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Stepwise Dissection Using the Extradural Transcavernous Approach (Dolenc's Approach) via a Modified Orbitozygomatic Craniotomy

Cheng-Mao Cheng[1*], Han-Kyu Kim[2], Chi-Tun Tang[1], Shih-Wei Hsu[1], Yuahn-Sieh Huang[3], Akio Noguchi[4], Aclan Dogan[5], Sean McMenomey[6], and Johnny B. Delashaw[7]

[1]Department of Neurological Surgery, Tri-Service General Hospital, National Defense Medical Center, Taipei, Taiwan, Republic of China;
[2]Department of Neurosurgery, Eulji University Hospital, Daejeon, Korea;
[3]Department of Biology & Anatomy, National Defense Medical Center, Taipei, Taiwan, Republic of China;
[4]Department of Neurosurgery, Kyorin University School of Medicine, Tokyo, Japan;
[5]Department of Neurological Surgery; [6]Department of Otolaryngology, Oregon Health & Science University, Portland, Oregon, USA;
[7]Departments of Neurological Surgery, University of California, Irvine, California, USA

Background: To present a stepwise dissection using the extradural transcavernous approach (Dolenc's approach). **Methods:** Two formalin-fixed and latex-injected imported cadaver heads were dissected at the Tri-Service General Hospital skull base laboratory. Extradural transcavernous dissections were made via a modified orbitozygomatic craniotomy. **Results:** The results were illustrated with a series of photographs of the scalp phase, skull phase, and dura phase sequences. **Conclusions:** Stepwise dissection using skull base approaches can be performed in a systematic manner so that workshop participants can efficiently learn more about the donated human cadaver.

Key words: Dolenc's approach, skull base surgery, workshop

INTRODUCTION

Skull base surgery is a surgical method for removing lesions on the base of the skull. All major neurovascular structures, such as the 12 cranial nerves, bilateral internal carotid arteries (ICAs), bilateral vertebral arteries, and bilateral sigmoid sinuses, exit or enter the skull base at very close vicinity to the brain stem. Hence, lesions of the skull base are either already entangled or will further compress one of the neurovascular structures. Skull base approaches were considered "no man's land" before the era of modern neurosurgery. However, modern neurosurgery consists of refined microneuroanatomy knowledge and delicate microneurosurgical techniques that have significantly improved patient outcome. A hands-on workshop is considered the most effective way to convey the knowledge and surgical techniques of skull base surgery. Despite of the rare and invaluable resource of a cadaver specimen, there is still a paucity of stepwise dissection manuals designed for participants who are attending a cadaver dissection workshop. Our goal is to prepare an electronic dissection manual, so that the participants of a particular cadaver dissection workshop can prepare themselves in advance and the donated cadaver specimen can be best utilized and appreciated.

Modified orbitozygomatic (MOZ) craniotomy was introduced by Balasingam and Delashaw *et al.*[1] in 2005 as a variant of supraorbital craniotomy.[2] Orbitozygomatic craniotomy was described by Zabramski *et al.*[3] This procedure provides wide exposure to the skull base but requires additional removal of the zygomatic arch and lateral-inferior part of the orbital rim; thus, it is time-consuming for beginners. In contrast, MOZ craniotomy spares the need for zygomatic arch removal and is an ideal method for practicing the skull base techniques around the orbital fissure, cavernous sinus, parasellar region, and upper third of the brain stem.

The indication of selecting MOZ craniotomy is to treat the vascular or tumorous lesion involving the area of the orbital apex, paraclinoid and parasellar regions, cavern-

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*Corresponding author: Cheng-Mao Cheng, Department of Neurological Surgery, Tri-Service General Hospital, National Defense Medical Center, No. 325, Sec. 2, Cheng-Gong Road, Taipei 114, Taiwan, Republic of China. Tel: +886-2-87927177; Fax: +886-2-87927178; E-mail: amourchinag@hotmail.com

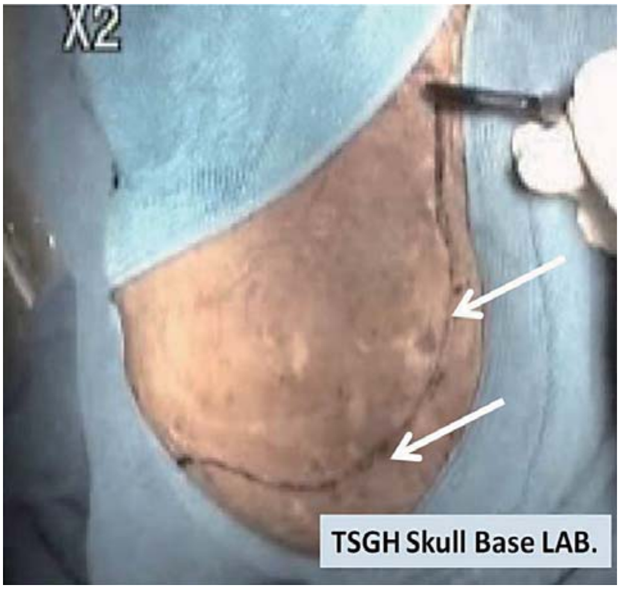


Fig. 1 Scalp marking from 0.5 cm below the zygomatic root and within 1 cm to the ipsilateral tragus, extending in the coronal plane across the midline to the contralateral superior temporal line.

