PROSPECTIVE OBSERVATIONAL STUDY OF PATIENTS UNDERGOING ANTERIOR PETROSECTOMY

Submitted for M.Ch Neurosurgery

By

Dr. MOHAMED AMAD JAMALUDDIN

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Department of Neurosurgery

Sree Chitra Tirunal Institute for Medical Sciences & Technology

Thiruvananthapuram – 695011

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CERTIFICATE

This is to certify that the thesis entitled **"PROSPECTIVE OBSERVATIONAL STUDY OF PATIENTS UNDERGOING ANTERIOR PETROSECTOMY"** is a bonafide work of Dr. Mohamed Amjad Jamaluddin, conducted in the Department of Neurosurgery, Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram (SCTIMST), under my guidance and supervision.

Prof. Mathew Abraham
Professor and Head of the Department
Department of Neurosurgery
SCTIMST, Thiruvananthapuram

DECLARATION

This thesis titled **"PROSPECTIVE OBSERVATIONAL STUDY OF PATIENTS UNDERGOING ANTERIOR PETROSECTOMY"** is a consolidated report based on a bonafide study of the period from January 2018 to July 2019, done by me under the Department of Neurosurgery, Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram. This thesis is submitted to SCTIMST in partial fulfilment of rules and regulations of MCh Neurosurgery examination.

Dr. Mohamed Amjad Jamaluddin,

Department of Neurosurgery,

SCTIMST, Thiruvananthapuram

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INTRODUCTION

The anterior petrous apex has been considered as a gateway to the posterior cranial fossa. The anterior petrosectomy as described by Kawase converts this deep narrow operative corridors into wider shallower exposures, improves manoeuvrability and minimizes retraction. It comprises of a sub-temporal craniotomy followed by extradural drilling of the petrous apex to reach the posterior fossa. The traditional Kawase approach provides a 10×5 mm fenestration at the petrous apex of the temporal bone between the 5th cranial nerve and internal auditory canal and the greater superficial petrosal nerve. Complications of this approach include palsies of facial, trigeminal and abducent nerve, CSF leak, hearing loss, injury to the vein of Labbe, etc. This study aims to calculate the amount of bone resected in an anterior petrosectomy done in this institute and with this knowledge, quantify the differential variations used in each surgery while achieving adequate exposure with respect to the local complications will provide a better understanding of this approach. The study ought to define minimal safe resection for a lesion with the best local outcome while preserving the adequacy of exposure.

REVIEW OF LITERATURE

As skull base surgeries advanced, the surgical corridors have become narrower, deeper but with improved manoeuvrability, minimum retraction and superior outcomes (1–3). Critical structures inside the cranium are protected by skull especially the skull base. Access to such areas need adjuncts in the standard craniotomies such as clinoidectomy and mastoidectomy. Similarly, anterior petrosectomy is performed by drilling off the Kawase triangle at the petrous apex. Anterior petrosectomy helps approach the upper clivus, upper petroclival area, medial cerebellopontine cistern, and the prepontine cistern even via an extradural corridor (4). This helps avoid dissection and retraction of the posterior fossa structures. After Kawase's demonstration of the technique of anterior petrosectomy and associated good outcomes, this technique became an established approach in tackling petroclival meningiomas, trigeminal schwannomas extending into posterior fossa, clival chordomas, ventrolateral brainstem lesions, upper vertebrobasilar circulation aneurysms as well as for lesions arising from the petrous apex such as chondrosarcomas and cholesteatomas (1). This corridor can help access cranial nerves III to VII. "The eye sees only what the mind knows". Petrous apex is surrounded by vital and critical neurovascular structures. Thorough knowledge of the anatomy of the petrous bone as well as a detailed study of the extent of the resection possible is necessary for meticulous skull base drilling and dissection which in turn helps avoid unnecessary mishaps.

Petrous bone

9-33% of the petrous apices can be pneumatized while unilateral pneumatization reported in 5-10% of patients (4). Liquoric fistula can be a dreadful complication if the skull base is not adequately repaired in a pneumatized petrous apex (4).

Intracranial Triangles

Parkinson was the first to describe an intracranial triangle, followed by Dolenc, Glassock, and Kawase (5). A good 3-dimensional perception of the skull base anatomy and the intracranial triangles is indispensable for mastering skull base approaches. These triangles include four cavernous, four middle fossa and two paraclival triangles. These triangles lie in close proximity to critical structures like the cavernous and petrous segments of the internal carotid artery, cavernous sinus, inner ear and cranial nerves II-VIII.

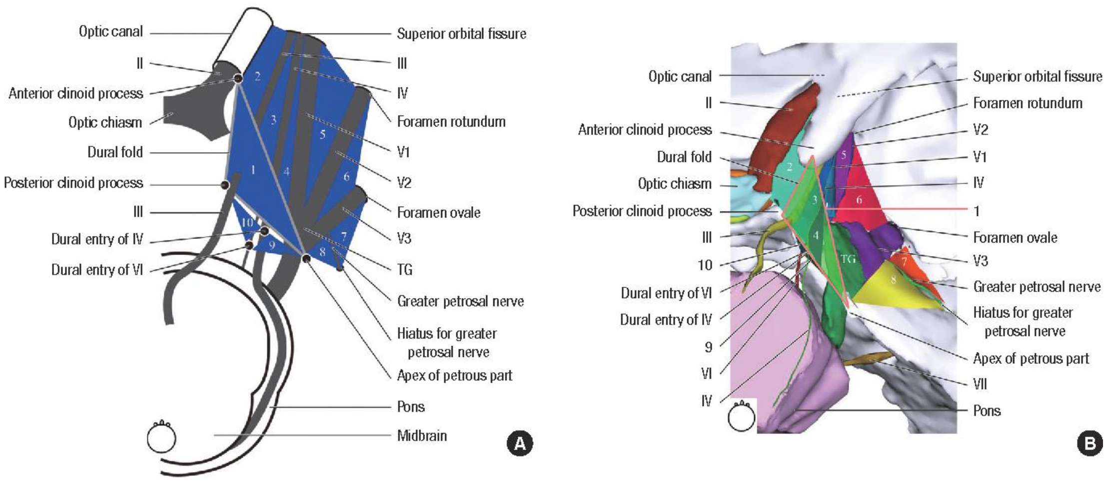


Figure 1: Cavernous Triangles (1 = superoposterior triangle; 2 = superior triangle; 3 = middle triangle; 4 = inferior triangle; 5 = anteromedial triangle; 6 = anterolateral triangle; 7 = posterolateral triangle; 8 = posteromedial triangle; 9 = lateral triangle; 10 = medial triangle; II = optic nerve; III = oculomotor nerve; IV = abducens nerve; V1 = ophthalmic nerve; V2 = maxillary nerve; V3 = mandibular nerve; VI = abducens nerve; TG = trigeminal ganglion) – adapted from Chung BS, Ahn YH, Park JS. Ten Triangles around Cavernous Sinus for Surgical Approach, Described by Schematic Diagram and Three-Dimensional Models with the Sectioned Images. J Korean Med Sci. 2016;31(9):1455

Cavernous triangles (5,6)

1. **Anteromedial triangle**

A.k.a Clinoidal triangle, Dolenc's triangle, Superior triangle

Borders

a. Optic nerve

b. Oculomotor nerve

c. Tentorial edge (dura from dural entry of oculomotor nerve to the optic nerve)

Contents

i. Clinoidal internal carotid artery

ii. Anterior clinoid process

Surgical importance

- Drilling anterior clinoid process exposes the anteromedial triangle area
- Resection of clinoidal meningioma

2. Anterior triangle

Borders

a. Lateral border of optic nerve

b. Medial wall of superior orbital fissure

c. Dural ring around internal carotid artery

Contents

i. Clinoidal internal carotid artery

ii. Optic strut

iii. Roof of cavernous sinus

3. Medial triangle

A.k.a Oculomotor triangle, Hakuba's triangle, Superoposterior triangle

Borders

a. Anterior petroclinoid dural fold - laterally

b. Posterior petroclinoid dural fold - base

c. Interclinoid dural fold - medially

Vertices

a. Posterior clinoid process

b. Porus oculomotorius

c. Subclinoidal carotid segment

Contents

i. Oculomotor nerve
ii. Trochlear nerve
iii. Horizontal segment of internal carotid artery
iv. Origin of meningohypophyseal trunk
v. Interclinoid ligament

Surgical importance

- Useful during exploration of oculomotor nerve and horizontal segment of internal carotid artery
- Helpful in accessing tumours in medial cavernous sinus and interpeduncular region
- Site of Posterior communicating artery aneurysms

4. Paramedian triangle

A.k.a supratrochlear triangle, Paramedial triangle, Middle triangle

Borders

a. Oculomotor nerve
b. Trochlear nerve
c. Dural fold between dural entries of oculomotor and trochlear nerve

Contents

i. Meningohypophyseal trunk
ii. Inferolateral trunk
iii. Medial loop of internal carotid artery occasionally

Surgical importance

- Used to explore the medial loop of intra-cavernous Internal carotid artery & the meningohypophyseal trunk
- Explored during clipping of cavernous ICA aneurysms

5. Infratrochlear triangle

A.k.a Superolateral space, Parkinson’s triangle, Inferior triangle

Borders

a. Trochlear nerve
b. Ophthalmic division of trigeminal nerve
c. Dural fold between dural entries of trochlear & ophthalmic nerve

Contents

i. Cavernous segment of internal carotid artery
ii. Abducens nerve

Surgical importance

- Can be used to enter cavernous sinus directly
- Entire intracavernous segment of internal carotid artery can be explored
- Permits exposure of entire length of abducens nerve from Dorello’s canal till the superior orbital fissure
- Access for resection of intracavernous meningiomas

Middle fossa triangles

1. Anteromedial middle fossa triangle

A.k.a Mullan’s triangle

Borders

a. Ophthalmic division of trigeminal nerve - medially
b. Maxillary division of trigeminal nerve - laterally
c. Line joining superior orbital fissure to foramen rotundum - base

Contents

i. Sphenoid sinus
ii. Superior orbital vein
iii. Superior ophthalmic vein

iv. Abducens nerve

Surgical importance

- Exposing Superior orbital vein, sixth cranial nerve, sphenoid sinus, ophthalmic vein
- For Access to carotico-cavernous fistulas

2. Anterolateral middle fossa triangle

A.k.a Lateral triangle

Borders

a. Maxillary division of trigeminal nerve - medially

b. Mandibular division of trigeminal nerve - laterally

c. Line joining foramen rotundum to foramen ovale - base

Contents

i. Lateral sphenoid wing

ii. Sphenoid emissary vein

iii. cavernous-pterygoid venous anastomosis

Surgical importance

- Expose the lateral sphenoid wing, sphenoid emissary vein, cavernous-pterygoid venous anastomosis
- Allows resection of lesions in the lateral part of cavernous sinus

3. Posteromedial triangle

A.k.a Kawase’s triangle, Kawase-Shibara’s triangle, rhomboid space

Named by Fukushima

First described by Kanzaki

Borders

a. Lateral margin of greater superficial petrosal nerve - medially

b. Lateral edge of Mandibular division of trigeminal nerve -laterally

c. Line joining Posterior border of mandibular division of trigeminal nerve and the crest of petrous apex to centre of geniculate ganglion

Alternate boundaries

a. Junction of greater superficial petrosal nerve with the lateral border of mandibular division of trigeminal nerve

b. Lateral margin of porus trigeminus

c. Anteromedial margin of arcuate eminence

Contents

i. Petrous apex

ii. Internal carotid artery

iii. Vertebrobasilar junction

Surgical importance

- Access to vertebrobasilar junction, root of trigeminal nerve, anterolateral brain stem
- Exposes the petrous apex or petroclival area & internal acoustic meatus
- Does not contain vascular or neural structures

4. Posterolateral triangle

A.k.a Glassock's triangle

Borders

a. Mandibular branch of the trigeminal nerve

b. Greater superficial petrosal nerve -base

c. Line joining Foramen spinosum to arcuate eminence -laterally

Vertices

a. Posterior rim of foramen ovale

b. Apex of Cochlea

c. Posterior border of Mandibular branch of the trigeminal nerve

<u>Contents</u>

i. Horizontal petrous segment of Internal Carotid Artery (Ahmed15, Hsu04)

ii. Infratemporal fossa

iii. Foramen spinosum and middle meningeal artery

iv. Greater and lesser petrosal nerves

v. Eustachian tube and tensor tympani muscle

<u>Surgical importance</u>

- Exposes the horizontal intra-petrosal segment of ICA for proximal control for a bypass graft or anastomosis
- Access to cavernous sinus for tumour resection

