The Intracranial Facial Nerve as Seen Through Different Surgical Windows: An Extensive Anatomosurgical Study

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BACKGROUND: The facial nerve has a short intracranial course but crosses critical and frequently accessed surgical structures during cranial base surgery. When performing approaches to complex intracranial regions, it is essential to understand the nerve's conventional and topographic anatomy from different surgical perspectives as well as its relationship with surrounding structures.

OBJECTIVE: To describe the entire intracranial course of the facial nerve as observed via different neurosurgical approaches and to provide an analytical evaluation of the degree of nerve exposure achieved with each approach.

METHODS: Anterior petrosectomies (middle fossa, extended middle fossa), posterior petrosectomies (translabyrinthine, retrolabyrinthine, transcochlear), a retrosigmoid, a far lateral, and anterior transfacial (extended maxillectomy, mandibular swing) approaches were performed on 10 adult cadaveric heads (20 sides). The degree of facial nerve exposure achieved per segment for each approach was assessed and graded independently by 3 surgeons.

RESULTS: The anterior petrosal approaches offered good visualization of the nerve in the cerebellopontine angle and intracanalicular portion superiorly, whereas the posterior petrosectomies provided more direct visualization without the need for cerebellar retraction. The far lateral approach exposed part of the posterior and the entire inferior quadrants, whereas the retrosigmoid approach exposed parts of the superior and inferior quadrants and the entire posterior quadrant. Anterior and anteroinferior exposure of the facial nerve was achieved via the transfacial approaches.

CONCLUSION: The surgical route used must rely on the size, nature, and general location of the lesion, as well as on the capability of the particular approach to better expose the appropriate segment of the facial nerve.

KEY WORDS: Anterior approaches, Cranial base, Cranial base neoplasm, Facial nerve, Microsurgical anatomy, Posterior approaches, Surgical approach

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A thorough knowledge of the courses of the intracranial nerves is essential for performing surgical approaches to complex intracranial regions and particularly to the cranial base. Anatomic structures take on different spatial perspectives as they are approached from different angles. Most of the intracranial nerves are encountered in surgical trajectories to deep intracranial targets, and their anatomic complexities necessitate proper selection of optimal surgical corridors.[1-7] The facial nerve has a short intracranial course but crosses critical and frequently accessed surgical structures during cranial base surgery.[2,6,7] Many surgical dissections expose the facial nerve in its intracranial route.[7,8] Its particular complex anatomy demands a comprehensive analytical study of the neurosurgical approaches in which it is frequently encountered. The facial nerve contains mostly motor fibers supplying the muscles used for facial expression as well as some visceral efferents to the sublingual and submandibular glands responsible for salivation and taste

ABBREVIATIONS: AICA, anterior inferior communicating artery; **CPA,** cerebellopontine angle; **GG,** geniculate ganglion; **IAC,** internal auditory canal; **PICA,** posterior inferior communicating artery sensation from the anterior two thirds of the tongue.[3,5] Because of its complex surgical anatomy, the facial nerve has already been the target of anatomic studies, and its intra- and extracranial course has been described in detail in previous studies.[1,2,4,6-8] Nevertheless, the perspective of the nerve, the structures that surround it, and the relationship between them change completely with every surgical approach. For this reason, it is not only necessary to know the conventional anatomy of the nerve, but the topographic anatomy from different surgical perspectives and its relationship with surrounding structures.

We describe the entire intracranial course of the facial nerve from its exit out of the brainstem to the stylomastoid foramen, through different surgical and topographic perspectives. Ultimately, we provide an analytical evaluation of the degree of nerve exposure provided by the most common otoneurosurgical approaches including the anterior transfacial approaches (mandibular swing, extended maxillectomy), the transmastoid approaches (translabyrinthine, transcochlear, and conservative perilabyrinthine), the retrosigmoid approach, the middle fossa approaches (conventional and extended), and the far lateral approach.

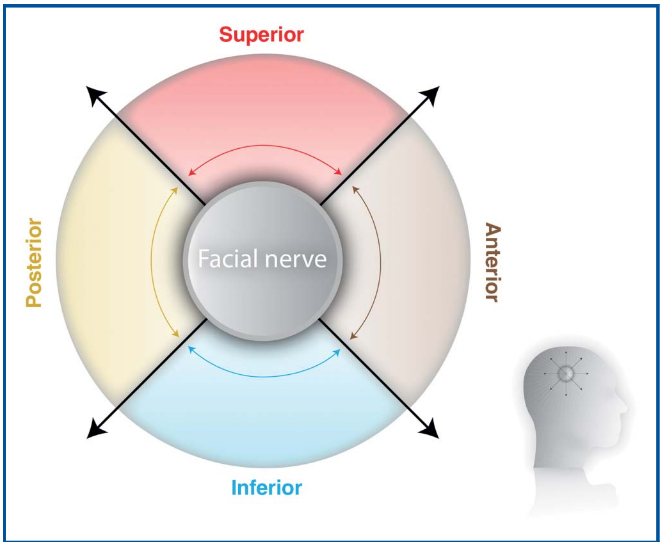

FIGURE 1. *Circumferential quadrants of the facial nerve. The nerve was divided into four 90-degree quadrants: superior, inferior, anterior, and posterior.*

MATERIALS AND METHODS

Using 10 formalin-fixed and preserved adult cadaveric heads (20 sides) injected with colored latex (red for arteries, blue for veins), using standard microsurgical equipment and instrumentation (Zeiss NC-2 Surgical Microscope and Anspach pneumatic drills), and a Mayfield Modified Skull Clamp, we performed anterior petrosectomies (middle fossa and extended middle fossa approaches), posterior petrosectomies (translabyrinthine, retrolabyrinthine, and transcochlear approaches), a retrosigmoid approach, a far lateral approach, and anterior transfacial approaches (extended maxillectomy and mandibular swing approach).

Each of these approaches exposed the facial nerve to different degrees. We graded the degree of exposure achieved from each approach using the following classification (Table 1) for the management of the facial nerve in transtemporal cranial base surgery: 0, no exposure; 1, limited exposure, surgical maneuvers are not possible; 2, limited exposure, surgical maneuvers are possible; 3, multiangled exposure, surgical maneuvers are difficult; and 4, multiangled exposure, surgical maneuvers are facilitated.[9]

The facial nerve was divided into four 90-degree quadrants: superior, inferior, anterior, and posterior (Figure 1). Grading was accomplished to evaluate surgical maneuverability on and around the facial nerve (Table 2). Accordingly, a value of exposure less than 90 degrees indicates that the facial nerve can be exposed from only 1 angle, but circumferential control is absent and surgical maneuverability is not possible. A degree of exposure between 90 and 180 degrees indicates that the facial nerve can be exposed from different angles, but full circumferential control and surgical maneuverability are still somewhat difficult, particularly if the facial nerve is completely encircled within the lesion. A degree of exposure greater than 180 degrees indicates that the facial nerve is fully exposed from different angles, control along its entire circumference is complete, and surgical maneuvers, including nerve repair and grafting, are possible.

Anterior Petrosal Approaches

Middle Fossa Approach

The specimen was positioned in a 90-degree lateral angle as in the standard subtemporal approach.[7,10-13] After performing a standard subtemporal approach, a cutting burr was used to remove any remaining bone to the level of the middle fossa floor and the dura was elevated along the petrous ridge to expose the superior surface of the petrous bone. The internal auditory canal (IAC) was identified and approximately 270 degrees of its circumference was unroofed. The dura was incised along the IAC exposing the contents of the canal, and the facial nerve was identified anteriorly and the superior vestibular nerve was found posteriorly (Figure 2).

