Comparison of conventional and skull base surgical approaches for the excision of trigeminal neurinomas

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Trigeminal neurinomas have traditionally been excised through conventional approaches. Because symptomatic tumor recurrence exceeds 50% after conventional procedures, the authors evaluated the use of skull base approaches to achieve complete resection and a lower rate of symptomatic recurrence. Comparisons of skull base with conventional approaches to trigeminal neurinomas have been limited to small series with short-term follow-up periods. The authors reviewed their experiences with conventional (frontotemporal transsylvian, subtemporal–intradural, subtemporal–transtentorial, and suboccipital) and skull base (frontotemporal extradural–intradural, frontoorbitozygomatic, subtemporal anterior petrosal, and presigmoid posterior petrosal) surgical approaches for the excision of trigeminal neurinomas. In this paper they report the results of 15 patients with trigeminal neurinoma who underwent 27 surgical procedures between 1980 and 1990. Seventeen of the procedures used conventional and 10 used skull base approaches. All patients had tumors arising from Meckel’s cave and the porus trigeminus either initially or on recurrence. Tumors located in the cavernous sinus recurred most frequently (83%); other tumors that recurred frequently were those located in Meckel’s cave and the porus trigeminus (67%), and the posterior fossa (17%). The tumor extended into the anterolateral wall of the cavernous sinus in 38% of patients with cavernous sinus involvement.

Tumor exposure and ease of dissection were superior with skull base approaches. Residual or recurrent tumors were found in 65% of patients following conventional approaches compared with 10% of patients following skull base approaches. Using skull base approaches, the surgeon was more accurate (90%) in estimating tumor excision than when using conventional approaches (43%). Perioperative complications were similar with both.

The authors discuss the indications, advantages, and limitations of each approach. Based on anatomical considerations, they propose a strategy to best resect these tumors.

KEY WORDS • cavernous sinus • Meckel’s cave • skull base approaches • trigeminal neurinoma

TRIGEMINAL neurinomas are slow-growing benign tumors that constitute 10% of intracranial neurinomas and less than 0.5% of all intracranial tumors.22 When totally excised, the patient is cured. However, the rate of tumor recurrence exceeds 50% following excision through conventional frontotemporal transsylvian, subtemporal–intradural, subtemporal–transtentorial, or suboccipital approaches.17,27 Theorizing that the high tumor recurrence rate after conventional approaches results from poor tumor exposure, we evaluated the exposure and outcome of skull base approaches such as frontotemporal extradural–intradural, frontoorbitozygomatic, subtemporal anterior petrosal, and presigmoid posterior petrosal. Preliminary results of skull base operations to excise trigeminal neurinomas are promising; however, these results have been limited to small series with brief follow-up periods.12,20,21,23,27

Skull base approaches, which are longer and technically more difficult than conventional approaches, can be associated with serious postoperative morbidity. Therefore, the superiority of skull base approaches over conventional ones must be shown in terms of tumor exposure, ease of tumor resection, tumor recurrence, and neurological outcome before they can be widely recommended to excise trigeminal neurinomas.

In this retrospective study, we report on the cases of 15 patients with trigeminal neurinomas who underwent 27 surgical procedures, including 17 conventional and 10 skull base approaches. The purpose of our review was twofold: to identify whether skull base approaches provide better exposure of the origin and extension of trigeminal neurinomas compared with conventional approaches and to identify whether they provide better excision of trigeminal neurinomas without increased neurological deficit compared with conventional approaches.
Clinical Material and Methods

Patient Population and Review of Records

Between 1980 and 1990, 15 patients (seven males and eight females) aged 6 to 53 years were treated for histologically proven trigeminal neurinomas. Patient records and imaging studies were reviewed to identify the anatomical location of initial and recurrent tumors, the surgical approach that was undertaken, operative exposure, operative findings, rate of tumor recurrence, perioperative morbidity, and neurological outcome. A variety of surgical techniques were used either alone or in combination. Conventional approaches included: frontotemporal transsylvian in one case, subtemporal–intradural in two cases, subtemporal–transtentorial in nine, and suboccipital in eight cases. Skull base approaches included: frontotemporal extradural–intradural as described by Dolenc in three cases, frontoorbitozygomatic as described by Hakuba in two, subtemporal anterior petrosal as described by Kawase in four, and presigmoid posterior petrosal as described by Samii and coworkers and Al-Mefty and colleagues in two cases. Approaches were chosen based on the anatomical location of the tumor and the surgeon’s preference.

