The abducens nerve

Anatomical variations in its course

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The authors describe the origins and course of the sixth cranial nerve in 62 cadaver or autopsy cases and describe three patterns. In Pattern 1 the nerve originates and runs all its way as a single trunk. In Pattern 2 it originates as a single trunk, but splits into two branches in the subarachnoid space, while in Pattern 3 it originates as two separate trunks. In both Patterns 2 and 3 the trunks perforate the dura mater independently and enter the cavernous sinus by passing one above and the other below the petrosphenoidal ligament. In the sinus the two trunks fuse into a single trunk which then continues to the lateral rectus muscle. The practical neurological importance of these variations is discussed.

KEY WORDS • abducens nerve • cavernous sinus • petrosphenoidal ligament

The abducens nerve (sixth cranial nerve) is normally identified as emerging from the brain stem by one or more rootlets and running its course toward the orbit as a single trunk. In some cases the rootlets have been observed to form two trunks that independently perforated the dura and merged in a single trunk in the cavernous sinus. A few cases of double trunks that did not fuse and reached the orbit separately have also been described.

From a series of cadaver dissections we have observed many variations in the origin and course of the sixth nerve. Among these, one was found in which the single sixth nerve trunk split into two; each of the two parts perforated the dura independently but the two merged into a single trunk again in the cavernous sinus.

Material and Methods

The abducens nerve was dissected in 62 bodies from various sources including cadaver and autopsy material. All were male and female adults. An operating microscope was used for dissections and photographs.

Observations

The abducens nerves followed one of three basic patterns on their path from the brain stem to the cavernous sinus and orbit (Fig. 1).

Pattern 1 (53 Cases, 86.5%)

In this group the nerve originated from one or more small rootlets and merged immediately into a single trunk. This trunk ran toward the orbit in accordance with classic textbook descriptions; it first ascended in the
Pattern 1 originates and runs all its course to the orbit as a single trunk. It passes under the petrosphenoidal ligament to enter the cavernous sinus. Pattern 2, like Pattern 1, originates as a single trunk, but splits into two branches in the subarachnoid space. Pattern 3 originates as two separate trunks. In both Patterns 2 and 3 the trunks perforate the dura independently and enter the cavernous sinus by passing one above and the other below the petrosphenoidal ligament. In the sinus the two trunks fuse into a single trunk that then continues to the lateral rectus muscle. Pattern 4 originates in two trunks as Pattern 3. However, the trunks run their full course independently without fusing and enter the lateral rectus muscle as two separate trunks. We did not find cases of this kind during our dissections, but they were described by Testut and Jain. Abbreviations for all figures: VI n. = abducens nerve; V n. = trigeminal nerve; I.C.A. = internal carotid artery; D.S. = dorsum sellae; P.C.L. = petroclinoid ligament (ligament of Gruber, or petrosphenoidal ligament); I.P.s. = inferior petrosal sinus; S.P.s. = superior petrosal sinus; D.M. = dura mater; S.T. = sella turcica; O.n. = optic nerve; S.O.f. = superior orbital fissure; L.R.m. = lateral rectus muscle; P.b. = petrous bone; C.s. = cavernous sinus.
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subarachnoid space between the pons and the basilar process, then pierced the dura mater as a single structure and entered the cavernous sinus. To reach the sinus, the nerve first ascended over the posterior surface of the petrous temporal bone near its apex and, bending over the superior border of the bone, descended a little on its anterior surface to pass lateral to the internal carotid artery in the cavernous sinus. While crossing the margin of the petrous bone, the nerve passed under the petroclinoid ligament (or petrosphenoidal ligament of Gruber). This ligament extended between the apex of the petrous bone and the lateral border of the dorsum sellae. The little space, through which the nerve passed, limited by the apex of the petrous bone, the petroclinoid ligament, and the dorsum sellae, is also known as "Dorello's canal." Very often there was obvious asymmetry in the thickness of the two nerves. The anatomical relations of the sixth nerve to the other structures in the cavernous sinus (internal carotid artery, sympathetic plexus, third, fourth, and fifth nerves) and in the orbit after it passed through the superior orbital fissure to reach the lateral rectus muscle will not be dealt with here.