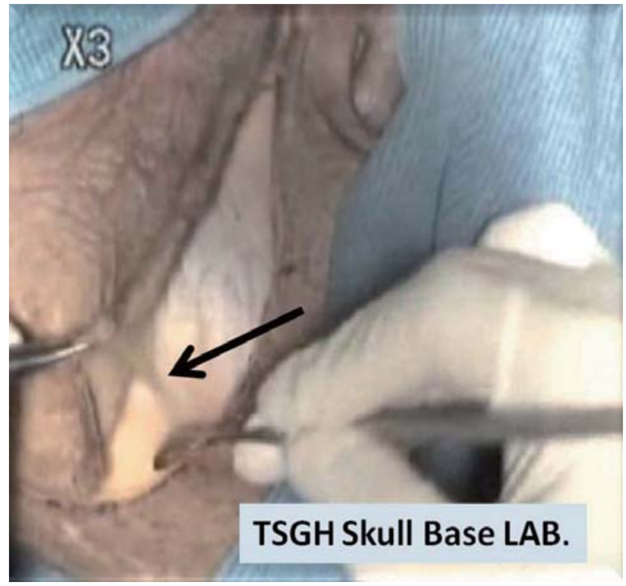


Fig. 2 The innominate ligament, which is the conjoining spot for the pericranium and superficial fascia of the temporalis.

ous sinus, and the anterior and middle fossa floor. Since the MOZ craniotomy involves the resection of the sphenoid ridge, it is not advisable to treat the lesions harboring the posterior temporal fossa, clival region below the jugular tubercle, and the cerebellar surface of the petrous ridge.

The advantages of MOZ craniotomy are as follows: (1) it is a simple and fast procedure that allows wide exposure of both anterior and middle fossa by eliminating the barrier of sphenoid ridge; (2) there is no need for removing the zygomatic proper, and thus less chance of injuring the frontal branch of facial nerve and greater ease for reconstructing the myocutaneous flap when compared with traditional orbitozygomatic craniotomy; (3) it provides early control of tumor bleeding by the devascularization of the vessel supply on the dura. Nevertheless, the MOZ craniotomy is always associated with inherent complications. For instance, the facial nerve might be injured if the interfacial dissection of the temporalis muscle is not well conducted; the unsecured fractured frontal sinus might lead to epidural abscess; and post-operative periorbital ecchymosis is frequently encountered and persists for weeks. These potential complications can be avoided and minimized by acquiring substantial surgical experience in cadaver hands-on workshop.

MATERIALS AND METHODS

Two imported cadaver heads were dissected at the Tri-Service General Hospital skull base laboratory. These specimens were fixed with 5% formalin; arteries were injected with red latex and veins were injected with blue latex. The cadaver heads were secured in wooden head holders, and dissected with a set of fine microneurosurgical instruments and a high speed drill (microMax, Anspach Companies, Palm Beach Gardens, FL, USA) under a surgical microscope (Zeiss OPMI, Carl Zeiss Surgical, Inc., Thornwood, NY, USA).

RESULTS

Scalp Phase

1a). Positioning

The head is rotated 10-15^{o} to the contralateral side (right side) and the vertex is brought down to the floor until the molar eminence reaches the uppermost part.

1b). Marking the incision line

Marking begins on the level 1 cm below the zygomatic root and stays within 1 cm of the ipsilateral tragus (Figure 1). The marking travels in a curvilinear fashion across the midline and ends anteriorly at the contralateral

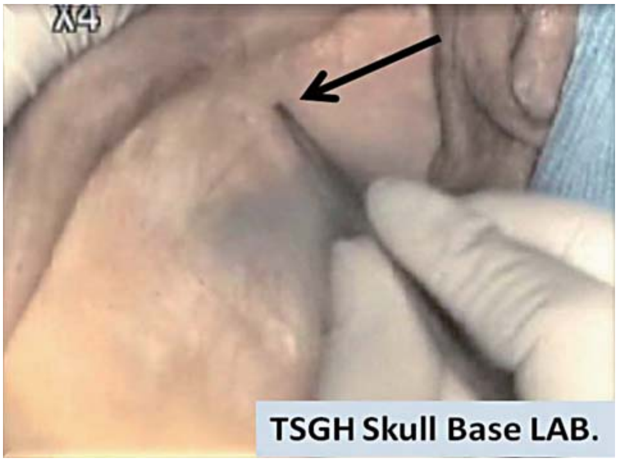


Fig. 3 The superficial fat pad unveiled by further scalp elevation (black arrow). At this point, any cutting or coagulation will damage the facial nerve before interfacial dissection of the temporalis.