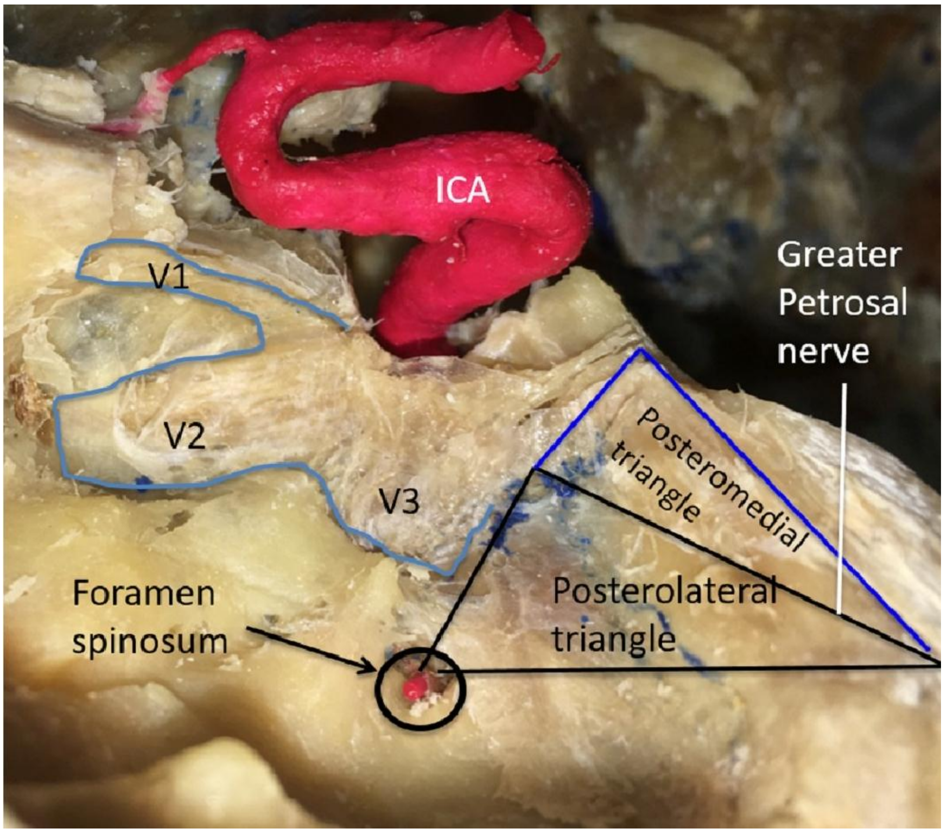


Figure 2: Posteromedial (Kawase) and Posterolateral (Glassock) triangles of the middle cranial fossa - adapted from Drazin D, Wang J, Alonso F, et al. Intracranial Anatomical Triangles: A Comprehensive Illustrated Review. Cureus 9(10): E1741

5. Modified Dolenc-Kawase rhomboid

Borders

a. Lateral margin of Mandibular branch of the trigeminal nerve after mobilisation of trigeminal nerve

b. Bony surface just lateral to petroclival ligament

c. Arcuate eminence

Paraclival triangles

1. Inferomedial paraclival triangle

Borders

a. Line between dural entries of Trochlear nerve and Abducens nerve - laterally

b. Line between dural entry of Abducens nerve and Posterior clinoid process - medially

c. Petrous apex - base

Contents

i. Porous abducens/ Dorello's canal with abducens nerve

ii. Gruber's petrosphenoid ligament

iii. Posterior genu of internal carotid artery

iv. Dorsal meningeal branch of meningohypophyseal trunk

Surgical importance

- Exposes the lateral edge of dorsum sellae, petroclival fissure, Dorello's canal

2. Inferolateral paraclival triangle

Borders

a. Line between dural entry of Trochlear nerve and Abducens nerve - medially

b. Line between dural entry of Abducens nerve and petrosal vein - laterally

c. Petrous apex -base

Contents

This triangle is divided into osseous triangle inferiorly and tentorial triangle superiorly by a line joining entry points of petrosal vein and trigeminal nerve. The tentorial artery, Meckel's cave and Superior petrosal sinus line in the tentorial triangle while the trigeminal nerve lies in the osseous triangle.

Sellar triangles

1. **Preinfundibular triangle**

Borders

a. Right optic nerve
b. Left optic nerve

Contents

- Sella

2. **Parasellar triangle**

Borders

a. Anterior & posterior petroclinoid dural fold
b. Tentorial edge
c. Anterior & posterior clinoid process

Contents

- Sella turcica

3. **Internal carotid artery triangle**

Borders

a. Anterior clinoid process
b. Posterior clinoid process
c. Optic nerve

Contents

- Sella

Others skull base triangles

1. **Parapetrosal triangle**

Borders

a. Spinopterygoidal line (from Spine of Henle to the foramen ovale)
b. Bispinal line (between two spine of Henle)
c. Midsagittal line (posterior margin of medial pterygoid plate)

Contents

- Spines of Henle

2. **Superior petrosal triangle**

Borders

a. Foramen spinosum
b. Root of zygoma
c. Head of Malleus

Contents

- Bony tegmen over the head of Malleus

3. **Trautmann's triangle**

A.k.a retromeatal triangle

Borders

a. Superior jugular bulb
b. Sino-dural angle
c. Posterior semi-circular canal

Contents

i. Posterior petrous bone
ii. Ventral brainstem
iii. Cranial nerves V, VII, VIII

Surgical importance

- Resected during posterior petrosectomy

Petroclival Region

Petroclival region is packed with critical neurovascular structures and lesions arising between these structures can prove to be a formidable challenge without causing significant deficits (7). Permanent cranial nerve deficits have been reported to the tune of 20-75% despite significant advances in imaging technology, micro-neurosurgery and intraoperative neuromonitoring (8). Gross total resection can be obtained in only 20-85% cases only (8). Because of the above factors, surgeons are preferring stereotactic radiosurgery in view of the good tumour progression control and better quality control than radical resection outcomes. Hence the surgical corridor gains more importance in achieving better completeness of resection but with lesser deficits. Petroclival meningioma has been described as the “King cobra among all skull base tumours” while the petroclival region has been notorious for being a “No man’s land” (9,10).

Approaches to the petroclival region require extensive bone work which envisages the need for a thorough knowledge of the vital neurovascular structures hidden behind the bone to be drilled. The surgical risk involved in the management of skull base meningiomas can be predicted by ABC Surgical Risk Scale based upon the following parameters (11)

1. **A**ttachment Size (<2 cm, 2-4 cm, >4 cm)
2. **A**rterial involvement (none, single, multiple)
3. **B**rainstem contact (CSF space present, No CSF space, perifocal oedema)
4. **C**entral Cavity (outside, partial involvement, inside)
5. **C**ranial nerve group involvement (none, one, >one)
6. History of Radiation or surgery (no, yes)

Petroclival region can be divided by Abdel Aziz, broadly based on the extent of exposure obtained and suggested appropriate approaches (11,12).

Zone 1/ upper zone: Dorsum sella to upper border of internal acoustic meatus

Zone 2/ Middle zone: Upper border of internal acoustic meatus to upper border of jugular tubercle

Zone 3/ Lower zone: Upper border of jugular tubercle to Lower border of clivus – best exposed by lateral suboccipital approach with combined petrosectomy

Xu et al has recommended a useful algorithm for the decision making in selection of surgical approaches. But the choice of the approach should be tailormade to suit the comfort and expertise of the surgeon while taking patient and tumour factors such as age, size, preoperative hearing, facial nerve dysfunction into consideration (8).

Relation of Tumour with Brainstem can be classified according as (11,13)

Stage I: High intensity T2 signal seen between tumour and brainstem suggestive of preserved arachnoid plane

Stage II: Obliteration of the above stated plane and thus absence of any T2 signal hyperintensity

Stage III: Brainstem oedema is noted on T2 weighed sequence suggestive of pial breech and strong adherence of tumour to brainstem

Approaches to the Petroclival Region (8)

1. Orbitozygomatic subfrontal transsellar-transcavernous or transylvian
2. Sub-occipital - Retrosigmoid
3. Posterior Transpetrosal – Retrolabyrinthine, Translabyrinthine, Transcochlear
4. Anterior Transpetrosal – Anterior petrosectomy/ Kawase approach
5. Combined
6. Transcervical Clivectomy
7. Transoral/ Extended transoral Clivectomy

Orbitozygomatic approach

This approach can give excellent exposure of the upper third of clivus and posterior fossa (8). But the size of lesion and the level of dorsal sella limits this approach (8).

Retrosigmoid Suboccipital approach

Retrosigmoid approach gives a wide surgical field with greater angles of attack when compared to any other approach. This approach is preferred in lesions lateral to the IAC, in the cerebellopontine angle. But drilling of the petrous bone anterosuperior to IAC gives working space to approach lesions extending into the Meckel's cave (8). Superior petrosal vein (ventral metencephalic vein, the vein of Dandy) which ultimately drain into the superior petrosal sinus might need to be sacrificed or may be injured in accessing the prepontine region via retrosigmoid approach. Even though Dandy suggested that petrosal vein can be safely cauterised which has also been supported by many surgeons, this can result in complications as high as 30% as shown in other studies (14).

"iKawase" or "inverted Kawase" approach has been put forward by Tatagiba et al. This encompasses retrosigmoid, intradural endoscopic drilling of the anterior petrous bone from the posterior fossa to gain access to the supratentorial compartment (15).

Retro-labyrinthine approach

An approach to middle and upper clivus with the minimum petrous bone drilling involved. Both inner ear and the facial nerve are avoided. The morbidity in terms of cranial nerve deficits is much less but is at the cost of exposure(8).

Trans-labyrinthine approach

This approach involves the removal of all 3 semi-circular canals and the lateral segment of IAC(8). This provides access to anterolateral brainstem and inferior clivus. Inner ear functioning is damaged (8).

Transcochlear approach

Petroclival and anterior brainstem tumours can be approached easily with resection of the cochlear, greater superficial petrosal nerve and skeletonising the facial nerve. Here inner ear and facial function are lost (8).

Anterior Petrosal approach

Middle cranial fossa extradural approach to intra-canalicular acoustic schwannoma was brought up by House and Crabtree in 1965. This extradural approach was extended to petrous apex lesion and ventrolateral brainstem lesions (16,17).

By the addition of anterior petrosectomy, upper and mid-petroclival lesions, as well as basilar trunk aneurysms, can be treated. This approach was popularised by Kawase and hence also known as Kawase approach. The approach is limited by greater superficial petrosal nerve laterally, petrous bone medially, V3 mandibular nerve anteriorly and IAC posteriorly**.** Kawase's approach is best suited for lesions medial to IAC and upper clivus**.** Facial palsy due to traction on greater superficial petrosal nerve and vein of Labbe venous injury due to temporal lobe retraction can occur (8)**.** Gupta et al have proposed a combination of Fronto-Temporo-Orbito-Zygomatic (FTOZ) approach with intradural anterior petrosectomy. This method helps avoid subtemporal retraction and minimizes the risk of CSF leak (7).

Additional removal of the zygomatic process appears to show no added advantage in surgical freedom during the Kawase approach. The additional drilling off the cochlea and skeletonising the anterior aspect of internal auditory meatus doubles the exposure but at the cost of hearing. Hsu et al concluded that not always more extensive bone removal equates to better exposure. They found that drilling of Glassock triangle in addition to the Kawase triangle provided no added advantage in respects of surgical freedom or exposure (16)

The common notion is that Kawase approach falls short of adequate decompression of lesions extending inferior to the internal auditory canal (11). But this is not true as proven by many studies. If the dural attachment can be transected via the narrow corridor, the entire lesion can be removed. But this judgment preoperatively seems difficult (11). As per Abdel Aziz zones, anterior transpetrosal approach was feasible only in Zone I tumours but studies show tumours extending to Zone II can also be resected by Kawase approach (11,12)

Various modifications and extensions of the original Kawase approaches have been proposed (10,18). Laligam Sekhar proposed the transcavernous route to the same technique by 3 modifications: intradural rather than extradural drilling of petrous apex and clivus; complete division rather than fenestration of the tentorium; and mobilization of the trigeminal nerve root, ganglion, and third division after dissection of Meckel's cave and cavernous sinus walls (18). Modified Dolenc-Kawase approach adds transcavernous medial mobilisation of the cisternal segment of the trigeminal nerve. This provides more exposure to the petrous apex, more surgical freedom at the prepontine area as well as allows more manoeuvres at Dorello's canal (10).

Combined transpetrosal approach

Different combinations of the above four approaches have used to obtain wider access and greater resection. But such procedures require extensive temporal bone drilling and can be time-consuming (8).

Radiosurgery

Stereotactic radiosurgery is being increasingly used in the management of petroclival lesions because of their good tumour control and lower incidence of deficits. The incidence of cranial nerve deficits after SRS to the petroclival region is at 8% (8). They can be offered for small to medium tumours or non-surgical candidates with larger tumours. But the SRS is largely recommended for the residuum in patients who have undergone subtotal excision(8).

Original Anterior Transpetrosal Procedure Described by Kawase

Dolenc in Europe and Hakuba in Japan developed on the works of William House to reach the petroclival region. Dolenc was inclined to interdural dissection of the lateral cavernous sinus while Hakuba was focused on following the bony landmarks of the petrous bone. This surgical technique of anterior petrosectomy was then elaborated by Takeshi Kawase in 1985 (19,20). The approach was used by

Kawase in tackling upper clival and prepontine tumours including meningiomas, schwannomas, chordomas and epidermoids, and as well as upper vertebrobasilar circulation aneurysms such as upper basilar trunk aneurysms and anterior inferior cerebellar artery aneurysms (11,19).

Preoperative Preparation

MR imaging and CT scan are essential for surgical planning (4). CSF diversion in the form of lumbar drainage helped in relaxing the temporal lobe and help retract the temporal lobe without much compressive element involved (19). The tapping of the trigone of the lateral ventricle can be helpful in further CSF drainage(19).

Position

The patient is placed supine under general anaesthesia with the head rotated laterally and head flexed (19). Intraoperative facial nerve monitoring and auditory Brain Stem Response (ABR) patient are used as adjuncts (19).

Incision and Exposure

Inverted U shaped scalp incision is made in the temporal region, muscle retracted anteriorly and temporal craniotomy is done. The craniotomy extends up to the spur of zygomatic arc and squamous suture. The rim of craniotomy is taken down till the foramen spinosum is exposed. Middle meningeal artery passing through the foramen spinosum is coagulated and cut. The temporal dura is stripped off from the middle cranial fossa floor. This step is facilitated greatly by CSF diversion. Great care is taken not to cause excessive traction on the greater superficial petrosal nerve (GSPN) as it arises from the facial nerve. Interdural dissection between the two layers of dura helps preserve the greater superficial petrosal nerve (19).

