Meningiomas of the tentorial notch: surgical anatomy and management

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Twenty-five meningiomas located at the tentorial notch were surgically treated between 1978 and 1993 at the Neurosurgical Department of Nordstadt Hospital in Hannover, Germany. Nineteen meningiomas were classified as originating from the lateral tentorial incisura (Group I) and six were from the posteros medial tentorial incisura (Group II). Clinically, the most common symptom was trigeminal neuralgia, followed by headache. Neuroradiologically, 64% of the meningiomas were larger than 30 x 30 mm. Further evaluation revealed signs of brainstem compression in 88% of the patients. Radical surgical removal (Simpson I and II) was achieved in 88% of the cases. There was no mortality. Follow up revealed that 80% of patients were able to return to their premorbid activity. Surgical approaches to the tentorial notch included the suboccipital retrosigmoidal or the combined subtemporal–presigmoidal approach for Group I tentorial notch meningiomas; and the supracerebellar–infratentorial or the suboccipital–transientorial approaches for Group II meningiomas. Because the best surgical approach to the tentorial incisura is still a matter of debate, the anatomy of the tentorial incisura, the clinical presentation of the patients, diagnostic indications, surgical findings, and follow up are discussed, with reference to the literature.

KEY WORDS • meningiomas • surgical approach • tentorial notch • tentorium
according to their location at the tentorial incisura. We report on the surgical management and outcomes of 25 tentorial notch meningiomas and discuss the different surgical approaches to the tentorial incisura.

**Clinical Material and Methods**

**Patient Characteristics**

In our department between 1978 and 1993, 25 patients underwent craniotomy for surgical resection of tentorial notch meningiomas. The exact origin of the tumors was established by means of neuroradiological studies and after a careful retrospective analysis of each operating record. The patients were divided into two main groups according to the location of the tumor attachment at the tentorial incisura: there were 19 lateral (Group I) and six posteromedial tumors (Group II) (Figs. 3 and 4).

**Radiological Studies**

Computerized tomography (CT) scans were obtained in all patients and enabled the correct preoperative diagnosis in each case. Magnetic resonance (MR) images were obtained in 13 cases, and angiography was obtained in only six of the early cases.

**Surgical Technique**

The choice of surgical approach is one of the crucial and sometimes most difficult decisions to make (Fig. 5). Each case should be individually analyzed with regard to the clinical signs and symptoms and the patient’s age in addition to the neuroradiological evaluation.

**Lateral Suboccipital–Retrosigmoidal Approach.** With the patient placed in the semisitting position and the head anteflexed and rotated 30° to the tumor side, a standard suboccipital–retrosigmoidal approach is performed, exposing the transverse sinus superiorly and sigmoid sinus laterally. The dura is incised along the sinuses. Before retracting the cerebellum, cerebrospinal fluid (CSF) must be released by opening the cerebellomedullary cistern. Therefore, enough relaxation of the cerebellum is obtained for the tumor to be exposed at the cerebellopontine angle (CPA) with minimal retraction of the cerebellum.

The tumor may be localized ventral to the fifth and seventh and eighth cranial nerves. In these cases the cranial nerves will be dorsally compressed and the surgeon will recognize them at the beginning of the surgery. The surgeon will then distinguish three different main surgical pathways as follows: 1) above the trigeminal nerve; 2) between the fifth nerve and the seventh and eighth nerve complex; and 3) between the seventh and eighth cranial nerves and the caudal cranial nerves. If the tumor extends

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**TABLE 1**

**Tentorial incisura spaces: important landmarks**

<table>
<thead>
<tr>
<th>Space</th>
<th>Neural Structures</th>
<th>Vascular Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>lateral</td>
<td>lateral surface of midbrain</td>
<td>anterior choroidal artery</td>
</tr>
<tr>
<td></td>
<td>upper pons</td>
<td>posterior cerebral artery</td>
</tr>
<tr>
<td></td>
<td>medial surface of temporal lobe</td>
<td>superior cerebellar artery</td>
</tr>
<tr>
<td></td>
<td>fourth and fifth cranial nerves</td>
<td>basal vein of Rosenthal</td>
</tr>
<tr>
<td>posterior</td>
<td>pineal region</td>
<td>internal cerebral veins</td>
</tr>
<tr>
<td></td>
<td>quadrigeminal plate</td>
<td>posterior basal veins</td>
</tr>
<tr>
<td></td>
<td>fourth cranial nerve</td>
<td>vein of Galen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>straight sinus</td>
</tr>
</tbody>
</table>

