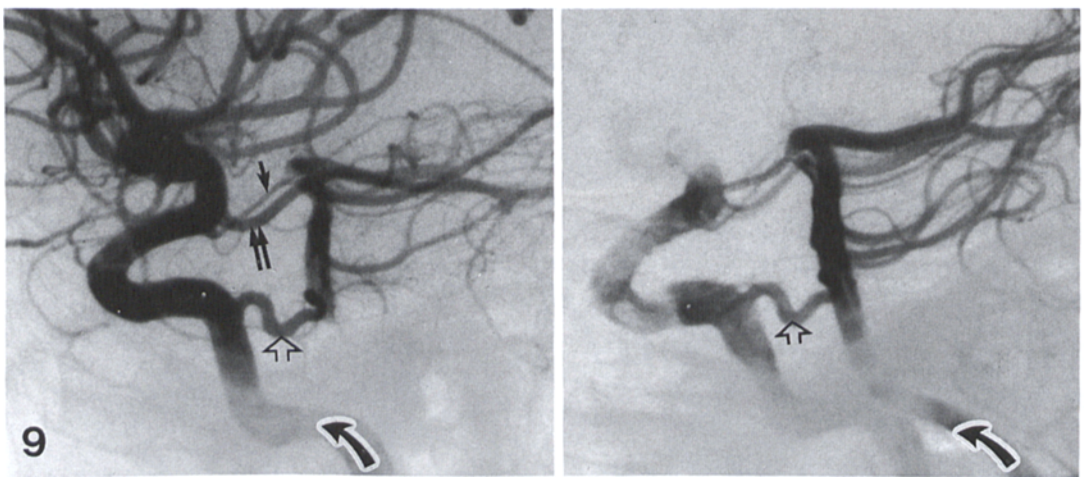


Fig. 7
Schematic representation of some of the "intracavernous" middle meningeal artery (MMA) origins **A** From the ILT **B** From the carotid branch of the ascending pharyngeal artery **C** From the basilar artery

Représentation schématique de quelques origines intra-caverneuses de l'artère méningée moyenne **A** du tronc inféro-latéral **B** de la branche carotidienne de la pharyngienne ascendante **C** du tronc basilaire





Figs. 8, 9
8 Internal carotid (**A**) and vertebral (**B**) angiograms in a case of persistent trigeminal artery (arrow) with segmental agenesis of the basilar artery (asterisk) **9** Internal carotid (**A**) and vertebral (**B**) angiograms (curved arrow) in a case of incomplete regression of the trigeminal artery (open arrow). Note the opacification of both posterior communicating arteries (single and double arrow)

8 Angiographie carotidienne interne (**A**) et vertébrale (**B**) dans un cas de persistance de l'artère trigéminée (flèche) associée à une agénésie segmentaire du tronc basilaire (astérisque) **9** Angiographie carotidienne interne (**A**) et vertébrale (**B**) (flèche courbe) dans un cas de régression incomplète de l'artère trigéminée (flèche creuse). Remarquer l'opacification des deux artères communicantes postérieures (simple et double flèche)

The trigeminal artery/Posterior group of intracavernous ICA collaterals

The trigeminal artery arises from the basilar artery (arteria basilaris) between the anterosuperior (ASCA) (arteria cerebelli superior anterior) and the anteroinferior cerebellar (AICA) (arteria cerebelli inferior anterior) arteries (Parkinson 1974, Salzman 1959). It connects with the posterior portion of the intracavernous ICA and usually regresses at its transdural segment.

The lateral artery of the clivus (ramus petrosus posterior) corresponds to the carotid remnant of the trigeminal artery. It arises laterally and gives off two branches : a medial one (ramus petrosus inferior) that