Identification of landmarks on the middle cranial fossa floor

Arcuate Eminence and the trigeminal impression act as a guide for the surgery. The internal auditory canal is slightly anterior to the arcuate eminence. The point of intersection of the line passing through the greater petrosal nerve with the line between the external and internal auditory meatuses is the landmark of the geniculate ganglion. Drilling is done medial and posterior to the greater superficial petrosal nerve, anterior to arcuate eminence and superior to IAM (19). Gasserian ganglion forms the anteromedial limit of drilling (7). The trigeminal nerve is mobilised after drilling off the trigeminal impression. At the end of drilling, the posterior fossa dura extending from the IAM to the Meckel's cave is visible (19). Trigeminal nerve serves as an important landmark during the middle cranial fossa approach to the petrous apex. The trigeminal nerve once displaced anteriorly can open up the surgical corridor leading to the petrous apex. But the trigeminal nerve anatomy can be subjective and difficult to reproduce in the future. Hence bony landmarks help define the Kawase approach better (4)

Greater superficial petrosal nerve serves as the most reliable landmark to identify geniculate ganglion and IAC. By following a proper identification protocol, the greater superficial petrosal nerve and the semi-circular canals can be preserved in most cases.

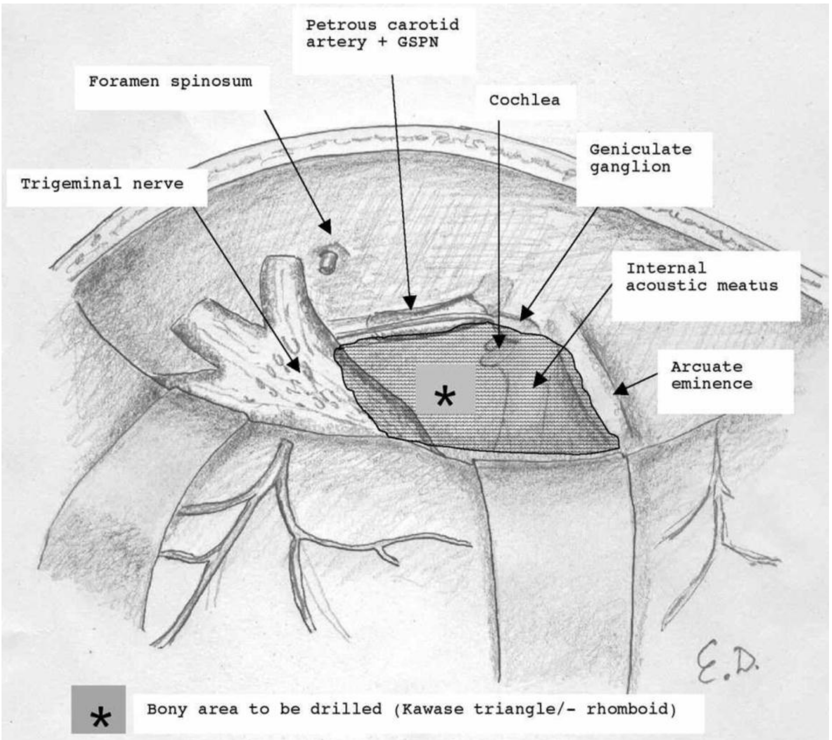


Figure 3: The Landmarks On The Anterior Petrous Bone Surface And The Area On The Anterior Petrous Bone To Be Drilled -Adapated from Badwal JS, Kumar SB, Sinha SK. The Kawase Approach To Petroclival Lesions Of Skull Base: A Landmark In Skull Base Surgery. World Journal of Pharmaceutical and Med Research 2017,3(3), 107-114

Dural opening and Tumour decompression

A stab incision on the posterior fossa dura helps enter the cerebellopontine cistern. The middle fossa dura is then incised for a length of 2 cm till the superior petrosal sinus. The dural incision is converted to a T-shape by extending the incision along the superior petrosal sinus. The superior petrosal sinus can be cut if necessary. Tentorium is then cut taking care not to injure the trochlear nerve at the free edge. Trigeminal nerve compressed beneath the superior petrosal sinus can be injured in this step. In cases of petroclival tumours, the tentorial artery can be encountered before the tumour and coagulated earlier thereby providing a bloodless field for tumour decompression (19).

Closure

Space drilled out is filled with temporalis fascia. Mastoid air cells are plugged with abdominal fat if needed. Dural margins are sutured to the fascial flap. Glue is used to the secure the above constructs and prevent CSF leak (19).

Advantages

1. A safe corridor for surgically challenging lesions like the petroclival meningioma (20)
2. Devascularization of the feeding artery from tentorial artery (20)
3. Separates any dural attachment from the tentorium as well as from dura of posterior fossa and clivus (20)
4. Brainstem can be visualised directly and tumour adhesion can be dealt with more safely (20)
5. Most of the drilling is extradural providing a barrier from the brain parenchyma and neural structures
6. Injury to lower cranial nerve is minimum
7. Low risk of sigmoid sinus and other venous complications
8. Lower chance of injury to Vein of Labbe

Disadvantages

1. The complexity of the anatomy and anatomical variants had deferred surgeons from choosing the middle cranial fossa approach. As skull base surgical approaches have advanced over the past 30 years, the middle cranial fossa approaches to posterior fossa lesions are being used more frequently (4)
2. Though anterior petrosectomy opens up a wide space, petrous apex is a well-defined space which cannot be extended beyond a particular dimension due to the critical structures surrounding it which in turn can limit the extent of resection in some cases (7)
3. Lesions extending beyond certain limits cannot be dealt with such as (20)
   a. Anterior loop of carotid artery
   b. Lower clivus
   c. Posterolateral to Internal auditory meatus
4. Entire bone work occurs in compact bone with no guidance during the drilling except external landmarks (16)
5. Success and low morbidity of endovascular management of posterior circulation aneurysms have deterred many surgeons from tackling these aneurysms by skull base approaches.
6. Brainstem adhesion dissection can be time-consuming and tiring (20)

Complications

1. Dehiscent wall can lead to unintentional exposure of the petrous carotids and even damage to the vessel
2. Vein of Labbe can interfere with dural opening (7)
3. Vein of Labbe can occasionally be injured during the temporal lobe retraction (7)
4. Temporal lobe contusion can occur due to retraction (7)
5. Injury to the greater superficial petrosal nerve resulting in facial palsy can occur due to traction of the greater superficial petrosal nerve (7)

6. Facial nerve palsy secondary to reactivation of latent herpes infection or traction of greater superficial petrosal nerve or vascular insult
7. CSF fistula or rhinorrhoea can occur due to the absence of improper dural closure in the presence of open air cells near the IAM or the craniotomy site (7)
8. Damage to inner ear structures such as cochlea and semi-circular canals occurs secondary to excessive posterior drilling(7)

Watanabe classification of the petrosal vein (21)

Type I: superolateral to facial nerve

Type II: drains between trigeminal nerve and facial nerve

Type III: superomedial to the trigeminal nerve

All variations of the petrosal vein drainage into the superior petrosal vein can be seen during anterior petrosectomy. In type I drainage, the vein may be difficult to visualise but will not offend the surgical corridor. Type 2 & 3 may necessitate the division of the vein or the superior petrosal sinus to provide the requisite visibility and room for manoeuvres. A similar classification has been mentioned by Tanriover and Rhoton (22)

Petroclival meningiomas

Petroclival meningiomas constitute the majority of the lesions that can be tackled via the anterior transpetrosal approach or the Kawase approach. The pure "petroclival meningiomas" are defined as those arising from the upper $2/3^{rd}$ of the petroclival junction and they lie medial to the trigeminal nerve and cranial to the jugular tubercle. "Anterior petrosal meningiomas" arise lateral to trigeminal nerve and medial to internal auditory meatus. For practical purposes, both of these are called as petroclival meningiomas.

Arterial supply of petroclival meningioma

1. Meningiomas extending to cavernous sinus and Meckel's cave is supplied mainly by dorsal meningeal artery

2. Tumours extending to midline are supplied by tentorial artery
3. Inferiorly extending tumours are predominantly fed by ascending pharyngeal artery
4. Other vessels supplying tumours of this region are inferolateral trunk, anterior inferior cerebellar artery and middle meningeal artery

Adachi et al suggested that anterior petrosal approach was not suitable for tumours supplied by ascending pharyngeal artery while tumours supplied by other arteries, irrespective of extension beyond internal acoustic canal, can be tackled by Kawase approach (11).

Epidural versus subdural approach

In the subdural/ intradural approach of anterior petrosectomy, drilling can be minimized and thereby injuries related to drilling. After visualising the tumour, the anterior petrosectomy can be customised than extensively drilling the petrous bone. The temporal lobe is mobilised from mediolaterally and CSF is let out during an anteroposterior sylvian dissection. This results in only minimal temporal lobe retraction (7). But in subdural approach superficial middle cerebral vein needs to be dissected during wide sylvian opening. 10% of the superficial middle cerebral vein can have drainage through the spheno-petrosal sinus and division of the spheno-petrosal vein can be dangerous in the above manoeuvre leading to venous infarcts (7,23). Intradural approach avoids the Vein of Labbe totally and hence avoid complications related to the vein. greater superficial petrosal nerve during intradural drilling is said to be safe (7).

Moreover, the subdural drilling of petrous bone can injure structures around the anterior part of tentorial incisura (23). Tomio et al disagree to subdural drilling stating that even though more than required drilling of the Kawase space occurs in many cases in epidural approach, the incidence of the speculated complications like an injury to the greater superficial petrosal nerve, the vein of Labbe and inner ear remains very low (23). Epidural drilling also requires a smaller temporal craniotomy and minimal temporal lobe retraction (23). Larger numbers of authors still follow intradural drilling compared to the original technique (7,18,24).

Future

Approaching petroclival lesions via an anterior petrosectomy approach is becoming more common. This, in turn, has reduced the morbidity and mortality associated with the surgeries for such conditions (4). Subsequent surgeons have expanded the corridor by providing an addition to the original technique described by Kawase et al (2,3,7,10,15,18–20,25)

Need for study

The approximate area of Kawase triangle has been determined by multiple studies especially cadaveric studies. The the area of anterior surface of petrous apex to be drilled for Kawase approach has been calculated by Day et al as 2.9 cm^2 (26). Determination of the volume of Kawase space is essential to understand the extent and feasibility of anterior petrosectomy (4). The optimal volume of drilling needed to have adequate exposure to the posterior fossa has not been studied. Over-drilling of the Kawase space can lead to damage to surrounding critical structures while under-drilling will result in inadequate exposure. Kawase space is a pyramidal bony space surrounded by internal auditory canal, cochlea and the semi-circular canal. It lies in close proximity to the petrous segment of the internal carotid artery (4). Mean area of Kawase triangle ranges from 62+/-43 mm^2 to 106.72+/-19.44 mm^2 as determined in many cadaveric studies (4,16,21). Cadaveric studies revealed the average dimensions anterior petrous space drilled out were 10.57 +/- 2.00 (anteroposterior), 9.39 +/- 1.67 (superoinferior), 17.67+/- 4.64 (mediolateral) and the average volume of the space was 1786.94 +/- 827.40 mm^3 (1). The angle of 13.01+/- 2.35 advantage was obtained by temporal retraction (1). The average volume of petrous apex has been calculated by Adams Perez et al is 1.89+/-0.52 cm^3 (4). These dimensions can have wide variations and will differ depending upon sex, pneumatization and anthropometry (4). But the amount of bone that can be drilled out of this space safely has not yet been determined. Ahmed et al documented 12 degree improvement in the angle of view as a result of anterior petrosectomy (1).

There is no proper clinical study available which correlates the volume of bone resection in anterior petrosectomy via Kawase approach with the outcomes. The extent to which cadaveric studies can be translated to operative outcomes is yet to be validated.

AIMS AND OBJECTIVES

Primary Objective

The study intents to assess

1. The baseline characteristics of the tumour that can be tackled by this approach
2. Tumour extension and feasibility of the tumour removal by this approach
3. Local complications related to the approach
4. Outcomes of the surgical approach

Secondary Objective

The study also intends to formulate

1. The appropriate range of safe volume of bone resection possible by Anterior petrosectomy/ Kawase approach
2. To assess the volumetric parameters and their associations with complications

MATERIALS AND METHODS

Study setting: The study was conducted in the Department of Neurosurgery, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram. Participants were recruited once they are admitted in the Neurosurgery ward for definite surgery. The initial and immediate postoperative assessment were carried out in the neurosurgery ward while the follow-up assessments was carried out in the outpatient clinic customised with the scheduled outpatient visits of the patients. No additional cost burden was incurred by any of the patients.

Study duration: Recruitment to the study was done after obtaining Institutional Ethics Committee (IEC) from January 2018 to May 2019

Study design: A prospective observational single-centre study

Study sample: The target study sample size was 10 consecutive patients operated by anterior petrosectomy approach. At the end of the study, approximately 15 consecutive patients were recruited for the study.

Inclusion criteria:

1. MR imaging showing lesions involving the upper clivus, petroclival, medial petrous regions, lesions occupying the prepontine or medial cerebellopontine cisterns and anterolateral brainstem lesions

2. Most appropriate corridor for approaching this lesion was by an anterior Petrosectomy

Exclusion Criteria

1. Less than 18 years of age
2. With current or prior history of any temporal bone or ear disease
3. Not willing for surgery
4. Not willing to participate in the study
5. Underwent Anterior petrosectomy earlier or some form of inner ear surgery

Since pathologies that can be treated via anterior petrosectomy was uncommon in patients less than 18 years of age, they were not included (4). No discrimination was done base on the gender, ethnicity, classic, race or caste

Ethical clearance

Ethical clearance was obtained from the Institute Ethical Committee of Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram as per order IEC/1147 dated 18.12.2017. Study was initiated only after obtaining ethical clearance.

Informed consent

Informed written consent was taken from all participants explaining the purpose of research, voluntary nature of participation, protection of confidentiality of the participants, right to withdraw from the study at any time, need for extra time during a follow-up visit for detailed clinical examination and no additional cost burden shall be incurred upon the participants.