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**Fig. 1.** Superior view of the tentorial notch displaying its neurovascular relationships. Basilar artery (ba); cerebellum (ce); internal carotid artery (ica); midbrain (mb); oculomotor nerve (oc.n.); optic nerve (o.n.); pituitary stalk (ps); posterior communicating artery (pca); superior cerebellar artery (sca); and trochlear nerve (tr.n.).

**Fig. 2.** Oblique view of the left tentorial incisura (lateral space) showing its neurovascular structures. The left tentorial edge is elevated with a dissector, displaying the trochlear nerve (tr.n.) running parallel to the tentorial margin to its entrance into the cavernous sinus. The oculomotor nerve (oc.n.) enters into the roof of the cavernous sinus. Beneath the trochlear nerve, the trigeminal nerve (t.g.n.) passes through Meckel’s cave. Note the close relationship between the trigeminal nerve and the superior cerebellar artery (sca). Basilar artery (ba); internal carotid artery (ica); midbrain (mb); optic nerve (o.n.); posterior communicating artery (pca); and third ventricle (3v).
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to the caudal cranial nerves, we first begin the tumor removal at this floor (between the ninth and 12th and seventh and eighth nerves). Tumor vascularization is reduced by bipolar coagulation and piecemeal tumor removal is performed, preserving arachnoidal planes. After debulking the tumor at this level, the surgeon will gain enough space for further tumor removal between the seventh and eighth cranial and the trigeminal nerves, without additional stretching of the cranial nerves. As a final step, the tumor extension above the trigeminal nerve can be removed.

In some cases cranial nerves cannot be recognized after opening the dura because the tumor envelops them. In such cases, the first step should be the identification of the cranial nerves at their entrance to the bone. Once the cranial nerves are recognized, the surgeon can proceed with tumor removal as described above.

Important aspects of the surgical procedure are: 1) tumor removal is accomplished from the lateral to medial aspect of the tumor, and the last part removed should be the one extending to the brainstem and preptontine cistern; 2) during tumor removal between the described surgical pathways, cranial nerves should be protected with cottonoids; 3) during tumor removal, continuous irrigation should be maintained to provide a clean operative field; and 4) continuous irrigation performed by an assistant allows the surgeon to use both hands to dissect the tumor from the surrounding neurovascular structures, preserving the arachnoidal sheets.

Combined Subtemporal–Presigmoidal Approach. After a temporosuboccipital craniotomy, a partial petrosectomy is performed with preservation of the labyrinth block and the fallopian canal. The dura is incised parallel to and anterior to the sigmoid sinus. We always try to preserve the trans-
verse sinus, even in cases of nondominant transverse sinus. The superior petrosal sinus and the tentorium are transected, permitting a wide exposure of the tumor. Tumor removal at the CPA is performed following the same principles as described above for the suboccipital–retrosigmoidal approach.

After infratentorial tumor removal, the temporal lobe can be gently elevated to better expose the rest of the tumor in the middle fossa and parasellar region. The tumor mass can then be dissected from two directions—from behind or from a lateral view (subtemporal). The third cranial nerve will usually be found above the tumor margin. In cases of involvement of the cavernous sinus, it is our policy not to open it if the patient does not present preoperatively with any kind of oculomotor dysfunction and the tumor shows an infiltrative pattern.

Considerations when using the subtemporal–presigmoidal approach are: 1) during transection of the tentorium, the trochlear nerve can easily be injured, especially on its distal part where it enters into the cavernous sinus; therefore transection of the tentorium should be approached more dorsally; 2) during tumor removal, the abducens nerve is usually more easily localized at the brainstem; 3) prolonged retraction of the temporal lobe, resulting in intracerebral bleeding; and 4) after careful closure of the dura, the petrous bone should be covered with muscle pieces and with fibrin glue because of the risk of CSF fistula.