Extended Middle Fossa Approach

This approach extends the standard middle fossa approach to involve resection of the anterior portion of the petrous bone.[14-17] A craniotomy was

TABLE 1. Exposure Score Definitions

Score	Exposure
0	No exposure
1	Limited exposure; surgical maneuvers are not possible
2	Multiangled exposure; surgical maneuvers are difficult
3	Limited exposure; surgical maneuvers are possible
4	Multiangled exposure; surgical maneuvers are facilitated

TABLE 2. Characteristics of the Different Degrees of Exposure

Amount of Exposure, deg	Angles Exposed	Circumferential Control
<90	Single	Absent
90-180	Multiple	Difficult
>180	All	Present

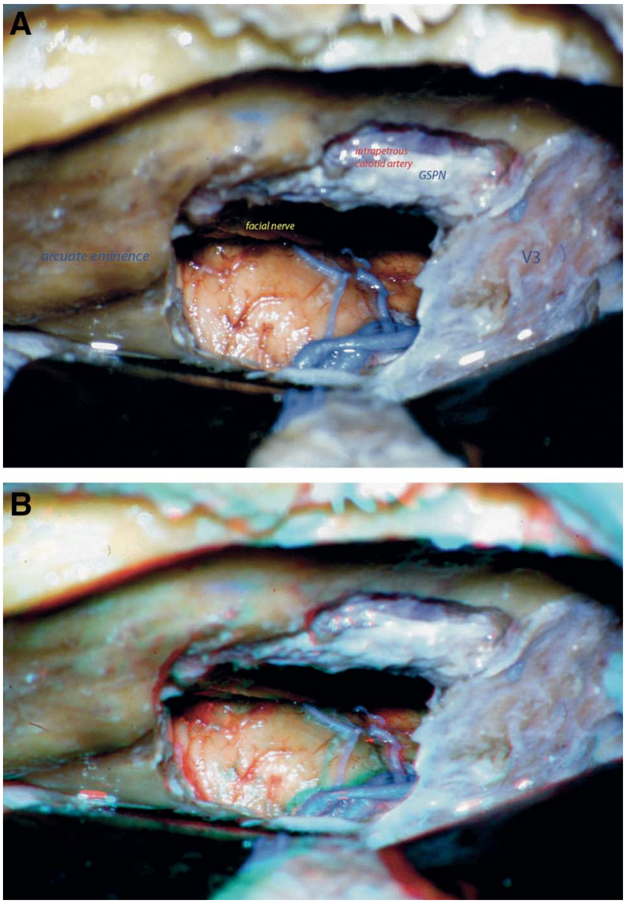

FIGURE 2. **A**, *2-dimensional exposure of the facial nerve via a left middle fossa approach. This approach provided an exposure of approximately 180 degrees of the facial nerve, ie, part of the anterior, the entire superior, and part of the posterior aspects of the nerve, of both the cerebellopontine segment and the intracanalicular portion of the nerve. The superior vestibular nerve is also visible. GSPN, greater superficial petrosal nerve; V3, mandibular branch of the trigeminal nerve.* **B**, *3-dimensional exposure of the facial nerve via a left middle fossa approach. This approach provided an exposure of approximately 180 degrees of the facial nerve, ie, part of the anterior, the entire superior, and part of the posterior aspects of the nerve, of both the cerebellopontine segment and the intracanalicular portion of the nerve. The superior vestibular nerve is also visible.*

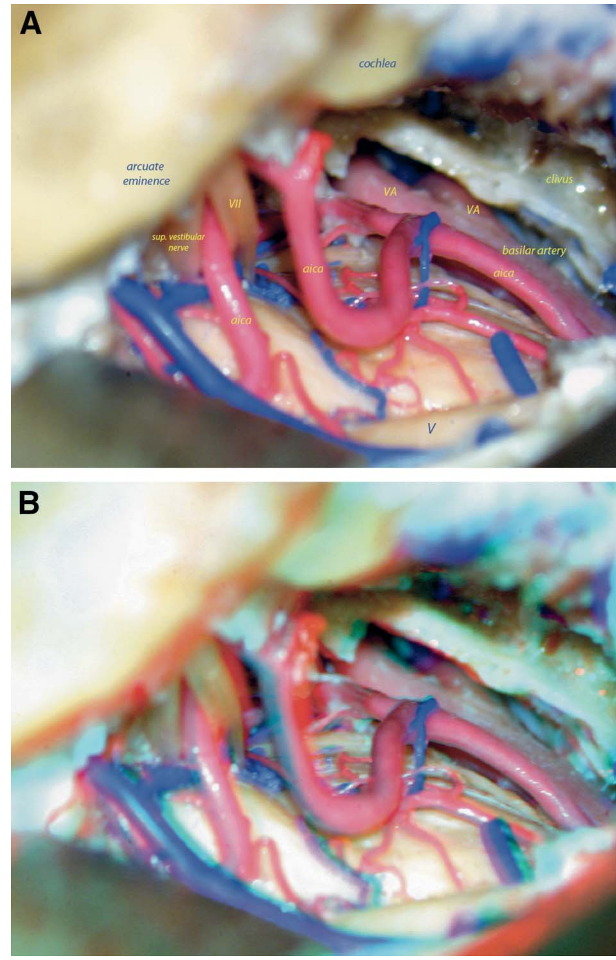

FIGURE 3. **A**, *2-dimensional exposure of the facial nerve via a left extended middle fossa approach. After the dura mater of the posterior canal fossa and the internal auditory canal (IAC) was sufficiently exposed, the dura mater of the IAC was incised, revealing a surgical window onto the posterior fossa region. The anterior inferior communicating artery, trigeminal nerve, petrosal vein, facial nerve, superior vestibular nerve, and vertebral basilar junction were observed. aica, anterior inferior cerebellar artery; Sup, superior; V, cranial nerve V; VII, cranial nerve VII; VA, vertebral artery.* **B**, *3-dimensional exposure of the facial nerve in a left extended middle fossa approach. After the dura mater of the posterior canal fossa and the IAC was sufficiently exposed, the dura mater of the IAC was incised, revealing a surgical window onto the posterior fossa region. The anterior inferior communicating artery, trigeminal nerve, petrosal vein, facial nerve, superior vestibular nerve, and vertebral basilar junction were observed.*

performed for the standard middle fossa approach to the base of the middle cranial fossa. The dura was elevated, and structures of the floor of the middle fossa were identified in a stepwise fashion. Bone was removed in the premeatal triangle, medial to the intrapetrous carotid artery, anterior to the IAC and posterior to V3 (Kawase triangle). Bone was also removed between the ICA and the superior semicircular canal (postmeatal triangle). When the dura mater of the posterior canal fossa and the IAC was sufficiently exposed, the dura mater of the IAC was incised, revealing a surgical window onto the posterior fossa region (Figure 3). The fifth cranial nerve limited exposure superiorly. Drilling within the clivus beyond the inferior petrosal sinus also exposed the vertebrobasilar junction.

Posterior Transpetrosal Approaches

Translabyrinthine Approach

The mastoidectomy, the facial nerve dissection, and the skeletonization of the IAC were performed, as is standard in the translabyrinthine route.[13,18-20] The posterior wall of the external auditory canal was removed, which opened the middle ear cavity. The ossicles and tympanic membrane were removed. The facial nerve was completely exposed from the stylomastoid foramen to the geniculate ganglion (GG). The dura of the IAC was opened, and the facial nerve was separated from the vestibulocochlear complex. The greater superficial petrosal nerve was sectioned at its origin from the ganglion, allowing the facial nerve to be transposed posteriorly. The cochlea was removed, and the intrapetrous carotid artery, located near its anterior limit, was exposed from its genu to the foramen lacerum. The dura was opened in a T fashion toward the clivus. After dural opening, cranial nerves V, VII, IX, X, and XI; the clivus; both vertebral arteries; and the basilar arteries were exposed (Figure 4).

Extended Posterior Petrosectomy (Transcochlear Approach)

The mastoidectomy, the facial nerve dissection, and the skeletonization of the IAC were performed, as is standard in the translabyrinthine route.[18,20-22] The posterior wall of the external auditory canal was removed, which opened the middle ear cavity. The ossicles and tympanic membrane were removed. The facial nerve was completely exposed from the stylomastoid foramen to the GG. The dura of the IAC was opened, and the facial nerve was separated from the vestibulocochlear complex. The greater superficial petrosal nerve was sectioned at its origin from the ganglion, allowing the facial nerve to be transposed posteriorly. The cochlea was removed, and the intrapetrous carotid artery, located near its anterior limit, was exposed from its genu to the foramen lacerum. The dura was opened in a T fashion toward the clivus. After dural opening, cranial nerves V, VII, IX, X, and XI; the clivus; and both vertebral arteries and basilar arteries were exposed (Figure 5).

Retrolabyrinthine Presigmoid Approach

The approach consisted of mastoid and labyrinthine exposure.[18,20,23] The mastoidectomy was performed as in the translabyrinthine dissection but without exposing the facial nerve in the fallopian canal. The presigmoid dura was uncovered from the sinodural angle to the sigmoid sinus inferiorly, and the labyrinth was exposed penetrating the dura.

