Transzygomatic Approach with Intraoperative Neuromonitoring for Resection of Middle Cranial Fossa Tumors*

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Abstract

The authors reviewed the surgical experience and operative technique in a series of 11 patients with middle fossa tumors who underwent surgery using the transzygomatic approach and intraoperative neuromonitoring (IOM) at a single institution. This approach was applied to trigeminal schwannomas ($n = 3$), cavernous angiomas ($n = 3$), sphenoid wing meningiomas ($n = 3$), a petroclival meningioma ($n = 1$), and a hemangiopericytoma ($n = 1$). An osteotomy of the zygoma, a low-positioned fronto-temporal craniotomy, removal of the remaining squamous temporal bone, and extradural drilling of the sphenoid wing made a flat trajectory to the skull base. Total resection was achieved in 9 of 11 patients. Significant motor pathway damage can be avoided using a change in motor-evoked potentials as an early warning sign. Four patients experienced cranial nerve palsies postoperatively, even though free-running electromyography of cranial nerves showed normal responses during the surgical procedure. A simple transzygomatic approach provides a wide surgical corridor for accessing the cavernous sinus, petrous apex, and subtemporal regions. Knowledge of the middle fossa structures is essential for anatomic orientation and avoiding injuries to neurovascular structures, although a neuronavigation system and IOM helps orient neurosurgeons.

Keywords

- ▶ middle fossa approach
- ▶ skull base surgery
- ▶ motor-evoked potentials
- ▶ intraoperative monitoring
- ▶ neurophysiology

Access to the floor of the middle cranial fossa (MCF) is often required when performing cranial base approaches to expose various lesions of the petrous apex, petroclival junction, internal auditory canal, and posterior cavernous sinus. In many patients with these lesions, a temporal craniotomy is sufficient to reach the floor of the MCF. However, the caudal limit of a simple temporal craniotomy is the zygomatic arch, which can present an obstacle in accessing the MCF in some individuals. Several authors have advocated mobilizing the

zygomatic arch by performing a simple zygomatic osteotomy or using extended frontotemporo-orbitozygomatic approaches to reach low-lying lesions.^{1–3}

Intraoperative neuromonitoring (IOM) is one of the methods in which modern neurosurgery can improve surgical results while reducing morbidity. Motor-evoked potentials (MEPs) obtained by transcranial electrocortical stimulation is routinely used to monitor major motor pathways intraoperatively during several neurosurgical procedures.^{4–6} Monitoring of oculomotor, trochlear, trigeminal, and facial nerve function is usually performed using free-running electromyography (EMG) or by direct stimulation of each cranial nerve.^{7–9}

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In the present study, we reviewed the surgical experiences and operative techniques in a series of 11 patients with MCF tumors who underwent surgery using a transzygomatic approach and IOM in a single institution.

Materials and Methods

We searched the database for any patients who underwent the transzygomatic approach for resection of tumors involving the MCF at our institution. Data from clinical notes, surgical reports, and radiologic findings were obtained for the analysis. Tumor location, size, and relation to neighboring anatomic structures were determined using preoperative computed tomography (CT) and magnetic resonance imaging (MRI). IOM was performed to preserve the cranial nerves and prevent the injury of neurovascular structures. Morbidity, follow-up, and outcome results were identified from entries in the clinical notes. The extent of the tumor resection was determined intraoperatively and confirmed by follow-up MRI taken postoperatively.

Anesthetic Protocol and Intraoperative Nerve Monitoring

Inhalational agents and neuromuscular blockade is avoided during anesthesia. After induction with propofol and rocuronium (1 mg/kg), neuroanesthesia was maintained using propofol (0.1 to 0.5 µg/kg/min) and a narcotic (remifentanyl [50 to 120 µg/kg/min]).

MEPs were monitored (Eclipse Neurological Workstation, Axon Systems Inc., NY) in all patients by a trained electrophysiologic team. A constant voltage stimulator is used for transcranial electrical stimulation; the stimulation is performed through a pair of spiral scalp electrodes using 3 to 5 pulses of 200 to 400 V with an interstimulus interval of 1 to 3 milliseconds, each pulse being 50 microseconds in duration. Muscle responses were recorded by subdermal needle electrodes placed in or over the following muscle groups bilaterally: flexor carpi radialis and flexor carpi ulnaris (arm); thenar and hypothenar muscles (hand); tibialis anterior (leg); medial gastrocnemius (leg); and abductor hallucis and abductor digiti minimi (foot).

