Intracranial sympathetic pathways associated with the sixth cranial nerve

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During a continuing study of the anatomy of the parasellar region, a macroscopically identifiable nerve has been observed to leave the foramen lacerum and join the abducens nerve within the cavernous sinus. A description and photographic documentation of this sympathetic branch to the fifth cranial nerve by way of the sixth cranial nerve are presented.

KEY WORDS sympathetic nerve · abducens nerve · cavernous sinus · carotid artery · trigeminal nerve

MONRO in 1746 wrote, “At the Place where this sixth Pair is contiguous to the Carotid, a Nerve, either goes from each of them in an uncommon Way, to wit, with the Angle beyond where it rises obtuse, to descend with the Artery, and to form the Beginning of the Intercostal, according to the common description; or, according to other Authors, this nerve comes up from the great Ganglion of the Intercostal, to be joined to the sixth nerve.”

During the 18th century, the sympathetic chain, then called the intercostal nerve, was believed to arise within the cavernous sinus as a branch of the sixth cranial nerve, called because of its angle of origin, “the reflected branch” (Fig. 1). Although there were some sceptics, Monro among them, who argued that this nerve joined the sixth rather than left it, it was a universally recognized anatomical entity. There was controversy, however, as to whether the ophthalmic division of the fifth cranial nerve also gave a branch to the “intercostal,” and Monro states with reference to this: “After dissecting the Nerves in a great many Subjects, I cannot determine whether or not there are nervous Filaments going from one to the other.”

By 1832 the intercostal nerve had changed its name to “the ganglionary nerve,” and it was recognized that the “reflected branch” of the sixth was in fact a branch of sympathetic distribution. The only other generally recognized branch, according to Meckel, was one to the vidian nerve which always arose within the carotid canal, now called the “deep petrosal nerve.”

Although many other branches had been described through the centuries since Galen, no other branches had gained universal acknowledgment. In the mid-19th century, however, a dramatic change occurred, and the current concept of the cephalic distribution of the sympathetic nervous system was born (Fig. 1). The precise origin of the concept is obscure. The first description we could find is that in Quain and Sharpey’s textbook of anatomy, the standard anatomy text of the mid-19th century. Quain contin-
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Since first noticing this connection during another study, we have performed 50 or more parasellar dissections and, in addition, serially sectioned three other specimens; we found this structure in every case.

Method

Gross Dissection

Our dissections were performed in the structure commonly known as the cavernous sinus, which lies within the dural layers in the parasellar region.

The first 30 dissections were performed with the cavernous sinus in situ in the base of the skull. An incision was made high in the lateral wall (Fig. 2), and the lateral wall, including Meckel's cave, the trigeminal ganglion, and the first and second divisions of the fifth cranial nerve were reflected laterally (Fig. 3). In the next 20 cases a 4-in. square central block was removed from the base of the skull to provide time for a more careful dissection. In 10 of these, the same lateral approach was used to the interior of the dural cavernous sinus. In 10 others, the roof of the cavernous sinus was incised between the anterior and posterior clinoid processes. Both bone processes were then removed and the incision carried down the posterior wall to the level at which the sixth nerve entered the dura (Dorello's canal). This superior approach enabled us to leave the relationship between the cranial nerves and the carotid artery undisturbed until they could be carefully dissected, the same approach used earlier by one of us to
FIG. 2. Central portion of the base of the skull viewed from the right. Large black arrow indicates the pituitary stalk, open arrow the crista galli, and black arrowhead the cut edge of the tentorium. Small black arrows indicate the line of incision in the lateral and posterior walls of the cavernous sinus. The cut ends of the cranial nerves II-VI are visible.

demonstrate the arterial branches. In three specimens, after we had dissected the nerves of the cavernous sinus, the carotid canal was unroofed and the carotid artery and internal carotid plexus dissected. In one specimen the superior cervical ganglion was removed in continuity with a central block of the base of the skull.

In some specimens, to facilitate identification, the arterial system was injected with red methyl acrylate.

**Microscopic Studies**

Serial sections were performed on three cavernous sinus specimens removed at autopsy. One was sectioned in the coronal plane and stained with hematoxylin and eosin (H & E) (Fig. 4). Two were sectioned in the sagittal plane, one stained with H & E, and one with Page Solochrome (Fig. 5).