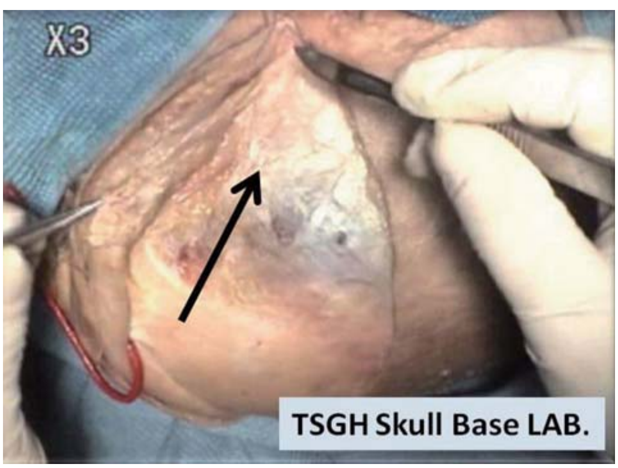


Fig. 4 The deep fat pad appearing during interfacial dissection. The superficial fat pad was flapped over the orbital rim.

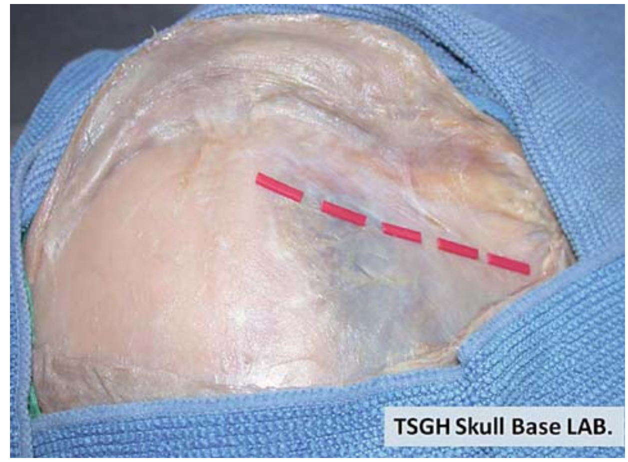


Fig. 5 Dotted red line is the incision line for an interfacial dissection.

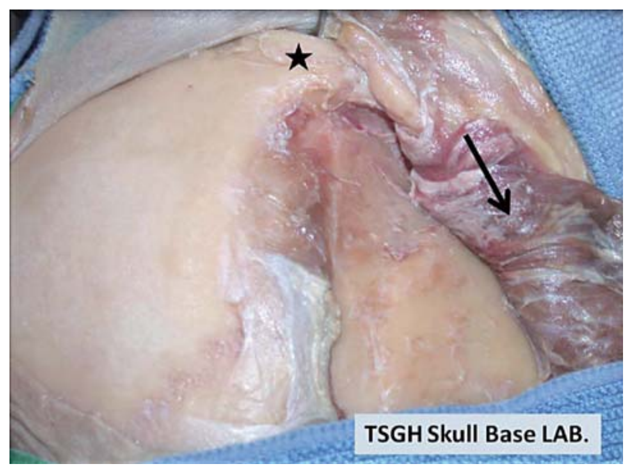


Fig. 6 Temporalis dissected downward to reveal the superior and lateral orbital rim.

superior temporal line. The imaginary line that connects start and end points must be anterior-inferior to the ipsilateral eyebrow.

1c). Scalp incision

The scalp incision (Figure 2) starts in an opposite direction. A bold and sharp incision is made into the skull bone from the contralateral superior temporal line to the ipsilateral superior temporal line. From this point, a scalp incision is carefully made into the layer beneath the galea aponeurotica downward to the start point mentioned above. Care should be taken not to violate the main trunk of the superficial temporal artery.

1d). Scalp flap dissection

The scalp flap in the subgaleal layer is carefully elevated and flapped toward the eyebrow. About 2 cm behind the frongozygomatic suture is a fat zone that spans the zygomatic root (Figure 3).

1e). Interfacial dissection of temporalis muscle

The fat plane consists of two layers (Figure 4): 1) the superficial fat pad, which is in the subgaleal layer with the facial nerve, and in conjunction with the periosteum along the superior temporal line; and 2) the deep fat pad, which lies underneath the superior temporal fascia. The periosteum is incised in a posterior-anterior fashion along the superior temporal line until 2 cm behind the frontozygomatic suture, where another incision is made

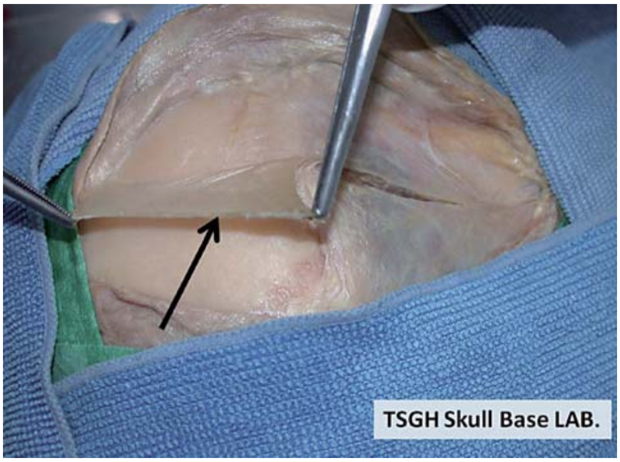


Fig. 7 Pericranial flap elevated from the underlying skull for reconstruction of the dura .