In 15 cases, the most common presenting symptoms for both initial and recurrent tumors were trigeminal sensory deficit (96%), trigeminal motor deficit (33%), headache (44%), and various cranial nerve palsies (Table 1). Symptom duration prior to diagnosis averaged 1 year (range 5 months to 4 years). Of the 17 conventional approaches employed, 11 were undertaken for initial tumors and six for recurrent tumors. Of the 10 skull base approaches, four were used for initial tumors and six for recurrent tumors. Six of the patients underwent one surgical procedure, six had two surgical procedures, and three had three surgical procedures. Preoperative computerized tomography (CT) was performed in all cases and magnetic resonance (MR) imaging in 12 cases. Tumor size ranged from 1 to 7 cm (mean 3.5 cm) in conventional approaches versus 1 to 8 cm (mean 3.9 cm) in skull base approaches. The average follow-up period was 6 years (range 3 to 11 years) for all procedures; the mean follow-up period was 6 years for patients after a conventional approach compared with 5 years for patients after a skull base approach. All patients had follow-up MR imaging. Results were compared using the chi-square test to establish significance (p < 0.05).

Results

Fifteen patients underwent 27 surgical procedures for trigeminal neurinomas. Seventeen of the surgical approaches used were conventional and 10 were skull base. To identify tumor origin, extension, and relationship to surrounding structures, we compared preoperative imaging studies with intraoperative findings, postoperative imaging studies, and locations of tumor recurrence. Both skull base and conventional approaches were compared in terms of ease of tumor resection, the surgeon’s accuracy in estimating the amount of tumor excised, the rate of tumor recurrence, and postoperative morbidity.

Tumor Location

All 15 patients had trigeminal neurinomas arising from Meckel’s cave and the porus trigeminus either initially or on recurrence (Table 2). In the middle fossa, the inferomedial portion of the tumor adhered to the posterolateral wall of the cavernous sinus. The tumor extended anteriorly to the lateral wall of the cavernous sinus in 13 patients (87%); in five (38%) of the 13 patients, the tumor extended to the superior orbital fissure or just proximal to it. Tumors usually recurs in the cavernous sinus (83%); other sites of tumor recurrence were Meckel’s cave and the porus trigeminus (67%) and the posterior fossa (17%) (Table 2).

Relationship of Tumor to Surrounding Structures

Trigeminal neurinoma in Meckel’s cave and erosion of the petrous bone displaced the precavernous portion of the internal carotid artery (lateral loop) anteromedially; when the tumor extended interdurally within the lateral wall of the cavernous sinus, it also displaced the carotid siphon anteroinferiorly, but without encasing it. The posterior fossa portion of the tumor occasionally adhered to the brainstem. The third, fourth, sixth, seventh, and eight cranial nerves were frequently attached to the tumor capsule; the fourth nerve was on the superior surface and the third...
nerve was on the medial surface of the tumor. The fifth nerve frequently was incorporated in the tumor capsule of large tumors. The sixth nerve occasionally was compressed in Dorello’s canal. The posterior and the superior cerebellar arteries usually were displaced medially and superiorly, whereas the anterior inferior cerebellar artery was displaced inferiorly.

**Tumor Exposure and Dissection**

Operating surgeons subjectively assessed that skull base approaches were superior for identifying tumor origin, extension, and relationship to surrounding structures. Tumor resection was easier with these approaches because the exposure provided better anatomical detail and versatile attack angles with minimal brain retraction. Complete tumor removal was a likely result of a single skull base procedure (Fig. 1).