Preoperative Preparation

All patients underwent at least an MR and CT imaging prior to surgery to help in surgical planning viz-a-viz the tumour characteristics and bone morphology. Position of the inner ear, superior petrosal vein, the vein of Labbe were also noted on MR imaging. Petrous apex pneumatisation, thinned out tegmen tympani, widening of the internal auditory canal, extension of the mastoid air cells into the root of zygoma were noted in CT imaging. This CT scan was later used for comparison and if needed for subtraction purposes. Annexure I was filled up during this period prior to surgery. All surgeries were performed by a single senior surgeon (MA).

Position

CSF diversion in the form of lumbar drainage helped in relaxing the temporal lobe and help retract the temporal lobe. Patient was placed supine under general anaesthesia with the head fixed on MFK clamp, rotated laterally with the head extended slightly. Intraoperative facial nerve monitoring and auditory Brain Stem Response (ABR) patient were used as adjuncts.

Incision and Exposure

A curvilinear C-shaped frontotemporal incision was made extending from the upper border of zygoma superiorly along 1 cm away the tragus and upper attachment of pinna and then anteriorly along the superior temporal line till the anterior hair line. Interfascial dissection was carried out in the anterior aspect while raising the flap to avoid damage to the frontal branch of facial nerve. The temporalis muscle was cut as low as possible usually at the root and upper border of zygoma and reflected anteriorly. Temporal craniotomy was done. The craniotomy was extended up to the spur of zygomatic arc and squamous suture. Bone on the inferior margin of craniotomy was drilled down till the foramen spinosum was exposed. Any mastoid air cells opened was exposed well and waxed. Middle meningeal artery passing through the foramen spinosum was coagulated and cut 2 mm above the foramen. The temporal dura was stripped off from the middle cranial fossa floor in anterior to posterior and lateral to medial direction. Temporal lobe was retracted superiorly using a Leyla® retracting system. This step was facilitated greatly by CSF diversion. Extradural subtemporal dissection was carried up to the anterior surface of the petrous bone and lateral wall of the cavernous sinus. Interdural dissection (between dura propria and dura membranosa) was carried out which helps prevent injury to the cranial nerves or its branches. The mandibular and maxillary divisions of the trigeminal nerve along with the greater superficial petrosal nerve were visualised. Great care was taken not to cause excessive traction on the greater superficial petrosal nerve (GSPN) as it arises from the facial nerve.

Identification of landmarks on the middle cranial fossa floor

Arcuate Eminence and the trigeminal impression act as a guide for the surgery. The lateral edge of the mandibular nerve and the Gasserian ganglion forms the anterior limit. The greater superficial petrosal nerve running above the petrous segment of carotid artery forms the lateral boundary while the roof of internal acoustic canal forms the posterior limit. The internal auditory canal is slightly anterior to the arcuate eminence. The point of intersection of the line passing through the greater petrosal nerve with the line between the external and internal auditory meatuses is the landmark of the geniculate ganglion. Drilling was done, with a diamond drill, medial to GSPN, anterior to arcuate eminence and superior to IAM.

Medtronic Midas Rex Legend® 10BA 10/20/30D drills were used for this purpose in our institute. Drilling is done deep in a perpendicular direction. At the end of drilling, the posterior fossa dura extending from the IAM to the Meckel's cave was visible.

Dural opening and Tumour decompression

A stab incision on the posterior fossa dura helps enter the cerebellopontine cistern. The middle fossa dura is then incised for a length of 2 cm across the superior petrosal sinus. The dural incision is converted to a T-shape by extending the incision along the superior petrosal sinus. The superior petrosal sinus can be divided if necessary. Tentorium is then cut taking care not to injure the trochlear nerve at the free edge (near porus trigeminus). Trigeminal nerve compressed beneath the superior petrosal sinus, can be injured at this step. In case of petroclival tumours, the tentorial artery can be encountered before the tumour and coagulated earlier thereby providing a bloodless field for tumour decompression. In cases of meningiomas the exposed dura can be cauterised well before starting debulking.

Closure

The common site of CSF leak is the mastoid cells, inadvertently opened middle ear fossa which are carefully inspected. After achieving haemostasis, crushed muscle graft is used to plug any visible mastoid air cells on the petrous bone especially near the internal acoustic meatus. Then fibrin glue is applied over the drilled part and the internal acoustic meatus. A pericrania patch is kept over the dural opening. Few tacking stitches are taken if possible else the dura is left open covered by the pericranial patch. Glue is again applied over the patch thereby sealing the dural opening. Temporal craniotomy margins are again waxed. Wound is closed in layers over a subgaleal suction drain. The lumbar drain is closed after placement of bone flap and is removed on postoperative day 1 or 2. Performa Annexure II was filled immediately after the surgery.

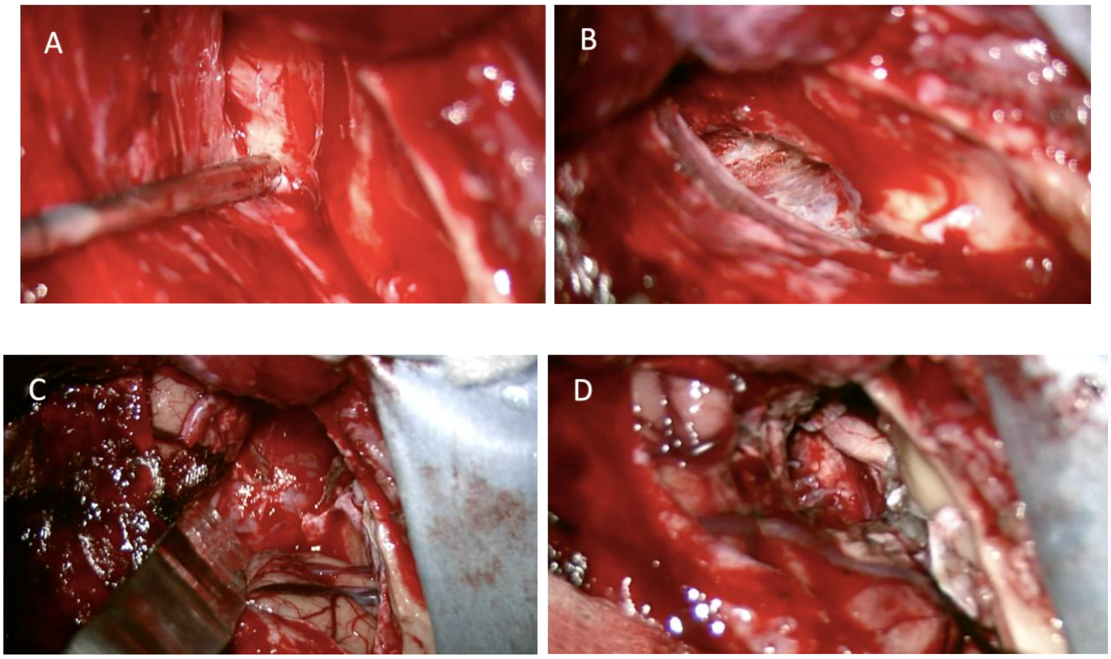


Figure 4: Intraoperative photographs (A) Anterior petrous bone after extradural dissection is complete showing the area of petrous bone intended to be drilled (B) Anterior petrous bone after extradural drilling (C) Temporal base dura opened, Tentorium and posterior fossa dura is incised and superior petrosal sinus divided. Tumor in the petroclival region is visible. (D) The operative cavity at the end of procedure showing gross total excision

Thin Slice CT scans of the temporal bone were performed using a 256-multidetector CT scanner (Philips Brilliance iCT). The following settings was used: spiral mode, tube voltage 120 kV, tube current 350 mA, 400 msec gantry rotation time, 20x0.625mm collimation, 0.25 pitch, 200 mm Field of View, Y-Sharp filter, 768 matrix and 0.67-mm slice thickness with no interslice gap. Thin cut CT scan of the temporal bone was the imaging modality of choice for measurement of the bony hiatus since it had a superior image quality when compared to MR imaging (4).

Brain imaging, during the immediate preoperative period, was done using same CT scanner (256 slice Philips Brilliance iCT). The following settings were used: axial mode, tube voltage 120 kV, tube current 250 mA, 750 msec gantry rotation time, 16x0.625mm collimation, 250 mm Field of View, 512 matrix and 2.5-mm slice thickness with no interslice gap.

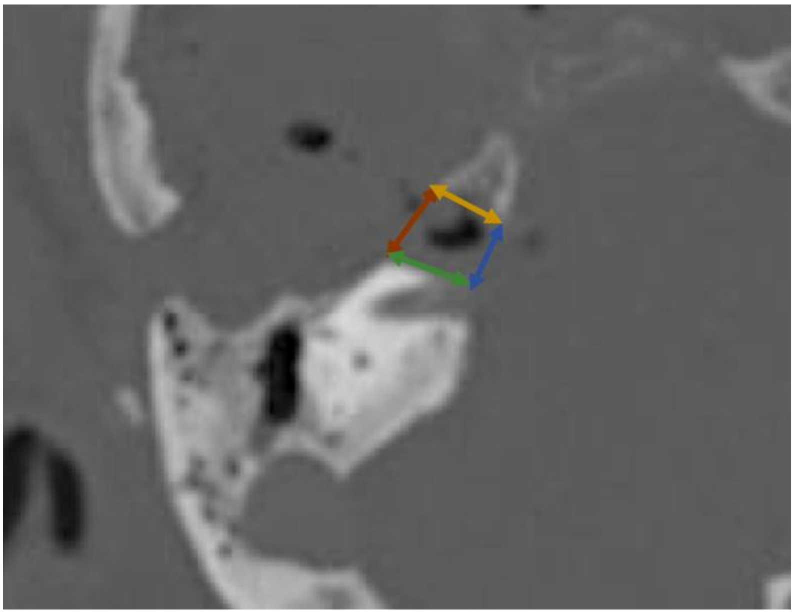


Figure 5: Postoperative CT scan of the temporal bone showing the bony corridor drilled in the anterior petrous bone. Red line is the “anterior mediolateral distance” which reflects which reflects the area of anterior petrous surface drilled. Yellow line is the “anterior anteroposterior distance” which reflects the amount of petrous apex retained. Green line is the “posterior anteroposterior distance” which reflects the depth of drilling done. Blue line is the “posterior mediolateral distance” which reflects amount of posterior fossa surface exposed.

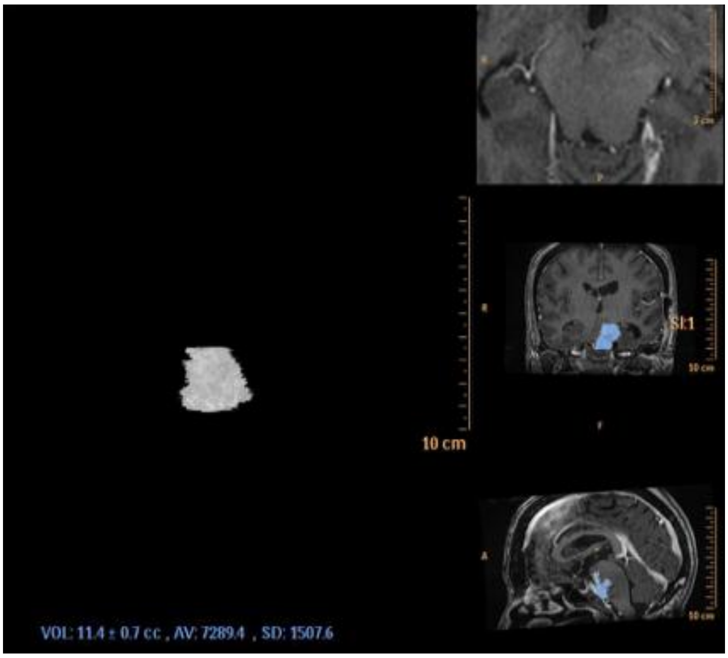


Figure 6: Volume measurement done using in house CT software. The current snapshot shows the volume measured for preoperative tumor size. Similar technique was used for measurement of postoperative tumor size and bony corridor created.

Volume measurement was performed using Philips extended Brillance software. This ensured uniformity across different CT scans irrespective of the tilt at which the scans were acquired. The measurement was done by an experienced radiologist under the supervision of a neuroradiologist (BT) and a neurosurgery resident (MAJ). The radiologist was blinded to the clinical details or the operative records of the patients.

The volume of the preoperative tumor was calculated using the formula (Volume = AP dimension x Mediolateral dimension x Craniocaudal dimension X 0.5). The measurements were obtained from the preoperative MR imaging. The tumor volume was also measured using the Philips extended Brillance software.

A postoperative MR imaging, 1-6 months after surgery, was obtained in all cases as per hospital protocol and tumor residue was measured in these scans in the in-house software mentioned above.

Performa Annexure III was be filled during the immediate postoperative period prior to discharge from hospital which was used to assess immediate postoperative complications, improvement or any fresh deficits. Performa Annexure IV will be administered at 3-6 months postoperative depending on the follow-up of the patient and routine postoperative imaging. This includes clinical evaluation inclusive of cranial nerve examination and MR imaging analysis for extent of resection as well as quality of life using the modified Rankin score and independence achieved at followup. There will be no interference on the followup dates of the patients based on the study.

Statistical Analysis

Descriptive Statistics were employed, with frequency & percentages calculated for categorical data, and mean & standard deviations calculated for continuous variables. The chi square and Fisher’s test were used to assess the significance of associations, while Pearson’s correlation was used to examine the relationship between volume of bone removed and other relevant clinical parameters. Data was analysed using the Statistical Package for the Social Sciences, version 22.00 (SPSS Inc, IBM, Chicago, IL, USA).

RESULTS

Patient demographics:

Average age of patients in the study was 45.067 years ranging from 18 to 64 years. Only 4 of the 15 patients (26.7 %) were male patients since most of the patients presenting with a lesion amenable for Kawase approach were petroclival meningioma (8 nos - 53.3 %) and all of them were females. There was three patients (20%) who had undergone surgeries through different approaches but none of them had undergone surgery through Kawase approach.

