Fukushima's

Microanatomy and Dissection of The Temporal Bone

for Surgery of Acoustic Neuroma, and Petroclival Meningioma

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AF-Neurovideo, Inc.

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Foreword

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Professor and Chairman
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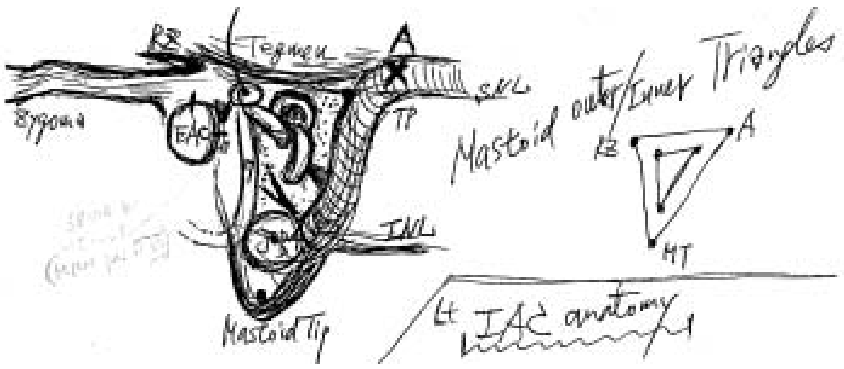


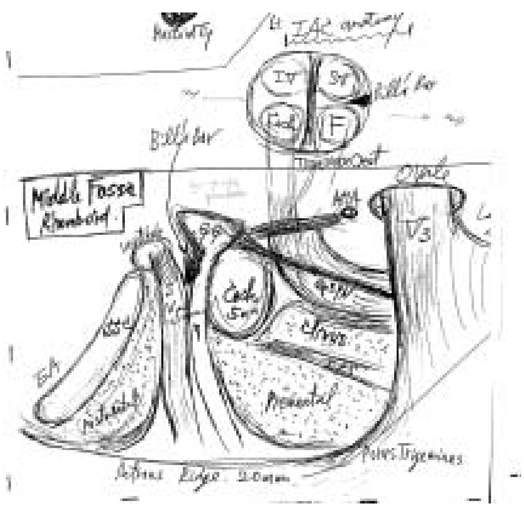
by Taka -1994-

Preface

Recent worldwide interest in developing strategies to deal with complex clinical problems related to the cranial base has spawned a super subspecialty of surgical practice. Neurological surgeons have joined forces with Otologists, Head and Neck surgeons, Plastic surgeons, Radiophysicists, Anatomists, and surgical instrument manufacturers in an attempt to make previously unapproachable or untreatable lesions treatable. It is clear that in order to participate in this burgeoning area of surgical practice, certain adjuncts and skills are mandatory. Detailed knowledge of the microanatomical and morphometric characteristics of various regions of the cranial base is a prerequisite. Facilities with special microsurgical instrumentation and microsurgical techniques for skull base surgery are a must. Complete confidence and expertise with bone removal instrumentation, especially high-speed power drills, used in restricted apertures, must be gained prior to initiating any strategies directed toward patient care. Development of a team approach using otolaryngology, plastic surgery, and other strategic associations as may be necessary, must be planned far in advance of clinical deployment. Familiarity with, or innovative development of, new approaches to particular regions of the skull base must be created. Practice in the skull base anatomy laboratory to the point where transferal of laboratory techniques to the operating theater is seamless will further enhance the functioning of the skull base team.

It is our hope that this dissection text of the temporal bone will serve as a practical manual to acquire operative techniques, as well as a resource to the developing skull base team. The authors of the manual, in many instances, were instrumental in either developing the approaches or modifying and popularizing the approaches for use in clinical medicine. The technical steps involved in accomplishing each approach have been based on both an intensive laboratory investigation, carried out using a number of cadaveric preparations, and their employment in thousands of clinical cases.

Takanori Fukushima, M.D.
Tetsuro Sameshima, M.D.



by Taka -1994-

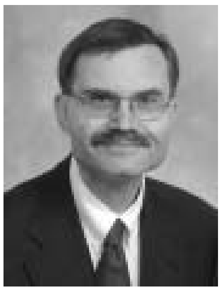
Authors

Takanori Fukushima, M.D.

Dr. Fukushima is internationally renowned for his research and clinical work in the treatment of skull base tumors, pituitary tumors, cerebral aneurysms and arteriovenous malformations, trigeminal neuralgia, and hemifacial spasms. Named Honorary Professor at Karolinska Institute, Stockholm, Sweden; University of the Mediterranean, Marseille, France; and University of Berlin, Germany, he served as Professor of Neurosurgery at University of Southern California, Los Angeles and at Allegheny Neuroscience Institute, Pittsburgh, Pennsylvania.

Dr. Fukushima is now Professor of Neurosurgery at both Duke University Medical Center, North Carolina and West Virginia University and Director of both Carolina Neuroscience Institute and International Neurosurgery Education Foundation.

Allan H. Friedman, M.D.



Allan H. Friedman, M.D., is an internationally recognized tumor and vascular neurosurgeon. His clinical interests are in the areas of cerebrovascular disease, brain tumors, and peripheral nerve surgery. He has a career-long interest in neuro-oncology, is responsible for over ninety percent of all tumor resections and biopsies conducted at Duke, and has authored hundreds of articles on the neurosurgical management of brain tumors and vascular lesions.

Dr. Friedman is the Guy L. Odom Professor of Neurological Surgery and the Chief of Neurosurgery at Duke University Medical Center. Dr. Friedman is also the Neurosurgery Program Director, Co-Director of the Clinical Neuro-Oncology Program of The Brain Tumor Center at Duke and Associate Chief of the Preuss Laboratory for Brain Tumor Research.

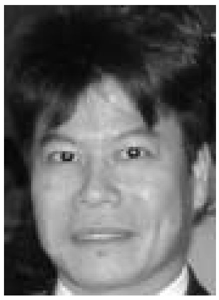
Luciano Mastronardi, M.D.

Luciano Mastronardi is a 44-year-old Neurosurgeon of the " Sant'Andrea" Hospital, Second Faculty of Medicine and Surgery, University La Sapienza of Roma. His main fields of surgical and scientific interest are skull base surgery, vascular surgery, and spine surgery. He published several chapters in books and booklets and over than 100 articles in international journals and did more than 150 lectures and meeting presentations. He is also referee for peer-review of several journals, including Spine and BMC Cancer.

Starting from 1999 he likes to consider himself one of the italian pupils of Takanori Fukushima: he did several Educational Fellowships at the Carolina Neuroscience Institute and at Duke University, attended over than 10 of Fukushima's skull base courses and was co-director with him of the Advanced Skull Base Microanatomy Workshop and Hands-on Dissection Course for Italian Neurosurgeons in West Palm Beach and of the first Roman Temporal Bone Dissection Course.

He is member of Italian and European Societies of Neurosurgery and Neuro-oncology, International Member of the Congress of Neurological Surgeons (with the position of International Ambassador for Italy), and is one of the Board of Directors of the *International Neurosurgery Education Foundation (INEF: T. Fukushima, T. Sameshima, K. Watanabe, K. Saitoh, H. Koga, L. DeWaele, L. Mastronardi, S. Emadian)*.

Tetsuro Sameshima, M.D.



Dr. Sameshima received his postgraduate training in neurosurgery at University of Miyazaki Hospital (formerly known as Miyazaki Medical College) in Miyazaki, Japan. He is certified by Japanese Board of Neurological Surgery. Presently, Dr. Sameshima is working as a Research Fellow, under the direction of Drs. Allen Friedman and Takanori Fukushima, at Duke University Medical Center, Durham, North Carolina. He is also affiliated with AF-NeuroVideo, Inc. and International Neurosurgery Education Foundation.

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For more information about this manual, contact Dr. Sameshima at: tetsuro@fc.miyazaki-u.ac.jp

Stan M. Coffman

Stan Coffman received his graduate training at the University of Texas Health Science Center in Dallas, Texas. He was Senior Medical Illustrator at the University of Cincinnati and presently is the Medical Illustrator for Duke University Medical Center, in Durham, North Carolina.

Mr. Coffman specializes in Medical Illustration and Web Site Development. Areas of specialization include Neurosurgery, Otolaryngology and Cardiothoracic Surgery. His illustrations have appeared in numerous textbooks, journals, he illustrated the **Atlas of Cardiothoracic Surgery**, published by W.B. Saunders and **Manual of Skull Base Dissection second edition**, published by AF-Neurovideo, Inc.

For more information contact Mr. Coffman at:
medartist@carolinaneuroscience.com

To Neurosurgery Residents

Any younger neurosurgeons who wish to be a very skillful microsurgeon (not inserting needles and endoscopes, not pushing radiation buttons), and wish to learn Fukushima's micron-neurosurgery, keyhole microtechniques, and advanced skull base approaches are cordially invited to participate in Fukushima's 3-day intensive whole head practical dissection course at West Palm Beach Anspach Microanatomy Lab. We practice only practical realistic microsurgical anatomy and dissection techniques. We have always many foreign participants from all over the world. Please come, join us and enjoy international friendship, two official dinners and Fukushima doctorine!

Carolina Neuroscience Institute
& International Neurosurgery Education Foundation

Takanori Fukushima, M.D.