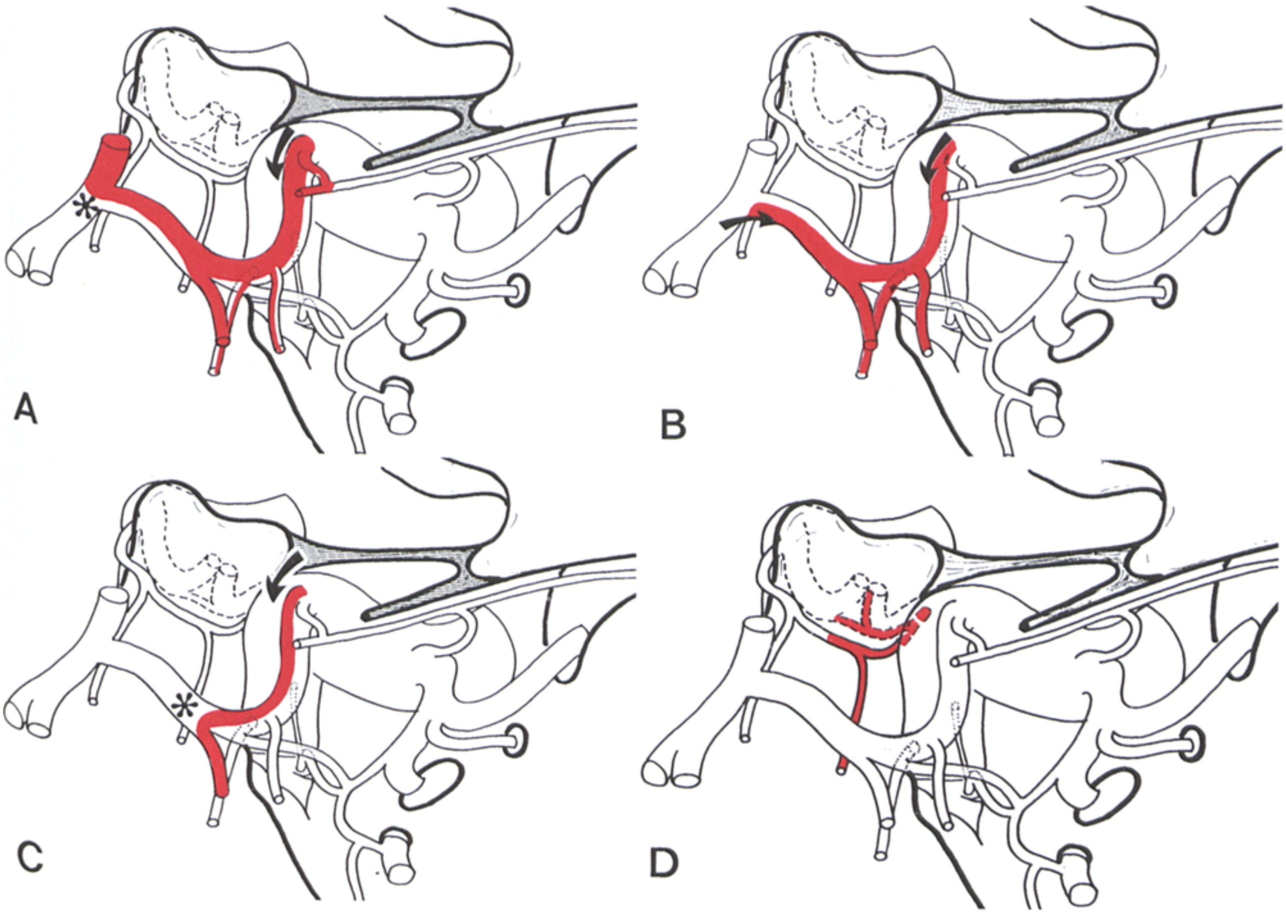


Fig. 10
Schematic representation of some variants involving the posterior intracavernous ICA branches **A** Trigeminal persistence **B** Incomplete trigeminal artery regression **C** ICA origin of a cerebellar artery **D** Posterior hypophyseal and medial clival arteries

Représentation schématique de quelques variations impliquant les branches postérieures de la carotide interne **A** persistance de l'artère trigéminée **B** persistance incomplète de l'artère trigéminée **C** origine carotidienne interne de l'artère cérébelleuse **D** artère hypophysaire postéro-inférieure et artère médiale du clivus