Baseline Characteristics

Audiometry revealed a bimodal distribution of ipsilateral hearing loss can be attributed to few patients having lesion extending up to or beyond the IAC while others had no compression or involvement of the VII-VIII nerve complex. Similar bimodal distribution was noted for preoperative facial palsy and reason may be the same as above. More than 50% of the patients had involvement of the trigeminal nerve as expected from the pathologies of the region. One patient had false localising sign in the form of hemifacial spasm on the opposite side. Another patient was detected to have a petroclival meningioma on imaging done as a part of mild head injury elsewhere and was referred here. All except two patients were conscious and fully oriented. Two patients who had altered sensorium preoperatively regained orientation at the time of discharge.

Average duration of stay was 5.467 days. Usual duration of any patients undergoing Kawase approach was 4-5 days. One patient had developed buccal cellulitis and had to be treated with intravenous antibiotics. This resulted in an increased mean for duration of stay.

Table 1: Details of 15 patients operated via Kawase approach

Sl. No.	Age	Sex	Diagnosis	Comments
1.	18	F	Intrinsic Brain stem high grade glioma	- Left cheek cellulitis in postoperative period - Lesion progressed in postoperative period
2.	58	F	Petroclival Meningioma	
3.	39	F	Petroclival Meningioma	
4.	39	F	Petroclival Meningioma	- Incidental
5.	44	M	Recurrent Posterior fossa Epidermoid	- Previously Middle cranial fossa component excised
6.	55	F	Petroclival Meningioma	- CSF Rhinorrhoea postoperatively
7.	44	F	Petroclival Meningioma	- Previously operated via Retrosigmoid Approach - Patient had altered sensorium despite no hydrocephalus which improved at follow-up. - Volume >34 cc - Only subtotal excision could be done in view of poor plane with surroundings
8.	42	F	Petroclival Meningioma	- Patient had altered sensorium despite no hydrocephalus which improved at follow-up.
9.	31	M	Clival Chordoma	- Underwent gamma knife therapy 2 years ago. Lesion progressed with new onset 3rd nerve palsy.
10.	35	F	Trigeminal schwannoma	- Opposite side hemifacial spasm - Postoperatively had CSF leak
11.	64	F	Petroclival Meningioma	
12.	55	F	Petroclival Meningioma	
13.	64	M	Recurrent Trigeminal schwannoma	- Previously operated via Retrosigmoid Approach - Bone partly eroded by tumour - CSF Rhinorrhoea postoperatively
14.	56	F	Vestibular schwannoma	- Preoperatively ventriculoperitoneal shunt inserted in view of significant hydrocephalus
15.	32	M	Residual posterior fossa Craniopharyngioma	- Patient had altered sensorium despite no hydrocephalus or electrolyte disturbance which improved immediately after surgery.

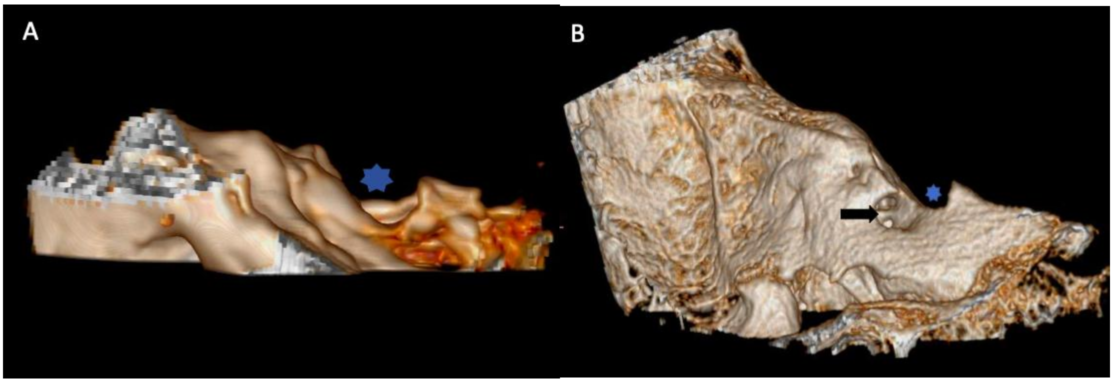


Figure 7: 3-D CT reconstruction A) anterolateral view (B) posteromedial view of the petrous bone showing anterior petrosectomy (star) and internal auditory meatus (arrow)

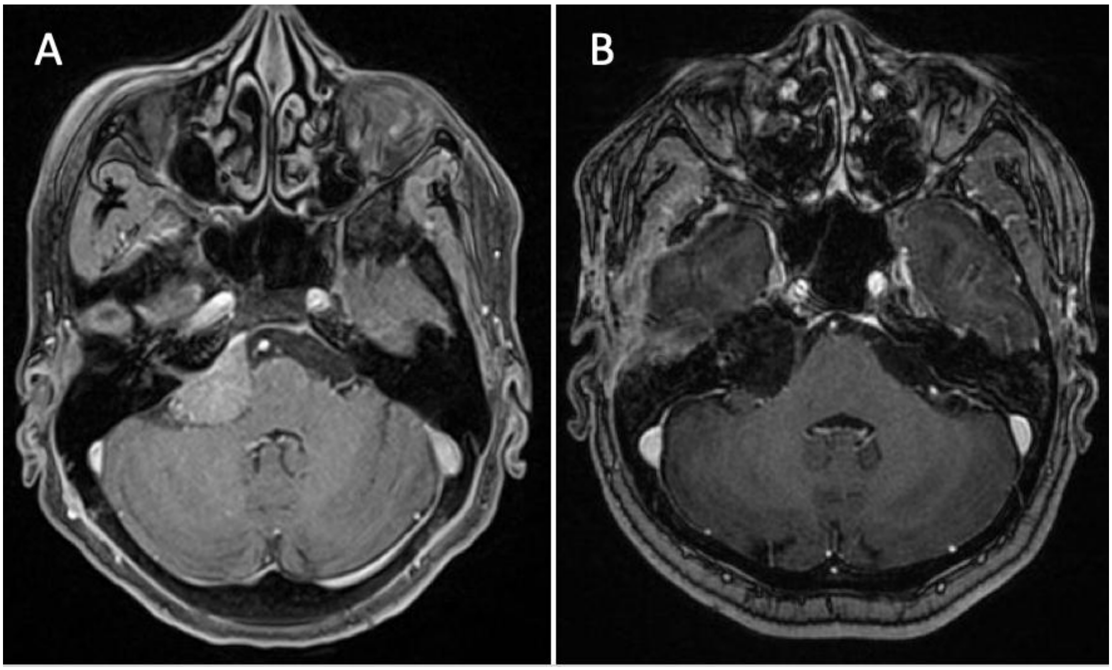


Figure 8: (A) Preoperative and (B) postoperative imaging of a case of petroclival meningioma operated via anterior petrosectomy approach

Table 2: Demographic and Baseline Characteristics (Part 1)

	Mean	Median	Std Dev	Minimum	Maximum
Age (years)	45.067	44.00	13.34	18	64
Duration of Headache (months)	10.267	0	25.4543	0	96
Facial palsy (HB score)	0.867	0	1.302	0	3.0
Duration of Stay (days)	5.467	5.00	2.2636	3	11
Duration of follow-up	8.6	9.00	4.579	2	18
Ipsilateral hearing (dB)	45.91	26.0000	38.122	13	120
Contralateral hearing (dB)	16.82	15.0000	5.742	10	32

Table3: Demographic and Baseline Characteristics (Part 2)

		Number	Percentage
Sex	Males	4	26.7 %
	Females	11	73.3 %
Side	Right	9	60%
	Left	6	40%
Pathology	Brainstem Glioma	1	6.7%
	Meningioma	8	53.3%
	Schwannoma	3	20.0%
	Craniopharyngioma	1	6.7%
	Chordoma	1	6.7%

	Epidermoid	1	6.7%
Symptoms	Vomiting	1	6.7%
	Squint	2	13.3%
	Diplopia	2	13.3%
	Gait difficulty	6	40%
	Seizures	1	6.7%
	Hearing loss	6	40%
	Facial sensory symptoms (numbness/neuralgia)	9	60%
	Facial deviation/ hemifacial spasm	6	40%
Signs	3rd nerve palsy	1	6.7%
	6th nerve palsy	4	26.7%
	Absent corneal reflexes	4	26.7%
	V1 sensory deficits	7	46.7%
	V2 sensory deficits	6	40%
	V3 sensory deficits	4	26.7%
	5th nerve motor weakness	5	33.3%
	Limb weakness	4	26.7%
	Limb sensory deficit	4	26.7%
	Cerebellar signs -Ipsilateral	3	20%
	Cerebellar signs - bilateral	3	20%

Figure 9: Histogram showing bi-modal distribution of facial palsy

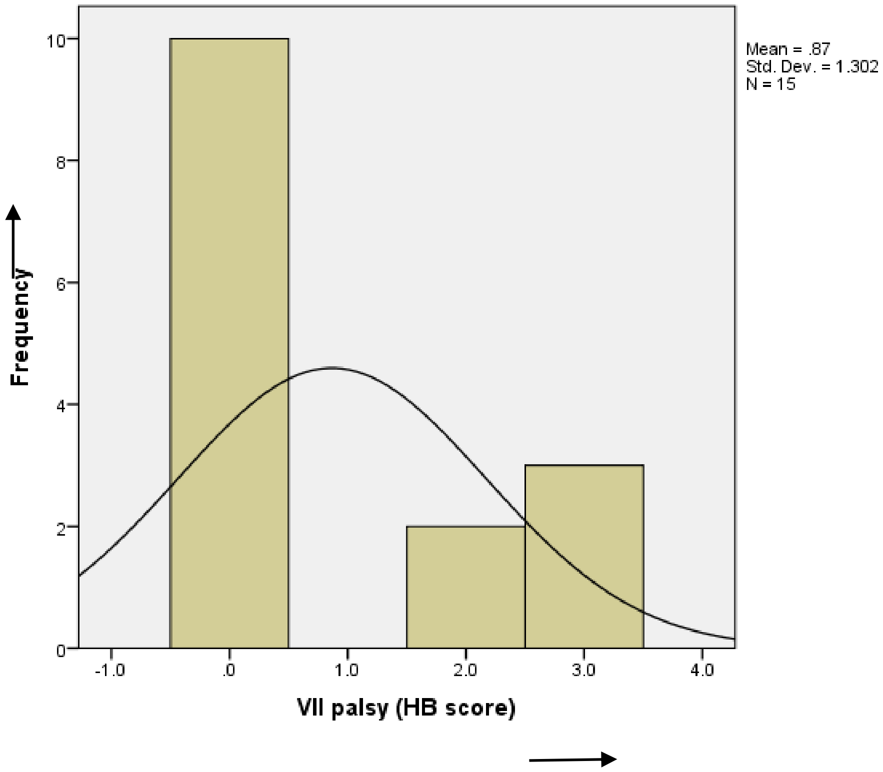
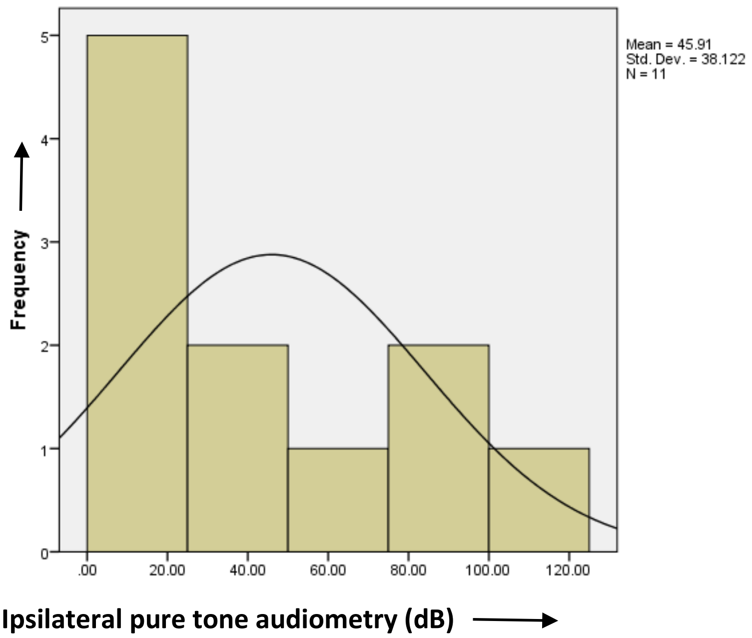


Figure 10: Histogram showing bi-modal distribution of ipsilateral hearing



Pre-operative radiological features:

The volume of tumour has a large range varying from 1064 cu mm to 34263 cu mm. Even though all the dimensions have similar ranges, the anteroposterior and craniocaudal dimension fell into taller histogram while the mediolateral dimension seem to fall over a broader range. This signifies the nature of petroclival meningioma which have broader base than height. Bony destruction was seen in 4 of the cases (26.7%) and out of which three of them were trigeminal schwannoma in which bony destruction of the anterior petrous bone along the Meckel's cave is expected

