A Combined Intradural Presigmoid-Transtransversarium- Transcondylar Approach to the Whole Clivus and Anterior Craniospinal Region: Anatomic Study

Abstract—Surgical exposure of the clivus is difficult because of its proximity to vital neurovascular structures. The anatomic bases of a new surgical approach to this area are discussed. A supra-auricular skin incision is extended toward the posterior border of the sternocleidomastoid muscle. The vertebral artery is exposed from C2 to the occiput unroofing the foramen transversarium of C1. The bone removal consists of a posterior temporal craniotomy, a suboccipital craniectomy, including mastoidectomy with sigmoid sinus unroofing, removal of the lateral margin of the foramen magnum, of the medial third of the occipital condyle, and retrolabyrinthine petrous drilling. Posterior retraction of the vertebral artery facilitates occipital condyle drilling. Intradural exposure of the petroclival region is achieved by L-shaped cutting of the dura with the long branch placed infratentorially anterior to the sigmoid sinus. Intradural exposure of the craniospinal/upper cervical areas is achieved by cutting of the dura medial to the distal sigmoid sinus and by longitudinal cutting of the dura anterior to the vertebral artery. This approach allows multiple ports of entry to the clivus with full control of the vertebrobasilar system, and of the dural sinuses, and is anatomically suited for controlled removal of tumors located in these areas. This approach, or segments of it, has been used successfully in the treatment of large neoplasms of the craniovertebral junction. (*Skull Base Surgery*, 3(4):193–200, 1993)

Surgery of benign intradural extra-axial tumors involving the clivus and craniospinal region is extremely demanding due to the close relationships between these tumors and vital neurovascular structures and to their frequent extension to adjacent areas. These factors call for

surgical approaches that are wide enough to gain access to multiple contiguous topographic regions, multiangled to vary the surgical angle to different parts of the tumor, and that allow full control of neurovascular structures while minimizing the amount of brain retraction. In this milieu

separate surgical approaches to the upper to midclivus and to the inferior clivus-upper craniospinal regions have been recently described.¹⁻⁵

We describe the anatomic bases of a modularly integrated single approach to the whole clivus-craniospinal region as well as its possible expansions. This approach allows unhindered exposure of the whole length of the clivus and of the craniospinal region together with the surrounding areas.

SURGICAL ANATOMY AND PROCEDURE

The procedure was performed bilaterally on 10 freshly embalmed cadaveric heads whose cephalic vascular system had been injected with colored silicone material. With the head maintained in an upright position using a Mayfield fixation device and turned 30° toward the side of interest, a curvilinear skin incision starting supra-auricularly in the posterior temporal region is extended suboccipitally 2 to 3 cm medial to the inner mastoid edge to the level of C2-C3 and then curved anteriorly toward the posterior border of the sternocleidomastoid muscle (Fig. 1).

A scalp flap is developed exposing the trapezius muscle. The point where the greater occipital nerve (the posterior branch of the C2 spinal nerve) pierces the trapezius muscle is identified. This point is located on the average 1.5 cm off the midline and 3 cm below the superior nuchal line.⁶ The trapezius is incised and separated from the underlying muscles. The semispinalis, splenius capi-

tis, splenius cervicis, and sternocleidomastoid muscles are visualized. It is possible to identify at this stage the external branch of the accessory nerve and nerves of the anterior cervical plexus in the slit between the posterior border of the sternocleidomastoid and the splenius cervicis muscles; the levator scapulae forms the floor of this slit (Fig. 2). The posterior portion of the sternocleidomastoid muscle is separated from the mastoid; the tip of the mastoid and the transverse processes of C1 and C2 are identified by palpation. The splenius capitis and, underneath it, the longissimus capitis muscles are separated from the mastoid and turned inferiorly. The entrance point of the greater occipital nerve in the semispinalis is identified, the muscle is cut horizontally just below this point and reflected inferiorly, taking care not to injure the greater occipital nerve. The obliquus capitis inferior and superior and the rectus capitis posterior major and minor muscles with the greater occipital nerve above them are identified (Fig. 3). The greater occipital nerve is followed distally where it circles the inferior border of the obliquus capitis inferior and even further where it joins the C2 nerve trunk (Fig. 4). The anterior branch of C2 spinal nerve is identified and followed anterolaterally where it crosses the vertebral artery exiting the foramen transversarium of C2 (Fig. 4). The C1-C2 joint is identified anterior to the C2 spinal nerve; the C2-C3 joint is identified as well. The vertebral artery is exposed over the posterior arch of C1; the obliquus and rectus muscles are freed from their bony attachments, allowing exposure of the posterior elements of C1 and C2 all the way to the midline (Fig. 5). The

