Extradural Approach to the Lateral Sellar Compartment

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This paper describes an extradural approach to the lateral sellar compartment (LSC, cavernous sinus), which represents a refinement of the original work performed on this topic by Parkinson, Dolenc, and Hakuba, and other enthusiastic neurosurgeons. This detailed description of the extradural approach is based on the dissection of 30 cadaver specimens and surgical experience of 110 LSC lesions. The extradural approach is based on the developmental anatomy of the LSC, and provides: (1) complete exposure of the entire LSC; (2) excellent control of the intracavernous carotid artery; (3) easier identification and less injury of the cranial nerves; (4) reduced brain damage with limited extradural retraction; (5) preserving the Sylvian vein and the sphenoparietal sinus; (6) minimal intradural blood spillage; (7) shorter operative time; (8) physiological reconstruction of the lateral wall to prevent CSF leakage; and (9) access to the contralateral LSC. As the LSC is an extradural space, the extradural approach may be safely employed to access lesions involving the LSC.

Key Words: Extradural, cavernous sinus, cranial nerve, internal carotid artery, microsurgery

INTRODUCTION

Advances in modern neuroimaging techniques and revived interest in microsurgical anatomy have resulted in more aggressive surgical approaches to the lateral sellar compartment (LSC, cavernous sinus). Surgical access to the LSC has traditionally been accomplished through a pterional, subtemporal, crano-orbitozygomatic intradural or combined intra-extradural approach. 8,10,12,21,25 It may be reasonable to access the LSC extradurally, because the LSC is an extradural space. The extradural approach includes the following components: 1) craniotomy with or without resection of the zygomatic arch; 2) extradural exposure of the superior orbital fissure and skull base foramina; 3) anterior clinoidectomy and unroofing of the optic canal; 4) extradural dissection of the lateral wall and the entire LSC. Detailed descriptions of the microsurgical anatomy and the various surgical approaches to the LSC are beyond the scope of this report. The purpose of this paper is to consider the concept of the extradural approach for LSC based on developmental anatomy.

MATERIALS AND METHODS

Fifteen formalin-preserved cadaver heads were dissected, yielding 30 specimens for study. The dissection study was performed under the operating microscope with standard microsurgical instruments, self-retaining retractors, and a high-speed air drill system. Microscopic photographs were obtained, and retouched with illustrations to highlight details. Histological study was performed with serial coronal sections of five adult LSCs and one fetal specimen. Personal experience of 110 LSC operations, over a 10-year period, is applied to discuss the surgical judgments and techniques.
SURGICAL APPROACH

Position and incision

The patient should be positioned as for routine pterional craniotomy, that is, in the supine position with slight neck extension and head turned 30 to 40 degrees to the contralateral side. The head should also be secured with a three-point skull fixation. A coronal skin incision is made starting at the level of the zygoma within 1 cm anterior to the tragus toward the midline and ending at the hairline. The interfascial approach is utilized to prevent injury to the temporal branch of the facial nerve. The superficial temporalis fascia is incised 3-cm posterior to the frontal process of the zygomatic bone and reflected anteriorly with the scalp flap. Subperiosteal dissection is carried out to expose the orbital rim, zygoma, and the zygomatic arch. The masseteric fascia and muscle attached to the inferior margin of zygomatic arch are then freed by dissection, below the level of the zygoma. The temporalis muscle and deep temporal fascia are then detached from the temporal bone, orbital rim, sphenoid wing, and zygomatic arch.

Craniotomy with or without resection of the zygomatic arch

Routine frontotemporal craniotomy is performed. The subfrontal dura is separated from the orbital roof, and the temporal dura is dissected from the sphenoid wing to expose the superior orbital fissure. The greater wing of the sphenoid is then drilled out to reach the most lateral part of the superior orbital fissure (Fig. 1). The subtemporal dura when elevated exposes the arcuate eminence and the middle meningeal artery.

Removal of the zygomatic arch provides additional exposure of the middle cranial base. The zygomaticofacial foramen forms the anterior margin of the osteotomy, and a posterior cut is made in front of the articular tubercle. The zygomatic arch is triangular in shape, and care should be taken to avoid injury to the temporomandibular joint while cutting the zygomatic process of the temporal bone. Resection of the zygomatic arch is not a mandatory procedure; however, it provides an unobstructed view of the temporal base and the superior orbital fissure by downward retraction of the bulky temporalis muscle.

Exposure of the superior orbital fissure and skull base foramina

About 1 cm of the lateral orbital roof should be removed at the orbital apex with a high-speed pneumatic drill and rongeurs to expose the superior orbital fissure (Fig. 2). With gentle retraction of the temporal pole, the foramen rotundum is exposed. The superior and lateral parts of this foramen are then drilled out to free the maxillary nerve. The lateral orbital wall between the foramen rotundum and the superior

Fig. 1. Exposure after right frontotemporal craniotomy with zygomatic arch resection. Basal temporal bone is drilled out to reach the floor of the middle cranial base.