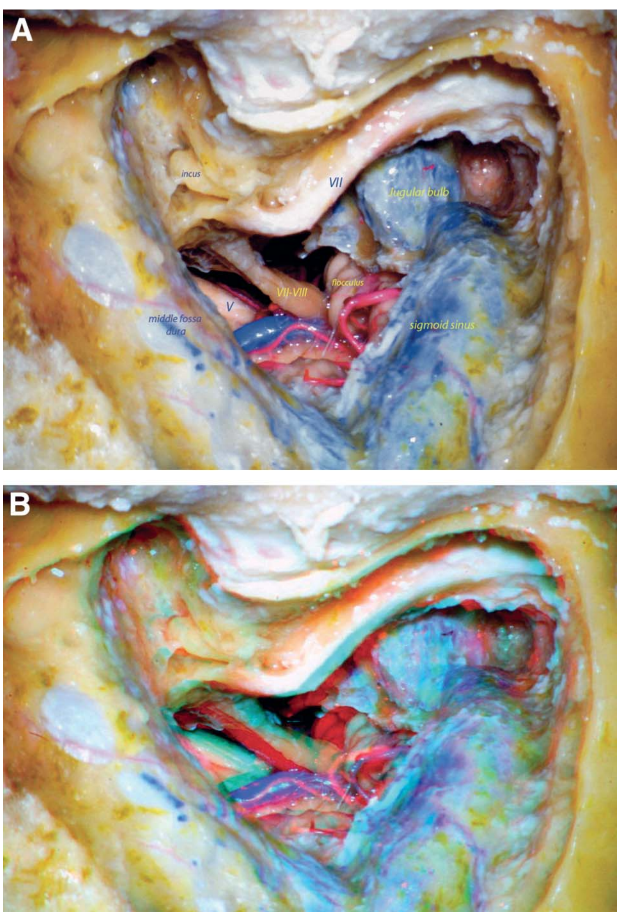

FIGURE 4. A, *2-dimensional exposure of the facial nerve in a right translabyrinthine approach. On dural opening, cranial nerves V, VII, and VIII; the flocculus; the pertrosal vein; and the superior and inferior vestibular nerves were exposed.* **B**, *3-dimensional exposure of the facial nerve via a right translabyrinthine approach. On dural opening, cranial nerves V, VII, and VIII; the flocculus; the petrosal vein; and the superior and inferior vestibular nerves were exposed.*

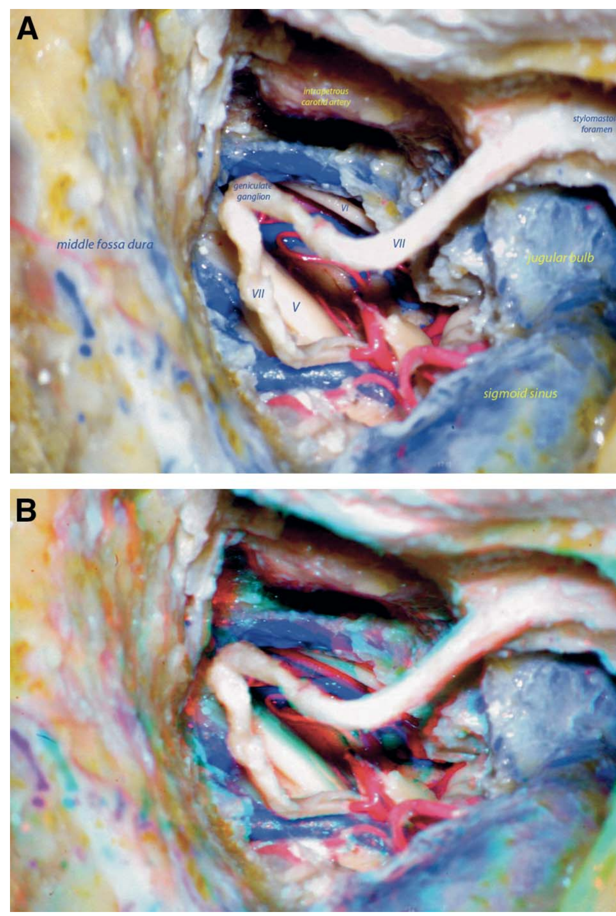

FIGURE 5. A, *2-dimensional exposure of the facial nerve in its entire course in a right transcochlear approach. On dural opening, cranial nerves V, VII, and IX; the clivus; both vertebral arteries and basilar arteries; and the flocculus were exposed. Cranial nerve VIII was incised before excising the cochlea.* **B**, *3-dimensional exposure of the facial nerve in its entire course in a right transcochlear approach. On dural opening, cranial nerves V, VII, and IX; the clivus; both vertebral arteries and basilar arteries; and the flocculus were exposed. Cranial nerve VIII was incised before excising the cochlea.*

To enhance the final exposure, we partially drilled the osseous portion of the posterior semicircular canal. The presigmoid dura was opened, revealing the cerebellopontine angle (CPA) and a portion of the facial nerve from the brainstem to the porus acusticus (Figure 6).

Retrosigmoid Approach

The craniotomy was performed, exposing the lower margin of the transverse sinus superiorly, the posterior margin of the sigmoid sinus laterally, and the inferior portion of the squamous part of the occipital bone inferiorly.[13,24-27] After removing the posterior wall of the meatus, its dura lining was opened, exposing the CPA, the ventral brainstem, and cranial nerves V through XII. The clivus and the vertebral and basilar arteries were also visualized. The facial nerve was identified near the origin of the facial canal at the anterosuperior quadrant of the meatus (Figure 7).

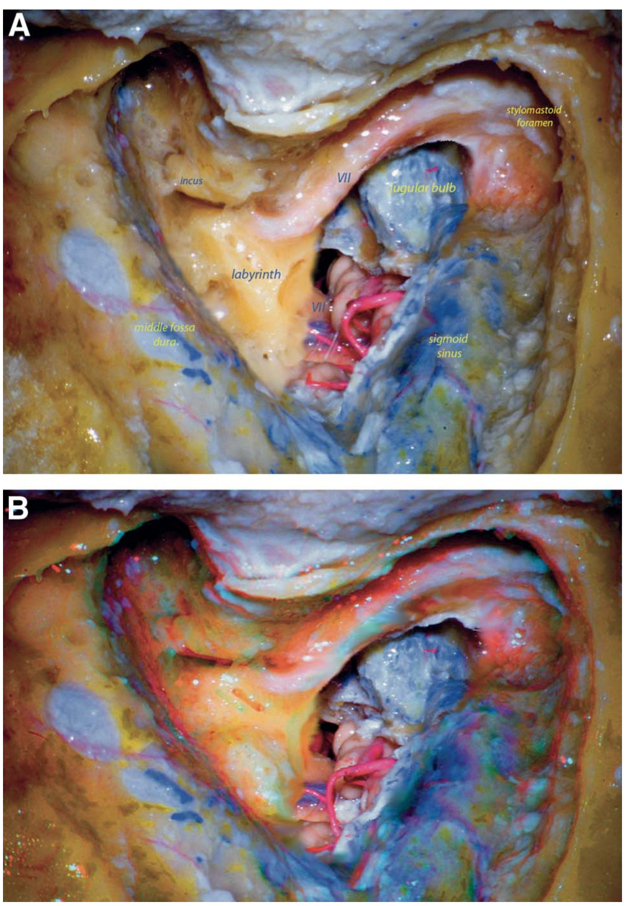

FIGURE 6. **A**, *2-dimensional exposure of the facial nerve via a right retrolabyrinthine presigmoid approach. This approach provided an exposure of approximately 180 degrees, ie, part of the superior, the entire posterior, and part of the inferior aspects of the nerve, of the cerebellopontine segment of the facial nerve without the need for cerebellar retraction.* **B**, *3-dimensional exposure of the facial nerve in a right retrolabyrinthine presigmoid approach. This approach provided an exposure of approximately 180 degrees, ie, part of the superior, the entire posterior, and part of the inferior aspects of the nerve, of the cerebellopontine segment of the facial nerve without the need for cerebellar retraction.*

Far Lateral Transcondylar Approach

A suboccipital craniotomy was performed, extending to the sigmoid sinus anteriorly and to the foramen magnum inferiorly.[28-32] The exposure was improved by performing a hemilaminectomy of C1. Extradural partial resection of the occipital condyle, at its posterior aspect, improved exposure of the ventral aspect of the craniovertebral junction. The extradural removal of the jugular tubercle improved intradural exposure across the anterior surface of the brainstem and midclivus. After dural incision, dissection of the arachnoid allowed visualization of cranial nerves V through XII, the basilar artery, the vertebral artery, the