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Temporal bone laboratory

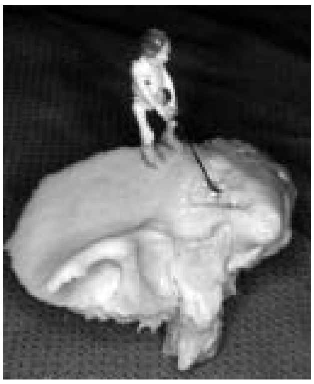
Temporal bone laboratory in Carolina Ear Institute, Raleigh, NC

House-Urban temporal bone holder

Safety Instructions for Skull Base Drilling

1. Use the highest quality stable power drill = Anspach® Microplus, eMax and xMax
2. Secure with one hand (3 fingers) holding - no tremor, no kick, no slip
3. Sucker guidance, retraction, cross protection
4. Selection of burrs
   Round Cutting 3, 4, 5, 6 mm
   Extra Coarse 3, 3.5, 4, 4.5, 5 mm
   Coarse 2, 2.5, 3, 4, 5 mm
   Smooth Diamond 1, 1.5, 2-6 mm

5. Use larger burrs
6. Burr shaft not contacting anything
7. Egg-shelling Technique: inside shaving, up-shave, side-shave, counter clockwise shave
8. RPM control with vari-pedal
9. Continuous irrigation - cooling
   Flag needle
   Suction-irrigation
   Drill irrigation
   Assistant-delivered needle irrigation
10. Hose holder for sterility and minimal resistance
11. Neurovascular tissue protection
    Gelfoam, Surgifoam
    Bone wax plate



Basic Principles of Drilling Technique

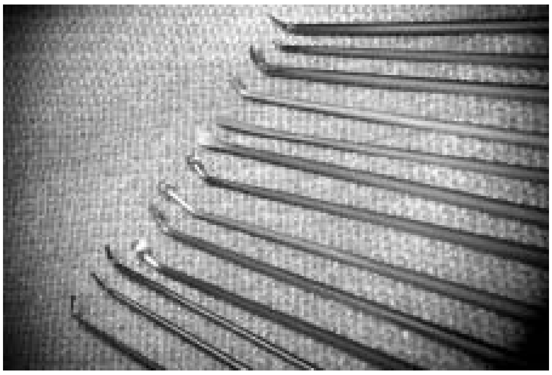
- **Stable one hand, 3 fingers holding technique**
- **RPM adjustable by foot pedal**
- **Wide selection of burrs**
- **Constant irrigation for cooling and clearing of bone dust**
- **Thinning of bone to egg shell over dura and soft tissues**
- **Avoidance of tremor, drill kick, and slip**

3 fingers folding technique

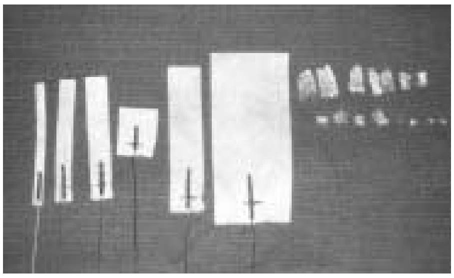
Tear drop shape side port
Pressure adjustable combined irrigation sucker

The most important instruments for acoustic neuroma

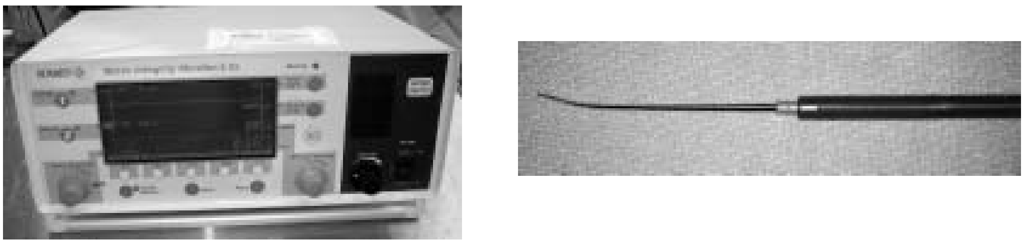
- **Hitzelberger-McElveen knife (Bullet tip)**
- **Sickle knife**
- **1 mm ring curette**
- **1, 1.5, 2mm cup curettes**
- **Rosen needle**
- **1mm micro alligator tumor forceps**
- **45 & 90 degrees sharp hook knife**
- **Sharp dog dissector**
- **Super-micro patties**
- **Thin blade micro-scissors**
- **Facial nerve stimulatior (Xomed)**



Fukushima CP angle super-micro dissectors



Micro-patties and Surgicel



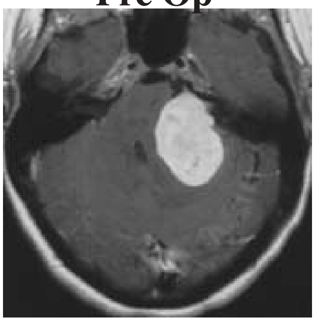
Facial nerve stimulatior (NIM-2 XL / Xomed)

Fukushima's universal retraction system

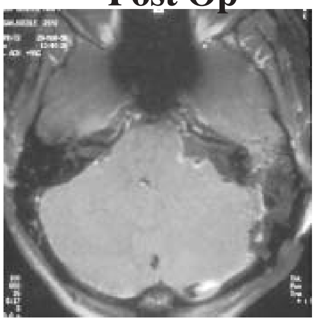
10 Principles of Acoustic Tumor Surgery

1: Fukushima-lateral position
2: Keyhole opening and micron-technique
3: CSF aspiration (Lateral medullary cistern)
4: Clean, bloodless and sharp dissection
5: Maintain arachnoid planes
6: Sufficient internal tumor coring and Debulking
7: "V"-cut technique for detachment of vestibular nerves (final capsule elevation)
8: Preserve AICA, PICA and perforating vessels
9: Preserve petrosal veins
10: Identify 7th nerve (Use facial nerve stimulator)

Pre Op



Post Op



Post -Op Hearing Grade A

<u>Goal: Give patients a normal face!!</u>

Operative Positioning

1: Lateral Position
Retrosigmoid and Occipital~Posterior Occipital Approach
for Regular~Fat, Big, Obese, Short Neck Patient

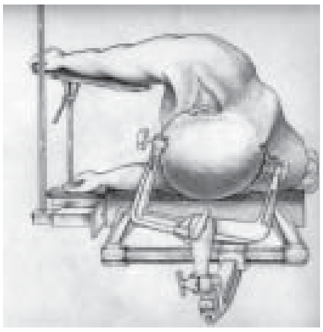
2: Supine-Head Lateral Position
Translab, Presigmoid and Combined Petrosal Approach
for Thin, Skinny, Slender Patient
or with High Medical Risk (Cardiopulmonary, One Lung etc,,,,)

1. Lateral Position

One of the more commonly used positions in procedures that require the combined skills of neurosurgeons and otologists is the lateral position. This position allows access to the middle fossa and access to the lateral skull base including the cerebello-pontine angle, the jugular foramen, the lower and mid clivus, and the anterior foramen magnum. This position can also be used for transtemporal and transcondylar approaches.

Following intubation, the tube is secured and the patient is placed in the lateral decubitus position. The operating table is flexed to raise the back of the table approximately twenty degrees from the floor. The patient’s back is brought close to the edge of the table with the shoulders positioned at the cephalad end of the table. The body is positioned to lay obliquely across the table. This allows the back to roll slightly posteriorly in order to expose the abdomen. Thus the abdomen is exposed in order to harvest an abdominal fat graft. The lower leg, or dependent leg is flexed ninety degrees at the knee, while the upper leg is kept only slightly flexed. After padding the heel and ankle of the lower leg, two pillows are placed transversely between the knees and one pillow placed longitudinally between the legs. A gel pad is placed underneath the hip to pad the trochanter. Improper positioning of this pad can lead to pressure sores and decubitus ulcers following prolonged operations. Next, a padded rest is positioned over the gluteal muscle to prevent the patient from rolling backwards. Care must be taken to avoid compression of the sciatic nerve. An axillary roll is placed in the axilla to avoid compression of the brachial plexus. Both arms are outstretched on arms boards with care to pad the ulnar nerve at the medial epicondyle and the radial nerve at the radial groove of the humerus. The dependent arm is positioned ninety degrees to the longitudinal axis of the body while the upper arm is positioned 45 degrees to the body. In positioning the non-dependent arm the shoulder must be rolled anteriorly and pulled gently in the caudal direction. Once in this position the shoulder is secured by tape to the arm board. This maneuver pulls the shoulder away from the surgeon and allows the surgeon to “look up” in a caudal to cranial direction if necessary. Additionally, in positioning the arm at a 45 degree angle from the body the abdominal area is exposed if an abdominal fat graft is necessary. The head is then placed in three-point fixation and positioned in such a manner as to keep the nose parallel with the floor and the cranial vertex tilted slightly down towards the floor. This position of the head allows access to the middle fossa, the cerebello-pontine angle, the mastoid process, the petrous temporal bone, and the far lateral skull base extending down to the foramen magnum and upper cervical spine.