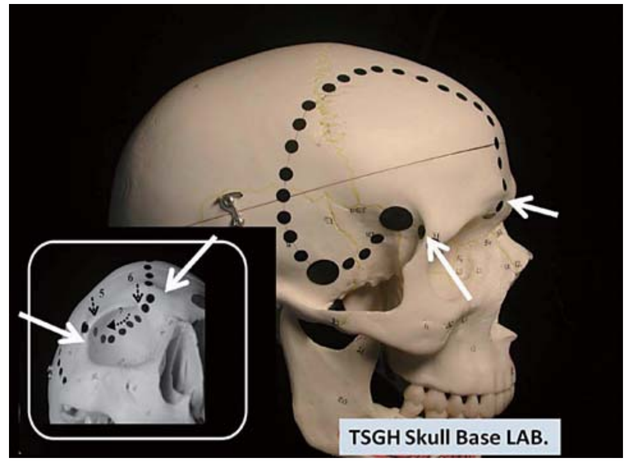


Fig. 9 A skull model depicting the bone cut for a MOZ craniotomy. White arrows indicate the orbital rim cut with a bone knife.

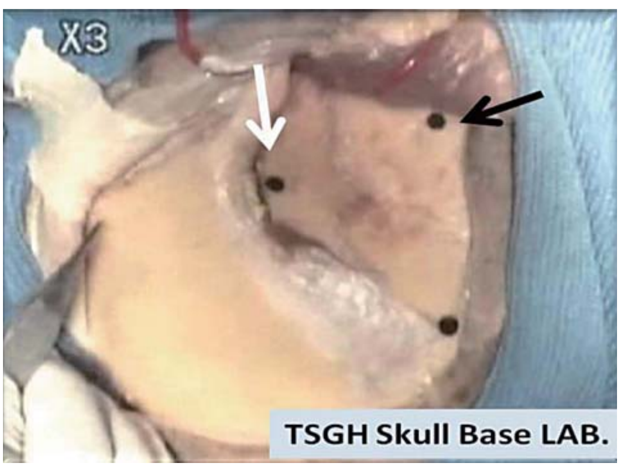


Fig. 8 Three burr holes for a MOZ craniotomy. White arrow indicates the anatomic keyhole hole behind the frontal process of the zygomatic bone. See text for detailed description.

Fig. 10 The supraorbital foramen being dissected downward along with the small orbital bone chip, which was divided with a bone knife (see text).

on the transparent fascia of temporalis muscle (Figure 5) toward the middle point of zygomatic arch. The interfacial dissection of temporalis muscle is conducted on the depth level of the deep fat pad. Dissection of the interfacial musculature (Figure 6) is performed, and the flap is elevated to reveal the zygoma and orbital rim.

1f). Preparation of periosteal flap

A square periosteal flap (Figure 7) is prepared. Its size should be large enough to cover the frontal sinus and supraorbital notch/or foramen. This flap is prepared for future closure of the opened frontal sinus.

1g). Temporalis dissection

The temporalis muscle is dissected from the skull toward the temporal base to reveal the entire lateral margin of the orbital rim (Figure 6) as well as the upper part of the zygomatic arch and the zygomatic root.

Skull Phase

2a) Location of three burr holes

The first burr hole is located in the anatomic keyhole (Figure 8), about 1 cm posterior and inferior to the zygomatic process of the frontal bone. The second burr hole is located immediately above the zygomatic root. The

Fig. 11 The bone knife for cutting the orbital rim. This bone knife consists of a ruler drill bit (long white arrow) and a short attachment (short white arrow).

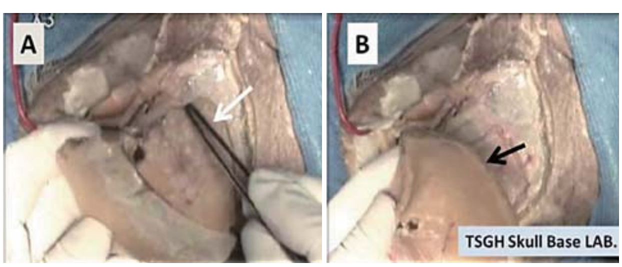


Fig. 12 Single-piece skull flap including the orbital rim osteotomy. (A) Outer view of the bone flap; (B) Inner view of the bone flap.

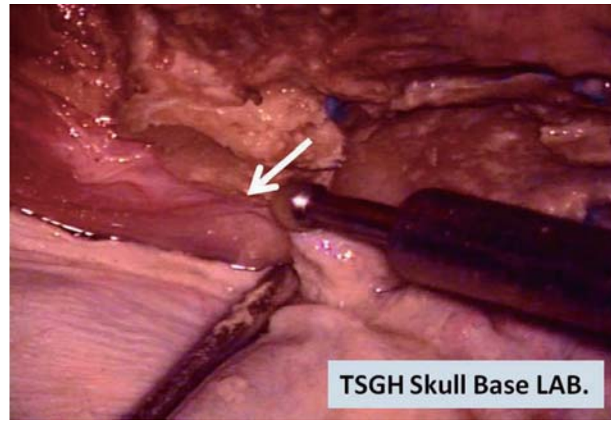


Fig. 13 Resection of the sphenoid ridge in the lateral-medial direction. The thick sphenoid bone was drilled off to visualize the meningo-orbital artery (white arrow).

