THE CAVERNOUS BRANCHES OF THE INTERNAL CAROTID ARTERY

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"We only see what we look for, And look for only what we know."

THE cavernous portion of the internal carotid artery, although usually depicted without tributaries, supplies branches to the dura at the base of the skull, the cavernous sinus, the sella turcica and its contents, and the tentorium. These vessels communicate with their mates of the opposite side and with meningeal branches of the external carotid, ophthalmic, and vertebral arteries. This freely anastomosing network at the base of the skull comprises a portion of the rete mirabile, analogous to that found in animals. It is the purpose of the authors to demonstrate angiographically the cavernous branches of the carotid artery and to determine the significance of their opacification in health and disease. This presentation of 50 cases includes a variety of lesions supplied by these arteries.

Within the cavernous sinus, the internal carotid artery is situated between layers of the dura mater forming the sinus. Its entrance into the cavernous sinus is frequently demarcated by a band-like impression of the dura. The initial portion of the S-shaped cavernous carotid artery ascends toward the posterior clinoid process forming, then, a convexity upwards. The relatively horizontal portion, approximately 2 cm. in length, is terminated by a concavity upward on the medial aspect of the anterior clinoid process where the artery perforates the dura mater of the roof of the sinus. Luschka (1860), McConnell (1953),11

Schnürer and Stattin (1963),15 Parkinson (1964)13 and others presented detailed dissections of the cavernous portion of the internal carotid artery, establishing the existence of these branches in the normal. Slightly different terminology was utilized by each; this is summarized in Table 1. Parkinson's anatomic investigation of the distribution of the branches of the cavernous segment of the carotid artery in 200 cadavers forms the basis for our observations (Fig. 1).

A. MENINGOHYPPHYSEAL ARTERY

The meningohipphyseal artery (dorsal main stem) is the most proximal branch arising from the posterior aspect of the initial curve of the cavernous carotid and existed in 100 per cent of Parkinson's dissections. This major trunk divides shortly
after its take off into three subdivisions of equal caliber: (1) tentorial, (2) dorsal meningeal, and (3) inferior hypophyseal.

Schnürer and Stattin\(^{13}\) noted that small vessels in the neighborhood of the siphon are visible in the lateral projection of most angiographic examinations. Figure 2 demonstrates the meningohypophyseal artery in an otherwise normal study.

1. **Tentorial Artery**

The tentorial branch (basal tentorial branch) is directed posteriorly and laterally. In the cavernous sinus, branches are given off to the III and IV nerves, to the roof of the cavernous sinus and anastomose with the meningeal branches of the ophthalmic artery. The tentorial vessel then runs along the free margin of the tentorium supplying the tentorium, the falx, and communicating posteriorly with the tentorial branch of the opposite side.

### Table I

**ANATOMIC CLASSIFICATION OF CAVERNOUS BRANCHES OF CAROTID ARTERY**

<table>
<thead>
<tr>
<th>Parkinson (1964)(^{13})</th>
<th>Schnürer and Stattin (1963)(^{13})</th>
<th>McConnell (1953)(^{11})</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Meningohypophyseal Artery</td>
<td>A. Dorsal Main Stem</td>
<td>A. Inferior Hypophyseal Trunk</td>
</tr>
<tr>
<td>1. Tentorial branch</td>
<td>1. Basal tentorial branch</td>
<td>— posterior branch</td>
</tr>
<tr>
<td>a. Branch to III and IV</td>
<td></td>
<td>— inferior hypophyseal branch to posterior hypophysis</td>
</tr>
<tr>
<td>b. Branch to roof of cavernous sinus</td>
<td></td>
<td>— anterior branch from inferior hypophyseal trunk</td>
</tr>
<tr>
<td>c. Branch to falx and tentorium</td>
<td>2. Clival branches</td>
<td></td>
</tr>
<tr>
<td>2. Dorsal meningeal branch</td>
<td></td>
<td>C. Capsular</td>
</tr>
<tr>
<td>a. Clival branch</td>
<td></td>
<td>1. Anterior capsular</td>
</tr>
<tr>
<td>b. Branch to VI</td>
<td></td>
<td>2. Inferior capsular from inferomedial aspect of internal carotid artery halfway along course</td>
</tr>
<tr>
<td>3. Inferior hypophyseal branch</td>
<td>2. Branch to gasserian ganglion IV, V, VI</td>
<td></td>
</tr>
<tr>
<td>a. Branch to dura at floor of sella</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Branch to dura of post clinoids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Branch to cavernous sinus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. Inferior Cavernous Sinus Artery