2-pins at the
Inion & mastoid body



Vertex down

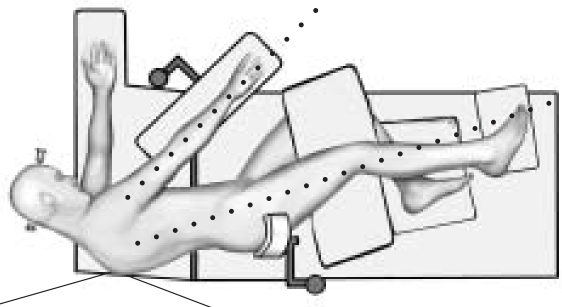
Frontal pin
inside hairline

Whole head elevated
to keep one hand space

Reverse Trendelenberg position 15~20° (mostly head up 30°)

45-degree, upper shoulder
to be 3/4 lateral prone

Oblique lying

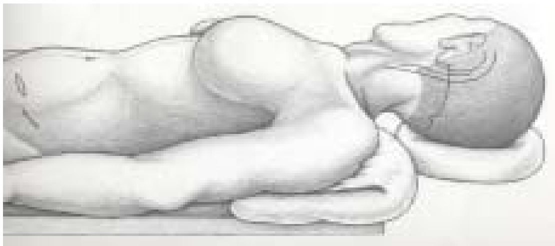


Silicon axilla pad
(under the shoulder)

Right on the edge

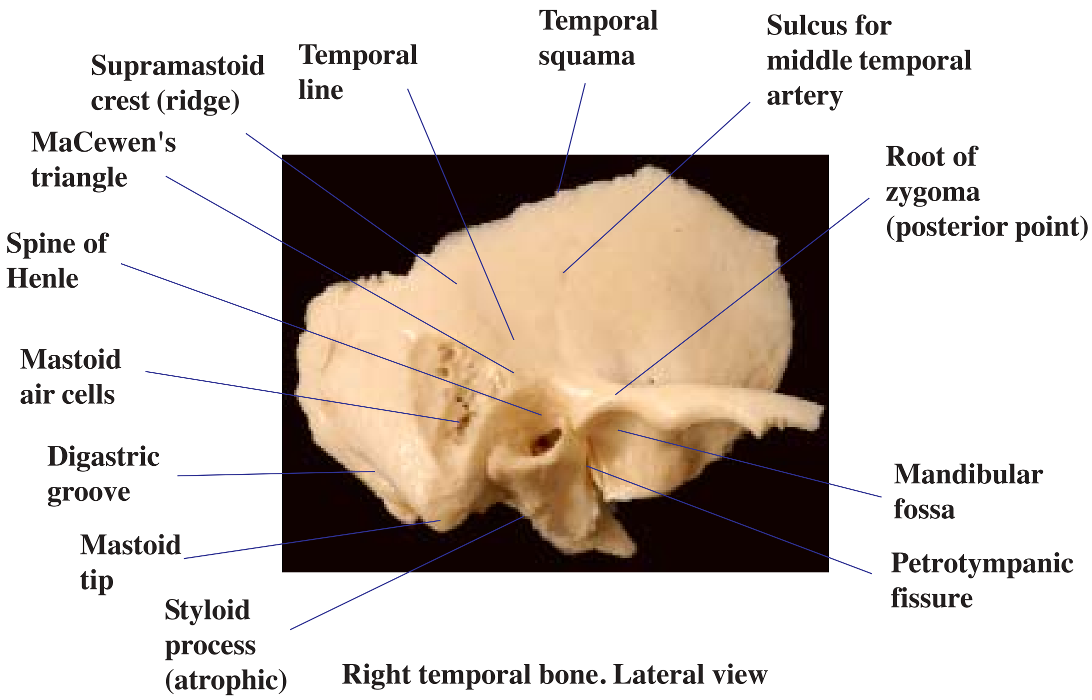
2. Supine Head Lateral Position

The supine position is the most commonly used and versatile positions in brain surgery. It is most frequently used for the “pterional” approach; however, it can be used for subtemporal or middle fossa approaches, translabyrinthine approaches, or bifrontal and transbasal approaches. The subtemporal and middle fossa approaches can be utilized for lesions of the middle cranial fossa, the internal auditory canal (IAC), or the petrous apex and upper clival region. This position is also used for anterolateral high cervical and transjugular approach.