Fig. 2. The superior orbital fissure is exposed. Note that the temporal dura forms a small fold at the junction of the greater and lesser wings of the sphenoid bone.
orbital fissure is removed partially by drilling the most antero-medial part of the greater wing of sphenoid. After this procedure, the lateral orbital apex should be released from bony constraints.

Dissection is then extended into the middle fossa. The basal part of the temporal bone and the greater sphenoid wing are drilled out to get a direct line of vision to the floor of the middle cranial fossa. The middle meningeal artery should be cut at the foramen spinosum, and the greater and lesser petrosal nerves identified and dissected from the basal temporal dura. The lateral part of the foramen ovale is drilled away to release the mandibular nerve. Drilling the petrous bone posterolaterally to the foramen ovale then exposes the horizontal portion of the petrous carotid artery (Fig. 3). It may be necessary to cut the greater petrosal nerve to complete this procedure. The tensor tympani muscle is located anterolaterally, running parallel to the carotid artery, and the Eustachian tube lies lateral to the carotid artery, and inferior to the tensor tympani muscle. The tensor tympani muscle and the Eustachian tube may have to be removed to expose the entire perimeter of the petrous carotid artery.

Anterior clinoidectomy and unroofing of the optic canal

The anterior clinoid process is removed extradurally. The temporal dura forms a small dural fold by squeezing the bone at the junction of the greater and lesser wings of the sphenoid bone. The dural fold that is located at the most lateral part of the superior orbital fissure is cut, and the dissection extended between the superior orbital fissure and the temporal dura of the greater sphenoid wing. The reflected periosteum along the superior orbital fissure is continuous anteriorly to the periorbita, and merges posteriorly with the deep layer of the LSC lateral wall. The superficial layer of the LSC is easily stripped by a gentle backward retraction of the temporal dura, because it is continuous with the basal temporal dura. This dissection leads to a cleavage plane between the periosteal reflection, at the superior orbital fissure and the temporal dura overlying the anterior clinoid process. The same dissection is continued at the junction of the temporal dura and the perioseal reflections at the foramina rotundum and ovale. The superficial layer of the LSC is continuous with the dura mater overlying the anterior clinoid process. Further backward dissection of the temporal dura will expose the anterior clinoid process extradurally, and the anterior part of the deep layer of the LSC, including the ophthalmic and maxillary branches of the trigeminal nerve (Fig. 3). As the entire length of the anterior clinoid process is exposed, it can be drilled out easily to expose the clinoid space covered with the deep layer of the lateral wall, and the clinoidal segment of the ICA (Fig. 4).

The optic canal marks the medial border of the clinoid space. The extradural optic nerve is exposed by further unroofing of the optic canal and drilling the optic strut, and the orbital apex is visualized together with its connection to the optic nerve, and the superior orbital fissure.

Extradural dissection of the lateral wall and the entire LSC

The same technique that is used for anterior clinoidectomy is applied to the dissection of the lateral wall of the LSC. Extradural dissection of the lateral wall can be extended to the anterior petroclinoidal dural fold anteriorly and to the tentorial edge posteriorly. Therefore, the entire

![Fig. 3. Extradural dissection of the superficial layer of the lateral sellar compartment. The anterior clinoid process is fully exposed. The petrous ICA is exposed by drilling the petrous bone posterolaterally to the foramen ovale. Note that greater petrosal nerve runs above the exposed carotid artery. V1, ophthalmic nerve; V2, maxillary nerve; V3, mandibular nerve; GSPN, greater superficial petrosal nerve; ICA, internal carotid artery.](image)
LSC can be exposed from the temporal base to the tentorial margin in a posterosuperior direction. The III, IV and V cranial nerves, Gasserian ganglion, and carotid artery are exposed extradurally, and the entire LSC may be explored using this extradural route. The VI cranial nerve is located inferomedially to the ophthalmic nerve, and inferior to the origin of the meningo-hypophyseal trunk (Fig. 5). The deep layer of the lateral wall consists of neural sheaths of the cranial nerves and interconnecting loose connective tissue. Venous branches of the Sylvian vein and the sphenoparietal sinus, which drains through the tentorium, may be preserved by careful dissection of the deep layer of the lateral wall at the level of the superior orbital fissure and foramen rotundum. Venous bleeding in the LSC may be managed by packing with collagen fibrils and Surgicel.