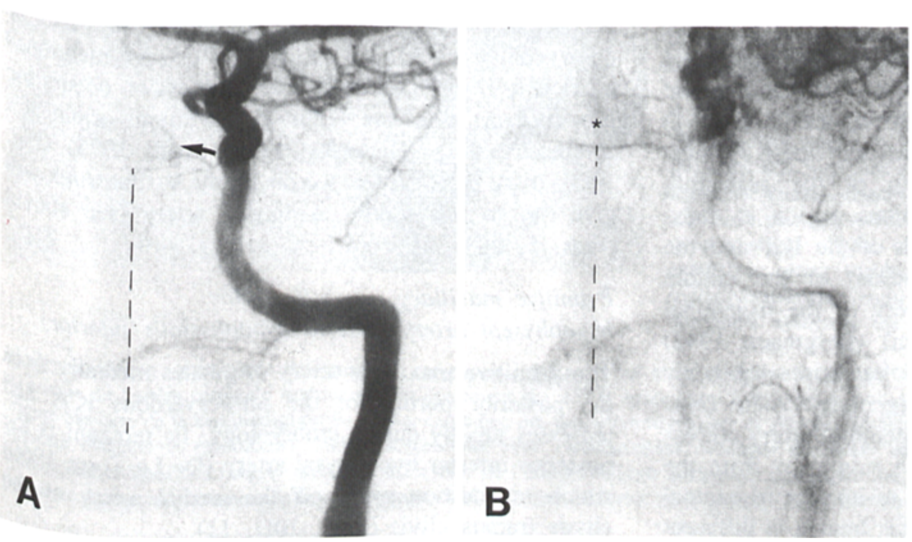
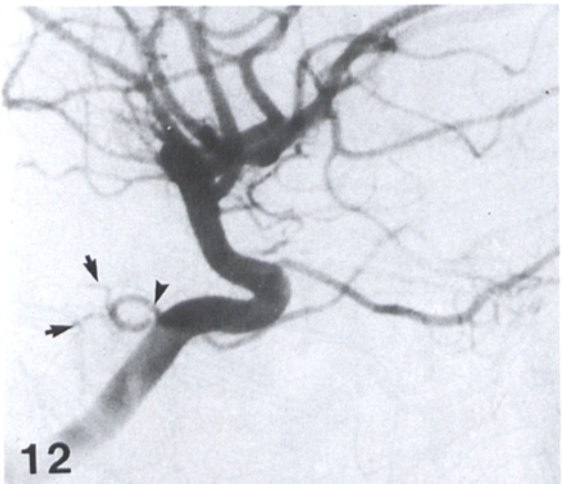
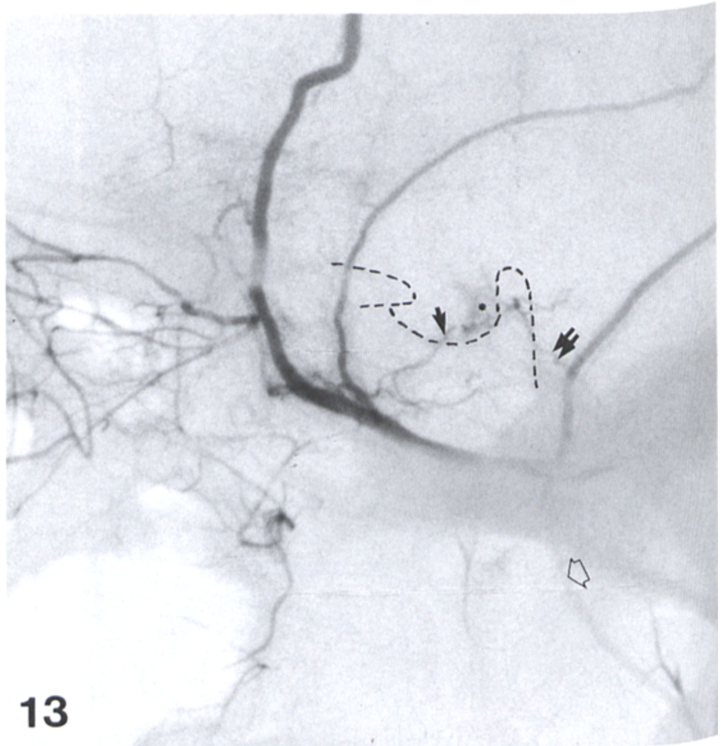


Fig. 11
Early **(A)** and late **(B)** phases of an ICA angiogram. Note the posterior hypophyseal artery (arrow) and the posterior hypophyseal blush (asterisk) *(with courtesy of J Moret)*

Temps précoce **(A)** et tardif **(B)**, d'une injection carotidienne interne. Remarquer l'artère hypophysaire postéro-inférieure (flèche) et la parenchymographie glandulaire (astérisque) *(cliché due à l'obligeance de J Moret)*