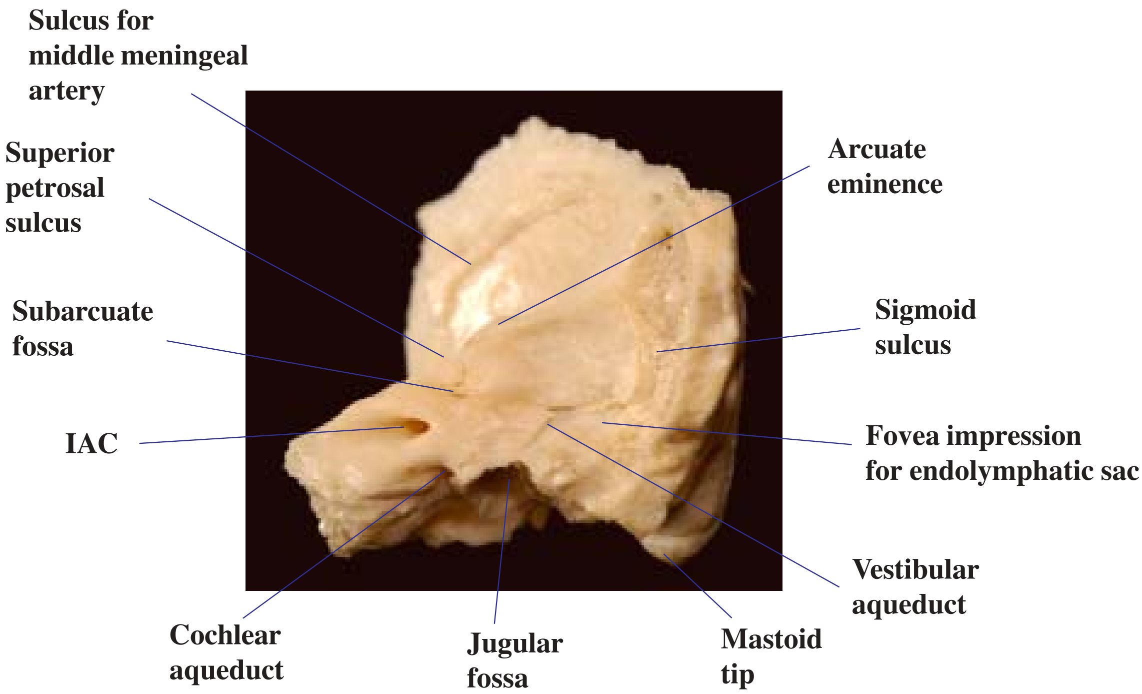


Supine Head Lateral Position

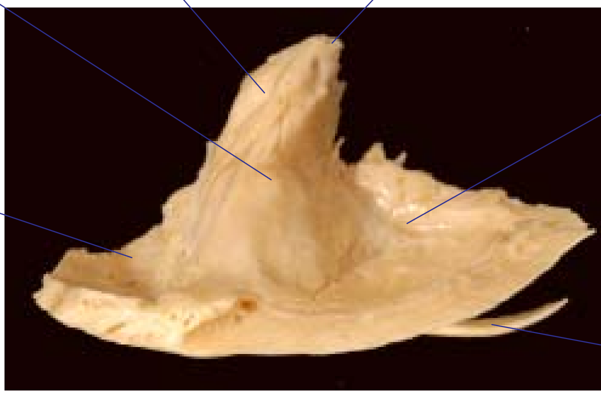
Surface of the Temporal bone



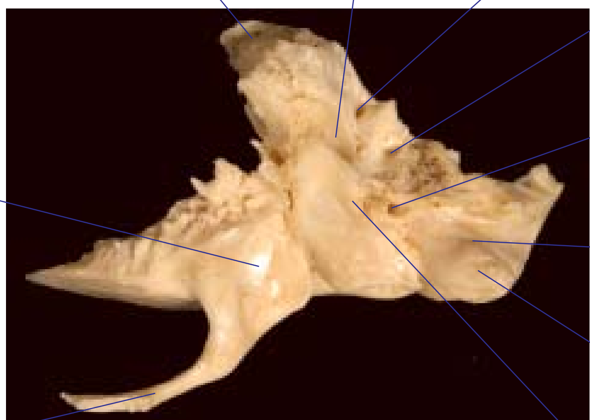
Right temporal bone. Lateral view



Right temporal bone. Medial view

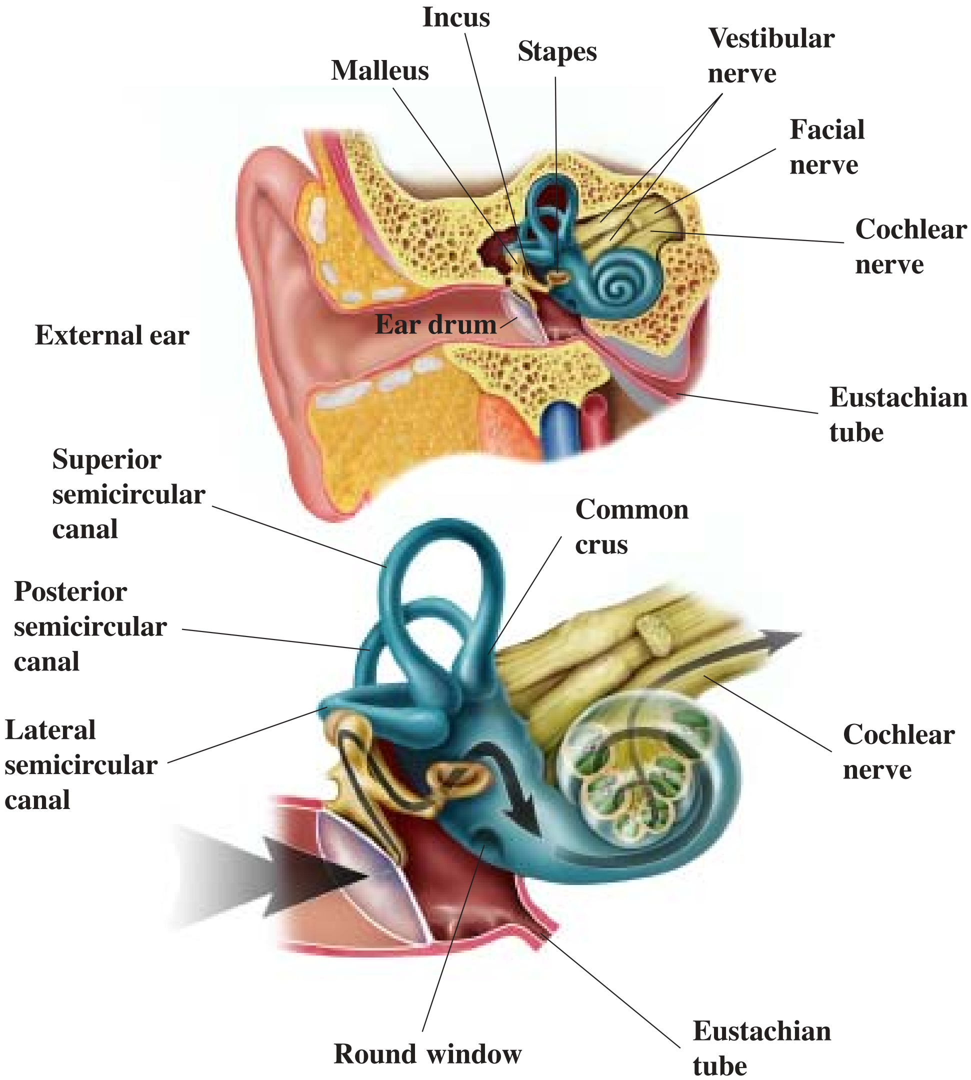


Right temporal bone. Superior view

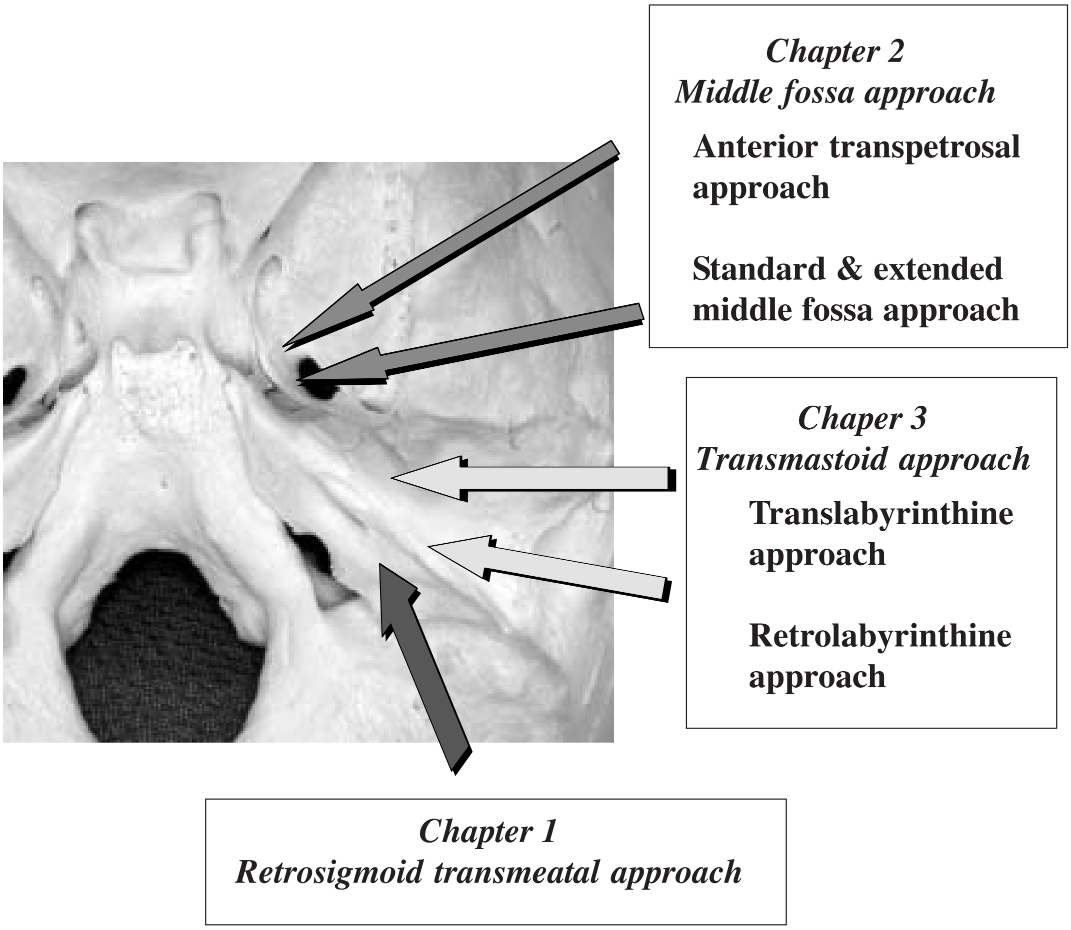


Right temporal bone. Inferior view

Labyrinth


Incus
Malleus
Stapes
Vestibular nerve
Facial nerve
Cochlear nerve
External ear
Ear drum
Eustachian tube
Superior semicircular canal
Common crus
Posterior semicircular canal
Lateral semicircular canal
Cochlear nerve
Round window
Eustachian tube

Approaches for CP angle and petroclival tumors



Chapter 1:

Inner Petrosa Anatomy for Retrosigmoid Transmeatal Appraoch

The retromastoid or retrosigmoid approach provides good exposure of the cerebellopontine angle and is the standard approach when attempting hearing preservation in acoustic neuroma surgery. The medial two thirds of the internal auditory canal can be reliably exposed without damage to the posterior semicircular canal or the vestibule. We find on average that 7~8 mm of bone from the posterior lip of the meatus can be drilled off safely without violating the vestibule. The tumor capsule locating at the far lateral fundus can be safely removed with Fukushima's super-micro curettes.

The purpose of this exercise is to provide surgeons with an appreciation of the anatomy of the inner petrosal surface and the relationship of the surface landmarks with the critical internal structures around the IAC.

Step 1: Positioning and Skin Incision

The patient is placed in the lateral position with the head supported with a three-pin head clamp. The body of the mastoid should be the highest point, with the mastoid surface parallel to the table (see ***"Operative positioning"***). In actual surgery, the retroauricular area is shaved and prepared, and after the placement of all monitoring electorodes (***Figure 1A & 1B***), the operative area is draped in an aseptic manner (***Figure 1C***).

The mastoid body and tip, the external auditory canal, the root of Zygoma and the supramastoid crest ridge should be identified prior to planning the skin incision.

A "C" shaped postauricular incision measuring 5 cm is performed to obtain adequate exposure of the mastoid bone and the suboccipital region. The incision begins just above the level of the supramastoid crest, passing 2 cm posterior to the body of the mastoid and terminating at the level of the mastoid tip (***Figure 1D & 1E***). The scalp is elevated in two layers in order to maintain the musculofacial-periosteal layer (***Figure 1F***).

