Surgical Strategy for Tumors Located in or Extending From the Intracranial Space to the Infratemporal Fossa
—Advantages of the Transcranial Approach (Zygomatic Infratemporal Fossa Approach) and the Indications for a Combined Transcranial and Transcervical Approach—

Kazunari YOSHIDA, Takeshi KAWASE, Toshiki TOMITA*, Kaoru OGAWA*, Hiromasa KAWANA**, Kaori YAGO**, and Soichiro ASANAMI**

Departments of Neurosurgery, *Otolaryngology, and **Dentistry and Oral Surgery, Keio University School of Medicine, Tokyo

Abstract
The surgical strategy for tumors located in or extending from the intracranial space to the infratemporal fossa was analyzed in 12 cases with various pathologies. A case of mandibular nerve schwannoma, which extended 1 cm below the external orifice of the foramen ovale, was completely removed via the epidural subtemporal approach without zygomatic osteotomy with partial removal of the middle cranial base. The inferior margin of infratemporal tumor could be accessed via the transcranial route with zygomatic or orbitozygomatic osteotomy without complications including facial nerve injury in nine cases, and the lowest level of the infratemporal tumors was approximately 4.5 cm below the outer surface of the middle cranial base. In five of these 9 cases (2 schwannomas, 1 myxoma, 1 chondrosarcoma, and 1 malignant peripheral nerve sheath tumor), the tumors were localized in the infratemporal fossa, and in the other 4 cases (2 meningiomas, 1 glioblastoma, and 1 ameloblastoma), the tumors extended to both the intracranial space and the infratemporal fossa. In two cases (recurrent jugular schwannoma and mandibular osteosarcoma), a combined transcranial and transcervical approach (mandibular swing approach) was essential, because the resection line of the lower margin was too far from the middle cranial base. These results indicate that the transcranial approach, with or without zygomatic or orbitozygomatic osteotomy (zygomatic infratemporal fossa approach), is safe and effective for removal of some infratemporal tumors, and that a combined transcranial and transcervical approach is useful for removing infratemporal tumors with extensive downward extension.

Key words: infratemporal fossa, transzygomatic approach, transcervical approach, schwannoma, epidural subtemporal approach

Introduction
Parapharyngeal tumors are rare but include various types of neoplasms, and are usually treated by otolaryngologists, using three different methods for the infratemporal fossa approach. The removal of these tumors is still challenging, because of the rarity and the complex anatomy surrounding the tumors. The parapharyngeal space is classically divided into two parts, the anterior (prestyloid) space and the posterior (poststyloid) space, and the main target of the conventional approaches is the posterior part of the parapharyngeal space. Recently, the anterior and posterior parapharyngeal spaces were subdivided into superior, middle, and inferior parts, based on anatomical landmarks to establish a standardized method for selecting surgical approaches. The infratemporal fossa consists of the anterior and superior-middle posterior parts of the parapharyngeal space. Some intracranial tumors may extend into the infratemporal fossa, thus requiring neurosurgeons to access this unfamiliar area. Trigeminal schwannoma is a typical type of tumor extending to the infratemporal fossa from the intracranial space.
tracranial space. The zygomatic or orbitozygomatic approaches were initially introduced to access deep-seated skull base lesions but zygomatic osteotomy also allows easy access to the infratemporal fossa via the transcranial route. However, the lower limit of access via the transcranial route through a zygomatic osteotomy has not yet been evaluated.

The present study analyzed 12 cases of tumors located in the infratemporal fossa or the intracranial space extending to the infratemporal fossa treated through the transcranial zygomatic or orbitozygomatic infratemporal fossa approach.

**Materials and Methods**

Twelve patients with tumors located in the infratemporal fossa or the intracranial space and extending to the infratemporal fossa have been treated by the first author since 2001, with or without the collaboration of otolaryngologists or oral and dental surgeons. The location, histology, and surgical approaches were analyzed. A summary of the cases is shown in Table 1.