**Medial Suboccipital–Transtentorial Approach.** Mediocipital craniotomy is performed, exposing the sagittal sinus, the torcular region, and the transverse sinus of both sides. The dura is opened in an L-shaped fashion, just bordering the sagittal and transverse sinuses on the right side. The occipital lobe is then gently retracted upward and laterally.

The tentorium is coagulated and transected as far as the tentorial incisura, allowing a wide exposure of the tumor with less brain retraction. Care should be taken not to damage the trochlear nerve. The deep venous system is usually recognized early by this surgical approach, allowing the surgeon better control of it during the tumor removal. First the tumor is debulked, then the tumor capsule is dissected away from the surrounding neurovascular structures.

**Infratentorial–Supracerebellar Approach.** With the patient in the semisitting position, a midline suboccipital craniotomy is performed, exposing the transverse sinus and the torcular region. The dura is opened below and parallel to the transverse sinus. Gentle retraction is applied to the cerebellum because gravity pulls it down naturally. Bridging veins are cautiously cauterized and divided. If not obstructed by the tumor, the quadrigeminal cistern is opened, and subsequent drainage of the CSF provides more brain relaxation. After tumor enucleation, continuous irrigation performed by an assistant will allow the surgeon the use of both hands to manipulate the capsule carefully with the aid of two forceps and to dissect it from the surrounding neurovascular structures. Dissection is first performed at both lateral aspects of the tumor, then the posterior aspect of the tumor is carefully dissected away from the deep venous structures (the great cerebral vein, basal veins, and straight sinus).

**Monitoring Methods.**

All patients undergoing surgery in the semisitting position are monitored with precordial Doppler ultrasonography, oximetry, and capnometry to detect air embolisms. Additionally, a catheter is inserted in the right cardiac atrium in case it is needed to aspirate an embolism.

Concerning neuroelectrophysiological monitoring, somatosensory evoked potentials (SEPs) and auditory evoked potentials are continuously monitored during the operation. Electromyographic monitoring of the facial nerve is also performed.

It should be stressed that SEP control must also be done during the positioning of the patient, especially in cases of huge meningiomas of the lateral margin of the tentorial notch with brainstem displacement and extension into the craniocervical region. Sometimes, due to neck flexion and rotation, additional compression of neurovascular structures can occur, and this compression results in alteration of the SEP monitoring. In these cases, the patient’s neck and head should be repositioned until normalization of the SEP monitoring is achieved.

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**TABLE 2**

Clinical presentation of 25 tentorial notch meningiomas

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>trigeminal pain*</td>
<td>9</td>
</tr>
<tr>
<td>headache</td>
<td>8</td>
</tr>
<tr>
<td>gait disturbance</td>
<td>7</td>
</tr>
<tr>
<td>hearing loss</td>
<td>6</td>
</tr>
<tr>
<td>hemianopsia</td>
<td>5</td>
</tr>
<tr>
<td>dizziness</td>
<td>3</td>
</tr>
<tr>
<td>diplopia</td>
<td>3</td>
</tr>
<tr>
<td>tinnitus</td>
<td>2</td>
</tr>
<tr>
<td>swallowing difficulties</td>
<td>1</td>
</tr>
<tr>
<td>mental changes</td>
<td>1</td>
</tr>
<tr>
<td>cranial nerve abnormalities</td>
<td></td>
</tr>
<tr>
<td>fourth</td>
<td>1</td>
</tr>
<tr>
<td>fifth</td>
<td>14</td>
</tr>
<tr>
<td>sixth</td>
<td>1</td>
</tr>
<tr>
<td>seventh</td>
<td>2</td>
</tr>
<tr>
<td>eighth</td>
<td>6</td>
</tr>
<tr>
<td>ninth</td>
<td>1</td>
</tr>
</tbody>
</table>

* All cases are from Group I, in which meningiomas were classified as originating from the lateral tentorial incisura.