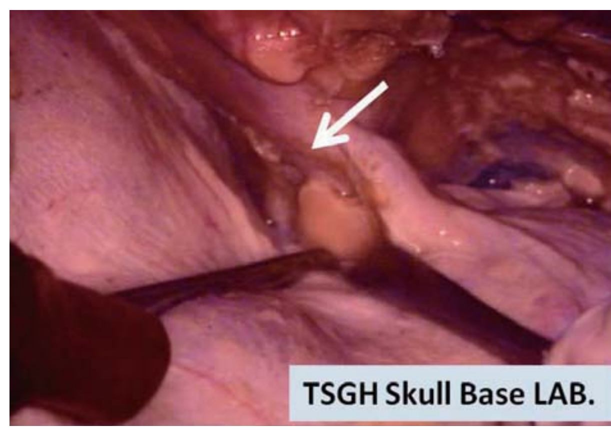


Fig. 14 Arrow depicts the optic canal unroofed with a diamond drill bit.

location of these two burr holes never changes. The location of the third burr hole is chosen depending on the size of the craniotomy. The bone cut for MOZ is described using a skull model (Figure 9)

2b). Preparation of supraorbital notch or foramen

In the case of the supraorbital notch, the supraorbital nerve is simply pushed over with the previously prepared scalp flap. However, in the case of the supraorbital foramen (Figure 10), the tiny bone chip on the orbital rim is fractured with the aid of an osteotome drill bit attached to the short hand guard piece, which serves as a bone knife (Figure 11).

2c). One-piece frontotemporal craniotomy with orbital osteotomy

The bone knife (the ruler drill bit with the short arm attachment) is employed to cut the orbital rim. The first cut starts from the anatomic keyhole to 0.5 cm lateral to the frontal process of the zygomatic bone, and the second cut commences 0.5 cm medial to the supraorbital notch or foramen to cut the medial orbital rim. The resection of this single-piece bone flap is completed by cutting from burr hole 1 to burr hole 3. The single-piece bone flap (Figure 12) can be elevated from the rest of the orbital roof using the fracture method.

2d). Sphenoid ridge resection

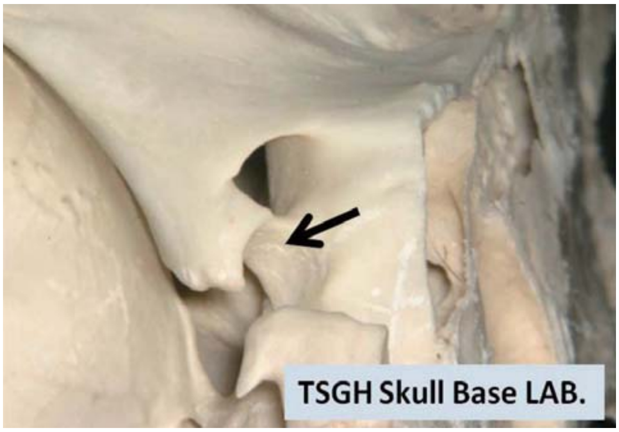


Fig. 15 Black arrow indicates the optic strut, dividing the optic canal and superior orbital fissure.

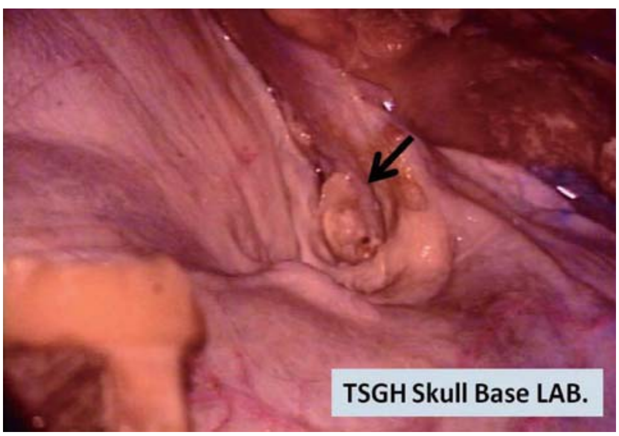


Fig. 16 Black arrow depicts the hallowed anterior clinoid process (ACP). Its drilling starts with a 2-mm cutting burr and is continued with a 2-mm diamond burr.

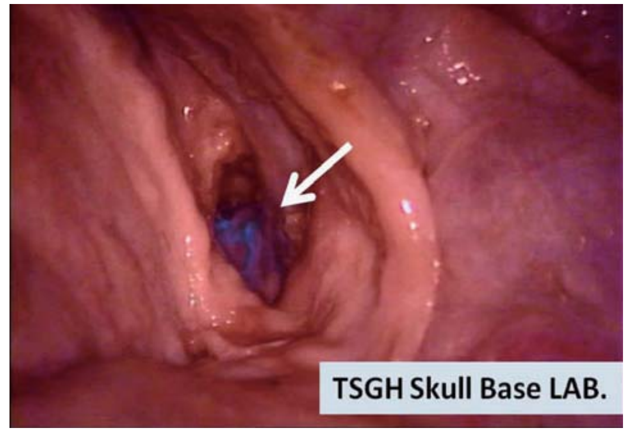


Fig. 17 An extradural view of the clinoid triangle. White arrow shows the clinoid segment of the internal carotid artery.