ABR monitor

Figure 1A

ABR and Facial nerve electrodes

Figure 1B

Figure 1C

Right retrosigmoid approach

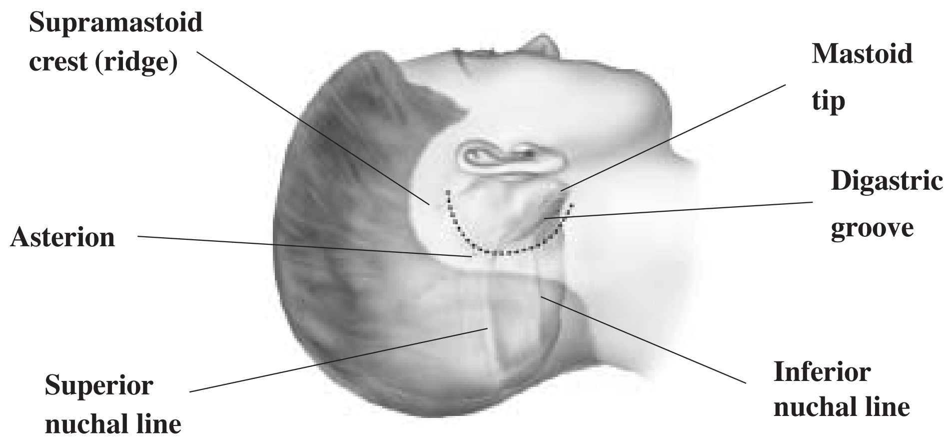


Figure 1D

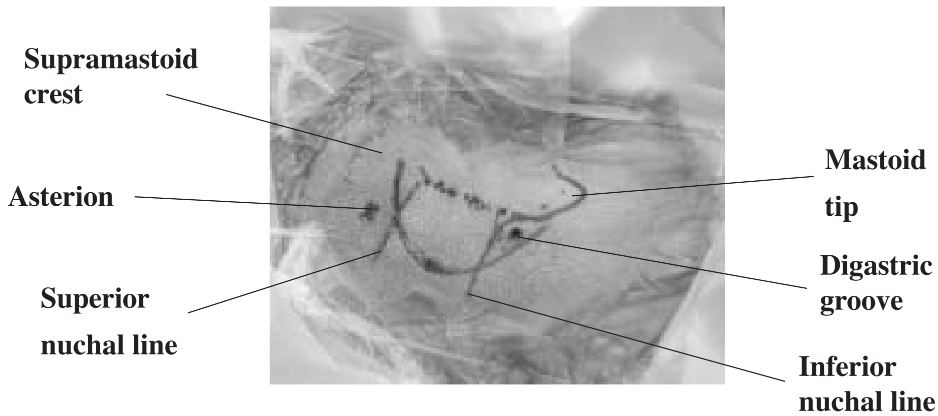


Figure 1E

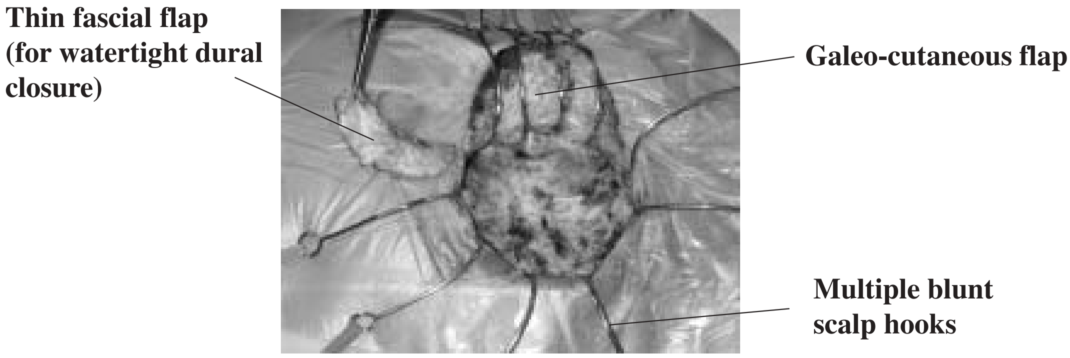


Figure 1F

Step 1

Step 2: Posterior Fossa Osteoplastic Craniotomy and Dural Incision

Prior to performing the craniotomy, the bone landmarks of the suboccipital region are appreciated (***Figure 2A***).

A 6 mm burr hole is made using a 5 mm extra-course diamond drill at the inner corner of the transverse and sigmoid sinuses (**1**). After exposing the intact dura, a 5 mm longitudinal groove is made at the posterior border of the mastoid body, exposing safely the sigmoid sinus and the retrosigmoid junction (**2**). Then, the groove is continued downward along the inferior edge of the proposed bone flap (suboccipital groove: **3**), as well as along the superior margin to expose the transverse sinus (**4**), using a 4 mm extra-course diamond drill. The entire dura is elevated around the bone margin, this craniotomy is ready to use to make a bone flap (***Figure 2B***)

The dura is incised in a curvilinear fashion and reflected anteriorly to achieve a direct unobstructed view of the under surface of the tentrium and the inner petrosa (***Figure 2C & 2D***). In actual surgery, prior to opening the dural flap, a small opening is made in the dura and the cerebellum is elevated towards the lateral corner of the foramen magnum and the cerebello-medullary cistern to identify XIth nerve. By incising the arachnoid over the cerebello-medullary junction, sufficient CSF drainage is removed to obtain satisfactory brain relaxation.

The most important in this skull base opening process is that all dura and sinuses to be maintained without any drill injury.

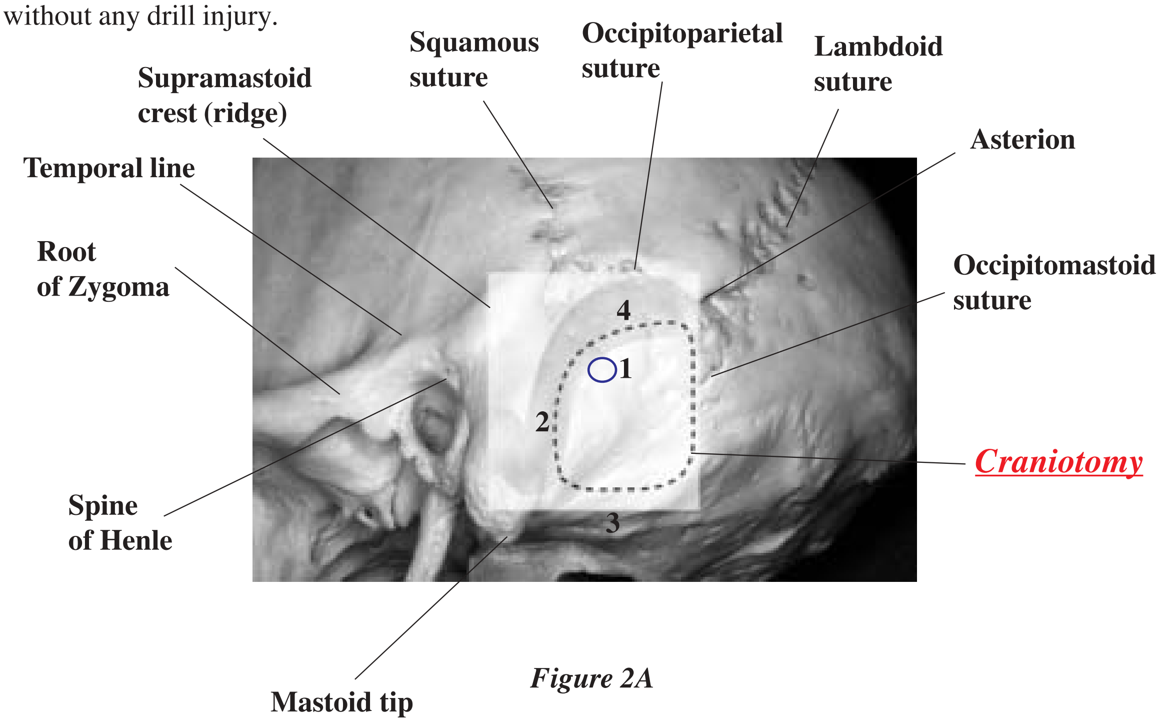


Figure 2A

Right retrosigmoid approach

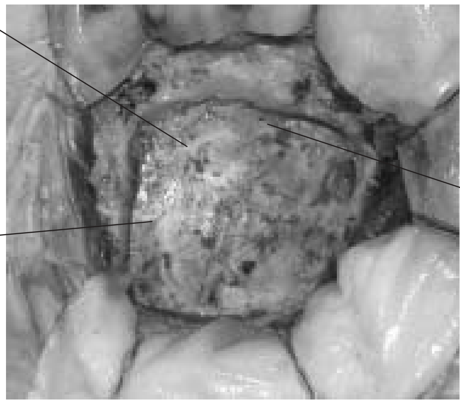


Figure 2B

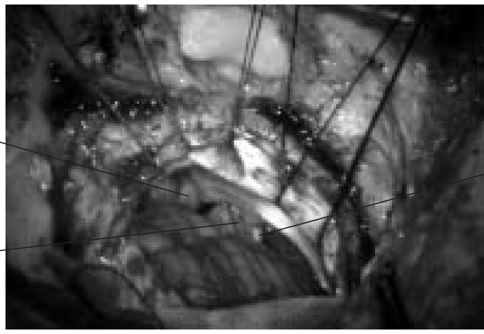


Figure 2C

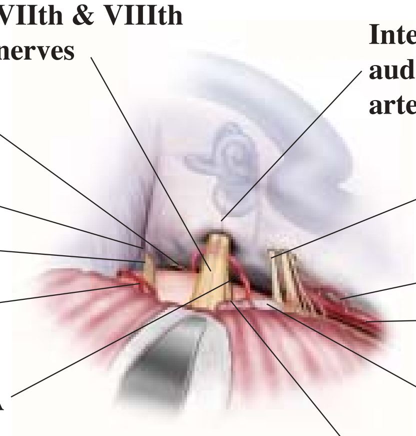


Figure 2D

Step 2

Step 3: Anatomy of the Medial Petrosal Surface

Identify the entrance of the IXth, Xth, and XIth nerves into the jugular foramen. This is a landmark for locating the jugular bulb. The jugular bulb may extend superiorly in close proximity to the inferior border of the IAC placing it at risk when the inferior canal wall is drilled. The location of the endolymphatic sac should next be identified. The sac rests in the foveate impression (so called fovea) of the inner petrous bone. A bony edge, the operculum, marks the medial aspect of this fovea. This landmark measures an average of 11.8 (9.8-14.9) mm from the inferolateral aspect of the porus acusticus.

From the angle of approach, the endolymphatic sac should lie along the line of approach or slightly caudal to the line of approach. It may be possible to identify the subarcuate artery entering the dura superior to the porus acusticus. A proximal portion of the artery may also be adherent to the dura prior to entering the bone in the subarcuate fossa (***Figure 3A-D***).