Recordings were considered stable when spontaneous fluctuation was <50% in amplitude and 10% in latency. Reproducible decreases in amplitude and increases in latency exceeding these limits compared with the preceding average recordings were considered a significant deterioration. Complete disappearance of motor responses was classified as a loss.¹⁰ All significant MEP changes, including recovery after impairment or loss, were reported to the surgeon and documented after exclusion for technical reasons (e.g., displacement of the stimulating electrode).

Monitoring of the third, fifth, sixth, and seventh cranial nerve function was performed using free-running EMG or direct stimulation using a concentric bipolar handheld stimulation probe. The responses were recorded in the subdermally-placed needle electrodes in the medial rectus,

masseter, lateral rectus, and orbicularis oculi, and oris muscles.

Results

Eleven patients who underwent surgery via the transzygomatic approach for the treatment of MCF tumors were enrolled in the present study. There were four males and seven females, and their ages ranged from 24 to 64 years (mean age, 50.5 years). The patients mainly presented with headaches (36.4%), dizziness (18.2%), hemiparesis (18.2%), and seizures (18.2%). The underlying pathologies included three cavernomas, three trigeminal schwannomas, three sphenoid wing meningiomas, one petroclival meningioma, and one hemangiopericytoma. Primary bone tumors and metastases were excluded. IOM, including MEP and EMG of the cranial nerves, was performed in all patients. The characteristics of the patients are summarized in ►Table 1.

Our surgical techniques included interfascial dissection of the temporalis muscle, osteotomy of the zygoma, low-positioned frontotemporal craniotomy, removal of the remaining squamous temporal bone, and extradural drilling of the sphenoid wing (►Fig. 1), thus making a flat trajectory to the skull base. Two cuts were needed for the osteotomy of the zygoma. Titanium miniplates were applied to both lateral sides and removed before the osteotomies to facilitate the exact repositioning of the zygoma segments. The first cut was made through the root of the zygoma, just anterior to the temporomandibular joint. The second cut began at the frontozygomatic suture, which was parallel to the lateral orbital rim. The zygomatic arch was removed by freeing attachments from the masseter muscle. Opening of the cavernous sinus and V_{2,3} mobilization were performed for treatment of the cavernomas (case nos. 1, 2, and 3). Anterior petrosectomies were performed for the treatment of dumbbell-shaped trigeminal schwannomas (case nos. 4 and 5). Total, subtotal, and partial resections were achieved in nine, one, and one patient, respectively. The following surgical complications occurred: remote hemorrhage (case no. 3); wound infection (case no. 4); and prolonged operative time due to massive tumor bleeding (case no. 11).

MEPs and cranial nerve monitoring (third, fifth, sixth, and seventh nerves) were performed in 11 and 3 patients, respectively. Significant deterioration occurred during MEP recording in one patient (case no. 10). New weakness developed postoperatively which was permanent. In the patient with a hemangiopericytoma (case no. 11), MEP loss occurred with lowered blood pressure because of tumor bleeding, which recovered after an increase in blood pressure with successful hemostasis.

Long-lasting bursts and trains of neurotonic discharges did not develop during free-running EMGs of cranial nerves. New neurologic deficits developed postoperatively in four patients. Postoperative third nerve palsies developed in three patients (case nos. 2, 7, and 9). Ocular/trochlear motor nerve function remained unchanged in one patient (case no. 2) and

Table 1 Clinical Summary of 11 Patients Operated Via Transzygomatic Approach

Patient No.	Sex	Age (Years)	Presenting Symptom	Histology	Size (mm)	Degree of Resection	Intraoperative Nerve Monitoring	Complication
1	M	46	Seizure	Cavernoma	28 × 30	Total	MEP	—
2	M	62	Hemiparesis	Cavernoma	50 × 65	Total	MEP Third, fifth, sixth, and seventh, cranial nerves monitoring	Third and fourth nerves palsy
3	F	64	Headache	Cavernoma	34 × 40 × 39	Partial	MEP	Remote hemorrhage
4	F	43	Dizziness	Trigeminal Schwannoma	35 × 40 × 40	Total	MEP Third, fifth, sixth, and seventh, cranial nerves monitoring	Infection
5	M	52	Facial Pain	Trigeminal Schwannoma	52 × 25 × 40	Total	MEP Third, fifth, sixth, and seventh, cranial nerves monitoring	Facial palsy Dysesthesia
6	F	63	Headache	Trigeminal Schwannoma	18 × 30 × 26	Total	MEP	—
7	F	37	Seizure	Sphenoid Wing Meningioma	20 × 32 × 28	Total	MEP	3 rd nerve palsy
8	F	58	Headache	Sphenoid Wing Meningioma	30 × 36 × 32	Total	MEP	—
9	F	63	Hemiparesis	Sphenoid Wing Meningioma	40x42x40	Total	MEP	Third nerve palsy
10	F	43	Dizziness	Petroclival Meningioma	28 × 46 × 32	Subtotal	MEP	Hemiparesis
11	M	24	Headache	Hemangiopericytoma	75 × 56	Total	MEP	Bleeding