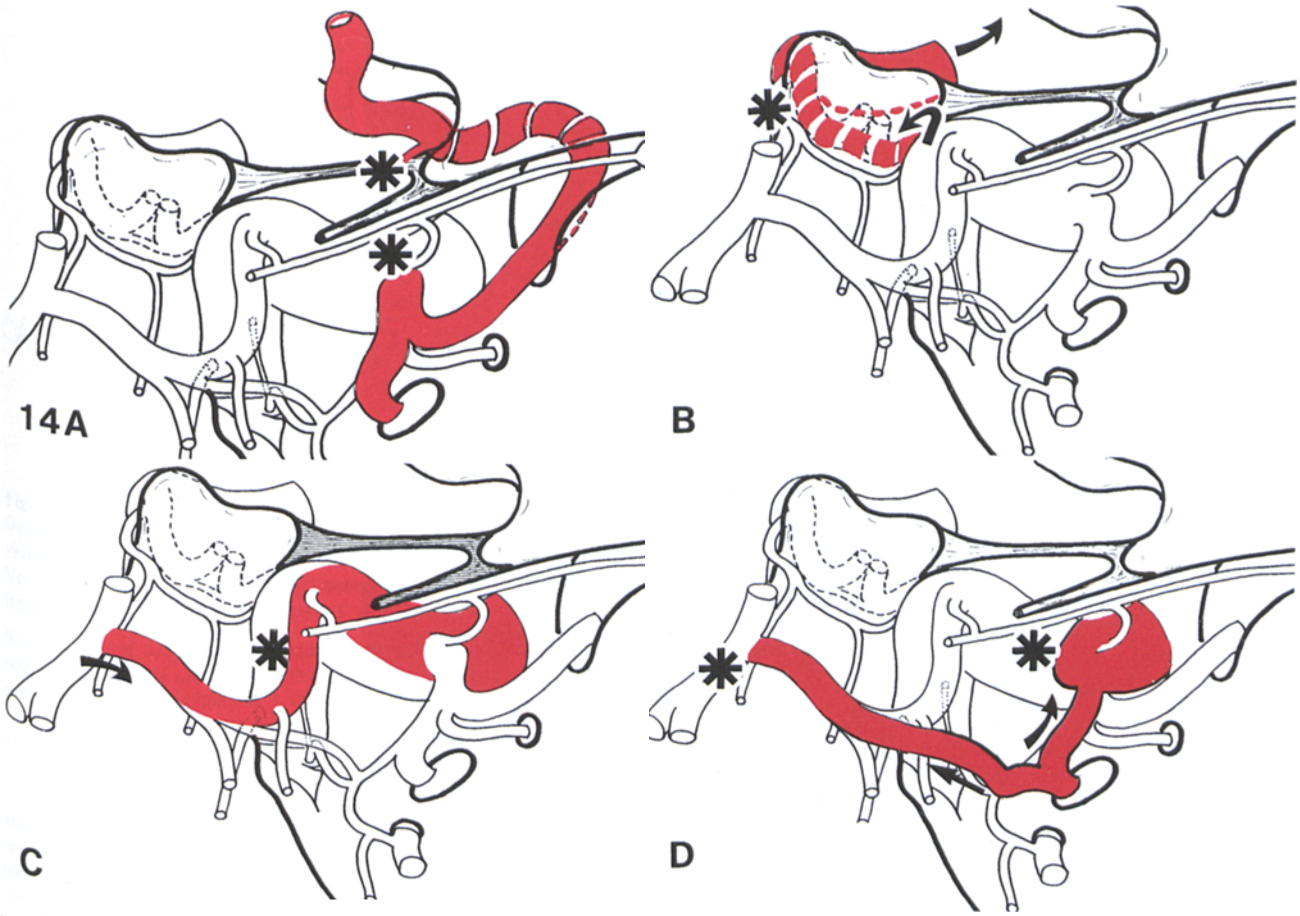
Figs. 12, 13
12 ICA angiogram with common origin of the trigeminal (arrows) and dorsal ophthalmic (arrowhed) remnants **13** Middle meningeal artery (open arrow) angiogram. The three territories of the lateral cavernous sinus region are opacified through direct anastomosis. The absence of visualization of the ICA siphon proves the common origin of the three embryonic vessels (as seen Fig. 1F). Note the ILT (arrow), the lateral clival and basal tentorial arteries (double arrow) and the posterior hypophyseal blush (asterisk)