**Results**

**Macroscopic Study**

During our early dissections, which were being performed in an attempt to identify fibrous trabeculae, we made what we thought was an original observation. Dissecting in the region between the foramen lacerum and the sixth cranial nerve lateral to the carotid artery, we found in every case from one to three nerves running upward to join the sixth cranial nerve. These nerves were pale pink, softer, more lucent and more fragile than the relatively white, opaque cranial nerves in the same region (Fig. 3).

On removing the lateral wall of the foramen lacerum, this branch (or branches) to the sixth cranial nerve were seen to receive branches from both the medial and lateral divisions of the internal carotid plexus. When the carotid canal had been unroofed, these nerves could be traced back down through the sympathetic plexus around the carotid artery to the superior cervical ganglion (Fig. 3). In one specimen, showing the not uncommon anomaly of a double sixth nerve, the sympathetic branches joined the composite nerve (Fig. 6).

Although we could not positively identify a direct macroscopic branch to any of the other cranial nerves of the region, there was usually, at the point where the sympathetic fiber or fibers joined the sixth cranial nerve, a thin wide band of tissue connecting the sixth cranial nerve to the first division of the fifth cranial nerve (Fig. 6). This, we believe, represents sympathetic filaments leaving the main sympathetic branch to the sixth cranial nerve. They adhere to the sixth nerve while crossing it to join the fifth cranial nerve. Some branches are visible macroscopically as they continued upward in the adventitia of the carotid artery (Fig. 3).
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FIG. 3. Upper Left: Dissection of the right cavernous sinus. The lateral wall (Lat. W) of the cavernous sinus has been reflected laterally exposing the carotid artery (CA) and the sixth cranial nerve (6th) within the dural cavity of the cavernous sinus. Solid white arrows indicate two nerves running from the region of the foramen lacerum (open black arrow) to join the sixth cranial nerve. Upper Right: The lateral wall, including Meckel's cave (solid black arrow) has been reflected from the floor of the middle fossa (M.F.) revealing the lateral boundary of the foramen lacerum (large white arrow). Lower Left: The lateral ligamentus and bony wall of the foramen lacerum has been removed, exposing the internal carotid sympathetic plexus on the internal carotid artery (CA) from which the branch to the sixth (6th) cranial nerve arises. Lower Right: The carotid canal in the petrous bone has been unroofed throughout its length, revealing the superior cervical sympathetic ganglion (bottom left) from which the internal carotid nerve arises. The sympathetic plexus (solid white arrows) has been freed from the carotid artery.


Microscopic Study

Serial sections confirmed in part the macroscopic findings. A large poorly myelinated nerve bundle left the carotid artery in the region of the foramen lacerum (Fig. 5) to join the sixth cranial nerve. On reaching the sixth cranial nerve, however, it divided into six or seven bundles. In all three specimens, two of these bundles pierced the sheath of the sixth nerve to run as separate funiculi within the epineurium (Figs. 4 and 5). The other bundles arranged themselves around the sixth nerve in no consistent pattern, but adherent to its sheath (Fig. 4). The majority of these bundles continued forward with the sixth nerve to the anterior cavernous sinus. A few small bundles left the sixth nerve to penetrate the dura of the inferior lateral angle of the cavernous sinus with some small arteries. Other bundles left the sixth nerve almost immediately to join the first division of the fifth nerve in the midcavernous sinus. There, at the point where the first division of the fifth nerve swings upward and medially to cross superior to the sixth nerve, all the sympathetic bundles formed an interlacing plexus between the fifth and the sixth nerves (Fig. 5). All the traceable branches of this plexus joined the first division of the fifth and could, for 60 μ, be seen as separate funiculi. They then became untraceable, possibly being redistributed and admixed with other components of this nerve. No sympathetic fibers were traced to the third or fourth cranial nerves (Fig. 4). The sixth cranial nerve was easily distinguishable from the third and fourth in any plane by its definite sympathetic component (Fig. 4).