Figure 11: Histogram showing tumour volume

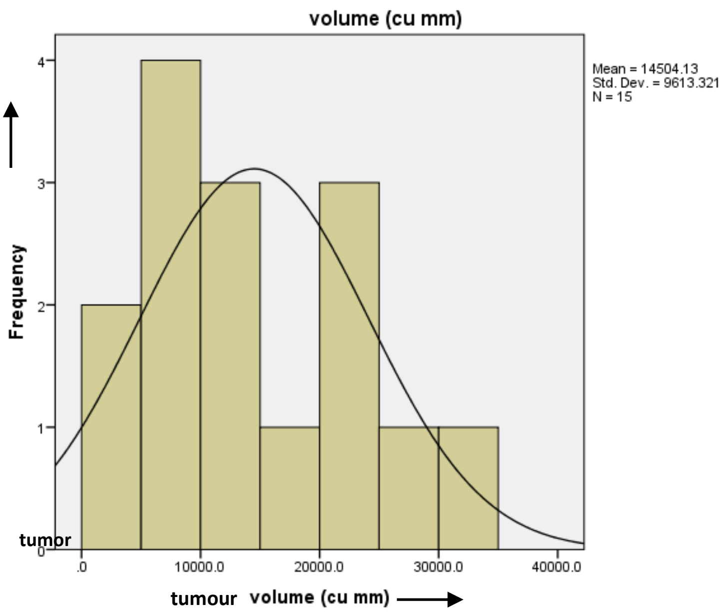


Figure 12: Histogram showing different dimensions of tumour

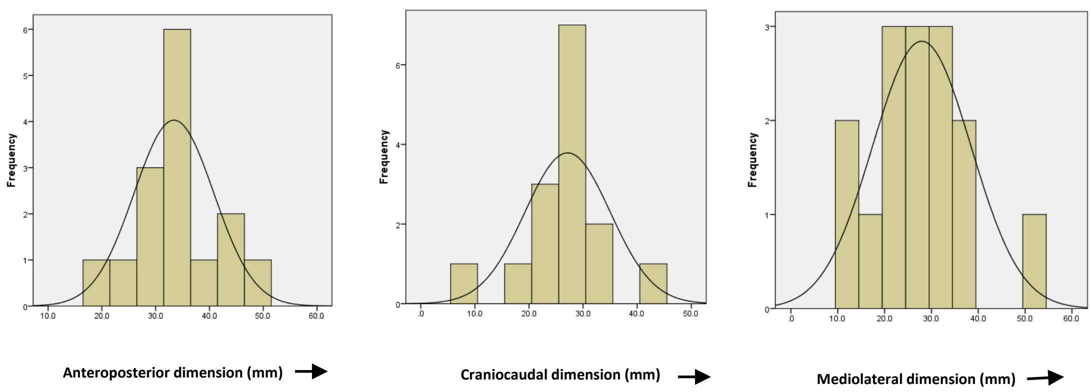


Table 4: Preoperative Imaging Finding (Part 1)

	Mean	Median	Std Dev	Minimum	Maximum
Anteroposterior (mm)	33.4	32.000	7.424	19	47
Craniocaudal (mm)	27.13	28.000	7.9	8	43
Mediolateral (mm)	27.93	10.5253	10.525	12	54
Tumour volume (derived in cu mm)	14504.13	11600.00	9613.32	1064	34263
Tumour volume (measured in cu mm)	16256.64	8850	21489.0	1918	84000

Table 5: Preoperative Imaging Characteristics (Part 2)

		Number	Percentage
MRI	**Contrast enhancement**	13	86.7%
	Extension into IAC	1	6.7%
	Extension lateral to IAC	4	26.7%
	3rd nerve compression	4	26.7%
	5th nerve compression or involvement	14	93.3%
	7th nerve compression	8	53.3%
	Brainstem compression & distortion	13	86.7%
CT	**Bone destruction**	4	26.7%
	Hydrocephalus	2	13.3%

One of the tumour was intra-axial and all other 14 (93.3%) tumours were extra-axial in location. The intra-axial tumour was arising from the anterolateral aspect of brainstem and histopathological examination turned to be a high grade glioma. As per calculation described in methodology, only 2000 cu mm of tumour was removed in this case.

Surgical technique:

Intra-operative temporal lobe contusion were noted in 26.7% of the cases but none of these patients had a significant clinical deficits related to the contusions.

Table 6: Intraoperative characteristics

		Number	**Percentage**
CSF diversion	**Lumbar drain**	14	93.3
	Preoperative Shunt Only	1	6.7
Skin Flap	**Frontotemporal**	11	73.3
	Temporal	2	13.3
	Previous	2	13.3
Craniotomy	**Frontotemporal**	6	40.0
	Temporal	7	46.7
	Previous	2	13.3
Complications	**Vein of Labbe injury**	1	6.7
	Temporal contusion	4	26.7
	Semi-circular canal	0	0
	IAM opened	3	20
	ICA injury	0	0
	4th nerve transection	1	6.7
	6th nerve transection	0	0
Consistency	**Cystic**	0	0
	Soft	1	6.7
	Soft to firm	6	40.0
	Firm	7	46.7
	Firm to hard	1	6.7

	Hard	0	0
Vascularity	**Mild**	3	20.0
	Moderate	7	46.7
	High	3	20.0
Plane with surroundings	**Good**	8	53.3
	Poor	6	40.0
Extent of resection	**Gross total excision**	12	80.0
	Near total excision	1	6.7
	Subtotal excision	2	13.3
	Partial excision	0	0
	Biopsy	0	0

Since one patient had significant preoperative hydrocephalus, patient underwent ventriculoperitoneal shunt followed by the definite surgery after an interval. Since there was no ventriculomegaly, it was planned to defer lumbar drainage and to tap ventricle intraoperatively if needed. Good temporal lobe retraction could be achieved even without lumbar drainage in this patient.

Complete visualisation of landmarks associated with Kawase quadrilateral was done in all cases before starting drilling the anterior petrous bone Superior petrosal sinus was coagulated and divided prior to cutting the tentorium and entering the posterior fossa. Most of the tumours (93.3%) in this region were firm or its variant thus limiting easy decompression. Ultrasonic aspirator was used in most cases for decompression.

In one case dural closure was attempted primarily while in all other cases, dura was covered with overlay graft and glue was applied. All cases where lumbar drain was used, lumbar drain was kept closed postoperatively and removed postoperatively after 1-2 days. None of the patients needed CSF drainage in the immediate postoperative period.

Table 7: Postoperative Complications

	Number	**Percentage**
CSF Leak	1	6.7%
CSF rhinorrhoea	2	13.3%
Wound dehiscence	0	0%
Tarsorrhaphy	3	20%

Table 8: Postoperative CT findings (Part 1)

	Number	**Percentage**
Semi-circular canal injury	0	0
Infarct	0	0
Temporal lobe contusion	4	26.7%
Hematoma	1	6.7%

Table 9: Postoperative CT imaging characteristics (Part 2)

	Mean	**Median**	**Std Dev**	**Min**	**Max**
Volume of bone resected (cu mm)	964.27	945.00	383.438	147	1574
Anterior AP distance (mm)	7.03	7.000	3.382	0	13
Posterior AP distance (mm)	13.07	12.500	3.022	7.8	17.0
Anterior Mediolateral distance (mm)	19.42	19.000	4.393	12.7	25.0
Posterior Mediolateral distance (mm)	17.45	18.000	5.079	5.6	25.0
Distance of IAC from the corridor edge (mm)	1.26	0	1.659	0	5.0
Distance of ICA from inferior wall of corridor (mm)	3.13	3.000	1.485	1.4	6.9

There was significant variation in the size of bony corridor made ranging from 147 mm^3 to 1574 mm^3. The distance of internal carotid artery from the inferior wall of corridor noted on imaging was different from the intraoperative findings. The distance varied from 1.4 mm to 6.8 mm even though in few patients the petrous segment of the internal carotid artery was deroofed during surgery. This may be due to errors arising due to slicing and reconstruction.

Figure 13: Histogram showing volume of bone drilled off

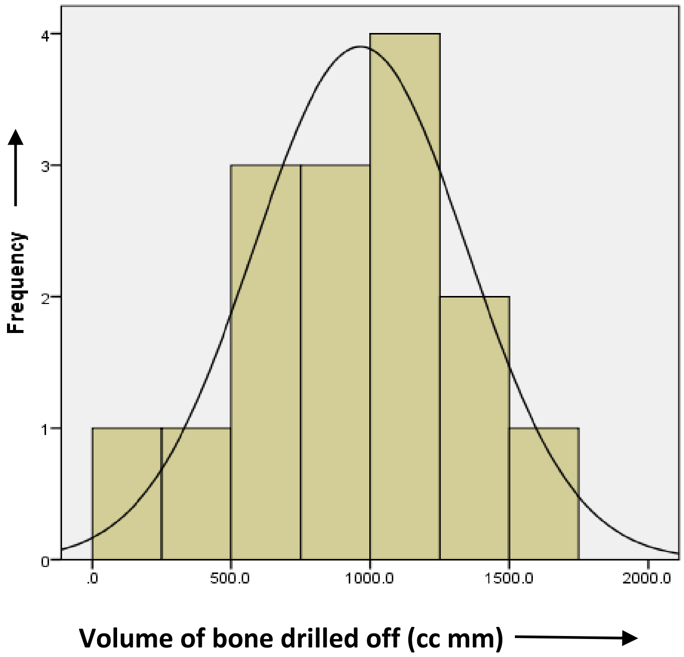


Table 10: Postoperative outcomes

	Mean	Median	Std Dev	Min	Max
Immediate postoperative Facial palsy (HB score)	1.615	2	1.8046	0	5
Follow-up Facial palsy (HB score)	1.333	0	1.857	0	5
Modified Rankin Scale	1.333	1	0.480	1	2
Glasgow Outcome Score	4.800	5	0.414	4	5
Postop tumour volume measured (cu mm)	7014	62	22367	0	84000
Tumour removed measured (cu mm)	9242.5	8550	5850	1918	20400

Table 11: Follow-up Antiepileptics usage

	Number	Percentage
Standard dose	0	0
Tapering dose	4	26.7%
Stopped	11	73.3%

Table 12: Immediate postoperative clinical findings compared to preoperative status

	No Change		Cured		Improved		deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
Diplopia	10	66.7					5	33.2
Seizure	15	100						
Hearing	15	100						
Facial numbness	12	80	0	0	2	13.3	1	6.7
Facial deviation	11	73.3			1	6.7	3	20.0
3rd nerve palsy	14	93.3	0	0	0	0	1	6.7
6th nerve palsy	12	80	0	0	0	0	3	20
Limb weakness	13	86.7	0	0	1	6.7	1	6.7
Limb sensory deficit	14	93.3	1	6.7	0	0	0	0

4 (26.7%) of our patients had diplopia on looking downwards with grossly normal extraocular palsy. Detailed examination revealed 2 out of the 4 patients had definite superior oblique palsy while other patients were indirectly attributed to trochlear near handling. Out of these 4 patients, two patient continued to have diplopia at the end of 6 months.

Table 13: Follow-up Clinical findings compared to preoperative status

	No Change		Cured		Improved		deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
Diplopia	10	66.7	0	0	3	20	2	13.3
Hearing	13	86.7	0	0	1	6.7	1	6.7
Facial numbness	10	66.7	0	0	5	33.3	0	0
Facial deviation	11	73.3	1	6.7	2	13.3	1	6.7
3rd nerve palsy	13	86.7	1	6.7	1	6.7	0	0
6th nerve palsy	14	93.3	0	0	1	6.7	0	0
V1 sensory deficits	9	60.0	0	0	5	33.3	1	6.7
V2 sensory deficits	10	66.7	1	6.7	4	26.7	0	0
V3 sensory deficits	11	73.3	1	6.7	3	20.0	0	0
Limb weakness	11	73.3	2	13.3	2	13.3	0	0
Limb sensory deficit	13	86.7	2	13.3	0	0	0	0

Table 14: Facial palsy – House Brackmann score

	Mean	Std Dev
Preoperative	1.000	1.3540
Immediate Postoperative	1.615	1.8046
Follow-up	1.538	1.8980

Figure 13: Comparison of the facial palsy over timeline

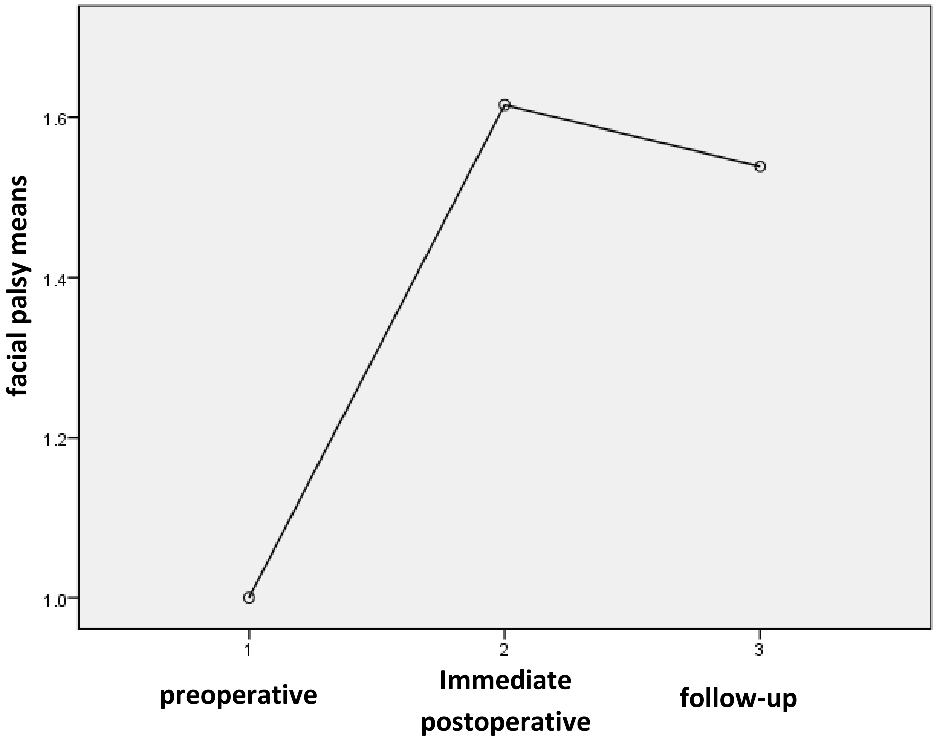


Table 15: Pairwise comparison of the facial palsy

	Preoperative	Immediate	Follow-up
Preoperative		-0.615 (p – 0.303)	-0.538 (p – 0.357)
Immediate postoperative	0.615 (p – 0.303)		0.077 (p – 0.239)
Follow-up	0.538 (p – 0.357)	-0.077 (p – 0.239)	