**Tumor Recurrence**

In nine patients (60%) tumors recurred 1 to 6 years (mean 3 years) after initial surgery (Table 3). Tumor recurrence was 65% after conventional approaches compared with 10% after skull base approaches. These results are statistically significant \( \chi^2 = 7.6; p = 0.006 \). In comparing the extent of tumor excision on postoperative imaging studies with the surgeon’s estimated excision, the surgeon’s estimate of tumor excision was wrong in 57% of the cases using conventional approaches compared with 10% of those using skull base approaches: a difference that is statistically significant \( \chi^2 = 5.5; p = 0.019 \).

**Neurological Outcome**

Patients’ neurological outcomes were similar after conventional and skull base approaches except for a higher incidence of transient cranial nerve deficits after skull base approaches \( \chi^2 = 3.8; p < 0.05 \) (Table 4). Most postoperative complications were related to the trigeminal nerve: 70% of patients had increased or new sensory deficits and 56% had increased or new motor deficits in the trigeminal nerve. Headache, facial pain, and motor long-tract signs improved in most patients. Two patients developed permanent ocular nerve palsy, one patient following sacrifice of the trochlear nerve during subtemporal–transtentorial approach, and the other patient following sacrifice of the abducens nerve after a frontoorbitozygomatic approach for a recurrent tumor in the cavernous sinus. Two patients developed aphasia: one from brain retraction during a subtemporal–intradural approach and the other from thrombosis to the vein of Labbé during a subtemporal–transtentorial approach. After undergoing a frontotemporal extradural–intradural approach, one patient developed *Streptococcus pneumoniae* meningitis, which was successfully treated with antibiotic medications.

### Discussion

In planning a surgical approach to excise trigeminal neurinomas, the surgeon must consider the size, extension, adherence to surrounding structures, and natural his-
Fig. 2. A schematic illustration showing the origin and extension of trigeminal neurinomas. These tumors arise in Meckel’s cave (hatched lines). The ring represents the porus trigeminus. When tumors extend beyond Meckel’s cave, they are classified as middle fossa neurinomas (1), middle and posterior fossa neurinomas (dumbbell; 2), and predominantly posterior fossa neurinomas (3). Reprinted with permission from Tew JM Jr, van Loveren HR, Keller JT: Atlas of Operative Microneurosurgery. Philadelphia: WB Saunders, Vol 2. In press.

tory of the tumor as well as the patient’s clinical presentation, age, and medical condition. The natural history of these tumors following subtotal excision is not known; some authors found a high incidence of symptomatic tumor growth following subtotal excision, whereas others found long periods of remission. Subtotal tumor excision may be a realistic goal for elderly patients, those in poor medical condition who cannot tolerate prolonged surgical procedures, and patients with minimal symptoms. However, total tumor excision is the preferred goal in most cases.

The results of this review document that skull base approaches can achieve total excision of trigeminal neurinomas without increased neurological deficits compared with conventional approaches. To understand why skull base approaches achieve better results than conventional approaches, one must identify the origin and extension of these tumors and the operative exposure provided by each surgical approach.

Tumor Origin

Trigeminal neurinomas (Fig. 2) arise from the trigeminal nerve or ganglion, but rarely from the trigeminal rootlets. These tumors were previously classified according to location: 50% were in Meckel’s cave, 30% were in the posterior fossa, and 20% straddled both the middle and posterior fossa (dumbbell tumors). In our 15 cases, all trigeminal neurinomas originated in the interdural space in Meckel’s cave. These tumors initially extended anteriorly into the wall of the cavernous sinus and posteriorly into the porus trigeminus. With further growth anteriorly in the middle fossa, trigeminal neurinomas occasionally penetrated the interlacing membranous sheath of the cranial nerves in the wall of the cavernous sinus and extended into the venous vascular channels in the cavernous sinus. Less frequently, tumors penetrated the dura propria of the temporal lobe to lie intradurally. In 38% of patients who had cavernous sinus involvement, the tumor extended into both the posterior and anterior compartments. When trigeminal neurinomas grew posteriorly, they extended into the intradural space in the posterior fossa by growing out of the porus trigeminus or by eroding the medial petrous bone. These findings are shared by other authors.