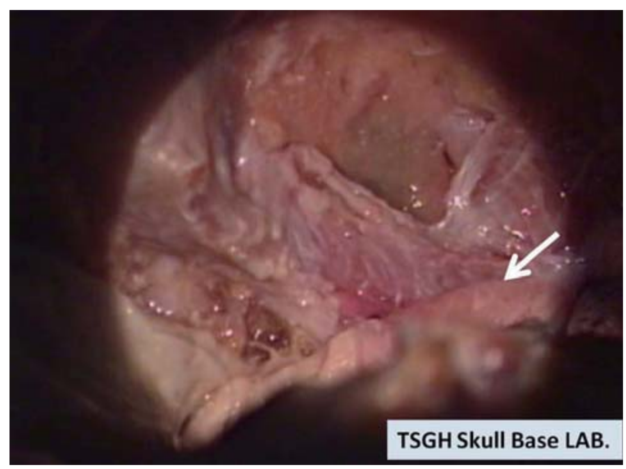


Fig. 18 Extradural temporal base dissection. White arrow indicates the interface between the dura propia and the outer layer of the cavernous sinus harboring V2 and V3.

The sphenoid ridge resection starts in the lateral-medial direction (Figure 13). First, the lateral part of the sphenoid ridge is drilled off with a drill burr until the orbitomeningeal artery is located. The anterior lateral part of the orbital roof is resected along with drilling of the remainder lateral part of the sphenoid ridge, until the lateral end of the superior orbital fissure is reached. At this point, the skull drilling stops. Participants proceed to the corresponding dura dissection (dura phase 3a).

2e). Release of optic canal

Resection of the orbital roof continues up to the optic canal region. A diamond burr is employed to release the upper part of the optic canal extradurally (Figure 14).

2e). Resection of anterior clinoid process (ACP)

The optic strut (Figure 15) is the ground pile of the ACP, and this strut separates the optic canal and the superior orbital fissure. Hence, drilling off the ACP until the optic strut is mandatory to release the boundary between the orbital cavity and temporal base. Hollowing of the ACP (Figure 16) is a crucial step. Drilling of the ACP starts with a 2-mm cutting burr and is continued with a 2-mm diamond burr, until the optic strut appears. At this point, the paraclinoid segment of ICA should be seen (Figure 17) (Go to procedure 3b).

Dura Phase

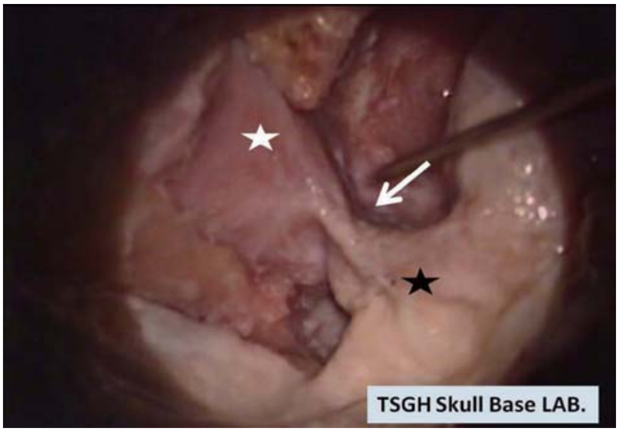


Fig. 19 White arrow depicts the junction of the periorbital tissue and the dura propia. Black star indicates the dura propia, and the white star indicates the periorbital tissue.

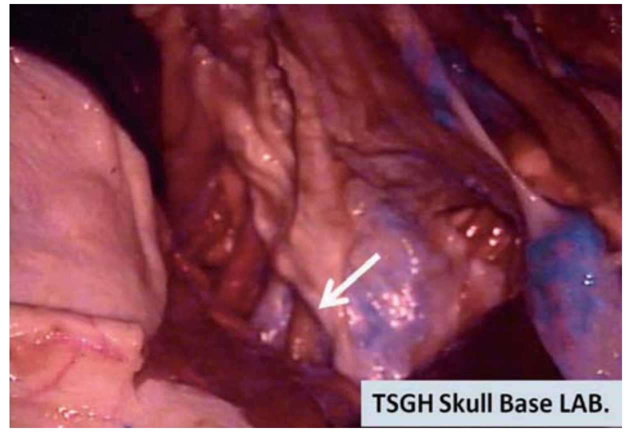


Fig. 21 White arrow depicts the oculomotor triangle bound with the anterior clinoid-petrous ligament, posterior clinoid-petrous ligament, and interclinoid ligament.

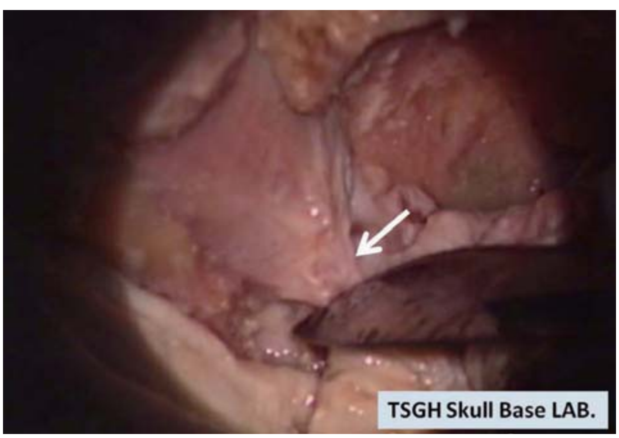


Fig. 20 White arrow shows the interface between the dura propia and periorbital tissue dissected with a sharp knife.