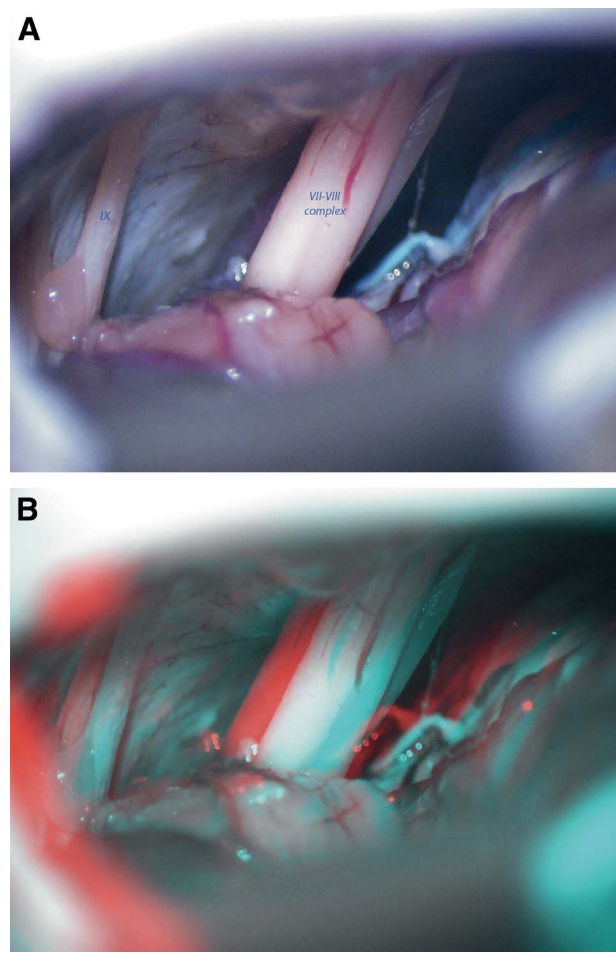

FIGURE 7. **A**, *2-dimensional exposure of the facial nerve via a left retrosigmoid approach. The cerebellopontine angle (CPA), ventral brainstem, and cranial nerves V through X are seen here. The posterior wall of the meatus was partially removed, and its dura lining was opened, exposing a portion of the intracanalicular segment. The facial nerve was identified near the origin of the facial canal at the anterosuperior quadrant of the meatus.* **B**, *3-dimensional exposure of the facial nerve via a left retrosigmoid approach. The CPA, ventral brainstem, and cranial nerves V through X are seen here. The posterior wall of the meatus was partially removed, and its dura lining was opened, exposing a portion of the intracanalicular segment. The facial nerve was identified near the origin of the facial canal at the anterosuperior quadrant of the meatus.*

vertebrobasilar junction, the posterior inferior cerebellar artery (PICA), and the anterior inferior cerebellar artery (AICA) (Figure 8).

Anterior Transfacial Approaches

Extended Maxillectomy

The superior maxilla was exposed by a modified Weber-Fergusson skin incision.[33] After incising the mucoperiosteum and exposing the nasal cavity, an oscillating saw was positioned behind the lateral pterygoid plate, into the nasopharynx and then behind the posterior margin of the hard palate into the oropharynx. A sagittal saw was used to divide the hard palate. The bony walls of the maxilla were divided. Removal of these tissues exposed the base of the cranium from the roof of the sphenoid sinus superiorly to the anterior wall of the foramen magnum inferiorly.

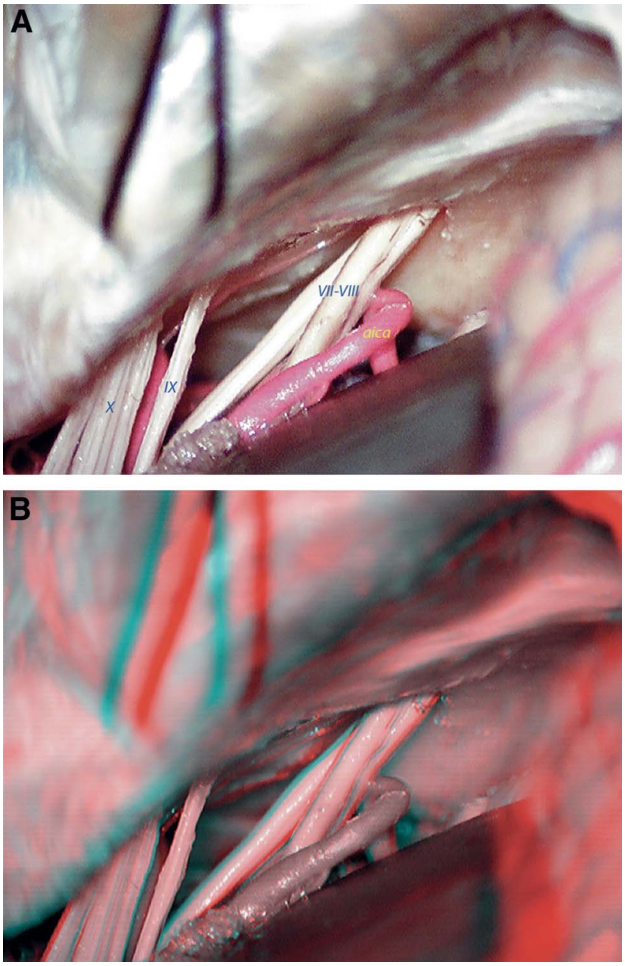

FIGURE 8. **A**, *2-dimensional exposure of the facial nerve in a left far lateral approach. After a dural incision, dissection of the arachnoid allowed visualization of cranial nerves VII through X, the anterior inferior cerebellar artery (aica) and the posterior inferior communicating artery.* **B**, *3-dimensional exposure of the facial nerve in a left far lateral approach. After a dural incision, dissection of the arachnoid allowed visualization of cranial nerves VII through X, the anterior inferior cerebellar artery and the posterior inferior cerebellar artery.*

The internal carotid arteries limited dissection along the upper half of the clivus, foramen lacerum, and base of the medial pterygoid plate. Following the clivus inferiorly to the rim of the foramen magnum, a more lateral dissection was defined by the inferior petrosal sinuses lying within the petro-occipital fissures, medial to the jugular tubercle and the hypoglossal canal containing cranial nerve XII (Figure 9).

Mandibular Swing Transcervical Approach

The skin incision began at the lower lip, extended inferiorly in the midline to the hyoid bone, and ended laterally over the sternocleidomastoid muscle reaching the mastoid tip.[34,35] After posterior retraction of the sternocleidomastoid muscle, the neurovascular structures within the carotid sheet were exposed. After meticulous muscular dissection, the mandible was freed and incised using a sagittal saw. The tongue was retracted superolaterally, and a mucosal incision was made in the floor of the mouth extending posteriorly along the maxillary tuberosity and turned superiorly and anteriorly on the hard palate. The posterior portion of the hard palate was drilled away and the nasal mucosa cut. The whole pharynx was freed from its attachment (the Eustachian tube and the tensor and levator palatini muscles) and retracted to the opposite side. This exposed the entire length of the clivus and the upper cervical spine.

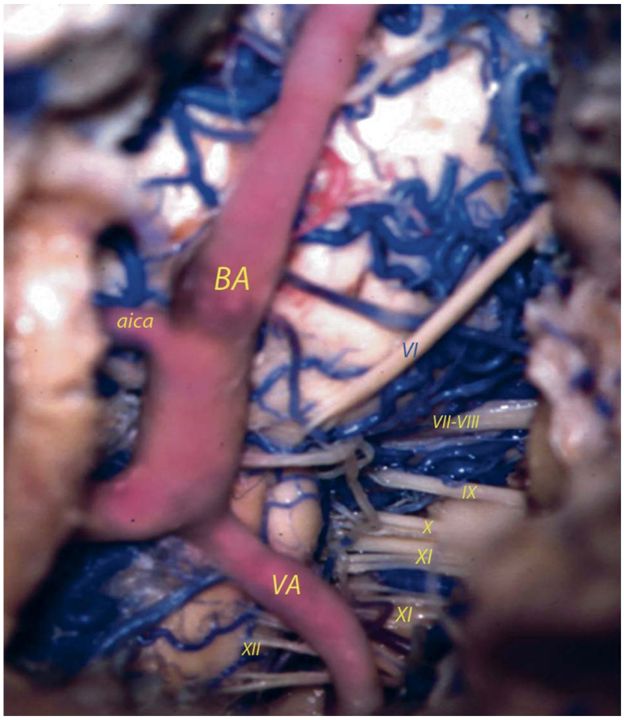

FIGURE 9. *Exposure of the facial nerve in a left extended maxillectomy. Following the clivus inferiorly to the rim of the foramen magnum, a more lateral dissection was defined by the inferior petrosal sinuses lying within the petro-occipital fissures, medial to the jugular tubercle and the hypoglossal canal containing cranial nerve XII. Good exposure of the cerebellopontine angle from the anterior perspective was achieved and cranial nerves VI through XII, the right anterior inferior cerebellar artery (aica), the left vertebral artery (VA), and the basilar trunk were observed. BA, basilar artery.*

The clivus was drilled to expose the dura. The intrapetrous internal carotid artery was completely exposed in its vertical and horizontal portions through the infralabyrinthine space ipsilateral to the skin incision. This approach allowed unobstructed exposure of the cranial base from the ipsilateral infratemporal fossa to the contralateral medial pterygoid plate. It offered extensive exposure of the midline and lateral compartments of the cranial base with full control of the carotid artery, internal jugular vein, and cranial nerves IX through XII (Figure 10).

Facial Nerve Surgical Anatomy

For surgical purposes, it is convenient to divide the facial nerve into surgically relevant segments (Figure 11A).[2,5] We divided the intracranial portion of the nerve into the following 3 segments.

Origin

The first segment or origin consists of the region where the facial nerve exits the brainstem. Because of the intricate and complex topography of brainstem structures, it is of paramount importance to identify anatomic and surgical landmarks in this region to help identify the nerve. The facial nerve exits the brainstem with a motor root and a sensory root. The sensory root, the nervus intermedius, gains its name from its position between the facial and vestibulocochlear nerves at the CPA. The 2 roots arise together from the pons, lateral to the recess, between the inferior olive and the inferior cerebellar peduncle, 1 to 2 mm anterior to the point at which the vestibulocochlear nerve joins the brainstem at the lateral end of the sulcus. In their emergence from the brainstem, they lie superiorly and slightly anteriorly to the vestibulocochlear nerves.