Figure 1. The skin incision is shown.

Figure 2. The external branch of the accessory nerve is seen disappearing under the trapezius muscle after having passed through the sternocleidomastoid muscle.

Figure 3. Drawing of the relationship between the greater occipital nerve, the vertebral artery, and the muscles in the suboccipital region.

foramen transversarium of C1 is posteriorly unroofed using a thin plate Kerrison rongeur exposing the vertebral artery that is circumferentially freed from above the foramen transversarium of C2 to its point of dural penetration medial to the occipitoatlas joint that is now identified (Fig. 5 inset).

Freeing the vertebral artery, one comes across variously developed venous channels concealed in the peri-

osteal sleeve of the artery. There are also one or two arterial branches⁷ that need to be transected. The vertebral artery can now be retracted medially fully exposing the occipitoatlas joint (Fig. 6). At this point, attention is shifted to the mastoid; the digastric incisura is identified and the posterior belly of the digastric muscle is removed. The facial nerve is visualized as it exists the stylomastoid foramen lateral to the digastric incisura, while the proxi-

Figure 4. The anterior and posterior ramus and the trunk of the C2 spinal nerve are shown. The anterior ramus crosses the vertebral artery above the foramen transversarium of C2. The pin is in the C1-C2 joint.

Figure 5. The vertebral artery is completely exposed from above the foramen transversarium of C2 to its dural penetration point. The inset shows the foramen transversarium of C1 posteriorly unroofed.

mal internal jugular vein is identified medial to the incisure. The posterior arch of C1, the lamina of C2, and the medial portion of the C1-C2 joint are removed and the C2 spinal nerve is transected close to its dural entry point (Fig. 7). After careful medial retraction of the fully mobilized vertebral artery, the medial portion of the occipitoatlas joint is drilled off (Fig. 7). The drilling of the joint is continued until there is enough space anterior to the vertebral artery dural entry point; it is not necessary to enter the XIIth cranial nerve canal.

The purpose of the joint drilling is to gain access to the dura anterior to the vertebral artery dural entry point. It is this dural exposure that allows dural opening lateral (anterior) to the vertebral artery and medial to the occipitoatlas joint that in turn exposes the lower clivus and the upper cervical cord. At this point, the cranial and spinal dura should be continuous medial to the occipitoatlas joint. At this stage of the procedure, a medially extended suboccipital craniotomy and a presigmoid bony removal are carried out as previously described³ (Fig. 8). The dura

Figure 6. The occipitoatlas joint is exposed after medial retraction of the vertebral artery. The pin is in the joint space.

Figure 7. The vertebral artery has been medially retracted. The medial portion of the occipitoatlas joint has been drilled and the posterior arch of C1 and the lamina of C2 have been removed. The C2 spinal nerve has been transected close to the dura. The inferior portion of the occipital squama has been rongeué away. The ghosted area represents the original position of the vertebral artery, before medial transposition.

is then cut horizontally above the transverse sinus on both sides of the petrous ridge; the basal temporal lobe veins (Labbé's) are dissected free from their arachnoidal sleeves. The dura is also cut anterior to the sigmoid sinus down to the jugular bulb (Fig. 8). If necessary the dura may also be cut posterior to the vertebral artery dural entry point in order to provide a different angle of view to the upper craniospinal region.