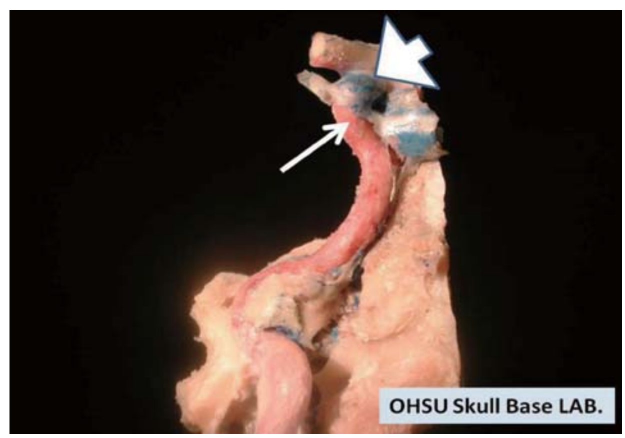


Fig. 22 Anterior view of the right disarticulated petrosal bone with the attached carotid artery. The proximal ring of the carotid artery (arrow) is seen to be spanning to the oculomotor nerve. The distal ring of the carotid artery (arrowhead) is seen to be connected to the optic nerve.

3a). Extradural dissection of temporal base

Extradural dissection of the temporal base starts in the posterior-anterior direction. Dissection begins by finding the interface (Figure 18) between the dura propia and the outer membrane of the mandibular branch of the trigeminal nerve (V3). The interface continues anteriorly to unveil the outer membrane of the maxillary branch of the trigeminal nerve (V2). At this point, parts of the periorbital tissue in the orbital cavity and temporal polar dura can be seen (refer to procedure 2e).

3b). Dissection of orbital meningeal band (OMB)

At this point, the only barrier between the orbitofrontal dura and temporal polar dura is the OMB (Figure 19). Sharp dissection of the OMB with a no. 15 knife (Figure 20) is recommended. As the dura propia is peeled off from the outer membrane of the cavernous sinus, the extradural transcavernous (Dolenc's) approach begins. The dissection continues to unveil the distal part of the optic and oculomotor nerves.

3e). Intradural dissection of cavernous sinus

A C-shaped incision of the dura is made and flapped centrally over the drilled off sphenoid ridge. Dissection begins by cutting the oculomotor triangle (Figure 21) to

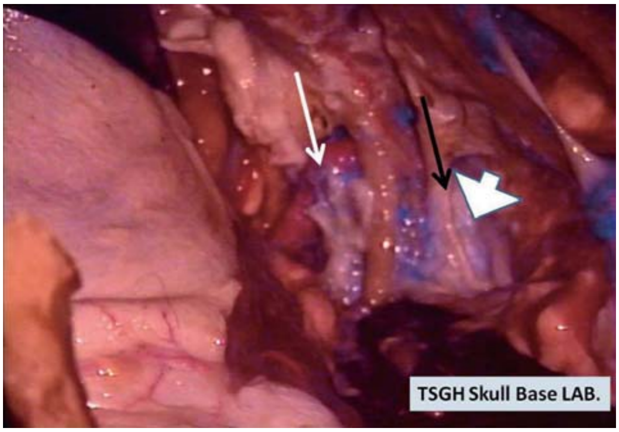
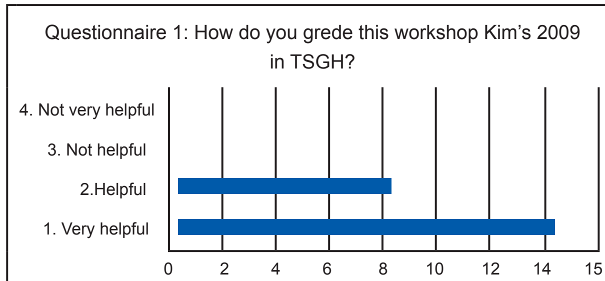


Fig. 23 Microscopic view of the right cavernous sinus. White arrow indicates the dissected proximal ring of the carotid artery. Black arrow shows the trochlear nerve. Lateral to the trochlear nerve is the intratrochlear triangle, which is also known as Parkinson's triangle.

Fig. 24 Parkinson's triangle, which contains the carotid segment of the internal carotid artery, the sixth nerve, and the meningohypophyseal artery.

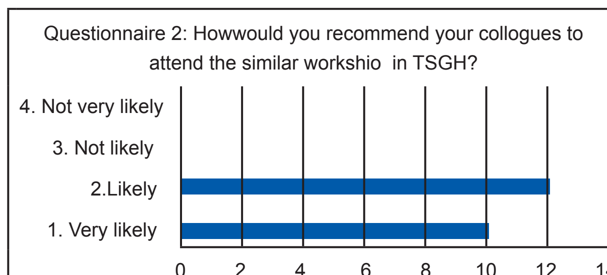
release the oculomotor nerve. Intradural dissection of the cavernous sinus starts by freeing the paraclinoid segment of the ICA. First, the distal ring spanning to the optic nerve is dissected free and cut. Next, the proximal ring (Figure 22) spanning to the oculomotor nerve is dissected free and cut (Figure 23). At this point, the entire paraclinoid segment of the ICA is released. By dissecting carefully along the ICA, the supratrochlear triangle is located by identifying the fourth cranial nerve. The infratrochlear (Parkinson's) triangle (Figure 24) is found lateral to the fourth nerve. The meningohypophyseal artery, carotid cave, and sixth nerve can be found in Parkinson's triangle.