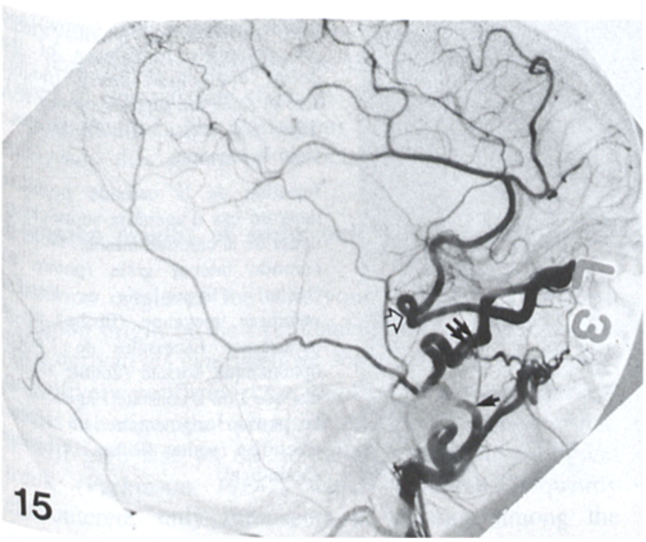
12 Angiographie carotidienne interne avec une origine commune de l'artère trigéminée (flèches) et de l'artère ophtalmique dorsale (pointe de flèche) **13** Injection de l'artère méningée moyenne (flèche creuse). Les trois territoires de la région latéro-sellaire sont opacifiés grâce à des anastomoses directes. L'absence de visualisation du siphon de la carotide interne prouve l'origine commune des 3 reliquats des vaisseaux embryonnaires (voir également fig. 1F). Noter que le tronc inféro-latéral (flèche) l'artère latérale du clivus, et tentorielle basale (double flèche) et le blush de la glande hypophysaire (astérisque)

descends to anastomoses with the jugular (ramus jugularis) division of the ascending pharyngeal artery; and a lateral one (ramus tentorii basalis) that anastomoses with the basal tentorial branch of the petrosal artery (ramus petrosus anterior) originating from the middle meningeal artery (Fig. 1). Arising from the same trunk, the recurrent artery of the foramen lacerum (Fig. 1) descends through the foramen lacerum where it anastomoses with the carotid branch of the ascending pharyngeal artery. In the cavernous region it anastomoses with the posterior branch of the ILT and the cavernous branch (ramus cavernosus) of the middle meningeal artery. The lateral artery of the trigeminal ganglion (ramus ganglii trigemini) (Bergmann 1942) also belongs to this group. It most often arises superiorly and courses laterally above the trigeminal cistern (Fig. 1). The basilar remnant of the trigeminal artery corresponds to a pontine branch, which originates from the basilar artery and courses laterally to join the trigeminal nerve and adjacent cerebellum. This branch is different from the anterosuperior and anteroinferior cerebellar arteries. Commonly in the trigeminal persistence there is basilar hypoplasia (Figs. 8, 10A). Incomplete trigeminal persistence with a patent basilar artery may also be observed (Figs. 9, 10B) (Teal 1972). As mentioned previously if the trigeminal artery regression occurs too proximal one will observe an intracavernous origin of a cerebellar artery (Haughton 1978, Scotti 1975) (Fig. 10C). If the regression is too distal, the basilar trunk will give rise to the middle meningeal artery (see above) (Figs. 5, 7C).

Primitive maxillary artery/Posterior hypophyseal artery (arteria hypophysialis inferior)

The primitive maxillary artery originates medially from the posterior portion of the intracavernous ICA and regresses rapidly during embryology. Its remnant is the posterior inferior hypophysal artery (De La Torre 1960) which in addition gives off the medial artery of the clivus (ramus clivi) (Figs. 10D, 11).