The landmarks on the medial or brainstem side of structures that are helpful in guiding the surgeon to the junction of the facial nerve with the brainstem are the pontomedullary sulcus, the junction of the glossopharyngeal, the vagus, and spinal accessory nerves with the medulla, the foramen of Luschka and its choroid plexus, and the flocculus. The facial nerve maintains a consistent relationship with the junction of the glossopharyngeal, vagus, and spinal accessory nerves with the medulla.

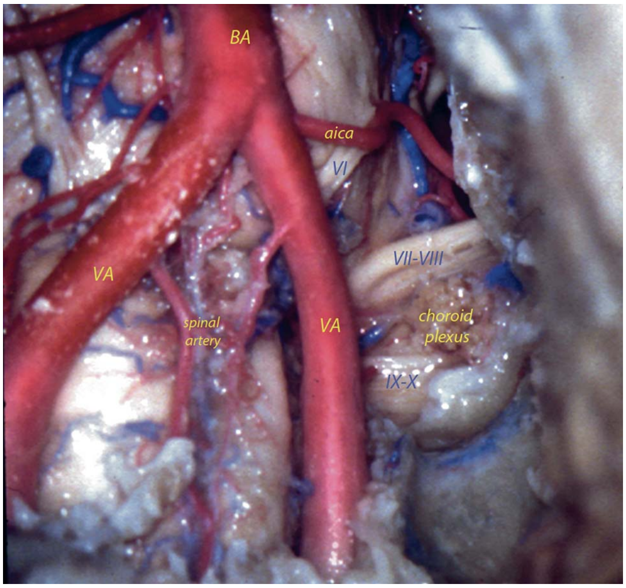

FIGURE 10. *Exposure of the facial nerve via a left mandibular swing transcervical approach. Unobstructed exposure of the cranial base from the ipsilateral infratemporal fossa to the contralateral medial pterygoid plate was achieved along with extensive exposure of the midline and lateral compartments of the cranial base with full control of the facial nerve, cranial nerves VI through X, both anterior inferior communicating arteries, both vertebral arteries, anterior spinal arteries, the flocculus, and the inferior segment of the basilar trunk. Good exposure of the cerebellopontine angle from the anterior perspective was achieved. aica, anterior inferior cerebellar artery; BA, basilar artery; VA, vertebral artery.*

Cerebellopontine Segment

As they emerge from the brain, the 2 roots course anterolaterally with the vestibulocochlear nerve to the internal acoustic meatus. The interval between the vestibulocochlear and facial nerves is greatest at the level of the pontomedullary sulcus and decreases as these nerves approach the meatus. The structures related to the lateral recess of the fourth ventricle that have a consistent relationship with the facial and vestibulocochlear nerves are the foramen of Luschka, along with its choroid plexus, and the flocculus. The arteries crossing the CPA, especially the AICA, enjoy a consistent relationship with the facial and vestibulocochlear nerves, the foramen of Luschka, and the flocculus. In most cases, the AICA passes below the facial and vestibulocochlear nerves as it encircles the brainstem, but it may, in some cases, pass above or between these nerves in its course around the brainstem. The vein of the pontomedullary sulcus, the veins of the cerebellomedullary fissure, middle cerebellar peduncle, and cerebellopontine fissure have a consistent relationship to the facial nerve at this level. It is particularly useful to understand the peculiar rotation of the nerve near the IAC. Although the cochlear nerve and vestibular nerves rotate 90 degrees from the brainstem to the inner ear, the facial nerve remains anterior in its course to the opening of the internal auditory meatus. As a result, the facial nerve is located anterior to the superior vestibular nerve in the lateral end of the meatus.

Intrapetrosal Segment

In its intratemporal course, the facial nerve is housed in a bony canal, which is narrowest at the meatal foramen. The facial nerve in the temporal bone can be subdivided into 3 segments.

Intracanalicular or Labyrinthine. The intracanalicular segment extends from the meatal fundus to the GG and is situated between the cochlea anteromedially and the semicircular canals posterolaterally. The intracanalicular segment ends at the site at which the greater superficial petrosal nerve arises from the facial nerve at the level of the GG located in the geniculate fossa. The geniculate fossa is tightly involved with its surrounding structures.

Tympanic. From the GG, the nerve turns laterally and posteriorly along the medial surface of the tympanic cavity, thus taking the tympanic name for this portion. The tympanic segment runs between the lateral semicircular canal above and the oval window below. The external aspects of the facial canal are important in exposing the nerve during surgical dissection.

Vertical or Mastoid. The second turn of the facial nerve is a curvature that starts in the horizontal plane and then becomes nearly vertical. As the nerve passes below the midpoint of the lateral semicircular canal, it turns vertically downward and courses through the petrous part adjacent to the mastoid part of the temporal bone. Thus, the third segment, which is housed in the fallopian canal and ends at the stylomastoid foramen, is called the mastoid or vertical segment. The vertical portion of the facial canal takes on a nearly rectilinear course and can be traced to the anterior