There are two constraining mechanisms operating with respect to neurovascular structures in the LSC. The first involves the entry and exit points. The bony foramina, fissure, and dural entry-exit points confine the cranial nerves and the carotid artery. The distal dural ring is the most significant, because it should be released by incising the dura mater to mobilize the carotid artery to undertake a superior approach to the LSC. To accomplish the superior approach to the anterior LSC, it may be preferable to use combined intra-extradural exposure. The second mechanism involves the petrosphenoid ligaments. The abducent nerve runs beneath the superior petrosphenoid ligament (Gruber’s ligament) together with the inferior petrosal sinus as it enters the LSC. This is one of the possible danger areas as the abducent nerve may be easily damaged during the packing of the inferior petrosal sinus. The inferior petrosphenoid ligament is a dense and thick fibrous tissue driven from the periosteum, which checks the carotid artery against the sphenoid bone. This ligament demarcates the internal carotid artery (ICA) in the LSC from the petrous ICA. The proximal and distal portions of the ICA are tightly bound by constraining mechanisms within the LSC.

**Clinical application**

Frontotemporal craniotomy is one of the most frequently used basic techniques in neurosurgery. The extradural approach of the LSC is a modification of traditional frontotemporal craniotomy, adding zygomatic arch resection when necessary, and increasing the basal temporal bone removal. The most significant part of the extradural approach is the identification and dissection of the cleavage plane between the temporal dura and the
deep layer of the lateral wall. The extradural exposure of the anterior clinoid process is another important aspect of this dissection. The ruling element is proper orientation while dissecting the dura mater of the superior orbital fissure. If the incision is too posterior, it will lead to opening the dura and entering the Sylvian fissure. If the incision is too deep and anterior, it may damage the nerves running within the superior orbital fissure. Therefore, it is very important to be familiar with the three dimensional configurations of bony and soft tissue structures around the anterior clinoid process, and to practice by cadaver dissection.

As the cranial nerves in the LSC are exposed with intact neural sheaths, they are probably better protected from mechanical injury during surgery. Moreover, as the entire length of the cranial nerves is exposed during the early stage of the surgery, they are easily identified even when the tumor has distorted the normal anatomy. It is also important to maintain the vascular supply to the cranial nerves within the LSC. The same principle applies to the identification and preservation of the meningo-ophyseal trunk, inferolateral trunk and their branches. Almost all lesions involving the LSC may be managed by the extradural approach, because this approach offers wide exposure of the entire LSC (Fig. 6). Vascular lesions around the clinoïd segment are better accessed by the combined extra- and intradural approach, since the distal dural ring must be dissected and released to mobilize the carotid and ophthalmic arteries.

**DISCUSSION**

Parkinson found a constant triangular space between the trochlear and ophthalmic branch of the trigeminal nerve in all 200 cadaver dissections he undertook, and named it Parkinson’s triangle. He also designed a lateral dural approach, which allowed safe and adequate exposure of the cavernous portion of the cavernous sinus, and later applied this approach in the treatment of traumatic carotid cavernous fistula without injuring the cranial nerves. This was the first published description of a lateral approach to the cavernous sinus. Fedor Krause pioneered the extradural approach to the Gasserian ganglion for the treatment of trigeminal neuralgia in the 1890s, and Cushing further developed this approach by resection of the zygoma, which provides a low approach. Dolenc and Hakuba applied this extradural approach to modern microneurosurgery. The number of reports published on the direct surgical approach to the LSC continues to increase. Inoue et al. carried out an extensive microanatomical study, and reviewed various approaches, including the superior intradural approach, the inferior extradural combined approach, the superomedial approach, the lateral extradural approach, the lateral extradural approach, the combined lateral and inferolateral approach, and the inferomedial approach. He believed that a single approach was not capable of providing access to all parts of the LSC. However, this contention may be groundless, especially in terms of the management of tumors, because they are quite easily removed by following the tumor’s pathway. Moreover, it is worthwhile to bear in mind that it is the character of the pathology that determines accessibility, rather than the approach itself. Most of the vascular lesions involving the LSC can be managed by the superior or anterior approach. Meningiomas and invasive pituitary tumors show

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Fig. 6. The entire lateral sellar compartment is exposed from the clinoïd space to the Gasserian ganglion. The greater petrosal nerve runs above the petrous ICA, and the tensor tympani muscle is exposed lateral to the greater petrosal nerve. ICA, internal carotid artery; II, optic nerve; IV, trochlear nerve; MMA, middle meningeal artery.
aggressive behavior by invading both sides of the LSC, and do not respect the limiting dural layer.\textsuperscript{1,2}\textsuperscript{10} Such pathologies warrant combined extra- and intradural approaches. However, more confined lesions such as schwannomas, juvenile angiofibromas, cavernous hemangiomas, chondromas, and chondrosarcomas may be managed by the extradural approach alone.\textsuperscript{14}