Right side

XII

Vestibular aqueduct

VI

Operculum

IX, X & XI

Superior perosal sinus

Tentorial edge

VII & VIII

V

III

Figure 3A

Figure 3B

1) Keep the petrosal ridge as vertical
2) 45 degrees oblique viewing angle to the inner surface

Right side

Figure 3C

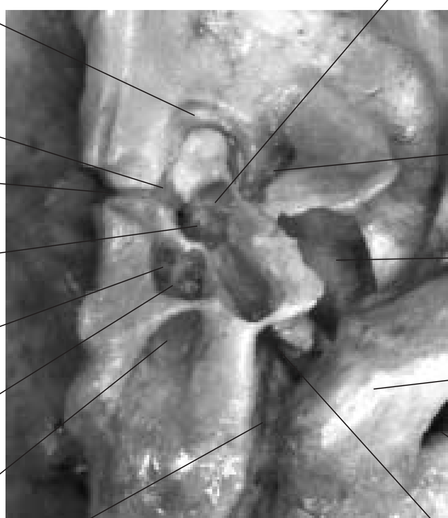


Figure 3D

Step 3

In acoustic tumor surgery, retract the superior dorsal aspect of the cerebellum to expose the tentorium and then working laterally expose the upper pole of the tumor. Using sharp dissection of the arachnoid membrane, the CP angle cistern is opened exposing the petrosal vein. The cerebellum is gradually elevated to separate the tumor capsule along the arachnoid dissection plane. At this point the dorsal surface of the tumor is stimulated and the facial muscles are monitored to make sure the facial nerve is not located over the dorsal surface of the tumor capsule (1% incidence). In turn, the upper pole is stimulated toward the ventral aspect of the tumor (20%) (***Figure 3E***). The trigeminal nerve is then separated from the tumor. In that way, we separate the capsule of the tumor along it's upper pole and medial side. With visual inspection at the level of the brain stem, the cochlear nerve is identified as a yellowish-white bundle of fibers. Usually adjacent to the cochlear nerve we visualize a normal remnant of the inferior vestibular nerve. Preservation of this remnant of the vestibular fibers is a key to avoiding cochlear nerve injury (***Figure 3F & 3G***). At this moment, the dorsal surface of the capsule is well coagulated and internal tumor coring is started. One of the most important issues for the easier elevation of the tumor capsule is the maximum tumor debulking and the progressing thinning of the tumor capsule. Ventral capsule penetration should not occur during internal decompression since such penetration will increase the risk of facial nerve damage. After identification of the proximal portion of the facial nerve, both physiologically and visually, we then perform the IAC drilling. The IAC drilling should be done earlier after appropriate debulking of the mass (***Figure 3H***).

Cource of facial nerve

Figure 3E

Right retrosigmoid approach

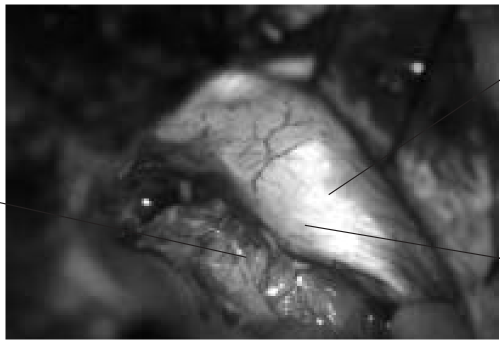


Figure 3F

Figure 3G

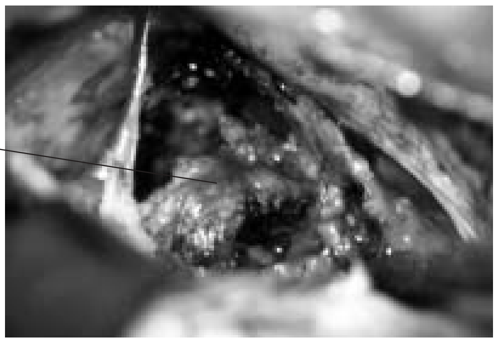


Figure 3H

Step 3

Step 4: Drilling of IAC

The dura is elevated over the inner wall of the IAC by making "U-cut" incision using an 11 or 15 blade knife. Begin 2 to 3 mm on either side of the porus acusticus and extend superio-laterally by approximately 10 mm, avoiding the endolymphatic sac. Elevate the dural flap from the bone using a sharp dissector (***Figure 4A***).

Before drilling of the IAC, hold the cerebellum using a 2 mm tapered brain retractor and remove all patties. A 2-layer bone wax plate is used to protect the VIIth and VIIIth nerves. Gelfoam is placed in the opened cisterns to avoid bone dust spread around the brain stem (***Figure 4B***).

The posterior (dorsal) wall of the IAC is unroofed using a 3~4 mm coarse diamond burr with continuous irrigation. The position of the endolymphatic sac and vestible are the lateral limits of the exposure. Remove the posterior wall of the IAC maintaining a relative uniform depth throughout the exposure until the dura of the canal is exposed. Because of the angle of approach, the length of exposure of the IAC is less than that of the lateral extent of bone on the petrous bone surface removed. Exposing the fundus of the IAC would require blind drilling around the corner, likely resulting in violation of the labyrinth or the vestibule. Keep in mind that the morphology of the temporal bone varies significantly between specimens. Following this exercise in the laboratory, the labyrinth or vestibule may be opened to confirm their relationship (***Figure 4C & 4D***).

Once the dura is exposed, diamond burrs 2 or 1.5 mm in diameter are used to remove the bone superior and inferior to the fundus of the IAC. The goal of this procedure is the exposure of the posterior (dorsal) 180 degrees of the canal (***Figure 4E***). Keep in mind the possibility of a high jugular bulb when dissecting inferior to the IAC (***Figure 4F***).