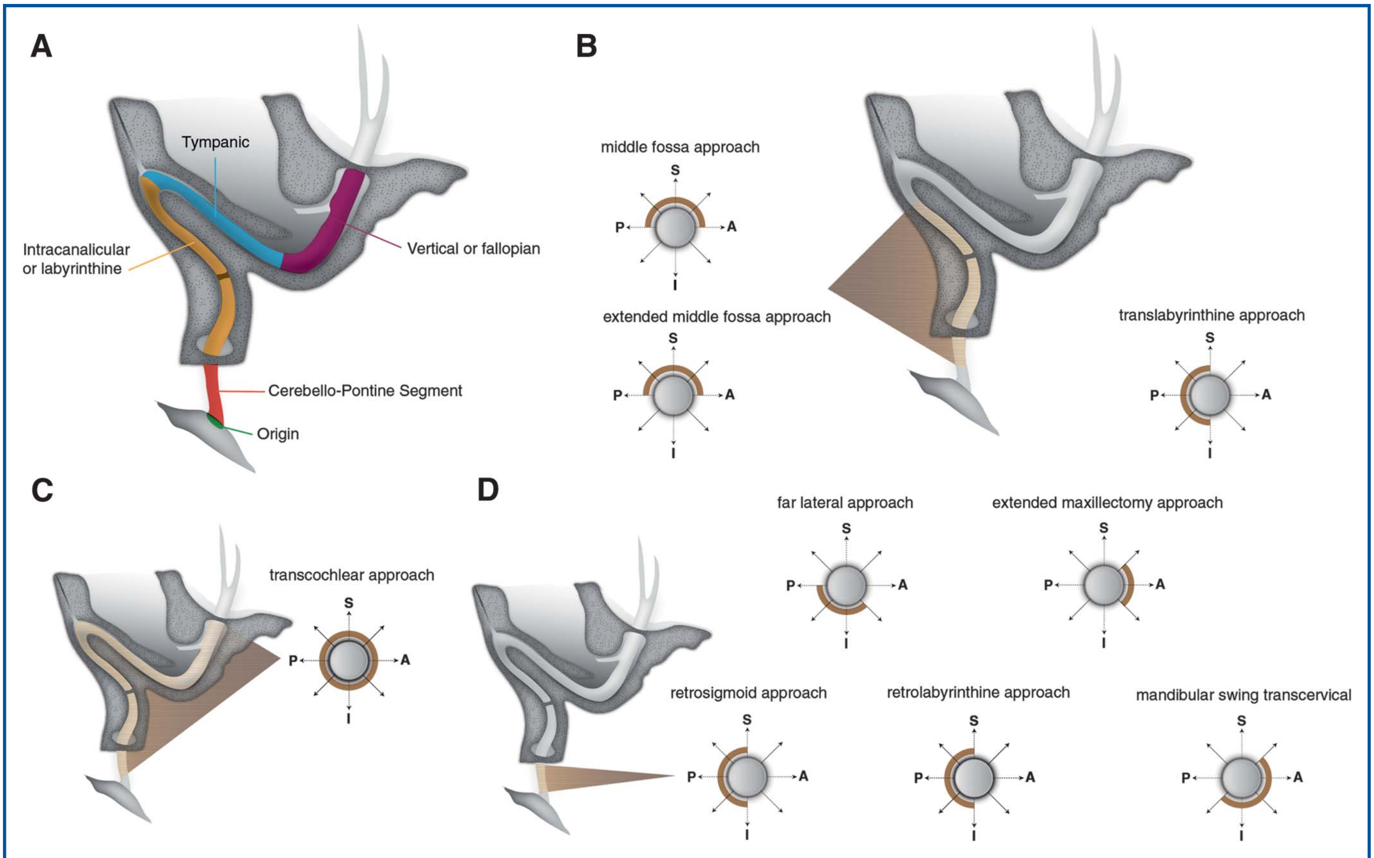

FIGURE 11. *Facial nerve segment exposure by approach.* **A**, *segments of the facial nerve. The facial nerve was divided into surgically relevant segments: origin (green), cerebellopontine (red), intracanalicular/labyrinthine (yellow), tympanic (blue), and vertical/mastoid (pink).* **B**, *depiction of the surgical exposure of the facial nerve achieved via the anterior petrosal approaches and the translabyrinthine approach. The middle fossa and extended middle fossa approaches provided an exposure of approximately 180 degrees of the facial nerve, ie, part of the anterior, the entire superior, and part of the posterior aspects of the nerve, in both the cerebellopontine segment and intracanalicular portion. The translabyrinthine approach provided an exposure of approximately 180 degrees, ie, part of the superior, the entire posterior, and part of the inferior aspects of the nerve, of the cerebellopontine and intracanalicular segments of the facial nerve.* **C**, *the transcochlear approach allowed optimal visualization of the entire course of the facial nerve from the origin to the stylomastoid foramen and permitted circumferential control of each segment of the nerve (cerebellopontine, intracanalicular, tympanic, and vertical).* **D**, *the retrolabyrinthine approach provided an exposure of approximately 180 degrees, ie, part of the superior, the entire posterior, and part of the inferior aspects of the nerve, of the cerebellopontine segment of the facial nerve. This approach provided an exposure of 180 degrees of the facial nerve in part of the superior, the entire posterior, and part of the inferior aspect of the nerve. The far lateral approach provided an exposure of approximately 130 degrees of the cerebellopontine segment of the facial nerve, ie, part of the posterior and the entire inferior aspects of the nerve. The extended maxillectomy afforded an exposure of approximately 90 degrees because it allowed visualization of the entire anterior aspect of the cerebellopontine segment of the facial nerve. The mandibular swing transcervical approach provided an exposure of approximately 180 degrees and allowed good visualization of the entire anterior and inferior aspects of the cerebellopontine segment of the facial nerve, and exposing it fully from the brainstem to its entrance in the internal auditory canal. A, anterior; I, inferior; P, posterior; S, superior.*

edge of the digastric ridge where the stylomastoid foramen lies, marking the end of the intratemporal segment. It is within this segment that the chorda tympani arises and marks the final separation of fibers that form the nervus intermedius. Medially, the facial canal may be dehiscent within the jugular fossa, although this relationship is highly variable.

RESULTS

Cranial base surgical approaches provide different levels of surgical access and exposure of the facial nerve. We describe the different degrees of exposure provided by the following approaches (Table 3).

Anterior Transpetrosal Approaches

Middle Fossa Approach

This approach provided an exposure of approximately 180 degrees of the facial nerve, ie, part of the anterior, the entire superior, and part of the posterior aspects of the nerve, in both the cerebellopontine segment and intracanalicular portion (Figure 11B). Surgical maneuvering at the intracanalicular segment was somewhat limited via this approach because of the narrow surgical corridor. However, visualization of the nerve was somewhat less direct at the level of the cerebellopontine segment because of the nerves' relative anatomic

TABLE 3. Segmented Facial Nerve Exposure by Approach[a]

Approach	Amount of Exposure, deg	Exposure Score by Segment				
				Intrapetrosal		
		Origin	Cerebellopontine	Intracanalicular	Tympanic	Vertical
Anterior petrosal						
Middle fossa	180	0	2	2	0	0
Extended middle fossa	180	0	4	4	0	0
Posterior Transpetrosal						
Translabyrinthine	180	0	3	3	0	0
Transcochlear	360	4	4	4	4	4
Retrolabyrinthine presigmoid	180	0	3	0	0	0
Retrosigmoid	180	3	3	1[a]	0	0
Far lateral transcondylar	130	0	2	0	0	0
Anterior transfacial						
Extended maxillectomy	90	0	2	0	0	0
Mandibular swing transcervical	180	0	3	0	0	0

[a]Partial drilling of the most medial aspect of the posterior wall of the internal auditory canal affords limited exposure of the intracanalicular segment of the nerve.

positions along their origin until the IAC. In the cerebellopontine segment, the facial nerve was found superomedial to the cochlear, the superior vestibular nerve superomedial, and the inferior vestibular nerve superolateral to the facial. As the nerves crossed to the porus acusticus, they rotated 90 degrees in the lateral direction. This rotation results in the superior vestibular nerve being superior, the inferior vestibular nerve being inferolateral, and the cochlear nerve being inferomedial relative to the facial nerve. Because of this complex anatomy, the surgical perspective provided by this approach enabled immediate visualization of the intracanalicular portion of the facial nerve after the dura was opened. This approach afforded a degree of exposure of 2, in the cerebellopontine and intracanalicular segments, with good exposure but somewhat difficult mobilization of the facial nerve.

Extended Middle Fossa Approach

This approach provided an exposure of approximately 180 degrees, ie, part of the anterior, the entire superior, and part of the posterior aspects, of both the cerebellopontine segment and the intracanalicular portion of the nerve (Figure 11B). This approach extends the middle fossa approach to achieve resection of the anterior portion of the petrous bone with improved visualization and mobilization of the anterior portion of the facial nerve. The surgical exposure extended from the lateral wall of the cavernous sinus, across the trigeminal nerve, to the area lateral to the acoustic meatus, and provided wide access to the anterior part of the posterior fossa. The dural opening revealed the facial nerve just anterior to the superior vestibular nerve in its entire course from the brainstem to the GG and provided an exposure of approximately 180 degrees of both the cerebellopontine segment and the intracanalicular portion of the facial nerve. The basilar artery was also identified, and the AICA was found with cranial nerve VI. This approach afforded a degree of exposure of 4 with improved visualization of the anterior portion of the nerve and better mobilization of the nerve compared with the middle fossa approach.

Posterior Transpetrosal Approaches

Translabyrinthine Approach

This approach provided an exposure of approximately 180 degrees, ie, part of the superior, the entire posterior, and part of the inferior aspects of the nerve, of the cerebellopontine and intracanalicular segments of the facial nerve (Figure 11B). It allowed visualization and mobilization of the nerve, achieving a value of exposure of 3. However, this approach exposed the facial nerve through only 1 angle without any room for manipulation. Because of the relative anatomic positions of the nerves, from their origin to the IAC as previously described, the anatomy presented to the surgeon after the dura was opened differs from the cerebellopontine to the intracanalicular segment. The superior and inferior vestibular, facial, and acoustic nerves were compacted at the cerebellopontine level and started separating at the porus acusticus, becoming well differentiated at the fundus of the canal. Inside the internal acoustic meatus, the facial nerve ran together with the cochlear nerve and with the inferior and superior vestibular nerves. The meatus is divided into a superior and an inferior portion by a horizontal ridge, called either the transverse or falciform crest. The facial and superior vestibular nerves are superior to the crest. The facial nerve was observed anterior to the superior vestibular nerve, separated from it at the lateral end of the meatus by the vertical crest. The cochlear and inferior vestibular nerves ran below the transverse crest with the cochlear nerve located anteriorly. Thus, the lateral meatus can be divided into 4 portions, with the facial nerve anterosuperior, the cochlear nerve anteroinferior, and the superior vestibular nerve posteroinferior. Therefore, the 2 vestibular nerves were the first nerves encountered once the dura was opened. The superior vestibular nerve covers the facial nerve, and the inferior vestibular nerve covers the cochlear nerve. The vestibular nerves, specifically the superior vestibular nerve, needed to be severed to achieve full exposure of the facial nerve.

Extended Posterior Petrosectomy (Transcochlear Approach)

This approach allowed optimal visualization of the entire course of the facial nerve from the origin to the stylomastoid foramen and permitted circumferential control of each segment of the nerve (cerebellopontine, intracanalicular, tympanic, and vertical) (Figure 11C). This approach permitted an added degree of exposure compared with the translabyrinthine approach, achieving a 360-degree exposure of the facial nerve. The nerve was completely freed from its bony canal and could be mobilized and transposed posteriorly, allowing complete control of the nerve and room for working around and manipulating the nerve. The value of exposure achieved was 4. The added mobilization and posterior transposition of the facial nerve resulted in better anterior exposure with an unobstructed view of the midportion of the clivus.