**TABLE 3**

Surgical removal of 25 tentorial notch meningiomas

<table>
<thead>
<tr>
<th>Surgical Grade (Simpson)*</th>
<th>No. of Cases†</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>14</td>
</tr>
<tr>
<td>II</td>
<td>2</td>
</tr>
<tr>
<td>III</td>
<td>1</td>
</tr>
<tr>
<td>IV</td>
<td>1</td>
</tr>
<tr>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>total</td>
<td>19</td>
</tr>
</tbody>
</table>

* Surgical grade according to the criteria of Simpson.‡
† Meningioma in Group I originated from the lateral tentorial incisura, and from the postero medial tentorial incisura in Group II.
‡ Meningioma en plaque.
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Results

Clinical Aspects

The patients’ ages ranged from 28 to 72 years, with a mean of 52 years. There were 18 women and seven men (3:1). The average time from the onset of symptoms to the diagnosis was 48 months (range 4–300 months). The presenting clinical symptoms and neurological signs are summarized in Table 2.

The most frequent symptoms were trigeminal pain (36%), headache (32%), gait disturbance (28%), hearing loss (24%), dizziness (12%), and diplopia (12%). The most common neurological signs were the impairment of the fifth (56%), eighth (24%), and seventh (8%) cranial nerves.

Radiological Findings

Tumor diameter ranged from $10 \times 15\text{ mm}$ to $60 \times 60\text{ mm}$, and most of the lesions (64%) were larger than $30 \times 30\text{ mm}$. In 11 cases (44%) the tumors extended supratentorially, and in 14 cases (56%) they were limited to the infratentorial region. Three tumors localized at the lateral tentorial incisura extended down to the foramen magnum and, in two cases, also into the internal auditory canal. One posteromedial tentorial meningioma extended into the third and lateral ventricles. Also, 88% of the patients, especially from Group I (lateral tentorial incisura), presented radiological evidence of brainstem compression or displacement.

Tumor Removal

Two patients required ventriculoperitoneal shunting and one required placement of an external drainage prior to the tumor resection. Of the 19 patients in Group I, surgery was performed via a lateral suboccipital–retrosigmoid approach in 16 (Fig. 3) and by a combined subtemporal–pre sigmoidal approach in three. In four patients from Group II, surgery was performed via an infratentorial–supracerebellar approach (Fig. 4). In the other two cases an occipital–transventricular approach was used.

The extent of tumor resection was determined using the operative records and postoperative radiographic studies (CT and MR studies) and further classified according to Simpson’s grades for tumor removal.33 Radical surgical removal (Simpson I and II) was achieved in 22 patients (88%), subtotal in two patients (8%), and surgical decompression in one (4%) (Table 3). Incomplete tumor removal was performed in three cases because of strong tumor adherence to vascular structures, cranial nerves, or the brainstem.

Total surgical extirpation with removal of the dural attachment was not feasible in four patients from Group II due to the presence of tumor infiltration or very strong adhesion within the sinus rectus. In all but one case, cranial nerves were anatomically preserved.

Early Postoperative Course

The immediate postoperative surgical complications are listed in Table 4. Palsy of trochlear palsy was the most common postoperative surgical complication (28%). Partial facial paresis was present in six and transient lower cranial nerve dysfunction was observed in two patients.

There was no surgical mortality. With regard to the clinical status of the patients at the time of discharge, 14 (56%) were able to return to their normal life activities, six (24%) were independent, and five (20%) needed a nurse’s assistance.

Long-Term Follow Up

We were able to evaluate 21 of the 25 patients in our series with a mean follow-up duration of 5.6 years. One patient died 11 years after the operation due to cardiovascular disease. Seventeen patients (80%) have resumed their normal life activities without difficulty. Three patients (14%) have needed some nursing assistance, one of them because of cardiovascular problems. Neuroradiological signs of tumor recurrence have not been observed so far in any case of totally resected tumor. Apart from two cases of complete trochlear palsy, all other cranial nerve deficits showed improvement on follow-up examination. The six cases of facial paresis showed improvement to House and Brackmann13 Grade II (four cases) and Grade III (two cases).