In our series, all tumors recurred in the lateral wall of the cavernous sinus (83%) and/or Meckel’s cave and the porus trigeminus (67%). These tumors were probably not recurrences but growth of existing tumors that were not recognized preoperatively or not well exposed intraoperatively. Therefore, to achieve total tumor excision with minimal tumor recurrence, surgeons should use a preoperative imaging study that best defines tumor location, that is, MR rather than CT imaging, and skull base approaches that expose the origin and extension of these tumors in their appropriate anatomical planes.

Surgical Approaches to Trigeminal Neurinomas

Trigeminal neurinomas can still be classified according to their location: 1) mainly in the middle fossa, 2) in both the middle fossa and posterior fossa (dumbbell tumors), and 3) mainly in the posterior fossa. Each tumor location can be approached through conventional or skull base operations. Contrast-enhanced MR imaging defines the surgical and pathological anatomy for planning the appropriate surgical approach. For each tumor location, the following surgical approaches are considered.

Middle Fossa Tumors. Trigeminal neurinomas of the middle fossa (Fig. 3 upper left and right) are conventionally excised through the frontotemporal transylvian or the subtemporal–intradural approach. Because these tumors originate in the interdural space from Meckel’s cave, a combined subtemporal–intradural and extradural approach best exposes the origin of these tumors and the trigeminal nerves. When the approach is combined with a zygomatic osteotomy, less brain retraction is required. Trigeminal neurinomas frequently extend anteriorly into the lateral wall of the cavernous sinus; thus, a subtemporal extradural–intradural approach, combined with drilling the bone margins of the superior orbital fissure, lateral wall of the cavernous sinus, and Meckel’s cave, better exposes and mobilizes the neural contents of the cavernous sinus and trigeminal ganglion. Unlocking the structures around the superior orbital fissure enables the dura propria of the lateral wall of the cavernous sinus to be reflected backward from the superior orbital fissure or downward from the oculomotor nerve. The superior orbital fissure forms the anterior border of the lateral wall.
of the cavernous sinus. The dura propria of the lateral wall of the cavernous sinus is the backward reflection of the temporal lobe dura at its junction with the superior orbital fissure. By starting dissection in the interdural space anterior to the tumor and working posteriorly, the surgeon can peel and lift the tumor off the inner membranous layer of the lateral wall of the cavernous sinus and trigeminal ganglion with minimal manipulation of the cranial nerves and the internal carotid artery.

Middle and Posterior Fossa Tumors. Figure 3 (center left and right) illustrates the conventional and skull base approaches to tumors of the middle and posterior fossa. When trigeminal neurinomas extend through the porous trigeminus into the posterior fossa, remain cephalad to the seventh–eighth nerve complex, and lie lateral to the brainstem, they can be partially removed through the subtemporal (subtemporal–transtentorial) approach by incising the tentorium. Resecting the apical pyramidal bone as described by Kawase’s anterior petrosal approach facilitates tumor extirpation by better exposing the tumor and the petroclinoid region down to the inferior petrosal sinus. The subtemporal extradural–intradural approach combined with an anterior petrosectomy can access the anterior surface of the ipsilateral pons, the origin of seventh–eighth nerve complex, the sixth cranial nerve, 1.5 cm of the basilar artery inferior to the trigeminal root, and the origin of the anterior inferior cerebellar artery while minimizing brain retraction. With this approach, the trigeminal nerve can be mobilized and Parkinson’s triangle can be enlarged to excise the tumor around the carotid siphon and in the posterior cavernous sinus. Compared with the subtemporal–transtentorial approach, the subtemporal extradural–intradural approach, combined with an anterior petrosectomy, better exposes the space inferior to the trigeminal ganglion that often hides the tumor, unlocks the porus trigeminus, and better exposes the brainstem to which the tumor may adhere. When combined with an anterior approach to the cavernous sinus, the tumor is exposed from the superior orbital fissure anteriorly to the internal auditory meatus posteriorly. Like the subtemporal–transtentorial approach, the anterior petrosal approach cannot adequately expose a tumor that extends below the internal auditory meatus or inferior to the inferior petrosal sinus.