The superior petrosal sinus is identified and the ten-

torium is transected just medial to the superior petrosal sinus all the way to the incisura; the tentorium is also cut in a lateromedial direction to develop a tentorial flap, setting the stage for gentle superior retraction of the occipitotemporal lobe. The craniospinal dura is then longitudinally cut medial to the sigmoid sinus and lateral (anterior) to the vertebral artery dural entry point while the vertebral artery is medially retracted (Fig. 8). The presigmoid dural opening gives full access to the petrous apex-upper mid-clivus (Fig. 9), whereas the craniospinal dural opening exposes the lower clivus, the jugular foramen, the hypoglossal foramen, and the upper cervical cord from the front with full control of all neurovascular structures (Fig. 10A).

The dura is reapproximated as much as possible. A dural graft is used to reinforce the dural closure together with fibrin glue. A free fat graft is placed above the dura and kept in place with fibrin glue. The sternocleidomastoid muscle is used to obliterate the mastoidectomy-petrosectomy cavity while the suboccipital muscles are reapproximated in the midline as usual. The subcut and skin are closed as per routine.

DISCUSSION

Anatomic Subdivision of the Clivus

The clivus may be divided into three portions; the upper portion is formed by the dorsum sellae and by the adjacent part of the sphenoid body; the midportion is formed by the upper half of the basiocciput; and the lower half of the basiocciput forms the inferior portion. The interpeduncular cistern corresponds to the upper clivus, and the prepontine and premedullary cistern lie in correspondence to the mid and lower clivus, respectively.⁸

Figure 8. The presigmoid bony removal and the medial suboccipital craniotomy have been executed. The dural incision lines are shown.

Figure 9. The cranial nerves III through X are shown after presigmoid dural opening.

Figure 10. The glossopharyngeal, vagus accessory, and hypoglossal nerves are seen after opening of the dura anterior to the vertebral artery dural penetration point; the vertebral artery and the posterior inferior cerebellar artery origin are also evident (A). After transection and inferior retraction of the jugular bulb and proximal internal jugular vein, the cranial nerves IX through XII are fully exposed from the brainstem to the upper cervical area (B).

Intradural Approaches to the Clivus

The upper clivus may be exposed through a frontotemporal craniotomy after wide opening of the sylvian fissure; some exposure of the midclivus may be achieved after apical petrous drilling and cutting of the tentorium.³ The upper midclivus may also be approached via a posterior temporal craniotomy after upward temporal lobe retraction and splitting of the tentorium.³ The mid to lower clivus may be exposed through a suboccipital craniectomy.³ The simple suboccipital craniectomy may be considered as the initial building module of all the other posterior fossa neurosurgical approaches. When properly executed this approach affords excellent visualization of the midclivus. Its anatomic limits are the sigmoid sinus laterally, the tentorium superiorly, and the occipitoatlas joint/vertebral artery complex inferiorly. The many variations of the combined supra-infratentorial approach to the clivus effectively eliminate the superior and lateral constraints of the simple suboccipital craniectomy. This is achieved by adding to the suboccipital craniectomy a posterior pyramidal drilling that brings the surgeon anterior to the sigmoid sinus, a tentoriotomy, and a posterior temporal craniotomy.^{3,9} These three surgical maneuvers may be collectively referred to as the presigmoid block. The target area is in such a way increased to include the upper clivus and the lateral incisural space.³ The inferior constraints of the suboccipital craniectomy are partially eliminated by any of the variations of the far lateral approach to the lower clivus and upper cervical region.^{2,4,5,9,10} These approaches add various degrees of occipitoatlas (occipital condyle and lateral mass of the atlas) drilling to the suboccipital craniectomy.