Recently, Parkinson pointed out that the cavernous sinus is not a dural sinus nor is it cavernous.\textsuperscript{18} The compartment is extradural, and the venous structures contained within consist of a greatly variable plexus of extremely thin-walled veins. Therefore, he made the reasonable proposal that the inaccurate and misleading name cavernous sinus should be changed to the more descriptive and accurate term LSC.\textsuperscript{18,19} Taptas stated that the morphology of the cavernous sinus and its neurovascular relations with the dura propria are the result of the embryonic development of the brain with respect to the formation of the anterior and middle cranial fossae. The cranial nerves have a dural as well as a leptomeningeal sheaths in the parasellar space. The internal carotid artery, extradural in its parasellar segment, is involved by the dura propria to become intradural at the level of the anterior clinoid process. Because of the adhesion between the dura propria and the intracranial periosteum, the artery is attached to the bone, whereas in its extradural and intradural segments it has some mobility.

A microsurgical anatomy of the LSC based on 30 cadaver dissections and a histological study was published previously,\textsuperscript{5,13} and results of the surgical treatment of 110 consecutive cases of tumors involving the LSC over the past 10 years has been reported elsewhere.\textsuperscript{14} Summarizing briefly: the lesion started within the LSC in 55 cases, and extended from the adjacent area in the other 55; the extradural approach alone was used in 42 cases, and 31 were approached intradurally; the combined extra- and intradural approach was performed in 14 cases. Gross total resection was achieved in all patients with schwannomas, cavernous hemangiomas, and epidermoid. However, total resection could be done in 48.6\% of the meningiomas, and 86.7\% of the pituitary tumors. Operative mortality of the series was 2.7\%, and the morbidity was 12.7\%. Permanent cranial nerve palsy occurred in 10\%. The histopathology of the tumor, invasion of the carotid artery, and history of previous surgery or radiation therapy were identified as the significant risk factors.

When the carotid artery is encased by a meningioma, it may be safer to leave the tumor and treat it later by gamma knife surgery rather than risking injury to the artery or its branches. With increased experience, less petrous carotid exposure is done, because it is not necessary to secure the proximal control. For the above reason, and to prevent postoperative dry eye, the greater petrosal nerve is preserved as much as possible. Pneumatization of the anterior clinoid process was encountered in a small number of cases, and was managed by plugging with Surgicel and bone wax, and applying fibrin glue. CSF leakage was not a problem using the extradural approach, because the dura was never opened in most cases, and the retracted temporal dura was repositioned to the dural cuffs left on the superior orbital fissure and the skull base foramina. When the results of cranial nerve outcome are compared for the intradural approach and the extradural approach, oculomotor nerve outcome was much better in the extradural group. This may be explained by the facts that the extradural approach was introduced after initial experiences with the intradural approach; extradural approach provides early and easy identification of the oculomotor nerve; the leptomeningeal sheath is not violated in the extradural approach; easier removal of the anterior clinoid process by the extradural approach; and a better chance of preserving branches of the inferolateral trunk. Removal of the anterior clinoid process is not a mandatory procedure when a small tumor is confined in the LSC, because the LSC could be approached from the temporal side using the extradural approach. In a recent series, postoperative third nerve palsy was avoided when the extra-axial tumor was confined within the LSC.

Another advantage of the extradural approach is that the sphenoid sinus and the contralateral side of the LSC are easily accessed without risk of infection when the sphenoid sinus is pushed down by the tumors.

The extradural approach is based on the developmental anatomy of the LSC, and provides: (1) complete exposure of the entire LSC; (2) excellent control of the intracavernous carotid artery; (3) easier identification and less injury to the cranial nerves; (4) less brain damage with limited extradural retraction; (5) preserving the Sylvian vein and the sphenoparietal sinus; (6) minimal intradural blood spillage; (7) shorter operative time; (8) physiological reconstruction of the lateral wall to prevent CSF leakage; and (9) access to the contralateral LSC. As the LSC is an extradural space, the extradural approach can safely be employed to access lesions involving the LSC. In spite of these advantages, the extradural approach is contraindicated in one situation, as this approach will cause catastrophic ischemic complications when the transtentorial anastomotic channels serve the collateral cerebral circulation in Moya Moya disease.

The accelerating advance of interventional techniques is reducing the frequency of the direct surgical management of vascular lesions of the LSC.13 The same may also be applied to neoplastic conditions involving the LSC, as gamma knife radiosurgery is competing with surgical treatment.2 However, with advanced knowledge and technique, most of the tumors in the LSC can be removed without additional neurological deficits.

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