Table 16: Immediate postoperative Facial nerve function outcome categorised based on preoperative function

	Same		Improved		Deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**
No facial palsy preoperatively	6	66.7	NA	NA	3	11.1
Preoperative facial palsy present	5	83.3	1	16.7	0	0%

Table 17: Follow-up Facial nerve function outcome categorised based on preoperative function

	Same		Improved		Deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**
Preoperative No facial palsy	8	88.9	NA	NA	1	11.1
Preoperative facial palsy	4	6.7%	2	33.4%	0	0%

Table 18: Immediate postoperative Facial numbness categorised on preoperative function

	Same		Improved		Deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**
No facial numbness/ trigeminal neuralgia preoperatively	5	83.3	NA	NA	1	16.7
Facial numbness/ trigeminal neuralgia present preoperatively	4	44.4	3	33.3	2	22.2

Table 19: Follow-up Facial numbness outcome categorised based on preoperative function

	Same		Improved		Deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**
No facial numbness/ trigeminal neuralgia preoperatively	6	100	NA	NA	0	0
Facial numbness/ trigeminal neuralgia present preoperatively	6	66.7	3	33.4	0	0

Table 20: Immediate postoperative 3rd nerve function outcome categorised based on preoperative function

	Same		Improved		Deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**
No 3rd nerve palsy preoperatively	14	100	NA	NA	0	0
Preoperative 3rd nerve palsy present	0	0	0	0	1	100

Table 21: Follow-up 3rd nerve function categorised based on preoperative function

	Same		Improved		Deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**
Preoperative No 3rd nerve palsy	14	0	NA	NA	0	0
Preoperative LR palsy	0	0	1	100	0	0

Table 22: Immediate postoperative 6th nerve function outcome categorised based on preoperative function

	Same		Improved		Deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**
No LR palsy preoperatively	8	72.7	NA	NA	3	27.3
Preoperative LR palsy present	4	100	0	0	0	0

Table 23: Follow-up 6th nerve function categorised based on preoperative function

	Same		Improved		Deteriorated	
	Number	**%**	**Number**	**%**	**Number**	**%**
Preoperative No LR palsy	11	0	NA	NA	0	0
Preoperative LR palsy	3	75	1	25	0	0

To understand the difference in the postoperative complications and cranial nerve deficits, participants were categorised into those with volume of bone resected more than 1000 mm^3 and those with volume less than 1000 mm^3. There were no significant difference in the postoperative cranial nerve deficits between the two groups of patients.

Table 24: Neurological deterioration categorised upon amount of bone resected

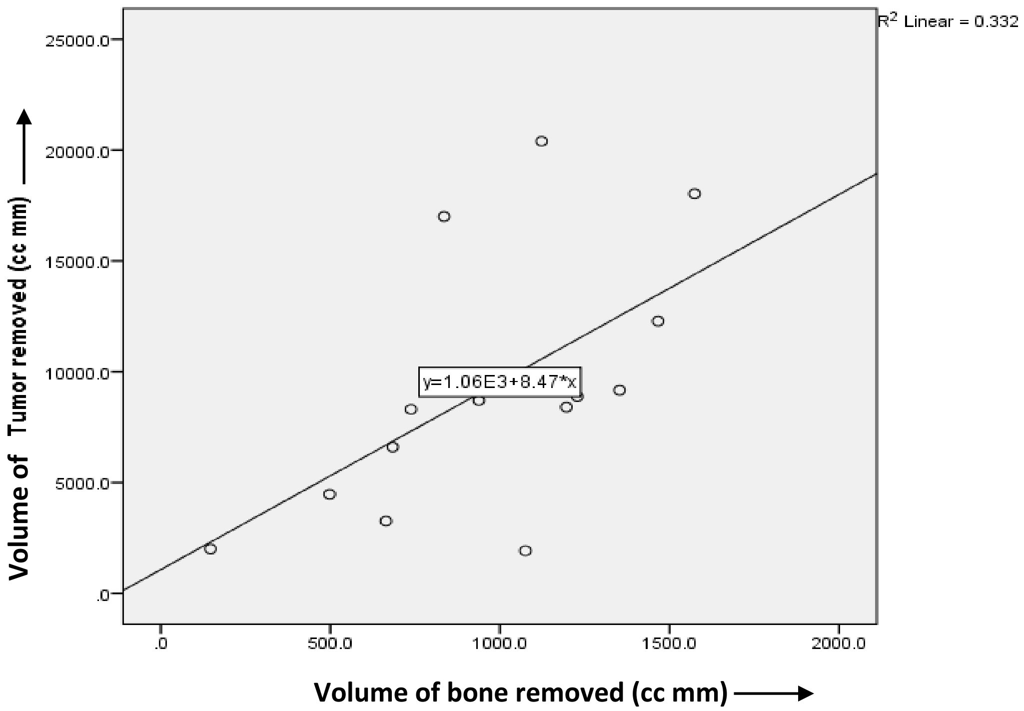
	Bone resected <1000 cu mm				**Bone resected >1000 cu mm**				**P value**
	No Change/ Cured/ Improved		**Deteriorated**		**No Change/ Cured/ Improved**		**Deteriorated**		
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	
Diplopia	6	75	2	25	4	57.1	3	42.9	0.464
Seizure	8	100	0	0	7	100	0	0	
Hearing	8	100	0	0	7	100	0	0	
Facial numbness	7	87.5	1	12.5	6	85.77	1	14.3	0.529
Facial palsy	7	87.5	1	12.5	5	71.4	2	28.6	0.506
3rd nerve palsy	7	87.5	1	12.5	7	100	0	0	
6th nerve palsy	6	75	2	25	6	85.7	1	14.3	0.605
Corneal complications	8	100	0	0	7	100	0	0	
Limb weakness	8	100	0	0	6	85.77	1	14.3	0.364
Limb sensory deficit	8	100	0	0	7	100	0	0	

There was good correlation between different parameters as detailed below.

Table 25: Correlation between different parameters measured

Parameters being Correlated		**Pearson correlation**
Volume of bone drilled off	Volume of tumour excised	+ 0.576
Lateral depth of the bone resected	Volume of tumour excised	+ 0.436
Length of anterior surface of anterior petrous bone drilled off	Volume of tumour excised	+ 0.531
Length of anterior surface of anterior petrous bone drilled off	Distance inferior wall of bony corridor from ICA	- 0.763
Length of posterior surface of anterior petrous bone drilled off	Distance inferior wall of bony corridor from ICA	- 0.532
Length of anterior surface of anterior petrous bone drilled off	Volume of bone drilled off	+ 0.705
Length of posterior surface of anterior petrous bone drilled off	Volume of bone drilled off	+ 0.434

Figure 14 : Correlation between volume of bone removed and volume of tumour excised



DISCUSSION

Baseline characteristics

Average age of patients in the study was 45.067 years ranging from 18 to 64 years. Only 4 of the 15 patients (26.7%) were male patients since most of the patients presenting with a lesion amenable for Kawase approach were petroclival meningioma (8 nos - 53.3 %) and all of them were females. There were three patients (20%) who had undergone surgeries through different approaches but none of them had undergone surgery through Kawase approach. These demographics go in line with other studies operated via this approach.

Audiometry, as well as preoperative facial palsy, revealed a bimodal distribution of ipsilateral hearing loss can be attributed to few patients having lesion extending up to or beyond the IAC while others had no compression or involvement of the VII-VIII nerve complex. Further subgroup analysis separating those with and without VII-VIII nerve complex deficits could not be done due to lack of numbers

Even though all the dimensions have similar ranges, the anteroposterior and craniocaudal dimension fell into taller histogram while the mediolateral dimension seems to fall over a broader range. This signifies the nature of petroclival meningioma which has a broader base than height. Bony destruction was seen in 4 of the cases (26.7%) and out of which three of them were trigeminal schwannoma in which bony destruction of the anterior petrous bone along the Meckel’s cave is expected. Our study has tumor characteristics similar to other studies as detailed below.

One patient who was operated had histopathology reporting brainstem high grade glioma and MR imaging over the course of time has progressed. The patient underwent radiotherapy, is currently alive and has developed multiple cranial nerve deficits that can be attributable to the intrinsic brainstem lesion.

Surgical technique:

Intra-operative temporal lobe contusion was noted in 26.7% of the cases but none of these patients had a significant clinical deficits related to the contusions. This questions the over-cautiousness most surgeons exert when temporal lobe is retracted in interdural or extradural approach. Significance of temporal contusions needs to be evaluated in detail by neuropsychological assessment.

Trochlear nerve palsy is a common finding after Kawase approach. This is due to the hidden nature of the displaced trochlear nerve which gets injured while opening the tentorium. Most of the cranial nerve deficits were temporary and improved at follow-up. This might be due to traction injury during surgery. A similar result was also noted by other authors (10,27).

To understand the difference in the postoperative complications and cranial nerve deficits, participants were categorised into those with the volume of bone resected more than 1000 mm^3 and those with the volume less than 1000 mm^3. There was no significant difference in the postoperative cranial nerve deficits between the two groups of patients. This suggests that if the landmarks are followed well and the surgical technique is meticulous, the bony corridor could be maximised without any significant deficits. A similar study comparing the volume of bone resected and the postoperative deficits are not available for comparison.

Outcomes

Only a handful of studies are available that has studied clinical outcomes of "anterior petrosectomy" or "anterior transpetrosal" approach or "Kawase approach" (4). Only three centres outside Keio University Hospital has come out with results pertaining to anterior petrosectomy. It is prudent to note that these authors not mentioned or has excluded lesions extending into or inferior to internal auditory meatus thus precluding comparison with our data. The Kawase approach has also been used for the management of retrosellar and upper clival basilar artery aneurysms (12,39). Aziz et al have studied the outcome of upper clival and basilar artery aneurysms operated via Kawase approach (12). There is a significant difference in the facial nerve palsy compared with our results and other studies probably due to the difference in pathologies involved in the studies. The data published by them cannot be compared with other studies involving lesions that can caused compression and vascular compromise of cranial nerves especially by petroclival meningioma extending laterally to the internal auditory meatus. The deficits and morbidity associated with basilar artery aneurysms treated by Kawase approach are can be attributed to the subarachnoid haemorrhage and related vasospasm (12).

A series of 5 cases of petroclival meningiomas were operated at the University of Turin via Kawase approach. But none had extension into/ beyond the internal auditory meatus and they could not achieve gross total excision in any cases. Volovici reported a large series of 25 cases of various pathologies operated at Erasmus Medical Center, Netherlands. In this study, there was two mortality – one due to uncontrollable intraoperative bleeding from the internal carotid artery and other due to embolic middle cerebral artery stroke secondary to mechanical aortic valve. Studies led by Professor Takeshi Kawase at Keio University Hospital has significantly better results compared to the above studies with near total excision achieved in 70-75% cases.

Gompel et al have studied 46 consecutive patients who had underwent anterior petrosectomy but they also considered patients who underwent combined petrosal approach. Though the majority (80%) of the study participants underwent anterior petrosectomy, the results were not categorised according to the procedure and hence cannot be compared with our data (38).

Study	Institute	Diagnosis	Number of Participants	Age	Female/ Male ratio	Mean dimension (mm)	IAC extension (%)	GTR/ NTR (%)	4^{th} nerve palsy (%)	CSF related complications (%)	Facial Weakness (%)	Mortality (%)
Kawase 1991 (32)	Keio University Hospital, Japan	Sphenopetroclival meningioma	10	55.3	4	32.5	40	70	40	10	0	0
Shimamoto 1999 (37)	Keio University Hospital, Japan	Prepontine Epidermoid	9	45	0.286	NM	NM	100	44	33.3	NM	11.1
Aziz 1999 (12)	University of Cincinnati, Ohio, US	Upper clival Basilar artery aneurysms	15	51.5	0.875	NA	NA	NA	13.3	6.7	6.7	0
Shibao 2015 (20)	Keio University Hospital, Japan	Petroclival meningioma	8	53.8	1.67	43.1	87.5	75	25	0	NM	0
Altieri 2016 (34)	University of Turin, Italy	Petroclival meningioma	5	45	4	43.4	0	0	20	NM	NM	0
Volovici 2019 (36)	Erasmus Medical Centre, Netherlands	Various	25	NM	NM	NM	NM	NM	24	28	20	8
Our study 2019	Sree Chitra Tirunal Institute for Medical Sciences and Technology, India	Various	15	45.07	4	33.4	33.4	86.7	26.7	20	20	0

*NM – Not Mentioned, NA – not applicable

#Only studies with or more than 5 case have been included

Volumetric Analysis

The volume of the bony corridor in Kawase approach for surgeries done at Keio University Hospital, Japan led by Professor Takeshi Kawase has not being analysed in detail (2,3,19,20,28,28–32). The study which retrospectively studied the CT scans of 30 patients of petroclival meningioma who underwent excision via Kawase approach at Keio University Hospital, Japan excluded cases which extended to/beyond the internal auditory meatus, though 87.5% of the petroclival meningiomas operated at Keio University Hospital had extension into/ beyond the internal auditory meatus (20,30). This volumetric study which aimed to study the safety of Kawase triangle in anterior petrosectomy did not mention the average volume drilled in the approach (30). Thus the original authentic approach is not available for comparison. Most morphometric studies done with regards to this approach are cadaveric or studies that have tried to improvise on the original steps stated by Kawase et al. The next ideal study available for comparison is the one done at All India Institute for Medical Sciences, New Delhi where the difference between the original Kawase approach and modified Dolenc-Kawase approach has been studied (10). They found out the average volume drilled out in Kawase approach was 666.614 mm^3 which is little less than our average volume of 964.27 mm^3. This might be due to the difference in the nature of drilling in these studies – cadaveric studies constrain the surgeon to abide by the predetermined protocol while in clinical studies the surgeon is impelled to remove more to achieve better resection. The average volume of bone resected in other studies mentioned seems much larger such as 1786 mm^3, 1978.29 mm^3, 1890 mm^3, etc (1,33,34). Even in cadaveric studies, under idealistic circumstances, the volume of bone drilled via Kawase approaches seems to vary greatly from 775.54 mm^3 to 3649.20 mm^3 (1). This is again substantiated by Adams Perez’s volumetric analysis of petrous apex in toto which has found a wide variation ranging from 980 mm^3 to 3560 mm^3 (4). Greater variation of the skull base morphology and volumes between gender, ethnicity, and races is well known (35). Many cadaveric studies have explored the area of the brainstem exposed by different approaches (40). But this does not translate the difficulties and clinical outcomes these approaches have (40). The average area of ventral brainstem & petroclival area exposed is approximately 55 mm^2 and 101.75 mm^2 respectively (40).