EMG, electromyography; MEP, motor evoked potentials.

Figure 1 Exposing the zygomatic arch after elevating the periosteum and superficial layer of the deep temporalis fascia (A). Inferior reflection of the temporalis muscle after detaching the zygomatic arch (B).

improved in two patients (case nos. 7 and 9). Postoperative facial palsies and dysesthesias developed in one patient (case no. 5), which slowly recovered.

Case Presentation

Case 1

A 62-year-old man presented for evaluation of left leg weakness of 3 months duration. The neurologic examination showed normal cranial nerve function. A brain MRI showed an extra-axial mass in the right MCF extending to the cavernous sinus, and parasellar and suprasellar regions. Compression of the midbrain and temporal lobe was noted. The tumor appeared as an iso-signal area on T1 weighted MRI, a high signal on T2 weighted MRI, and delayed centripetal enhancement on dynamic Gd-MRI (►Fig. 2). The patient underwent tumor excision using a transzygomatic approach and IOM (►Fig. 3). There was no significant deterioration of MEPs and trains of neurotonic discharges of a free-running EMG of the third, fifth, sixth, and seventh cranial nerves. A postoperative MRI revealed the total removal of the lesion (►Fig. 4). The histopathology report confirmed the lesion to be a cavernous hemangioma. A third and fourth nerve palsy was noted postoperatively, which persisted for 6 months. The motor power of the left leg was not changed.

Case 2

A 52-year-old man was referred for assessment of right facial pain and dizziness. Preoperative radiologic images showed a dumbbell-shaped mass in Meckel's cave on the right compressing the pons (►Fig. 5). The lesion measured 52 × 25 × 40 mm. The patient underwent tumor excision using a transzygomatic approach and IOM. There were no trains of neurotonic discharges of a free-running EMG of the third, fifth, sixth, and seventh cranial nerves during the surgery. A reduction in the amplitude of the MEPs recovered after re-adjustment of the retractor (►Fig. 6). A postoperative MRI revealed total removal of the lesion (►Fig. 7). The histopathologic findings were consistent with a schwannoma. The postoperative facial palsy improved slowly; however, the facial dysesthesia remained. Motor weakness did not develop.

Discussion

We have performed the transzygomatic approach for the resection of MCF tumors with the following characteristics: the long diameter is >30 mm; access to the floor of the MCF is required; and trigeminal nerve mobilization and cavernous sinus manipulation are needed. A zygomatic osteotomy with drilling of the remaining temporal bone and sphenoid wing helps to reach low-lying lesions because the caudal limit of a temporal craniotomy is the zygomatic arch. This approach offers wide visualization of the extradural structures, such as the three divisions of the trigeminal nerve and the cavernous sinus.^{11,12} Arterial feeder coagulation, peeling of the MCF dura, trigeminal nerve mobilization, and petrosectomy can be achieved with minimal brain retraction during the early stage of tumor resection by this technique. In our series, there was no morbid cerebral retraction, except for the petroclival meningioma (case no. 10). In our opinion, the main advantages of the transzygomatic approach are the simplicity and the direct access to the lesion with minimal elevation of the temporal lobe. However, the risk of temporalis muscle atrophy, facial nerve palsy, and temporomandibular joint injury, such as dislocation or ankylosis could be increased. A simple zygomatic osteotomy was preferred, which was associated with low procedure-related morbidity. A recent report has suggested that a zygomatic osteotomy may be reserved for lesions that extend well below the floor of the MCF or in cases in which the zygomatic arch is very high above the floor of the MCF or in patients with an exceptionally thick temporalis muscle.¹³ We agree that the routine use of the transzygomatic approach for the resection of MCF tumors is not necessary. The decision should be individualized based on the size and location of the lesion, the surgical goals, and the neurovascular anatomy surrounding the tumor.