Discussion

The surgical treatment of tentorial meningiomas has been a challenge for most neurosurgeons over the years.5,9,10,32 These tumors represent 2% to 4% of all intracranial meningiomas and have been recently classified by many authors according to their sites at the tentorium cerebelli.3,5,6,10,11 Indeed, these tumors represent different problems from the surgical point of view.

Of 765 intracranial meningiomas that were surgically removed between 1978 and 1993 in our department, 250 were located in the posterior fossa. Of these, 20% were classified as tentorial meningiomas. Tentorial notch meningiomas represented 10% of all posterior fossa meningiomas in our series or 3% of all intracranial meningiomas.

Anatomically, the tentorial notch can be divided into anterior, lateral, and posterior spaces.20 Meningiomas at the posteromedial tentorial margin, also called pineal region meningiomas, are very rare22,31,36 and accounted for 24% of our cases. Different surgical approaches have...
been proposed for these tumors,\textsuperscript{1,4,14,21} supracerebellar–infratentorial, occipitoparietal, and suboccipital–transtentorial are most frequently performed. Advantages and disadvantages of each approach (Table 5) have been described in the literature and correlate with the surgeon’s own experience.\textsuperscript{15,30,31,37,38}

Most of the Group II meningiomas can be successfully removed via a supracerebellar–infratentorial approach. Whereas we used the prone position in a few cases, in the majority of cases we advocate the semisitting position, which yields, in our opinion, several advantages. A large exposure of the tumor region with modest retraction of the cerebellum is achieved, because the cerebellum shifts down in this position due to gravity. Likewise, we avoid the deep venous structures that normally lie dorsally and laterally to the tumor.\textsuperscript{3,25,35,36} Indeed, the cerebellum tolerates retraction better than do the parietal and occipital lobes. Retraction of these latter structures is often related to hemiparesis, contralateral sensorial loss, and homonymous hemianopsia.\textsuperscript{3,21,22,36,38} Nevertheless, Ausman, et al.,\textsuperscript{2} reported successful results in 13 patients with pineal region neoplasms operated on via an occipitoparietal approach in the three-quarter prone position.

In our experience, meningiomas located at the lateral tentorial incisura and extending mainly into the CPA are very well managed through a lateral suboccipital–retrosigmoidal approach. This allows the early identification of the cranial nerves, especially the seventh to eighth complex. During the tumor dissection, care should be taken to respect the arachnoidal layer to preserve the cranial nerves that are usually dorsally compressed.\textsuperscript{27,29} On the other hand, meningiomas at the lateral tentorial notch invading the middle fossa and with little extension to the CPA can be successfully managed via a transsylvian or subtemporal approach.\textsuperscript{21,23,34,39,46} The tumor is first enucleated and then the tentorium is incised, permitting the removal of the tumor attachment on the tentorial edge. During the incision and retraction of the free tentorial edge, special care is required to preserve the trochlear nerve in its course inferomedial to the lateral tentorial space. Drake\textsuperscript{8} suggested elevating the free tentorial edge with a suture to avoid affecting the trochlear nerve.

Despite the frequent CPA extension and compression or engulfing of the cranial nerves in the posterior fossa, Group I meningiomas were totally resected in 84% of our cases. The surgical complications are usually related to deficits in the fourth, fifth, seventh, and eighth cranial nerves.\textsuperscript{9,33} Although fourth nerve palsy occurs in almost 25% of patients, it should be stressed that this deficit is usually transient. Close follow up is mandatory in cases of facial palsy; nowadays no facial nerve paralysis should be left untreated. Facial nerve reconstruction or reanimation techniques usually show satisfactory results. Whereas in the majority of cases good functional recovery will develop within the 1st postoperative year, regular outpatient...
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follow up will detect the few cases requiring reconstructive measures in time.

Conclusions

These results show that with the development of microneurosurgical techniques and the understanding of the different problems related to this region, tentorial notch meningiomas can be successfully removed with minimum morbidity.

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References


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