The surgical strategy was designated according to the pathology, extension pattern, and location of each tumor. The surgical strategies for these 12 cases were classified into three groups: epidural subtemporal approach, zygomatic or orbitozygomatic infratemporal fossa approach, and combined transcervical approach (zygomatic infratemporal fossa approach and mandibular swing approach), as shown in Table 2. The designs of the skin incision, craniotomy, zygomatic or orbitozygomatic osteotomy, and mandibulotomy for these approaches are all shown in Fig. 1.

**Results**

**I. Subtemporal epidural approach**

One patient presented with a schwannoma arising from the proximal portion of mandibular nerve (Case 1). Magnetic resonance (MR) imaging and three-dimensional computed tomography (3D CT) bone imaging are shown in Fig. 2A, B. The tumor extended to the infratemporal fossa from the foramen ovale. The lower margin was approximately 1 cm below the external orifice of the foramen ovale. The tumor was completely removed through the epidural subtemporal approach without zygomatic osteotomy, preserving the main bundles of the mandibular nerve, part of which formed the origin of the tumor. Postoperative 3D CT bone imaging clearly demonstrated the area of bone resection (Fig. 2C) and postoperative MR imaging showed complete tumor removal (Fig. 2D).

**II. Zygomatic or orbitozygomatic infratemporal fossa approach**

Nine patients were treated using the transcranial approach with zygomatic or orbitozygomatic osteotomy (zygomatic infratemporal fossa approach).

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Tumor location</th>
<th>Histological diagnosis</th>
<th>Clinical symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36</td>
<td>F</td>
<td>IT</td>
<td>schwannoma (rt V3)</td>
<td>rt facial pain, facial paresthesia (V3 region)</td>
</tr>
<tr>
<td>2</td>
<td>67</td>
<td>F</td>
<td>IT</td>
<td>myxoma</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>M</td>
<td>IT</td>
<td>schwannoma (rt V3lin)</td>
<td>rt repeated tympanitis</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
<td>F</td>
<td>IT</td>
<td>schwannoma (rt V3lin)</td>
<td>rt facial pain, facial paresthesia (V3 region)</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>F</td>
<td>IT</td>
<td>MPNST* (lt V3)</td>
<td>lt facial pain, facial paresthesia (V3 region)</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>F</td>
<td>IT</td>
<td>chondrosarcoma*</td>
<td>disturbance of mouth opening</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>M</td>
<td>IC, IT</td>
<td>glioblastoma</td>
<td>headache</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>M</td>
<td>IC, IT, OR</td>
<td>meningioma</td>
<td>lt visual disturbance, lt exophthalmos</td>
</tr>
<tr>
<td>9</td>
<td>47</td>
<td>M</td>
<td>IC, IT, OR</td>
<td>meningioma</td>
<td>lt exophthalmos</td>
</tr>
<tr>
<td>10</td>
<td>70</td>
<td>F</td>
<td>IC, IT, OR</td>
<td>ameloblastoma (recurrent)</td>
<td>lt exophthalmos, double vision</td>
</tr>
<tr>
<td>11</td>
<td>28</td>
<td>F</td>
<td>IT</td>
<td>osteosarcoma**</td>
<td>swelling of rt cheek</td>
</tr>
<tr>
<td>12</td>
<td>63</td>
<td>M</td>
<td>IC, IT</td>
<td>schwannoma (jugular, recurrent)</td>
<td>lt deaf, cerebellar ataxia</td>
</tr>
</tbody>
</table>

*Final histological diagnosis has not been confirmed. **Surgery was performed after neoadjuvant chemotherapy. IC: infratemporal fossa, MPNST: malignant peripheral nerve sheath tumor, OR: orbit, V3: mandibular nerve, V3lin: lingual nerve.
Table 2  Level of lower margin, surgical strategy, and results