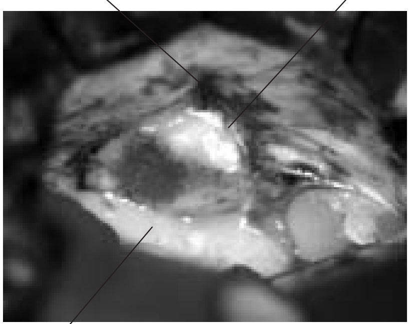


Figure 4A

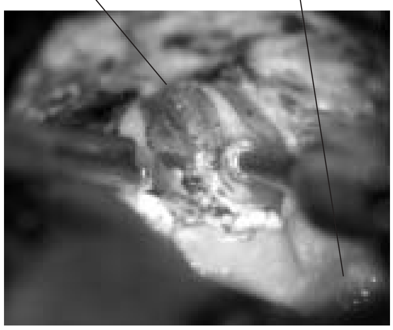


Figure 4B

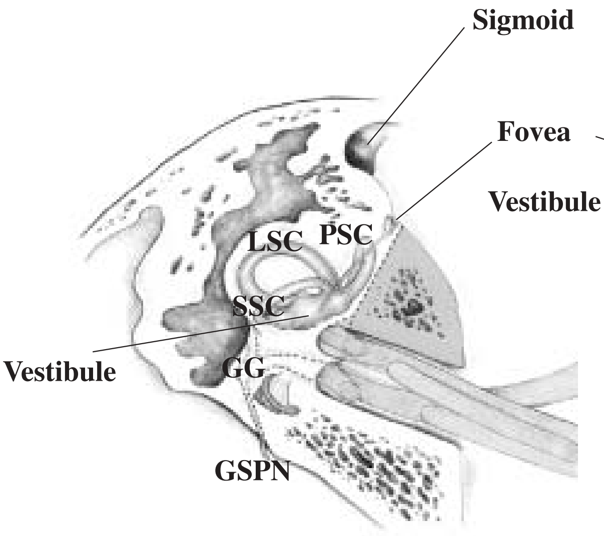


Figure 4C

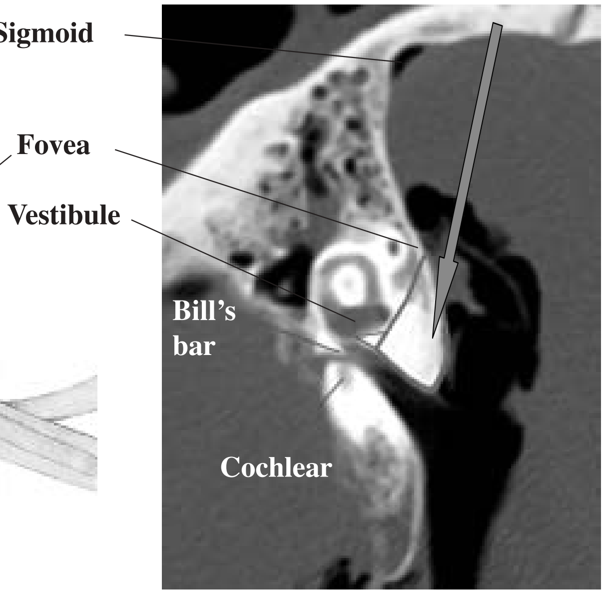


Figure 4D

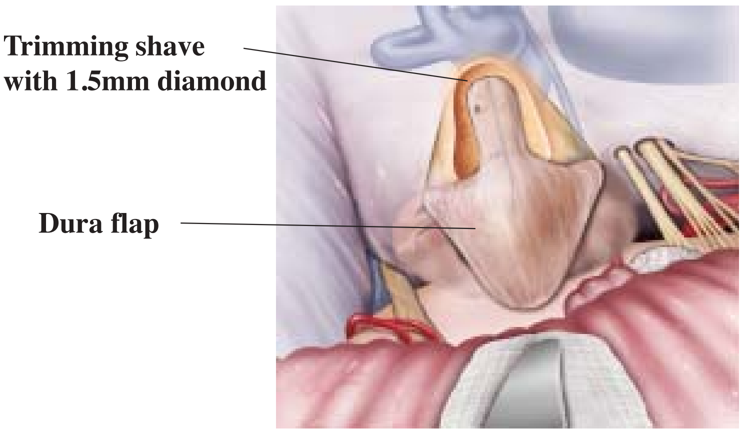


Figure 4E

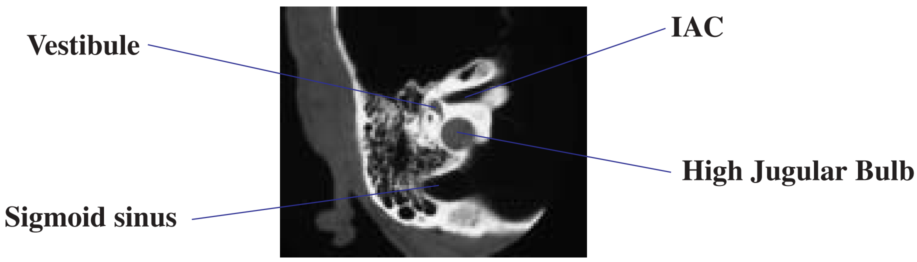
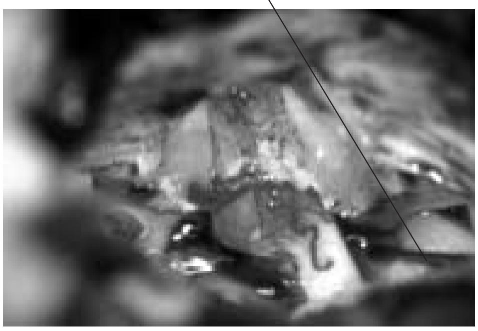


Figure 4F

Step 4

After the IAC is sufficiently exposed (***Figure 4G & 4H***), we excise the dura over the tumor (***Figure 4I***). The intracanalicular portion of the mass is cored and then the capsule is gradually elevated. The capsule is first elevated rostral-ventral to identify the facial nerve. The dissection along the VIIth nerve is continuing distally to the fundus and medially to the extra meatal portion of the tumor. Here the nerve is often very adherent to the tumor. Then medially, while elevating the flocculus, we identify the VIIIth nerve and cut the vestibular nerves in the shape of a "V". A dissection plane is established between the vestibular nerve and the tumor bed. The degenerated flattened vestibular nerve can provide protection to the cochlear nerve. The true tumor capsule is then elevated from the vestibular tumor bed (***Figure 4J-L***). The cochlear and facial nerves are always protected with a 1~2 mm micro-thin cottonoid (so called super-micropatties / American Surgical Sponges, Inc.) (***Figure 4M***). Then gradually the tumor is elevated from the brain stem and separated from the facial nerve using various Fukushima CP angle dissectors (***Figure 4M-R***). The Hitzelberger-McElveen knife is indispensable in the removal of tumor from the IAC (***Figure 4N & 4R***). Of added importance is the preservation of the meatal loop of the anterior inferior cerebellar artery (AICA) which is located between the facial and cochlear nerves and the labyrinthine artery which is usually located between the distal portion of the cochlear and facial nerves.

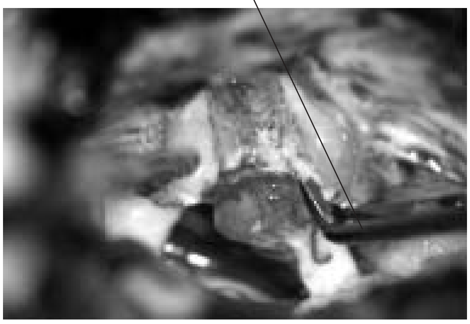
Facial nerve stimulator



Identification of facial nerve

Figure 4G

45 degrees sharp hook knife



Cutting the IAC dura

Figure 4H

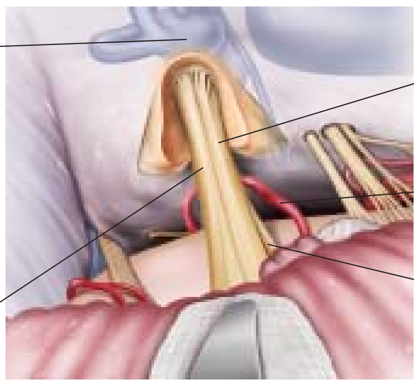


Figure 4I

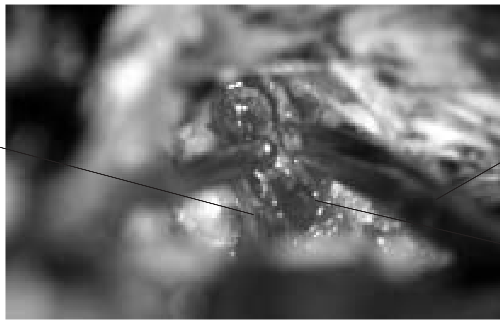


Figure 4J

Figure 4K

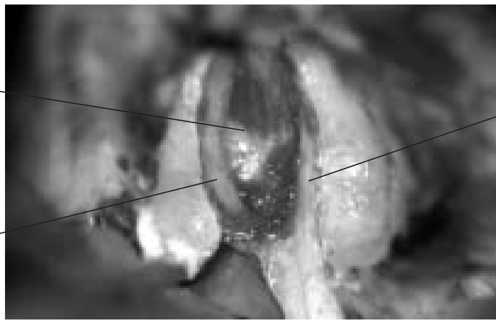


Figure 4L

Final capsule elavation with V-cut technique

After the total removal of the tumor, hemostasis is secured. The drilled out portion of the petrous bone is filled with bone wax and the nerves are protected with a small piece of Gelfoam. Duragen (Integra Neuroscience) is applied to seal the IAC. The dura is closed watertight with the galeo-cutaneous graft. We use Mimix hydroxyapatite bone cement (Lorenz Surgical) and titanium mesh (Lorenz Surgical) to fill the mastoid bone defect, for cosmetic restoration and to avoid postoperative pain. The scalp is closed in two layers. The entire surgical procedure is completed with the teamwork of the skull base surgeon, the neurosurgeon, and the otologist.

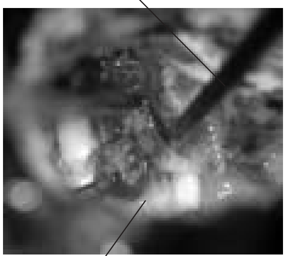


Figure 4M

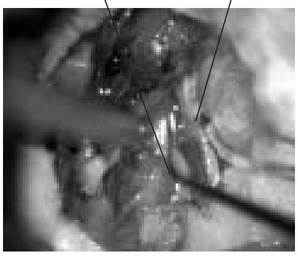


Figure 4N

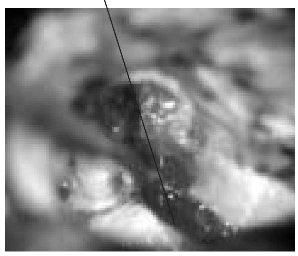


Figure 4O

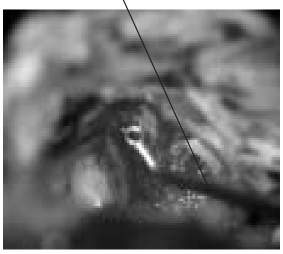


Figure 4P

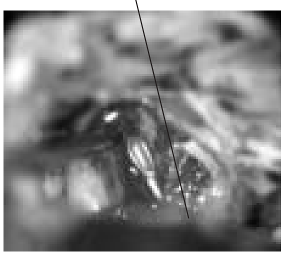


Figure 4Q

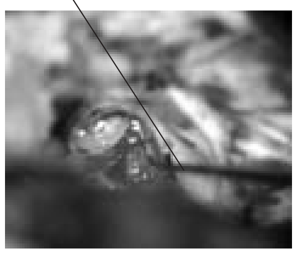


Figure 4R

Hearing loss in patients whose cochlear nerve was preserved at surgery

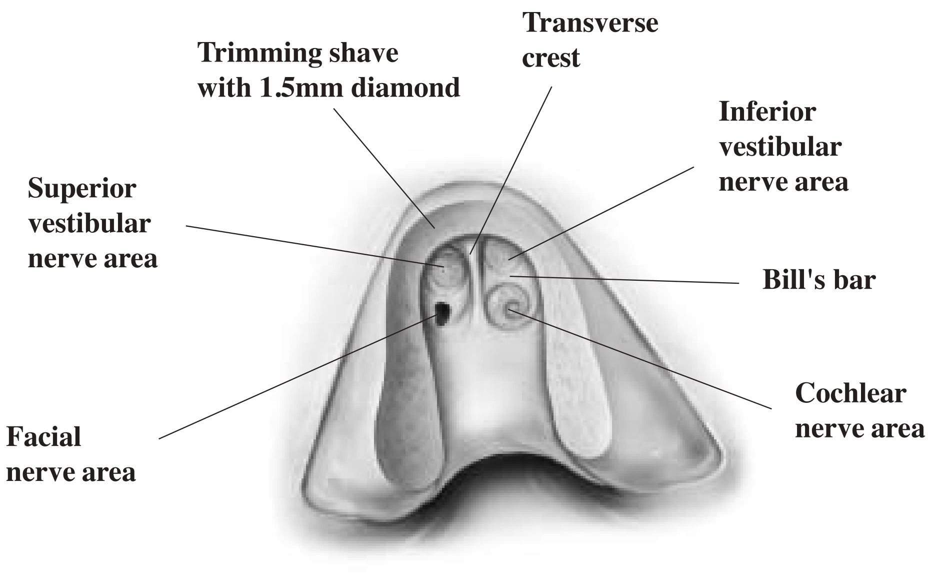
1: Nerve retraction (at CP angle)
2: Nerve or cochlear ischemia
   (manipulations and coagulation of small vessels)
3: Overheating or mechanical damage of the nerve
4: Opening of the labyrinth (while the IAC is drilled open)

Figure 4S

Extended drilling of the inner petrosa;

This exercise demonstrates the location of the vestibule, common crus, posterior semicircular canal, and vestibular aqueduct in relation to the IAC.