1. Branch to gasserian ganglion
2. Anastomosis with middle meningeal and accessory meningeal arteries

C. Capsular Arteries

1. Anterior capsular
2. Inferior capsular from inferomedial aspect of internal carotid artery halfway along course
Bernasconi and Cassinari (1956) first reported the angiographic visualization of a tentorial artery supplying tentorial meningiomas. Krayenbühl and Yasargil (1957) demonstrated this vessel in a patient with a subtentorial arteriovenous malformation. In 1958 Wickbom and Stattin recognized that the tentorial artery originated from the cavernous portion of the carotid. Schnürer and Stattin (1963) stated that the tentorial branches also have a characteristic wavy appearance, similar to other dural vessels. They have seen the tentorial artery in the "normal" ranging from 5 mm. to 35 mm. in length; if longer than 40 mm. and prominent, a pathologic lesion was considered probable. This vessel is illustrated in an otherwise normal examination (Fig. 3A), in patients with a tentorial meningioma (Fig. 3B), and a tentorial arteriovenous malformation (Fig. 3, C and D). It has also been seen with occlusive vascular disease (Fig. 10, A–D) in which it supplies collateral circulation and in 2 cases of invasion of the tentorium by malignant lesions, an ependymoma (Fig. 4A), and a glioblastoma (Fig. 4, B and C). Zimmer has also observed the tentorial branch supplying a metastatic focus involving the tentorium. We have visualized an enlarged tentorial artery in a trigeminal neuroma. This has also been reported by Westberg.

Fig. 3. Tentorial artery. (A) Normal (↑). (B) Tentorial meningioma. Note the wavy appearance of the tentorial artery (↑). A tumor stain is observed. (C and D) Tentorial arteriovenous malformation. Several tentorial branches (↑) supply an arteriovenous malformation that drains eventually into the great vein of Galen (VG).
Cavernous Branches of Internal Carotid Artery

2. DORSAL MENINGEAL ARTERY

The dorsal meningeal artery (clival branch) takes a posterior, inferior, medial direction through the cavernous sinus. It then passes down the dorsum and clivus to freely anastomose with the dorsal meningeal of the opposite carotid sending a branch to the VI nerve. The vessel has also been opacified in the normal, in occlusive disease of the internal carotid distal to the cavernous carotid (Fig. 12D) and in lesions of the clivus, e.g. a chordoma (Fig. 5A).

3. INFERIOR HYPOPHYSEAL ARTERY

The inferior hypophyseal artery (Luschka and McConnell) projects anteriorly and medially in the posterior sellar floor, supplying the posterior lobe of the pituitary gland and the dura of the floor of the sella, anastomosing with a similar vessel from the opposite side. Branches to the dura of the posterior clinoids and to the cavernous sinus may also be present. The inferior hypophyseal artery has been observed supplying a pituitary adenoma (Fig. 4).
FIG. 5. Dorsal meningeal and inferior hypophyseal arteries. (A) Chordoma. The meningo-hypophyseal trunk divides into the inferior hypophyseal artery (↑) and dorsal meningeal artery. The dorsal meningeal branches supply the chordoma (↑↑). (B) Pituitary adenoma. The inferior hypophyseal (↑), inferior capsular (↑↑), and anterior capsular arteries (↑↑↑) supply the pituitary tumor. A tumor stain is seen (↑↑↑). (C) Carcinoma of the sphenoid sinus. The inferior hypophyseal and dorsal meningeal vessels are opacified in a patient with a sphenoid sinus carcinoma. A tumor stain is observed (↑↑↑). The irregularity of the internal carotid artery is secondary to the tumor.
Similar cases have been reported by Ecker and Riemenschneider, Kricheff and Schotland, and Doron and Schwartz. The inferior hypophyseal artery was also observed in a patient with a carcinoma of the sphenoid sinus (Fig. 5C).