**Pattern 2 (4 Cases, 6%)**

In this pattern are included sixth nerves which, after originating as a single trunk as in Pattern 1, split into a superior and inferior branch during their subarachnoid course. Each of these branches pierced the dura mater independently and ran a somewhat different course in order to reach the cavernous sinus (Fig. 2). The inferior branch followed the same course as in Pattern 1, that is, it passed over the apex of the petrous bone and below the petroclinoid ligament. The superior branch, however, passed above the ligament, or perforated it. Thus, the two branches remained separated from each other by the ligament (Fig. 3). After reaching the cavernous sinus, both branches fused again into a single trunk, which continued its course toward the orbit, following exactly the same route and relations as the sixth nerve in Pattern 1. The two branches were almost equal in diameter in some cases, and of different thickness in others. The respective points of perforation of the dura were also variable. In some instances one was lateral to the other; in others, they pierced the dura, one above the other in a vertical or oblique line. The distance between the points of perforation also varied greatly, from 2 to 4.5 mm. The length of the sixth nerve from its origin to the point of splitting, and thence to the point of merging again in a single trunk, was also variable.

**Pattern 3 (5 Cases 7.5%)**

In this group, the sixth nerve originated from the brain stem as two separate trunks or branches; each of these trunks followed the same course as the two branches of the nerve described in Pattern 2, that is, after piercing the dura independently, one of the trunks passed over the apex of the petrous bone and below the petroclinoid ligament, and the other one passed above the ligament, or perforated it, to enter the cavernous sinus where the two trunks fused into a single trunk and continued their way to enter the orbit as in Patterns 1 and 2. The thickness of each of the trunks, the distance between the points of perforation, as well as their respective positions, and the point of merging into a single trunk in the cavernous sinus varied greatly, as with the two branches in Pattern 2.

One case was found in which the sixth nerve originated from a number of small rootlets that organized into three separate main trunks (Fig. 4); the course of these trunks and relations were similar to those of the two branches in Pattern 3. In this particular case, there were anastomotic connec-

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**FIG. 2.** Bilateral sixth nerve Pattern 2. The nerves originate as a single trunk and split into two branches, which perforate the dura mater separately. Note that on the right, one branch perforates the dura above the other in a vertical line. On the left, the perforation is in a horizontal line.
FIG. 3. **Left:** Dissection showing one of the branches of a split sixth nerve passing above and the other below the petrosphenoidal ligament. Both branches fuse again into a single trunk in the cavernous sinus. **Center:** Schematic drawing of dissection. **Right:** Dissection after removal of ligament showing the branch below the petrosphenoidal ligament passing above the sharp edge of the petrous bone close to its tip.

fig. 4. Parasagittal cut passing through the pons, close to the exit of the sixth nerve. This figure shows the left VI n. emerging as a conglomeration of rootlets, which organize into three main trunks. Each of the trunks perforates the dura independently. Note the anastomotic interconnections between the three trunks.

sitions between the various branches during their subarachnoidal course. One of the three branches passed below the petroclinoid ligament, and the other two passed above it. In this case, too, as in Pattern 3, the branches fused into a single trunk in the cavernous sinus. Therefore, this case may be considered only as a simple subvariation of Pattern 3.

The manner in which the sixth nerve perforated the dura mater is summarized in Table 1; our results are compared with those of Jain\(^1\) in the same table. In 56 cases (91%), the two sixth nerves followed symmetrical patterns.