Posterior Fossa Tumors. Figure 3 (lower left and right) illustrates the conventional and skull base approaches to predominantly posterior fossa tumors. Trigeminal neurinomas ventral to the lower brainstem and below the seventh–eighth cranial nerve complex cannot be excised safely through subtemporal approaches, but are usually approached via a primary or secondary suboccipital cra-

FIG. 3. Upper Left: Conventional approach to middle fossa neurinoma (Type 1). Hatched area represents boundaries of frontotemporal craniotomy for transsylvian approach to tumor. Upper Right: Skull base approach to middle fossa neurinoma (Type 1). Hatched area represents: 1) boundaries of frontotemporal craniotomy, posterior orbitotomy, and anterior clinoidectomy; 2) extradural expansion of foramen rotundum; 3) extradural expansion of foramen ovale; and 4) extradural exposure of petrous carotid artery. Center Left: Conventional approach to dumbbell neurinoma (Type 2). Hatched area (1) represents boundaries of subtemporal craniotomy and dotted line (2) represents tentorial incision for subtemporal–transtentorial approach to tumor. Center Right: Skull base approach to dumbbell neurinoma (Type 2). Hatched area represents boundaries of 1) subtemporal craniotomy and 2) anterior petrosectomy for subtotal anterior petrosal approach for tumor. Lower Left: Conventional approach to predominantly posterior fossa neurinoma (Type 3). Hatched area represents boundaries of suboccipital craniotomy for suboccipital approach to tumor. Continued ➜

niotomy. A primary suboccipital approach can decompress but cannot totally resect the tumor. Trigeminal neurinomas arising from Meckel’s cave are not exposed adequately and the region anterior to the brainstem to which these tumors may extend is not exposed safely. When subtemporal—intradural and suboccipital approaches are combined, ligation of the lateral sinus may be necessary. Disadvantages of this combined approach include risk of venous infarction by obstructing the lateral or sigmoid sinuses, injury to the vein of Labbé when working between two separate compartments, and excessive brain retraction. A subtemporal extradural—intradural approach combined with presigmoid posterior petrosectomy provides excellent exposure of the tumor with minimal brain retraction and without sacrifice of the lateral or sigmoid sinuses in these locations: the posterior fossa, posterior and anterior to the internal auditory canal; the posterior, lateral, and anterior aspects of the brainstem; and Meckel’s cave and the porus trigeminus. When combined with an anterior petrosectomy, various attack angles are feasible for tumors that extend from the lateral wall of the cavernous sinus superiorly down to the lower cranial nerves inferiorly.19

Neurological Outcome

In this series of 15 patients permanent neurological deficits following skull base approaches did not exceed those following conventional approaches. Tumors excised by skull base approaches were larger, in locations more difficult to access such as the cavernous sinus and the anterior brainstem, and totally excised more often by a single approach than tumors resected by conventional approaches. Therefore, it should not be surprising that more transient ocular cranial nerve deficits occurred following skull base approaches. As with conventional approaches, most patients developed postoperative sensory or motor trigeminal deficits after skull base surgery. In large trigeminal neurinomas, the trigeminal rootlets are often incorporated within the tumor capsule. A future study might examine whether skull base approaches, by virtue of their superior exposure and mobilization of Meckel’s cave and the trigeminal rootlets, can minimize postoperative trigeminal nerve deficits after excision of small tumors (that is, before the trigeminal rootlets become severely adhered to the tumor capsule) compared with conventional approaches.

Conclusions

This review demonstrates that trigeminal neurinomas originate in the interdural space in Meckel’s cave and extend anteriorly into the wall of the cavernous sinus and the middle fossa and posteriorly into the porus trigeminus and the posterior fossa. Skull base approaches provide better exposure of these tumors, multiple working angles with minimal brain retraction, and more complete tumor excision without increased morbidity compared with conventional approaches. This review should not be interpreted to minimize the usefulness of conventional surgical approaches in excising small trigeminal neurinomas confined to Meckel’s cave or in decompressing large tumors. Selecting one approach over the other should be guided by tumor extension on MR imaging, the patient’s medical condition, and the surgeon’s experience with different surgical procedures. Additional patient follow-up data are needed to determine long-term tumor recurrence and overall efficacy of skull base approaches to trigeminal neurinomas.

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