B. INFERIOR CAVERNOUS SINUS ARTERY

In 80 per cent of Parkinson’s specimens there was another major trunk originating 1/2 cm, distal to the meningohypophyseal artery. The inferior cavernous sinus artery (lateral main stem) takes off from the lateral aspect of the midportion of the cavernous carotid and supplies the dura of the inferior aspect of the cavernous sinus and the sinus itself. Branches extend to the gasserian ganglion, while others anastomose with the middle meningeal arteries. Schnürer and Stattni noted another branch of the inferior cavernous sinus, the marginal tentorial artery, running along the tentorial edge.

The inferior cavernous sinus artery is demonstrated in 2 patients, one with a sphenoid sinus carcinoma (Fig. 6A) and the other with a parasellar meningioma (Fig. 6, B and C).

C. CAPSULAR ARTERIES

The capsular arteries (McConnell) one or two branches, originate further distally. The inferior capsular artery comes from the inferomedial aspect of the internal carotid artery, halfway along the course of the cavernous carotid. This vessel runs medially in the dura covering the inferior surface of the anterior lobe of the hypophysis. It anastomoses with branches of the inferior hypophyseal artery, giving branches to the floor of the sella.

The anterior capsular artery originates along the medial aspect of the internal carotid immediately before this vessel pierces the dura over the cavernous sinus. It runs medially in the dura at the anterior margin.
Fig. 7. Capsular branches. (A) Carcinoma of the sphenoid sinus. The inferior capsular branch originates in the mid-portion of the distorted cavernous carotid (†). External carotid branches (EC) are superimposed. (B and C) Cranio-pharyngioma. The anterior capsular branch is visualized (†). It is enlarged and distorted by the lesion.
Fig. 8. Multiple cavernous branches. (A and B) Parasellar meningioma. Multiple branches originating from the cavernous carotid artery (↑) supply the tumor. The internal carotid artery is distorted. (C) Angiofibroma of the sphenoid sinus. Numerous fine branches (↑) are noted extending from the displaced cavernous carotid.
of the roof of the sella, anastomosing with its fellow of the opposite side. McConnell\(^{11}\) observed these two branches in half of the specimens.

These arteries were opacified in a patient with a sphenoid sinus carcinoma (the inferior capsular artery) (Fig. 7A), and in a craniopharyngioma (anterior capsular artery) (Fig. 7, B and C).

At times, multiple branches of the cavernous portion of the internal carotid artery may be visualized when the base of the skull is extensively involved as was observed in patients with a parasellar meningioma (Fig. 8, A and B) and an angiofibroma of the sphenoid sinus (Fig. 8C). In such cases, specifically named branches are difficult to delineate but rather a plethora of small vessels may be seen.

**D. RETE MIRABILE**

Each of the branches of the cavernous carotid anastomoses with its mate from the opposite carotid artery, and with the meningeal branches of the external carotid, the ophthalmic, and the vertebral arteries. This basilar plexus has been termed the carotid rete or rete mirabile. These vessels are of utmost importance as collateral pathways in the event of occlusion of the internal carotid artery below the cavernous sinus. The reconstitution of the cavernous carotid artery by the external carotid artery via the cavernous branches is illustrated in a patient with a proximal internal carotid artery occlusion (Fig. 9, A and B). In still another case (Fig. 10, A–D), a child with multiple stenotic segments within both internal carotid arteries, the tentorial branch served as a collateral pathway reforming the posterior cerebral artery to the point of stenosis at its origin. Minagi and
Newton reported the presence of multiple cavernous branches anastomosing an enlarged external carotid artery with the cavernous portion of the carotid compensating for a hypoplastic cervical segment of the internal carotid artery.