Original Features of the Combined Presigmoid-Transtroversarium Transcondylar Approach to the Clivus

The approach we have described completely eliminates the superior and inferior constraints of the simple suboccipital craniectomy by adding a presigmoid sinus block and by extensive drilling of the occipitoatlas joint coupled with medial translocation of the vertebral artery (occipitoatlas/vertebral block). In this way the suboccipital craniectomy opens up superiorly into the upper clivus and lateral incisural space and inferiorly into the lower clivus and upper craniospinal region. Our approach differs from previously described routes to the clivus because it combines the presigmoid avenue with a lateral craniospinal approach and because of the full mobilization of the vertebral artery. Even though the presigmoid sinus avenue^{1,3} and the lateral approach to the craniospinal region^{4,11} have been previously described, it is their combination that allows access to the whole clivus. We stress, as others have already done in the context of removal of foramen magnum tumors,^{10,12} the importance of a complete vertebral artery mobilization and retraction in safely drilling the occipitoatlas joint and in gaining access to the anterior craniospinal dura ventral to the vertebral artery dural entry point. It is this longitudinal dural opening anterior to the vertebral artery dural entry point that gives a satisfactory ventral tangential exposure of the lower clivus and upper craniospinal region. In addition, the anterior expansion of our approach completely exposes the lower cranial nerves from the brainstem to the midneck area, making possible their transposition in order to remove safely tumor located in close approximation to them. Also immediate lower cranial nerve reconstruction may be performed in case their continuity is interrupted. This approach, or segments of it, has been successfully used to remove large neoplasms located at the craniovertebral junction.¹³

Possible Expansions of the Combined Presigmoid-Transtroversarium Transcondylar Approach to the Clivus

Our approach by virtue of its muscle dissection may be expanded to include access to the extracranial portion of the internal jugular vein and to the vascular and nerve package of the neck. The inferior limits of this approach are the posterolateral elements of the upper cervical spine that can be judiciously removed, if necessary. The lateral limits are the hypoglossal canal, the lateral portion of the occipitoatlas joint, and the jugular bulb. Full exposure of the jugular bulb is possible without entering the XIIth cranial nerve canal. However, exposure of the jugular bulb does not improve the access unless the sigmoid sinus is transected above the jugular bulb and the distal sigmoid sinus, jugular bulb, and proximal internal jugular vein are

luxated inferiorly. This maneuver improves the access to the posterolateral cranial base and allows unhindered exposure of the lower cranial nerves from the brainstem to the midneck area, making possible their immediate reconstruction should they be interrupted (Fig. 10B). The anterior limit of our approach is represented by the posterior semicircular canal and by the endolymphatic sac. If these structures are removed, then a posterior petrosectomy may be performed up to the internal auditory meatus and internal auditory canal, with consequent improvement of the exposure anterior to the brainstem.⁹

Anatomic Morbidity of the Combined Presigmoid-Transtroversarium Transcondylar Approach to the Clivus

The basic integrated approach described does not involve resection of any important anatomic structure. Its proposed expansions might and must be carefully considered. Extensive removal of the posterolateral elements of the cervical spine may cause instability requiring stabilization procedures; luxation of the jugular bulb requires demonstration of adequate contralateral venous drainage and may still then carry some risks, and a posterior petrosectomy destroys hearing.

CONCLUSIONS

Our approach is anatomically suited for controlled removal of intradural extra-axial tumors spanning the

Figure 11. Schematic overview of the surgical exposure.

whole clivus and the anterior craniospinal/upper cervical areas (Fig. 11). It may also be easily used to access the extradural portion of tumor involving the upper part of the vascular-nerve bundle of the neck. Its lateral expansion gives full access to the jugular foramen both in its intra- and extradural component and may be useful for tumors involving this area intra- and extradurally, such as chemodectoma or large jugular foramen neurinomas. The inferior extension of our approach may be used to reach tumors anterior to the midcervical cord, while its anterior extension further decreases the distance to the upper clivus-lateral incisural space and may be definitely considered when functional hearing is absent.

It is anticipated that the controlled extensive bone removal described in our approach will translate into decreased amount of brain retraction to reach the target areas.

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