Table 1 Question 1: How you find this workshop "Kim's 2009" at TSGH?
The numbers to the right of the bar denote the numbers of participants who gave the corresponding responses.



	1. Very helpful	2. Helpful	3. Not helpful	4. Not very helpful
Number of person	14	8	0	0

Table 2 Question 2: Would you recommend colleagues to attend similar workshops at TSGH?
The numbers to the right of the bar denote the numbers of participants who gave the corresponding response.



	1. Very helpful	2.Helpful	3. Not helpful	4. Not very helpful
Number of person	14	8	0	0

In 2009, Kim's stepwise cadaver dissection of skull base surgery was held in the National Defense Medical Center. A total of 39 participants from 18 hospitals attended the workshop. Of the 39 participants, 37 were male and 2 were female, 20 participants were neurosurgical residents and 19 were attending physicians. Twenty-two of the participants gave their feedback anonymously on secured website designed by the first author during the teaching course. The feedback comprised responses to two questionnaires (Tables 1 and 2). When asked to grade the workshop on its helpfulness, 14 (63.6%) participants graded this workshop as very helpful, and 8 (36.4%) participants rated it as helpful. When asked whether the participants would recommend the workshop to others, 10 (45.4%) participants scaled this workshop as very recommendable, and 12 (54.6%) ranked it as recommendable. All the participants gave positive feedback.

DISCUSSION

Profound knowledge of microneuroanatomy has been propagating in neurosurgical society, which ensures better patient care and outcome. As the central nervous system is the most blood flow-dependent system and also the most vulnerable one in the entire body, sophisticated skull base anatomy cannot be learned completely by live surgery. Among the variety of teaching materials for skull base surgery, a hands-on cadaver workshop is the most effective way to learn. However, there is paucity of manuals of stepwise cadaver dissections for participants who are going to attend a skull base surgery workshop.

The principles of a skull base surgery have remained unchanged in the past few decades. They include 1) maximal exposure of the skull base; 2) minimal retraction of the brain; 3) preventing neurovascular injury; and 4) reconstructing the basal skull and dura. The MOZ craniotomy is an excellent approach for participants to practice the techniques that provide wide exposure to the mid-clival region without disturbing the vital neurovascular structures.

We must define the meaning of maximal "exposure of the skull base". Here, exposure has two meanings: 1) the area of exposure of the skull base; and 2) degree of freedom with surgical instruments. Figuiredo *et al*. compared the area of skull base exposure between mini-supraorbital and standard frontotemporal craniotomy. They found no difference between these two craniotomies, implying that the size of the craniotomy above the skull base does not affect the area of exposure in skull base surgery. Schwarz *et al*.[4] studied the benefits of orbital rim and zygoma removal in addition to the standard pterional approach and found a 26-39% ($p < 0.05$) increase in surgical exposure by orbital rim osteotomy and an additional 13-22% (not significant) increase with removal of the zygomatic arch. Gonzalez *et al*.[5] also reported that the angle of attack was significantly greater with the orbitozygomatic approach (37.2 ± 4.7^{o}) than that with the pterional approach (27.1 ± 4.3^{o}). These studies had great influence on the choice of certain types of skull base surgery. First, the size of the craniotomy is not as important in terms of exposing the skull base; and second, the portion of the skull base resected matters. Removing the orbital rim is a very helpful procedure for gaining significant surgical freedom. Jane *et al*.[2] reported the technique of supraorbital craniotomy and illustrated its clinical application in treating disease of the parasellar region. Additional removal of the orbital rim by standard craniotomy had been reported in a large series report as a skull base approach.[6-9] Actually, MOZ craniotomy is a combination of an orbital rim osteotomy and a standard frontotemporal craniotomy, and is thus very useful for treating a wide variety of anterior-lateral skull base lesions.[10-12]

There is constant argument about the feasibility of orbital rim osteotomy. Nakamura *et al*.[13] used a frontolateral approach to treat large olfactory groove meningiomas without violating the orbital rim. In their treatment outcomes, total tumor removal was achieved in 91.2% of 82 patients; however, postoperative brain edema was noted in 7 patients (15.2%), suggesting that additional resection of the orbital rim might minimize brain retraction and improve patient outcome.

CONCLUSION

MOZ craniotomy is an excellent skull base approach to mastering the following surgical techniques: 1) orbital osteotomy; 2) repair of torn frontal sinus; 3) preservation of the supraorbital nerve; 4) interfacial dissection for protecting the facial nerve; 5) resection of the sphenoid ridge; 6) extradural removal of the ACP; 7) optic canal decompression; and 8) extradural dissection of the cavernous sinus. MOZ craniotomy enables surgeons to break the barrier between the orbital cavity, frontal base, and temporal base, and offers a low surgical corridor to vicinity of brain stem without over-traction of the brain.

DISCLOSURE

All authors declare no competing financial interests.

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