The communication between the external and internal carotid arteries by way of the cavernous branches is of significance in the diagnosis and management of carotid cavernous fistulæ. Selective injection of the external carotid artery demonstrated a fistula as well as the internal carotid opacification (Fig. 11, A–C). Hayes observed similar findings following carotid artery ligation. The proper approach to the treatment of these fistulæ will be dependent upon knowledge about all communicating channels.

**DISCUSSION**

The ability to demonstrate carotid cavernous branches is dependent upon their size, for under normal circumstances these branches are filamentous. The cavernous branches have generally escaped recognition. Undoubtedly the utilization of high quality serial angiography, subtraction, and perhaps angiotomography may aid in their demonstration.

The visualization of branches of the cavernous portion of the carotid artery does not necessarily indicate the presence of a lesion but should precipitate close scrutiny of the base of the skull and tentorium. The appearance of these branches has been observed in a variety of pathologic entities (Table 11) occurring at the base. Schnürrer and Stattin designated a maximum normal length of 35 mm. for the tentorial artery. Length has not been found to be helpful in distinguishing the normal from the pathologic. These vessels are considered to have pathologic significance when there is enlargement of caliber, increased undulations in their course, the presence of
Fig. 11. Rete mirabile. Carotid cavernous fistula. (A) Internal carotid artery opacification demonstrates the carotid cavernous fistula (↑). (B and C) Selective external carotid artery injection at the same time demonstrates the carotid (external) communications filling the fistula (↑↑↑).
multiple branches and the occurrence of tumor stain. Tumor stains (Fig. 3, 4, 5, 6, and 8) have been observed in benign and malignant lesions. In our 3 pituitary tumors with stains, histologic examination revealed that all were benign adenomas.

Opacification of the cavernous branches may also occur with alterations in cerebral dynamics, e.g., increased intracranial pressure of any etiology, the presence of an intracranial lesion at a distance (tumor and aneurysm), and cerebral vascular disease in which these branches do not appear angiographically, to function as collateral pathways (Fig. 12, A–D). The carotid cavernous branches may act as the rete mirabile in animals and in some patients with proximal internal carotid artery occlusions. This type of collateral may also be demonstrated in patients with carotid cavernous fistulae. Lack of appreciation of this alternate pathway may account for the failures observed in some cases following carotid artery ligation.

SUMMARY

Knowledge of the anatomy of the cavernous branches of the carotid artery has led to their recognition with increasing frequency during cerebral angiography. These branches have been observed in the normal, benign and malignant lesions at the base of the skull and tentorium, and in cases with altered cerebral circulatory dynamics.

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Table II

Conditions in which cavernous branches have been observed

A. Normal

B. Alteration in Cerebral Circulatory Dynamics
   1. Increased intracranial pressure
   2. Lesions at a distance
      a. Tumor
      b. Aneurysm
      c. Cerebral vascular disease—not a collateral

C. Congenital and Neoplastic Lesions
   1. Tentorial arteriovenous malformations
   2. Tentorial meningiomas
   3. Tentorial invasion by intracranial neoplasm
      a. Glioblastoma
      b. Ependymoma
      c. Metastasis (Zimmer)
   4. Trigeminal neurona (Westberg)
   5. Pituitary adenoma
   6. Cranioopharyngioma
   7. Parasellar meningioma
   8. Chordoma
   9. Nasopharyngeal carcinoma
   10. Nasopharyngeal angiofibroma
   11. Sphenoid sinus carcinoma
   12. Rhabdomyosarcoma of the orbit

D. Rete Mirabile
   1. Oclusive or stenotic cerebral vascular disease
   2. Carotid-cavernous fistula

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