Figs. 14, 15
14 Schematic representation of complex of variations involving the intracavernous ICA branches **A** Accessory meningeal supply to the anterior cerebral territory through the orbit. The ipsilateral ICA is present but non anastomosed with this system (asterisks) (see Fig. 15) **B** Transsellar anastomosis, with ICA segmental agenesis (asterisk) **C** Basilar artery supply to the ICA siphon via a trigeminal remnant. Ipsilateral ICA segmental agenesis (asterisk). **D** Basilar and IC arteries segmental agenesis (asterisk). Accessory meningeal supply through a trigeminal and ILT arteries (arrows) **15** Accessory meningeal artery (arrow) origin of the anterior cerebral artery. Note the dorsal ophthalmic artery (double arrow) and the absence of the usual supracavernous anastomosis of the embryonic anterior cerebral-ventral ophthalmic system to the ICA (open arrow)

14 Représentation schématique de variations complexes impliquant les branches intra-caverneuses de la carotide interne **A** origine méningée accessoire de l'artère cérébrale antérieure (voir également fig. 15) **B** anastomose trans-sellaire avec agénésie carotidienne interne (astérisque) **C** origine basilaire de la vascularisation du siphon carotidien par une artère trigéminée et agénésie homolatérale de la carotide interne (astérisque) **D** agénésie basilaire et carotidienne interne segmentaire avec vascularisation méningée accessoire de la fosse postérieure et de l'hémisphère homolatéral (flèches) **15** Origine méningée accessoire de l'artère cérébrale antérieure. Remarquer l'artère ophtalmique dorsale (double flèche) et l'absence d'anastomose habituelle supra-caverneuse entre l'artère cérébrale antérieure et l'artère ophtalmique ventrale embryonnaire (flèche creuse)