**Discussion**

Both Patterns 1 and 3 are familiar from previous reports. Testut\(^1\) and more recently Jain\(^2\) observed cases in which the two trunks of the sixth nerve ran independently all the way from the brain stem to the lateral rectus muscle, without fusing into a single trunk. This variation could well be considered as a fourth pattern as it is represented in Fig. 1. We did not encounter any such case during our dissections.

Our Pattern 2, however, in which the sixth nerve arises and ends as a single trunk, but splits and runs part of its course as two separate branches, is to the best of our knowledge described here for the first time. Sunderland and Hughes\(^7\) described a case in which the nerve was split in the cavernous sinus into irregular anastomotic bundles, by fibrotic septa from the dura mater. The bundles fused again and continued anteriorly...
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### TABLE 1

Summary of course of abducens nerve in 62 cases

<table>
<thead>
<tr>
<th>Perforation of Dura Mater by VI n.</th>
<th>No. of Perforations in Each Case*</th>
<th>No. of Cases</th>
<th>Nathan, et al. (%)</th>
<th>Jain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>symmetrical:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56 cases</td>
<td>1 1</td>
<td>53</td>
<td>86.5</td>
<td>94</td>
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<tr>
<td>91%</td>
<td>2 2</td>
<td>2</td>
<td>3.5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3 3</td>
<td>1</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>asymmetrical:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 cases</td>
<td>1 2</td>
<td>2</td>
<td>3.5</td>
<td>1.5</td>
</tr>
<tr>
<td>9%</td>
<td>2 1</td>
<td>4</td>
<td>6</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>62</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

* Pattern 1 = one perforation. Patterns 2 and 3 = two perforations.

as a single nerve. This variation is somewhat similar, but not the same as our Pattern 2. Wolff described cases in which the nerve passed totally or partially above the petrosphenoidal ligament.

The possibility of the sixth nerve being absent unilaterally or bilaterally is also mentioned in the literature. In such cases the lateral rectus muscle receives its innervation from the third cranial nerve. Extra branches to the lateral rectus muscle from the third nerve in addition to the normal sixth nerve, as well as anastomosis between the third and sixth nerves in the cavernous sinus have also been described. We saw no instance of an absent sixth nerve in our dissections.

The variations of the abducens nerve are not only of academic anatomical interest but may also have some practical application. This knowledge could result in a better orientation and recognition of the structures during neurosurgical procedures, on the one hand, and a more precise interpretation of the symptoms in pathological conditions involving the abducens nerve, on the other. It is well known that the abducens nerve is very often affected in trauma of the skull with fracture of the petrous temporal bone, in suppurative processes of the same bone (Gradenigo's syndrome), and in cases of intracranial hypertension. In all these circumstances the nerve is usually affected while it is passing over the sharp superior border of the apex of the petrous bone. In increased intracranial pressure, the mechanism of damage to the sixth nerve has been interpreted as a displacement of the encephalic mass toward the foramen occipital magnum, thus putting more tension on the nerve where it straddles the petrous bone. In some cases there is only a partial lesion of the nerve with paresis of the lateral rectus. This could be explained by the anatomical splitting of the nerve as in Patterns 2, 3, and 4, so that only one of the two branches is affected by the pathological process. As described, each of the branches crosses the border of the petrous bone independently and shows a different relationship to it. While one branch is passing over the apex in direct contact with the sharp superior margin of the bone, the other branch (or branches) passes above the petroclinoid ligament or perforates it. The first branch thus appears to be in a more vulnerable position than the other. Branches of the basilar arteries, particularly the anterior inferior cerebellar artery and the internal auditory (or labyrinthine) artery, have been described as occasionally passing between the roots of the sixth nerve. Compression and kinking of the sixth nerve by arteries running such a course have also been considered a possible cause of paralysis of the nerve in brain tumors with displacement of the brain stem. Here again, these arteries may affect only one or two branches of the nerve described. Finally, the possibility of a carotid aneurysm in the cavernous sinus affecting only one branch of a divided sixth nerve should be considered.

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