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Level of lower margin* (cm)</th>
<th>Strategy</th>
<th>Extent of removal**</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>epidural subtemporal approach</td>
<td>total removal</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>zygomatic infratemporal fossa approach</td>
<td>total removal</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>4.4</td>
<td>zygomatic infratemporal fossa approach</td>
<td>partial removal</td>
<td>none</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>zygomatic infratemporal fossa approach</td>
<td>total removal</td>
<td>none</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>zygomatic infratemporal fossa approach</td>
<td>total removal</td>
<td>none</td>
</tr>
<tr>
<td>6</td>
<td>0.5</td>
<td>zygomatic infratemporal fossa approach</td>
<td>radical resection</td>
<td>none</td>
</tr>
<tr>
<td>7</td>
<td>2.5</td>
<td>zygomatic infratemporal fossa approach</td>
<td>gross total removal</td>
<td>none</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>orbitozygomatic infratemporal fossa approach</td>
<td>subtotal removal</td>
<td>none</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>orbitozygomatic infratemporal fossa approach</td>
<td>subtotal removal</td>
<td>none</td>
</tr>
<tr>
<td>10</td>
<td>4.5</td>
<td>orbitozygomatic infratemporal fossa approach</td>
<td>gross total removal</td>
<td>deformity of cheek</td>
</tr>
<tr>
<td>11</td>
<td>4.5</td>
<td>combined transcranial and transcervical approach#</td>
<td>radical resection</td>
<td>transient lt facial nerve paresis†, transient pharyngeal edema††</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>combined transcranial and transcervical approach##</td>
<td>subtotal removal</td>
<td>none</td>
</tr>
</tbody>
</table>

*Distance from outer surface of middle cranial base. **Macroscopic total removal and removal with safety margin of malignant tumor was defined as “gross total removal” and “radical resection,” respectively. #Zygomatic infratemporal fossa approach and mandibular swing approach. ##Zygomatic petrosal approach and mandibular swing approach. †Caused by manipulation of cerebellopontine angle tumor. ††Caused by transcervical approach.

Five tumors were localized in the infratemporal fossa, as shown in Fig. 3A–E (Cases 2–6). Four tumors were completely removed, but one tumor was unintentionally only partially removed in a patient with minimal symptoms, because of the multilobular extension pattern and the presence of a fibrous septum in the tumor (Case 3). Two cases of schwannomas originated in the lingual nerve and other branches of the mandibular nerve were preserved. One case of malignant peripheral nerve sheath tumor (MPNST) was thought to originate from a branch of the mandibular nerve, but continuity of the tumor to any nerve was not possible to identify, and both the mandibular and maxillary nerves were preserved.

Representative postoperative bone defects are shown in Fig. 4. Figure 4A shows the osteotomy for the complete radial removal of the mandibular joint in a patient with a chordrosarcoma (Case 6). Figure 4B indicates the maximal resection of the middle cranial fossa, preserving the third to sixth cranial nerves, the cochlea, the optic nerve, the mandibular joint, and the internal carotid artery in a patient with massive skull invasion of a meningioma (Case 8).

One patient with myxoma was asymptomatic, and two patients with trigeminal schwannoma and MPNST presented with facial pain, which immediately disappeared after tumor removal. Postoperative radiotherapy was performed in a patient with MPNST, who showed no local recurrence for 10 months, but developed a single skull metastasis, which was radically removed. A patient with a mandibular joint tumor with disturbance of mouth opening was treated under a tentative diagnosis of chondrosarcoma, and the preoperative symptoms immediately improved after radical tumor resection with a safety margin.

The other 4 patients had tumors extending to the infratemporal fossa from the intracranial space (2 meningiomas and 1 glioblastoma) or extending to the intracranial space from the infratemporal fossa (recurrent ameloblastoma) as shown in Fig. 3F–I (Cases 7–10). Gross total resection was performed without complications in these four patients, but one patient with glioblastoma died of recurrence 16 months after tumor removal despite postoperative chemoradiotherapy.

III. Combined transcranial and transcervical approach

Two patients were treated via a combined transcranial and transcervical approach (Cases 11 and 12). One patient with mandibular osteosarcoma (Fig. 5A) underwent complete radical tumor resection fol-
following methotrexate and cisplatin-based neoadjuvant chemotherapy. The lines of the osteotomy for complete radical removal were along the level of the second molar of the mandible and the mandibular fossa of the temporal bone as indicated in Fig. 5B. The combined transcranial approach with zygomatic osteotomy and transcervical approach were essential. Intraoperative views during this combined approach are shown in Fig. 5C, D. The osteosarcoma was radically removed with the collaboration of dental and oral surgeons, and the defect of the mandible was reconstructed with a titanium plate (Uni-Lock Plate®; Synthes Holding AG, Solothum, Switzerland) without major complications, followed by additional chemotherapy. No recurrence was detected for 6 years after the tumor removal.