Retrolabyrinthine Presigmoid Approach

This approach provided an exposure of approximately 180 degrees, ie, part of the superior, the entire posterior, and part of the inferior aspects of the nerve, of the cerebellopontine segment of the facial nerve (Figure 11D). This approach allows good surgical control of the cerebellopontine segment of the nerve, although complete manipulation is somewhat limited by the narrow surgical corridor, achieving a value of exposure of 3. The anteromedial limit of the surgical exposure was the cranial nerve VII-VIII complex, the anterolateral limit was the IAC, the medial limit was the pons, and the posterior limit was the sigmoid sinus. The trigeminal nerve limited the exposure superiorly while the glossopharyngeal and vagus nerves bound the exposure inferiorly. The presigmoid surgical perspective allowed a more direct exposure of the cerebellopontine segment of the facial nerve without the need for retracting the cerebellar hemisphere compared with the retrosigmoid exposure. This approach is particularly useful for lesions that involve this segment of the facial nerve and that do not invade the acoustic canal. The main disadvantage of this approach is that, because of the more anteroposterior direction of the surgical trajectory, it does not afford good control of lesions involving the facial nerve that extend more anteriorly toward the clivus.

Retrosigmoid Approach

This approach provided an exposure of 180 degrees of the facial nerve in part of the superior, the entire posterior, and part of the inferior aspect of the nerve (Figure 11D). Additionally, it allowed surgical maneuvers around the nerve and manipulation of the AICA as it courses around the nerve. The retrosigmoid approach exposed the facial nerve from its origin at the brainstem near the lateral end of the pontomedullary sulcus, 1 to 2 mm anterior to the point at which the vestibulocochlear nerve joins the brainstem at the lateral end of the sulcus. The interval between the vestibulocochlear and facial nerves is greatest at the level of the pontomedullary sulcus and decreases as these nerves approach the meatus. The retrosigmoid approach, after cerebellar retraction, allowed good exposure of the structures of the CPA and the relationships with the facial nerve at this level. The facial nerve is overlaid by cranial nerve V, the superior petrosal vein, and the subarcuate artery, which comes from the AICA. The AICA that comes from the midportion of the basilar trunk makes a loop around the facial nerve. In most cases, the AICA passed below the facial and vestibulocochlear nerves as it encircled the brainstem, but it also was observed to pass above or between these nerves in its course around the brainstem. The labyrinthine, recurrent perforating, and subarcuate branches arise from the AICA near the facial and vestibulocochlear nerves. The foramen of Luschka is situated at the lateral margin of the pontomedullary sulcus, immediately posteroinferior to the junction of the facial and vestibulocochlear nerves with the brainstem. The flocculus projects from the margin of the lateral recess and the foramen of Luschka into the CPA, just posterior to where the facial and vestibulocochlear nerves join the pontomedullary sulcus. Partial drilling of the most medial aspect of the posterior wall of the IAC affords limited exposure of the intracanalicular segment of the nerve. The anterior surgical boundaries of this approach are the same as the ones of the presigmoid route. The disadvantage is the cerebellar retraction, and the advantage is the more posterior-to-anterior surgical trajectory, which facilitates better visualization of the anterior surface of the brainstem toward the midline. This approach afforded sufficient but not complete control of the facial nerve because of a lack of anterior exposure and achieved a degree of exposure of 3 at the origin and in the cerebellopontine segment.

Far Lateral Transcondylar Approach

This approach provided an exposure of approximately 130 degrees of the cerebellopontine segment of the facial nerve, ie, part of the posterior and the entire inferior aspects of the nerve (Figure 11D). The far lateral approach allowed good exposure and surgical control of the nerve but did not permit complete manipulation because of the lack of anterior and superior visualization and therefore achieved a degree of exposure of 2. This approach also allowed a posterior and inferior view of the trigeminal nerve and good overall control of cranial nerves IX, X, XI, and XII, the lower third of the basilar artery, the vertebral artery, the vertebrobasilar junction, the PICA, and portions of the AICA.

The far lateral approach afforded an inferior perspective of the surgical anatomy of the facial nerve from its origin in the brainstem to its entrance in the IAC, particularly of its relationships with the lower cranial nerves. The facial nerve maintained a consistent relationship to the junction of the glossopharyngeal, vagus, and spinal accessory nerves with the medulla. It arose 2 to 3 mm above the most rostral rootlet forming these nerves. The structures related to the lateral recess of the fourth ventricle that were found to have a consistent relationship with the facial and vestibulocochlear nerves include the foramen of Luschka along with its choroid plexus and the flocculus. The foramen of Luschka was found posteroinferior to the junction of the facial and vestibulocochlear nerves with the brainstem. The PICA was observed to have a much more complex relationship with these nerves. The proximal part of the PICA passed around or between and often stretched or distorted the rootlets of the nerves in the lower complex. At the anterolateral medulla, the PICA passed around or between the rootlets of the hypoglossal nerve. At the posterolateral margin of the medulla, it passed between the glossopharyngeal, vagus, and spinal accessory nerves.

Anterior Transfacial Approaches

Extended Maxillectomy

This approach afforded an exposure of approximately 90 degrees because it allowed visualization of the entire anterior aspect of the cerebellopontine segment of the facial nerve (Figure 11D). This approach provided an overall good degree of exposure of the midline and lateral compartment of the cranial base. The facial nerve was visualized in its cerebellopontine segment, from its exit from the brainstem until it entered the internal acoustic meatus. It was visualized from only an anterior perspective. This approach provided only a narrow surgical corridor to the anterior aspect of the facial nerve without good surgical maneuverability. Therefore, the value of exposure was 2.

Mandibular Swing Transcervical Approach

This approach allowed unobstructed exposure of the cranial base from the ipsilateral infratemporal fossa to the contralateral medial pterygoid plate. It offered an extensive exposure of the midline and lateral compartments of the cranial base with full control of the carotid artery, internal jugular vein, and control of the cranial nerves IX through XII. The facial nerve was fully exposed from the brainstem to its entrance in the IAC in its anterior and inferior aspects. This approach provided an exposure of approximately 180 degrees and allowed good visualization of the entire anterior and inferior aspects of the cerebellopontine segment of the facial nerve (Figure 11D). It afforded sufficient anterior and inferior control of the facial nerve in its cerebellopontine portion and achieved a degree of exposure of 3.

DISCUSSION

The inherent difficulty in the surgical exploration of the facial nerve is derived from its length and complex anatomic course.[36,37] Anatomic variations exist in length and/or thickness of all intracranial segments of the facial nerve as well as frequent dehiscence, which can lead to challenging surgical ventures. Close relationships with the surrounding structures in the intracisternal and intracanalicular segments must be well understood. Thorough knowledge of the surgical and topographic anatomy of the facial nerve is mandatory for preserving functionality, whether the nerve is the main surgical target or it is on the surgical route to neighboring structures.

The facial nerve can be involved in a number of lesions and is frequently on the surgical route to deeper targets.[38] The facial nerve can be exposed through multiple surgical windows, and the number of windows has increased in recent years because of new operative advances in cranial base surgery.[6-8,13-19,23,30] Approach selection is governed by many factors including, but not limited to, lesion location, extension, size, pathology, surgical goal, and excision type (radical, subtotal removal, or biopsy), the preference and confidence of the surgeon, degree of exposure of the nerve, and risk of postoperative deficits and morbidity.[13,15-18,22,23,30,32] To assist with approach selection, because of the high number of approach variants and governing variables, we evaluated the degree of exposure of the facial nerve via numerous approaches, noting the boundaries of the approaches and the complex surgical anatomy of the facial nerve in each (Figure 12).

The anterior petrosal approaches offer good visualization of the facial nerve in the CPA and in the intracanalicular portion from a superior perspective. These approaches provide good exposure of the facial nerve without sacrificing the labyrinthine structure and therefore preserving hearing. The middle fossa approach is particularly suited for small lesions that involve purely the intracanalicular portion of the facial nerve. The advantage of the middle fossa approach is the preservation of hearing. However, the exposure afforded by the middle fossa approach is limited to the superior aspect of the facial nerve, and surgical control is inadequate if the nerve is involved in a larger lesion. The extended middle fossa approach provides more working space anteriorly by removing the portion of petrous bone anterior to the IAC and medial to the intrapetrous carotid artery. This technique allows anterior control of the nerve and increases the possibility for surgical manipulation. However, both anterior transpetrosal approaches only offer limited control of the nerve in its posterior aspect and inadequate control at its inferior aspect.