Strip the dura widely from the inner petrosal surface lateral to the IAC. Check for the location of the operculum and the endolymphatic sac. With a small diamond burr, expose the fundus of the IAC by removing the bone posterior to the IAC. Locate the horizontal crest, separating the superior and inferior vestibular nerves. Reflect the superior and inferior vestibular nerves to identify the transverse crest and Bill's Bar. Enter the vestibule with the drill if you have not done so in exposing the fundus. Continue to remove bone until the common crus, superior semicircular canal, and posterior semicircular canal are opened (***Figure 4S-U***).



Right IAC

Figure 4S

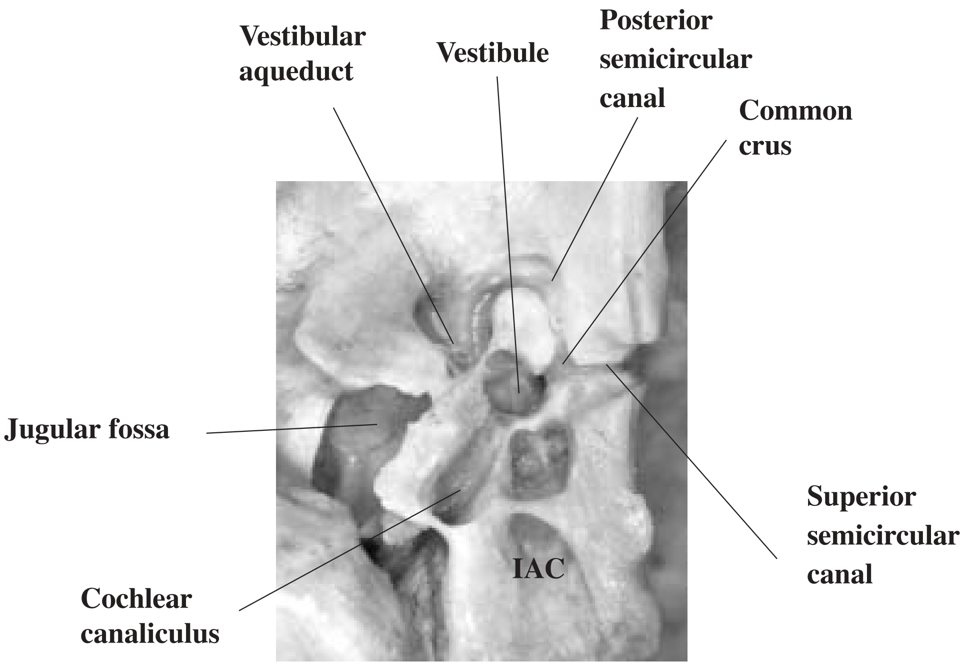


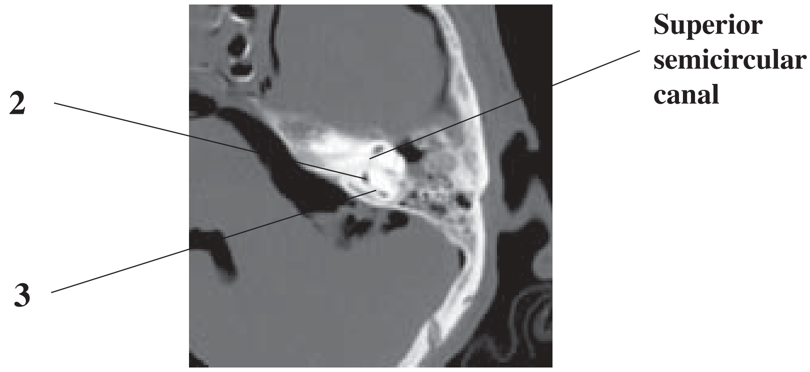
Figure 4T

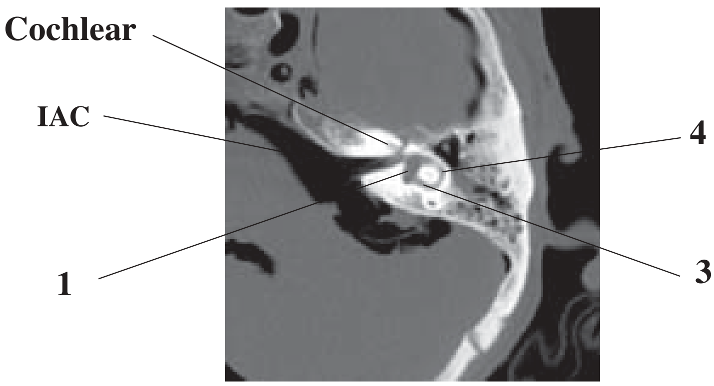
Figure 4U

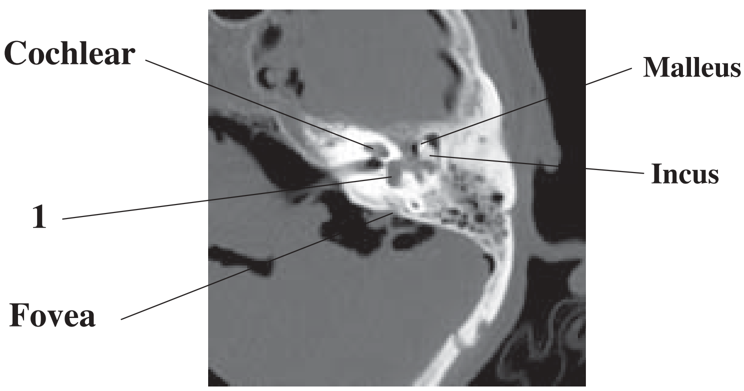
Step 4

Labyrinth injury in the retrosigmoid approach

1: Vestibule
2: Common crus
3: Posterior semicircular canal
4: Lateral semicircular canal







Retrosigmoid Approach

Advantages

1: Familiarity

2: Easily identified anatomical landmarks

3: Avoidance of excessive manipulation of the facial nerve

4: Avoidance temporal lobe retraction

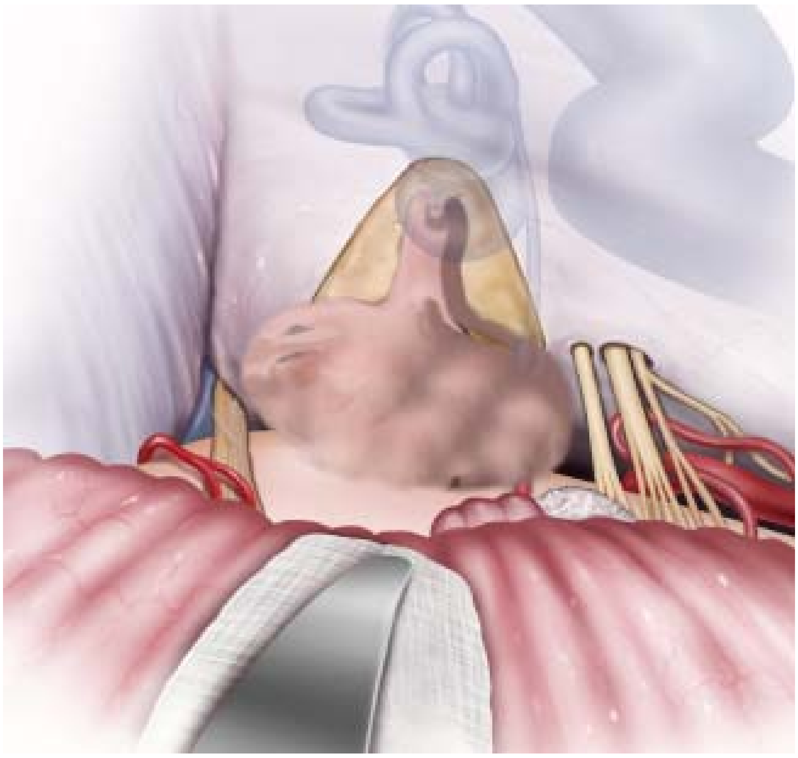
Disadvantages

1: Lateral end of the IAC (2-3mm blind)

-Risk for residual tumor capsule

2: Cerebellar retraction and edema

Caurse of the facial nerve (Total 86 cases)



V : Ventral	48 cases	55.8 %
VR : Ventro-Rostral	23 cases	26.7 %
VC : Ventro-Caudal	4 cases	4.7 %
R : Rostral	5 cases	5.8 %
C : Caudal	4 cases	4.7 %
D : Dorsal	2 cases	2.3 %