The other patient with recurrent jugular schwannoma presented a very complicated tumor extension pattern (Fig. 6A, B). Total removal of this tumor required three distinct approaches; the zygomatic petrosal approach, the transcervical approach, and the transsphenoidal approach. Figure 6C shows the residual tumor after tumor removal through the combined transcranial and transcervical approach with the collaboration of otolaryngologists, which was totally removed through the staged transsphenoidal approach, as indicated by postoperative MR imaging (Fig. 6D, E). The patient suffered postoperative transient mild facial nerve paresis and pharyngeal edema, which completely subsided within a month.

Discussion

Our experiences clearly indicated that we can access the superior portion of the infratemporal fossa through the epidural subtemporal approach without requiring zygomatic osteotomy by performing only partial resection of the middle cranial base. In most cases, zygomatic osteotomy and drilling of the middle cranial base were essential for the removal of infratemporal tumors through the transcranial ap-
Fig. 3  T₁-weighted magnetic resonance images with gadolinium (A, B, D–H) and T₂-weighted images (C, I) of Cases 2–10 (A–I, respectively) treated by the zygomatic or orbitozygomatic infratemporal fossa approach. A: myxoma; B, C: lingual nerve schwannoma; D: malignant peripheral nerve sheath tumor (histological diagnosis not confirmed); E: chondrosarcoma (histological diagnosis not confirmed); F: glioblastoma; G, H: meningioma; I: ameloblastoma.

Fig. 4 Postoperative three-dimensional computed tomography bone images of Case 6 (A) and Case 8 (B).

Fig. 5 Case 11. A: Coronal T₁-weighted magnetic resonance image with gadolinium showing a mandibular osteosarcoma (arrow). B: Three-dimensional computed tomography bone image illustrating the osteotomy for radical resection (lines) of the tumor (asterisk). C: Intraoperative photograph after mandibulotomy via the transcervical approach. D: Intraoperative photograph showing the right mandibular nerve and the proximal portion of the lingual and inferior alveolar nerves exposed via the transcranial approach. IAN: inferior alveolar nerve, LN: lingual nerve, MN: mandibular nerve, MT: mandibulotomy, SMG: submandibular gland.

Fig. 6 Case 12. A, B: Preoperative axial (A) and sagittal (B) T₁-weighted magnetic resonance (MR) images with gadolinium showing a recurrent jugular schwannoma. C: T₁-weighted MR image with gadolinium showing a residual tumor in the sphenoid sinus after the combined transcranial (zygomatic petrosal approach) and transcervical approach (mandibular swing approach). D, E: Axial (D) and sagittal (E) T₁-weighted MR images with gadolinium showing no residual tumor after the second stage transsphenoidal surgery.

proach. This series included four tumors localized in the infratemporal fossa and a small mandibular joint tumor, which were removed through the transcervical approach with zygomatic osteotomy. The lowest margin of these tumors was 4.5 cm below the outer surface of the middle cranial base. The
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otolaryngologists were ready to participate in tumor removal via the transcervical approach in some cases, but the inferior margin of the tumors could be accessed via the transcranial route with zygomatic osteotomy. Some of these tumors may be totally removed via the transcranial approach, such as the transparotid approach or the mandibular swing approach.9,10,16) Transcranial approach has some advantages for the removal of these tumors: no skin incision on the face and the neck, and no manipulation of the facial nerve. Therefore, the transcranial approach with zygomatic osteotomy should be considered as one of the main routes to access infratemporal tumors.