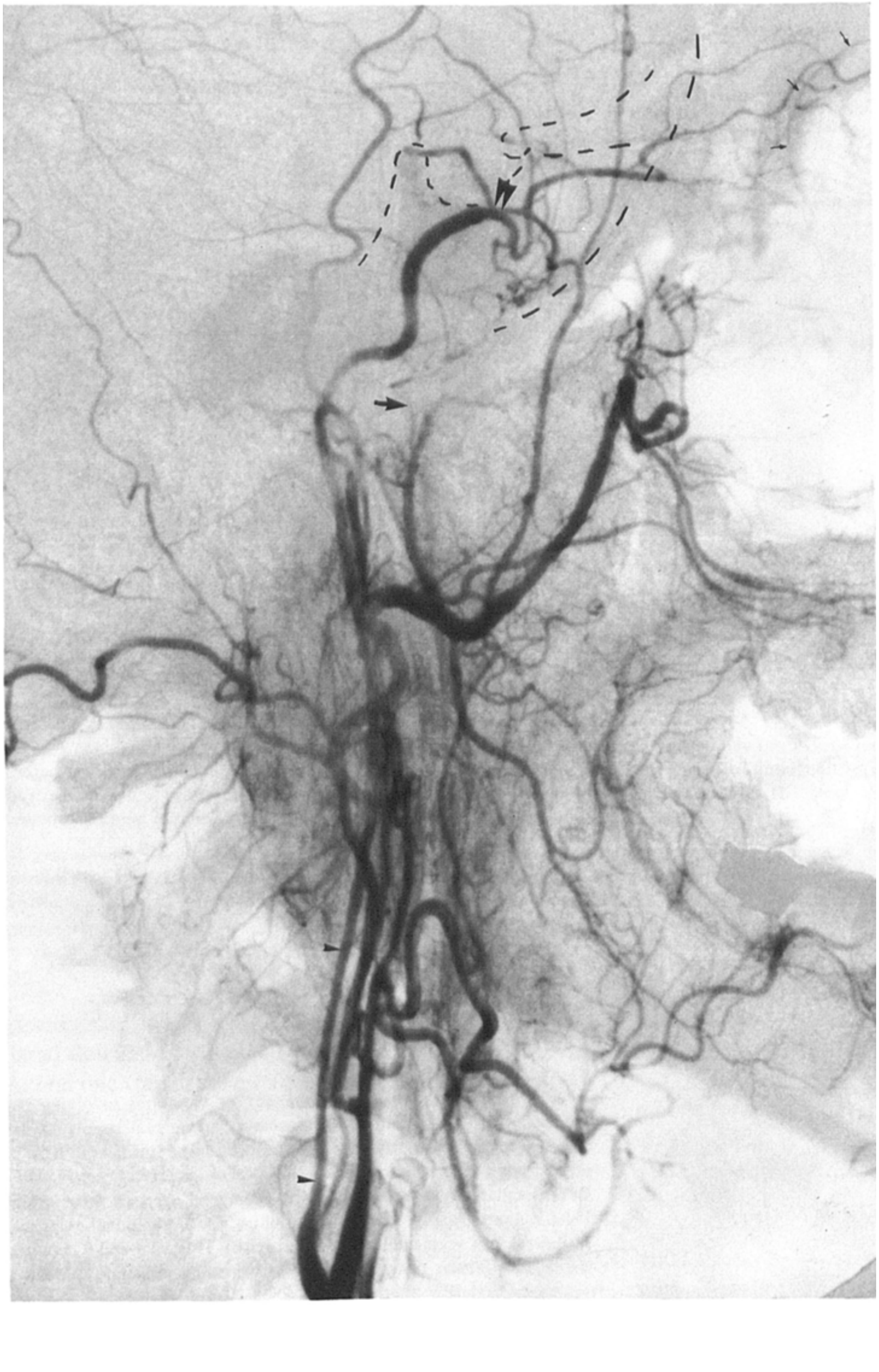


Fig. 16
Common carotid angiogram in a case of supracavernous segmental agenesis of the ICA. Note the slender ICA (arrowheads), the hypoplastic middle meningeal artery (arrow), and the necessary persistence of the dorsal ophthalmic artery (double arrow) since the supracavernous ICA does not exist. Small arrows : choroid crescent

Injection de la carotide primitive dans un cas d'agénésie supra-caverneuse de la carotide interne. Noter la carotide interne grêle (pointe de flèche), l'hypoplasie de l'artère méningée moyenne (flèche) et la persistance nécessaire de l'artère ophtalmique dorsale (double flèche) dès que l'on a constaté l'agénésie de la portion segmentaire du siphon carotidien (petites flèches : croissant choroïdien)

Both the posteroinferior hypophyseal artery and the medial artery of the clivus anastomose with their contralateral counterpart (Fig. 1). The clival branch also anastomoses caudally with the hypoglossal division of the ascending pharyngeal artery (Fig. 1). Anomalies involving this system will be seen later.

Capsular arteries (Fig. 1)

These arteries arise medially from the horizontal portion of the intracavernous ICA; they are divided into anterior and posterior, and anastomose in the midline (Mac Connel 1953) with their contralateral counterpart. They

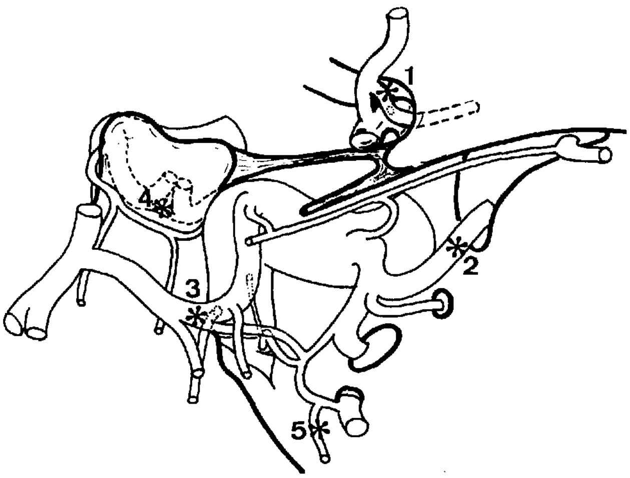


Fig. 17
Generic drawing of the vessels involved in the intracavernous arterial variations. The asterisks point to the site of normal regression *1* Ventral and *2* dorsal ophthalmic arteries *3* Trigeminal artery *4* Primitive maxillary artery *5* Stapedial artery

Schéma général des vaisseaux impliqués dans les variations artérielles latéro-sellaires. Les astérisques figurent le lieu habituel des régressions des vaisseaux embryonnaires *1* artère ophtalmique ventrale *2* artère ophtalmique dorsale *3* artère trigéminée *4* artère maxillaire primitive *5* artère stapédienne

supply the dura of the sellar floor and the sphenoid sinus roof. They cannot be linked to the previously described embryonic system. They may be related to the supply to the pharyngeal component of the pituitary gland. We failed to demonstrate them in a satisfactory fashion in our dissections. No angiogram has so far helped us in analyzing this group of branches.