Transcranial electrical MEP is feasible for intraoperative monitoring during MCF tumor surgery. Significant MEP changes occurred in 3 of 11 patients. Retractor adjustment and bleeding control restored the MEPs and prevented injury of the motor pathway in two patients (case nos. 5 and 11). A significant decrease in amplitude and latency

Figure 2 Preoperative magnetic resonance image showing a well-demarcated mass in the right middle cranial fossa involving the cavernous sinus (A: T2-weighted axial, B: T2-weighted coronal image). Faint enhancement was noted early after Gd injection in T1-weighted and enhanced axial images (C). The delayed image (25 minutes later) showing strong enhancement (D).

Figure 3 Conventional electromyography needles were inserted into the lateral rectus muscles (A). Intraoperative motor evoked potentials recording showed no significant changes (B). Recordable baseline motor evoked potentials were not exhibited in the left anterior tibialis.

Figure 4 Postoperative magnetic resonance image showing total removal of a middle cranial fossa tumor (A: T1-weighted axial, B: T1-weighted enhanced axial image, C: T1-weighted enhanced coronal image). Abdominal fat (asterisk) was placed for the prevention of cerebrospinal fluid leakage.

Figure 5 Preoperative magnetic resonance image showing a dumbbell-shaped mass in the right middle cranial fossa involving the cavernous sinus (A: T1-weighted axial, B: T1-weighted enhanced axial image). Heterogeneous enhancement was noted.

Figure 6 Motor evoked potentials recovery of the left anterior tibialis after re-adjustment of the retractor.

deterioration was observed and was irreversible in surgery involving a petroclival meningioma. Although cessation of surgery was determined, the initial weakness was severe. A new motor deficit secondary to intraoperative events is predicted by MEP deterioration and is reversible within a short time if MEP recovery is achieved by early signs and ensuring a surgical reaction, such as re-adjustment of the

retractors, application of papaverine, and temporary or definite cessation of resection at a specific critical site. However, the monitoring procedure did not completely prevent permanent MEP loss and severe or long-lasting new paresis in 6.1% cases, despite surgical intervention.¹⁰ Newly developed motor weakness occurred without intraoperative MEP alterations in other patients with supratentorial meningiomas and malignant gliomas in whom postoperative imaging showed severe brain swelling and rebleeding. MEPs recorded during dissection cannot predict late postoperative paresis caused by postresectional effects.¹⁴ Currently, it is acceptable that a persistent intraoperative MEP reduction of >50% is associated with postoperative motor deficits.^{15,16}

Cranial nerve paresis is usually an inevitable byproduct of treating MCF tumors. The oculomotor and trochlear nerves are the most vulnerable nerves resulting in this complication owing to the trajectory through the cavernous sinus and tentorial incisura.^{17,18} Therefore, EMG and nerve conduction studies have been used to monitor the oculomotor, trochlear, trigeminal, abducens, and facial nerves during surgery in the MCF.^{19–21} In our series, a free-running EMG of the third, fifth, and seventh cranial nerves failed to predict new neurologic deficits postoperatively, although direct electrical stimulation could help to identify and distinguish the cranial nerves. The reasons for the failure could be explained by needle malposition or misunderstanding of the signal-to-noise ratio. Saline irrigation and electrical cautery induce trains of neurotonic discharges without production damage to motor or sensory axons. Neurotonic discharges do not necessarily indicate nerve damage and their absence do not exclude nerve injury. Controlled studies are not available to determine whether or not cranial nerve monitoring during MCF surgery reduces the risk of postoperative ophthalmoplegia,²² although there are

Figure 7 Postoperative magnetic resonance image showing total removal of middle cranial fossa tumor (A: T1-weighted axial, B: T1-weighted enhanced axial image).

controlled data to suggest that monitoring reduces the risk of cranial nerve injury in selected situations (e.g., facial nerve during acoustic schwannoma resection, and auditory nerve during acoustic schwannoma and microvascular decompression for hemifacial spasm).^{23–25}

Conclusion

The transzygomatic approach for surgical treatment of large MCF tumors provides a wide surgical field without retraction injuries of the brain. Significant motor pathway damage can be avoided using MEP changes as an early warning sign. The efficacy of a free-running EMG of cranial nerves should be investigated by further studies.

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