In cases of lesions involving the facial nerve and extending posteriorly or if the surgical target is the anatomic region posterior to the nerve, a posterior petrosectomy type of approach and the retrosigmoid approach are the routes of choice. The posterior petrosectomies provide more direct visualization of the facial nerve without the need for cerebellar retraction. In addition, the transcochlear approach exposes the facial nerve in its entire intracranial and intrapetrosal course until the stylomastoid foramen. The translabyrinthine and retrolabyrinthine approaches offer good exposure of the posterior and superior aspect of the cerebellopontine segment of the facial nerve with more direct visualization and good surgical control of this portion without the need for cerebellar retraction. The translabyrinthine approach also provides good exposure and control of the posterior aspect of the intracanalicular segment of the facial nerve. The limit of both the translabyrinthine and retrolabyrinthine approaches, however, is the lack of anterior exposure and control of the facial nerve, which could be crucial in cases in which lesions extend considerably beyond the nerve. The transcochlear approach affords total control and manipulation of the facial nerve in its entire circumference and, by transposing the nerve, allows good exposure of the entire posterosuperior surface of the

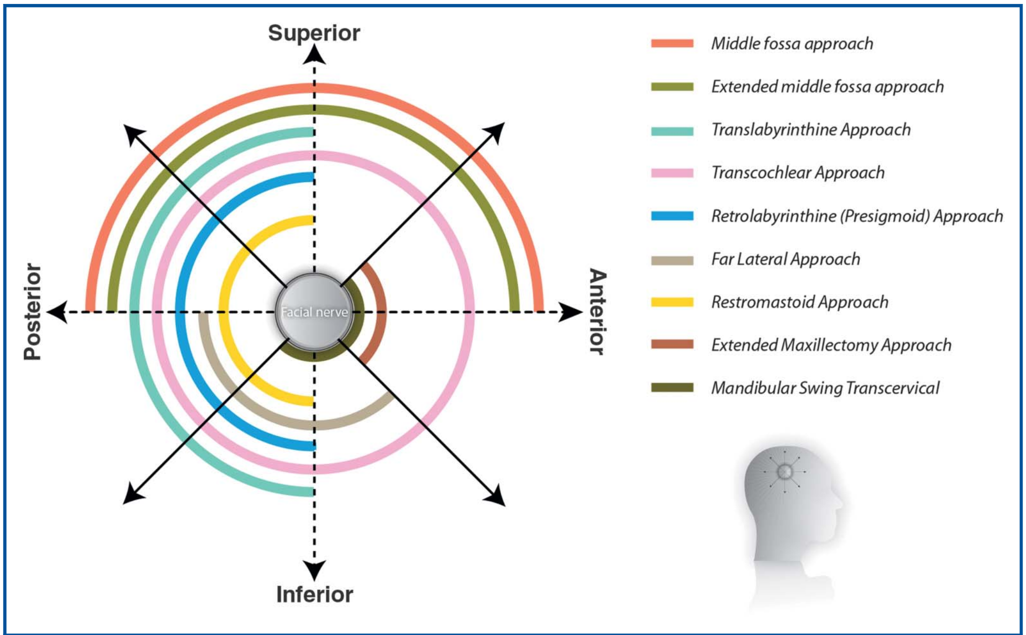

FIGURE 12. *Depiction of facial nerve quadrant exposure by approach. The anterior petrosal approaches exposed the facial nerve in part of the anterior, the entire superior, and part of the posterior quadrants. The translabyrinthine approach exposed part of the superior, the entire posterior, and part of the inferior quadrants. The transcochlear approach exposed all 4 quadrants. The retrolabyrinthine approach exposed part of the superior, the entire posterior, and part of the inferior quadrants. The far lateral approach exposed part of the posterior and the entire inferior quadrants. The retrosigmoid approach exposed part of the superior, the entire posterior, and part of the inferior quadrants. The extended maxillectomy exposed only the anterior quadrant. The mandibular swing transcervical approach exposed the entire anterior and inferior quadrants.*

petrous bone and midportion of the clivus until the midline. For this reason, it is the most suitable approach for lesions extending from the cerebellopontine region to the midline or for those instances when the main target is the midportion of the clivus. The main advantage of the presigmoid retrolabyrinthine exposure is preservation of the labyrinthine structure and thus hearing, as well as the lack of cerebellar retraction with more direct exposure of the region. Therefore, it is the approach of choice when exposing the posterior aspect of the facial nerve and for lesions that are confined to the CPA. The transpetrosal approaches can be combined to different degrees to improve exposure of the facial nerve, particularly when the nerve is involved in large lesions with significant extension into surrounding areas. A combined extensive transpetrosal (translabyrinthine and transcochlear) approach with transtentorial extension can increase the exposure of tumors originating from the facial nerve and involving the petrous bone with superior and anterior extension. Additionally, a conservative perilabyrinthine transtentorial approach that spares the labyrinth and combines a perilabyrinthine dissection with a subtemporal exposure and tentorial incision can expand the limits of the retrolabyrinthine approach by adding improved superior and anterior visualization of the facial nerve. The retrosigmoid approach affords good exposure of the entire posterior aspect and part of the inferior and superior aspects of the cerebellopontine portion of the facial nerve. It offers limited exposure of the surgical corridor in front of the facial nerve toward the clivus, but it has the advantage of preserving hearing. As such, it remains the most popular approach among neurosurgeons for lesions of the CPA and for lesions extending along the posterior surface of the petrous bone until the midportion of the clivus.[13,24-26] Although proper training in surgical techniques for transpetrosal dissection could afford better surgical trajectories to access these more anterior regions. Nonetheless, the retrosigmoid approach affords better visualization of the surgical corridor in front of the facial nerve compared with the presigmoid retrolabyrinthine because of the better surgical perspective from posterior to anterior and the ease of access to deeper targets along the posterior surface of the petrous bone. In cases in which the inferior aspect of the facial nerve needs to be exposed or the lesion involves the facial nerve and has considerable inferior extension, the far lateral approach is the surgical route of choice. The far lateral approach affords good exposure of the inferior portion of the cerebellopontine segment of the facial nerve, although lack of control of the anterior and posterosuperior aspects of the facial nerve limits proper surgical manipulation of the nerve.

Anterior and anteroinferior exposure of the facial nerve can be achieved with the transfacial approaches, ie, the extended maxillectomy and the mandibular swing transcervical approach. The extended maxillectomy provides good exposure of the region just anterior to the facial nerve, but offers only visualization of the anterior aspect of the cerebellopontine segment of the facial nerve. Surgical control is not possible because of the narrow and angled surgical corridor. On the other hand, the wider surgical dissection of the mandibular swing transcervical approach provides a broader surgical corridor to the lateral aspect of the intracranial surface of the cranial base with good visualization of the anterior aspect of the cerebellopontine segment of the facial nerve. Surgical control and manipulation of the cerebellopontine segment of the facial nerve is possible, but only in the region anterior to the nerve and with a lack of control of the entire region posterior and superior to the nerve.

CONCLUSION

Comprehensive knowledge of the surgical anatomy and a thorough familiarity with the often complex surgical techniques used in the various approaches allows a broader spectrum of operative choices. Each approach should be tailored to provide the best access to the particular surgical region and to afford optimal control of the intracranial course of the facial nerve, whether the nerve is the main surgical target or on the surgical route to deeper targets. We quantified the exposure of the facial nerve provided by numerous surgical approaches and discussed how proper selection of the most appropriate surgical route must rely not only on the size, nature, and general location of the lesion, but also on the capability of the particular approach to better expose the appropriate region of the facial nerve.

The choice of surgical approach is based on the preference of the surgeon, patient symptomatology, and the specific pathology. Anterior approaches to the facial nerve (extended maxillectomy and mandibular swing transcervical) provide good exposure to the anterior aspect of the cerebellopontine segment of the facial nerve, but surgical manipulation is somewhat limited because of the narrow and deep surgical corridors. Anterior petrosal approaches provide a safe and convenient exposure of the anterior aspect of the cerebellopontine segment of the facial nerve, although a combined transpetrosal approach would be a more adequate choice in the presence of a voluminous lesion. The superior aspect of the cerebellopontine segment of the facial nerve, particularly if involved by a small lesion, is adequately accessed via a middle fossa approach, although larger lesions involving the superior aspect of the cerebellopontine portion of the nerve are better accessed via a retrolabyrinthine approach extended by the incision of the tentorium. The posterior aspect of the cerebellopontine segment of the facial nerve is adequately exposed by the retromastoid and retrolabyrinthine approaches. The inferior aspect of the cerebellopontine segment of the facial nerve is adequately accessed by the retromastoid and far lateral approaches.

The middle fossa approach is particularly useful for small lesions involving and confined to the intracanalicular portion of the facial nerve, and it is the route of choice in patients with intact hearing. The retromastoid approach is also a valid means of surgical access for facial nerve lesions extending from the CPA to the medial portion of the IAC. The translabyrinthine approach provides adequate access to lesions extending to the intracanalicular segment of the facial nerve up to the fundus of the canal and is particularly useful in patients with impaired hearing. Conversely, the transcochlear approach provides full circumferential exposure and is therefore the surgical access of choice for accessing lesions involving the entire course of the facial nerve.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

The facial nerve is one of the primary and most important anatomical structures encountered during surgeries at the cerebellopontine angle. Its preservation is extremely important for functional and esthetic reasons that significantly affect the quality of life of the patient. This preservation depends on, among other factors, the type of lesion, its size, the lesion's relationship to the nerve, and particularly on the technical experience and expertise of the surgeon.

The authors should be congratulated for this thorough and comprehensive anatomical study providing detailed information regarding the exposure of the facial nerve as seen with different surgical approaches. It provides a useful contribution for better understanding of its intricate anatomy with the ultimate goal of preoperative planning for postoperative anatomical and functional preservation of the nerve.

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