The sympathetic pathway to the ciliary ganglion is described in Gray’s Anatomy as either passing directly from the internal carotid artery plexus to the ganglion or as
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**FIG. 5.** *Upper Left:* Sagittal section, posterior portion, of the right cavernous sinus showing the sympathetic bundle (white arrow) just beneath the lateral wall of the carotid artery (CA). Sixth cranial nerve (6th) has been cut obliquely to the right of (anterior to) the carotid artery. The fibers of the first division of the fifth cranial nerve (5th) are visible in the right lower corner. Page solochrome, × 4. *Upper Right:* A slightly more medial section showing the sympathetic bundles (white arrows) joining the sixth cranial nerve (6th). Page solochrome, × 4. *Lower Left:* A sympathetic fasciculus (white arrows) within the epineurium of the sixth cranial nerve (6th). Other small sympathetic bundles can be seen superiorly, adjacent to the sixth cranial nerve. Page solochrome, × 10. *Lower Right:* Sagittal section of the right cavernous sinus more anteriorly showing the sympathetic fasciculus (white arrow) leaving the sixth nerve. The right white arrow points to multiple sympathetic filaments between the fifth and sixth cranial nerves. The solid black arrow indicates a fasciculus of the first division of the fifth cranial nerve containing multiple ganglion cells. Page solochrome, × 10.

...joining the sensory root from the naso-ciliary nerve. In our macroscopic dissections we were never able to identify a direct branch to the ciliary ganglion. If such a branch exists it must be so small that it is identifiable only under the microscope or by using special staining before dissection. Of our specimens used for microscopic section, only one included the ciliary ganglion. In this specimen the sympathetic fibers left the internal carotid plexus in the branch to the sixth nerve in the posterior cavernous sinus and continued forward on the medial aspect of the sixth nerve to the anterior cavernous sinus, left the sixth to run to the first division of the fifth cranial nerve. There they joined a funiculus that contained multiple ganglion cells and was traced directly to the ciliary ganglion; throughout its course it could be easily identified by the presence of numerous ganglion cells within it (Fig. 5), but nonmyelinated fibers could not be distinguished as separate fasciculi.

**Discussion**

Considerable doubt has been cast on the intracavernous sympathetic distribution as depicted by Quain and Sharpey’s and Gray. Koch in 1916, studying histological sections of the third, fourth, fifth, and sixth cranial nerves, was unable to find nonmyelinated fibers joining the third, fourth, and fifth, and stated that the sixth could be easily identified by the large nonmyelinated sympathetic component. Sunderland and Hughes in 1946 confirmed the absence of sympathetic fibers in the third and fourth...
FIG. 6. The left cavernous sinus viewed from above. P = posterior, A = anterior. The roof of the cavernous sinus has been incised between the anterior and posterior clinoid (Post. Clin.) processes and the incision carried down the posterior wall to the point of entry of the sixth cranial nerve. The lateral wall (Lat. W) has been reflected laterally. The carotid artery (CA) is held medially against the sella by a forceps. A double sixth nerve (6) is seen. The sympathetic branch (white arrows) is seen emerging from the foramen lacerum to join the sixth cranial nerve. At the point where it joins the composite sixth cranial nerve, a thin sheet of tissue of similar color can be seen plastering the sixth nerve to the first division of the fifth cranial nerve.

Our work has confirmed Sunderland and Hughes' findings microscopically. In addition, we have found that the branch to the sixth cranial nerve is of sufficient size to be recognizable macroscopically. Its description in current anatomy texts as a "filament" invokes, we believe, a misconception as to its size.

Summary

We believe this to be the first photographic demonstration of a consistently present, macroscopically identifiable branch or branches from the internal carotid sympathetic plexus to the sixth cranial nerve. Microscopically we have confirmed that part, at least, of this branch penetrates the epineurial sheath of the sixth nerve but...
Sympathetic nerve fibers to 5th and 6th cranial nerves remains as a separate funiculus. Distally, in the anterior cavernous sinus, this sympathetic branch leaves the sixth cranial nerve to be redistributed mainly to the first division of the trigeminal nerve. The sympathetic fibers to the ciliary ganglion follow this route.

Acknowledgments

We wish to acknowledge the cooperation of the Department of Pathology, Health Sciences General Centre, for allowing the use of autopsy cadavers, and the tremendous help given by Mrs. Marcia Yaren, Technician, Health Sciences General Centre, in the preparation of the sections, and also the Department of Photography, Health Sciences General Centre.

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