The combined transcranial and the transcervical or transfacial approaches have been applied to remove massive infratemporal fossa tumors.7,10,11,17) In two cases of the present series, a combined transcranial and transcervical approach was performed. In a case of osteosarcoma, the transcranial approach was very useful to dissect the mandibular joint and the upper part of the mandible with the surrounding muscles without manipulating the parotid gland, which is penetrated by the facial nerve. The mandibulotomy should be performed with a safety margin from the tumor, and dissection of the tumor with the surrounding muscles was completed via the transcervical route. Another case of recurrent jugular foramen schwannoma showed an unusual extension pattern to the cervix via an eroded pyramidal apex and upper clivus. The inferior margin of the tumor was 6 cm below the outer surface of the middle cranial base, which could not be accessed via the transcranial route. The mandibular swing approach, which is one of the standard methods to access the anterior part of the parapharyngeal space,1,19) was effective to remove the lower part of the tumor. These results indicate that the transcervical approach is essential to manipulate the anterior inferior part of the parapharyngeal space.

Many crucial structures, such as the internal carotid artery, the jugular vein, the lower cranial nerves, and other important anatomical structures, are located in the posterior part of the parapharyngeal space, so tumors should be treated differently.2,4,9,10,16) The current findings clearly indicate that tumors in the anterior superior and anterior middle parts of the parapharyngeal space could be accessed via the transcranial route, via the zygomatic infratemporal fossa approach, and that this approach has some advantages in both cosmetic concerns and preservation of the facial nerve. This approach is familiar to neurosurgeons, whereas tumors localized in the infratemporal fossa are the territory of otolaryngology or dental and oral surgery. The collaborations of surgeons from different fields are essential for the management of tumors in the infratemporal fossa. Despite the rarity of these tumors and the complexity of the surgical anatomy of this area, accumulated knowledge and experiences from clinical cases and cadaveric studies have helped to improve the surgical strategy to remove tumors in the infratemporal fossa.8,14,15,20)

The present analysis indicates that the transcranial approach, via the zygomatic infratemporal fossa approach, should be considered to access the anterior and superior-middle parts of the parapharyngeal space, including the infratemporal fossa.

References


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region is too difficult to be explored for someone who has not devoted enough time to microanatomical dissection of the region. Even more, these tumors in the lateral and under aspect of the skull base can only be successfully surgically resected with a well coordinated and qualified team. According to the extent of the lesion, the team has to be put together regarding the specialty. It is impossible to discuss the details in comments regarding these complex anatomical compartments, where so many crucial neural and vascular structures are involved in the tumorous lesions.

The authors have to be congratulated for demonstrating the complexity of the pathological conditions, also in front of a neurosurgical audience. For sure, these pathologies in the infratemporal fossa and parapharyngeal space related to the region where the neurosurgical domain has to be involved in the team if at least relatively good results are to be expected. And what are relatively good results in this uppermost splanchnocranial region? It means that all the benign structures, all CNs, and all the vascular structures should be left without surgical lesion. A lot of work lies ahead of those teams which will be involved in the domain. And I can only see a great future for microsurgical interventions in the above mentioned region(s).

Vinko V. DOLENC, M.D.
Department of Neurosurgery
University Medical Center Ljubljana, Slovenia

This is a nice report describing the management of tumors located high in the infratemporal fossa with and without extension intracranially. The authors have described a variety of tumor types in this region. The tumors have been approached by 3 types of surgical approaches with progressively increasing exposure and access to the infratemporal fossa. A subtemporal extradural approach is combined with a zygomatic or orbitozygomatic osteotomy in most of the cases. In larger tumors this approach is combined with other approaches such as the transcervical approach and even with a midline mandibulotomy. They have achieved good results in terms of tumor resection with minimal complications. The 2 cases of en plaque meningiomas, as expected, were removed subtotally. It was interesting to note the case of the glioblastoma multiforme where they also used this approach achieving complete removal. Despite this, the patient died from recurrence. The present report reemphasizes this versatile approach to a difficult area that has also been described by other authors. Larger tumors may require the combination with other approaches. The biology of the tumor is an important consideration in the ultimate prognosis of the patient.

Chandranath SEN, M.D.
Department of Neurosurgery
St. Luke’s-Roosevelt Hospital Center
New York, New York, U.S.A.

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