Common origins of embryonic vessels

Common origin of the embryonic vessels may lead to common origin of their remnants. However the fact that their derivatives can originate separately from the siphon definitively confirms their identity. The most classical one is the trigeminal-primitive maxillary common trunk; it will give rise to the so-called meningohypophyseal trunk (Parkinson 1964), which although frequently encountered, only represents a variation among the possible origins of these arteries (Fig. 1A-E). Due to their different embryonic origins the arteries involved should be named the posterior group of intracavernous ICA collaterals instead, and the term " meningohypophyseal" should be abandoned because it is misleading and improperly used. Less frequently trigeminal-dorsal ophthalmic common origin will be seen (Fig. 12).

Common origin of the 3 ICA embryonic vessels (trigeminal, primitive maxillary, and dorsal ophthalmic), will give rise to a single intracavernous ICA trunk (Figs. 1F, 13). Obviously all variations mentioned for each specific embryonic system can theoretically be encountered with common embryonic trunks.

Complex variations following ICA segmental agenesis

Accessory meningeal origin of the anterior cerebral artery (Figs. 14A, 15)

This variant results from the following anomalies grouped together :

Intracavernous origin of the ophthalmic artery (the primitive dorsal ophthalmic fails to regress)

Dominant accessory meningeal supply to the area (the proximal ILT regresses)

Persistance of the ventral ophthalmic artery (from the anterior cerebral artery) with no supracavernous ICA anastomosis.

Regression of the proximal anterior cerebral artery.

Infraoptic course of the ACA and duplicated origin of the ACA (Besson 1980, Isherwood 1969, Bosma 1977, Nutik 1976), belong to the carotico-ophthalmic-anterior cerebral junction anomalies, (Brismar 1977) but will not be discussed here.

Segmental agenesis of the internal carotid artery

Complete agenesis is known for a long time (Quain 1844); in case of segmental agenesis of the ICA (Lasjaunias 1984) each of the embryonic vessels presented above may represent an alternate route to bypass the agenesis (Teal 1980). The discussion on true or false rete mirabile will not be considered here (Daniel 1953). Three types illustrating the role of each vessel will be shown here :

Contralateral origin of the ICA through a transsellar anastomosis (Fig. 14B) (Elefante 1983, Janicki 1979). It involves the primitive maxillary artery and its midline anastomosis. It corresponds to a cervical and petrous ICA agenesis.

Basilar origin of the intracavernous ICA (Fig. 14C) (Lasjaunias 1984). It concerns the trigeminal artery which functions in this case from posterior to anterior. It also corresponds to a cervical and petrous ICA agenesis.

Accessory meningeal origin of the intracavernous internal carotid and distal basilar trunk (Y Kawata's case) (Fig. 14D). It involves the trigeminal and dorsal ophthalmic arteries. It corresponds to a segmental mid basilar agenesis associated to a cervical, petrous and posterior intracavernous ICA agenesis, resulting in ECA dominance to the supply of these regions.

Any agenesis distal to the dorsal ophthalmic ILT origin gives a proximal hypogenetic ICA (Slender ICA of Tode 1787 cited by Quain 1844) (Fig. 16), and a circle of Willis recruitment to compensate distally the supracavernous ICA agenesis (Lasjaunias 1986). Bilateral cervical or petrous agenesis may recruit the circle of Willis (Dilenge 1976) or a rete mirabile type of compensation (Ernest 1973).

Conclusion

From a single scheme and a general overview of the arterial embryology, it is possible to link all the variations presently described in the literature (Fig. 17). Some additional ones can be predicted. Understanding the variants is now important clinically because they may represent a hazard or a favorable disposition for endovascular treatment of cerebral lesions (Lasjaunias 1986).

The ICA is not a direct feeding artery but a succession of independant segments which can be the site of various anomalies (Lasjaunias 1984). Its specific anatomy cannot be directly linked to its apparent cerebral territory : the partial or complete absence of an internal carotid does not imply an anomaly of a cerebral hemisphere. Therefore, cerebral arterial supply can only be appreciated as a full bilateral dorsoventral system which must include an embryonic transdural perisellar arterial circle, as well as the traditional suprasellar circle of Willis. This transdural circle is constituted by the trigeminal arteries posteriorly, the ICA siphon anteriorly, the transsellar anastomosis and internal maxillary artery connections. Although regressions usually occur in this embryonic transdural circle, these anastomoses may represent alternate pathways in both congenital or acquired arterial pathologies in patients; it also constitutes the key system in determining the arterial variations in the perisellar region.

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