These results whether can be translated to clinical outcomes needs to be validated. The study of the volume of bone is essential to understand the upper limit of tumor volume as well as the maximum extensions that can be tackled by anterior petrosectomy approach. The average dimension of tumors tackled by this approach seems to be 43 mm. In the study led by Professor Kawase at Keio University Hospital, the 87.5 % of the petroclival meningiomas operated via this approach seemed to have involvement into internal acoustic meatus while at University of Turin, none of the petroclival meningiomas of the same dimension had extension into/ beyond the internal auditory meatus. A detailed study of the volume and the angle of bone drilling as well as the outcomes, between tumors with differences mentioned above, is warranted.

Correlations

Correlative analysis done revealed a positive correlation between the volume of bone resected positively correlated and the volume of tumour resected. This suggests that the volume of bone that can be drilled should be maximised to achieve the best results in terms of tumor removal. It should be noted that the subgroup analysis between tumor and non-tumor indication for Kawase approach could be not done as there was no aneurysms or similar pathologies that were tackled via this approach. Within the tumors itself, comparison between tumors arising brainstem and those arising based petroclival regions was not possible due to lack of number. There stands a possibility that brainstem lesions and aneurysms can be tackled via smaller corridor while petroclival meningiomas, due to their broader attachment to the petrous bone, might need a wider corridor for more extensive decompression.

There was positive correlation between the width of the surface of the anterior surface of anterior petrous bone drilled with the volume of bone resected as well as with the volume of tumor excised suggesting that it is essential to identify all the landmarks on the anterior petrous bone and surrounding before starting drilling. Once drilling is started the entire surface of area indented to be drilled should be drilled layer by layer into the depth. This helps in maximising the volume of the truncated cone shaped space drilled out of the anterior petrous bone. Volume of the truncated cone increases as the surface area of the base increases.

There was no correlation with the petrous apex removal with the volume of bone resected or the volume of tumor excised suggesting that that that onus of drilling need to be anteroposterior manner towards the brainstem than towards the clivus. As suggested by Tripathi et al, opening up the interdural space and releasing the dural ring around the trigeminal nerve can help medial mobilisation of the trigeminal nerve and aid in tumor removal at this region (10). Additional bone drilled off in the medial direction does not give any added advantage but has the disadvantage of the injuring the trigeminal nerve near the Meckel's cave. This fact is confirmed by the finding that volume of bone removed correlated directly with width of bony corridor on the posterior surface of the anterior petrous bone. The volume of tumor removed also showed positive correlation with the length of the lateral wall (depth) of the bony corridor drilled. The angle of view towards the prepontine cistern is not increased by added drilling onto the medial aspect while the tumor resection into and beyond the internal auditory meatus is significantly increased by drilling the anterior petrous bone in an anterior petrous bone from the Kawase's rhomboid towards the anterior inner lip of internal auditory meatus.

As the area of anterior surface of anterior petrous bone drilled is maximised to increase the volume of bony corridor, the inferior extent of this corridor is also increased. This is suggested by strong negative correlation noted between the distance of inferior wall of bony corridor from the internal carotid artery and the anterior width of the bony corridor. This decreasing distance points towards the fact that increasing the surface area of drilling corridor carries the risk of jeopardising the petrous segment of internal carotid artery. Usage of diamond drill with a good knowledge of the landmarks in the petrous bone can help increase the inferior extent of bony corridor with deroofing of the petrous segment of the internal carotid artery without any injury to the same. Volovoci et al describes a mortality due to uncontrollable intraoperative bleeding which the surgeons retrospectively felt bleeding could be from the cavernous segment of internal carotid. But the events leading to the injury is unclear from the description provided and the exact location of injury seems to be more of a speculation (36).

Study	Institute	Type of Study	Average Dimensions (mm)	Average area (mm^2)	Average volume (mm^3)	Mean Distance from IAC (mm)
Day 1994 (26)	University of Southern California, US	Cadaveric		290		
Maina 2007 (41)	Illinois Neurological institute, US	Cadaveric		106.72		
Tripathi 2015 (10) (Kawase)	All India Institute for Medical Sciences, India	Cadaveric	21.71 17.11 13.05	269.13	666.614	
Tripathi 2015 (10) (modified Dolenc-Kawase)	All India Institute for Medical Sciences, India	Cadaveric	13.15 24.53 12.54	408.09	1349.272	
Borghei-Razavi 2015 (30)	Keio University Hospital, Japan	Clinical (Excluded IAC extension/ beyond)				2.65
Ahmed 2015 (1)	Louisiana State University Health Sciences Centre, US	Cadaveric	10.57 9.39 17.46		1786/94	
Rigante 2015 (33)	Uniklinik Tubingen, Germany	Cadaveric			1978.29	
Altieri 2016 (34)	University of Turin, Italy	Cadaveric			1890	
Dones 2019 (42)	University of California, San Francisco, US	Cadaveric	17.6 10.5 9.5			
Our study 2019	Sree Chitra Tirunal Institute for Medical Sciences & Technology India	Clinical			964.27	1.26

Future

Study involving more number of patients with a single pathology can help in the creating a correlative curve regarding the extent of resection and amount of bone drilled. Addition of neuronavigation system to assess the cone of view and surgical freedom with respect to the drilled out bony cylinder or truncated cone and the corridor obtained by temporal retraction can help in assessing the blind spots generated during the anterior petrosectomy.

LIMITATIONS

Strict inclusion and exclusion criteria led to fewer participants in the study and hence poorer results. Follow up studies with larger sample size needs to be done for the findings to be generalised. Longer follow up can show a different outcome as temporary deficits improve over time. Measured parameters can often underestimate the bony corridor needed for the resection viz-a-viz the operating microscope optics and ergonomics. 3D dimensional volumetrics may still prove insufficient to characterise the irregular cavity drilled out (4). Correlation between maximal size of tumour that can be resected and corresponding size of bony hiatus made, can be misleading since the drilling often proceeds until maximum possible limits surgeons is able to achieve. Overestimation of the volume can occur when bone drilled away might not contribute significantly to the surgical field or tumour debulking (4). Volumetric analysis was done on single software and often cannot be reproduced in a similar manner on another workstation (4). Subgroup analysis between tumor and non-tumor indication for Kawase approach could be not done as there was no aneurysms or similar pathologies that were tackled via this approach. Within the tumors itself, comparison between tumors arising brainstem and those arising based petroclival regions was not possible due to lack of number. Lesions that distort the bony landmarks can cause incorrect measurements especially trigeminal schwannoma. Comparison with patients who underwent other approaches was not done which precludes the ability of the study to suggest the best approach to a case scenario.

CONCLUSION

1. The volume of bone removal positively correlated with the extent of tumour removal

2. As the larger area of bone is drilled from the anterior surface, more volume of bone can be drilled off but with increased probability of exposing the petrous segment of internal carotid artery.

3. Increasing the extent of bone resection does not significantly increase any morbidity except for temporary facial numbness

4. Most of the cranial nerve deficits associated with the approach are temporary and are cured by 6-12 months postoperatively

5. Facial palsy can occur more frequently, but with lesser incidence , in petroclival lesions extending laterally beyond the internal auditory meatus

Further detailed studies with added parameters and larger number of participants as well as comparative studies with other approaches are needed for proving the superiority of this approach. Careful patient selection, through knowledge of the bony landmarks and meticulous drilling can produce favourable results in patients with petroclival lesions through anterior petrosectomy.

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QUESTIONNAIRE

"PROSPECTIVE OBSERVATIONAL STUDY OF PATIENTS UNDERGOING ANTERIOR PETROSECTOMY"

CODE NO: _____

ANNEXURE I

GENERAL INFORMATION

Hospital No.	
Age	
Sex	M/ F
Date of admission	
Date of discharge/ death	

CLINICAL DETAILS

Mode of Presentation	**Duration**
Headache	
Vomiting	
Diplopia	
Gait difficulty	
Seizure	
Tremors	
Hearing loss	
Long tract symptoms	
Other cranial nerve deficit	
Others	

Co-morbid factors: Hypertension/ Diabetes/ Heart disease/ CVA

PERIMETRY (DD/MM/20YY)

RE VA	
LE VA	
RE VF	
LE VF	

AUDIOMETRY (DD/MM/20YY)

PTA L	
PTA R	
Speech Discrimination score	

EXAMINATION FINDINGS (DD/MM/20YY)

GCS		
Fundus		
Eye Movements		
Pupil Size		
Pupil Reaction		
Corneal Reflex		
Corneal haziness	Yes/ No	
Masseter bulk		
Facial Sensations		
Jaw opening		
Facial Deviation		
Weber's test		
Any other cranial nerve deficits		
Sensory Loss		
Weakness		

MR IMAGING (DD/MM/20YY)

Site	
Side	Right/ Left
Preop Imaging Diagnosis	
Extend	
Extension below IAC	Yes/ No
Volume	
Maximal Dimension	
Hydrocephalus	Yes/ No
Edema (grade)	
5th nerve compression	Yes/ No
6th nerve compresssion	Yes/ No
7th nerve compression	Yes/ No
8th nerve compression	Yes/ No
Relation to brainstem	Intra-axial/ Extra-axial/ Compression
Vascular involvement	Yes/ No

CT IMAGING (DD/MM/20YY)

Preop Imaging Diagnosis	
Extend	
Volume	
Maximal Dimension	
Bony involvement	Hyperostosis/ Erosion/
Hydrocephalus	
Edema (grade)	

ANNEXURE II

SURGERY

Date of surgery	**(DD/MM/20YY)**
Intraoperative Impression of lesion	
CSF drainage	No/ EVD/ Lumbar Drain
Skin Flap	
Type of craniotomy	
Sinus Opened	Yes/ No
Temporal lobe retraction (in mm)	
Temporal lobectomy	Yes/ No
Temporal vein sacrificied	Yes/ No
Opening of cavernous sinus	Yes/ No
Amount of petrous bone removed (approximate in mm)	
Complete visualization of Kawase Quadliateral	
Additional resection if mentioned	
Intra operative events if any	
Injury to semicircular canal	Yes/ No
Injury/ Sacrifice of petrosal sinus	Yes/ No
Injury to GSPN	Yes/ No
Injury to VIth Nerve	Yes/ No
Internal Carotid artery injury	
Extend of lesionectomy.	
Use of hemostats – descriptive	
Nerve monitoring	Yes/ No
Dural closure	
EVD/ lumbar drainage	NA/ removed/ intemittent/ continuous

ANNEXURE III

CLINICAL DETAILS

Complaints	**Duration**
Diplopia	
Gait difficulty	
Seizure	
Tremors	
Hearing loss	
Long tract symptoms	
Other cranial nerve deficit	
Others	
CSF leak	No/ Wound/ Otorrhea/ Rhinorrhea
Days of post op stay.	
Days of intensive care unit stay	
Days of ventilator	
Tracheostomy	Yes/ No
GOS at discharge	
Wound at discharge	
Antiepileptics	
Tarsorraphy	

EXAMINATION FINDINGS (DD/MM/20YY)

GCS		
Eye Movements		
Pupil Size		
Pupil Reaction		
Corneal Reflex	Present/ Absent	Present/ Absent
Corneal haziness	Yes/ No	Yes/ No
Facial Sensations		
Jaw opening		
Facial Deviation		
House-Brackmann score		
Weber's test		
Any other cranial nerve deficits		
Weakness		

CT IMAGING (DD/MM/20YY)

Extend of bone removal	
Volume of bone removal	
Maximal Dimension of bony defect	
Hydrocephalus	
Edema (grade)	
Arterial infarcts	Yes/ No

Tumour removal	Total/ Near (90%)/ Partial (70%)/ < 50%
Volume of tumor residue	
Venous infarcts	Yes/ No
Haematoma	Yes/ No
Anterior AP dimension	
Posterior AP dimension	
Anterior mediolateral dimension	
Posterior mediolateral dimension	
Distance of corridor from IAC	
Distance of corridor from ICA	

ANNEXURE IV

CLINICAL DETAILS

Mode of Presentation	**Duration**
Headache	Yes/ No
Vomiting	Yes/ No
Diplopia	Yes/ No
Gait difficulty	Yes/ No
Seizure	Yes/ No
Tremors	Yes/ No
Hearing loss	Yes/ No
Long tract symptoms	Yes/ No
Other cranial nerve deficit	
Others	
CSF leak	No/ Wound/ Otorrhea/ Rhinorrhea
Visual disturbance	Yes/ No
mRS	
Tracheostomy	NA/ Present/ Absent
Pathological diagnosis	
Adjuvant treatment	
Need for Shunt	
KPS	
GOS	
Antiepileptics	
Tarsorraphy	

EXAMINATION FINDINGS (DD/MM/20YY)

GCS		
Eye Movements		
Pupil Size		
Pupil Reaction		
Corneal Reflex	Present/ Absent	Present/ Absent
Schirmer's test		
Corneal haziness	Yes/ No	Yes/ No
Facial Sensations		
Jaw opening		
Facial Deviation		
House-Brackmann score		
Weber's test		
Any other cranial nerve deficits		
Sensory Loss		
Weakness		
Wound scar		

PERIMETRY (DD/MM/20YY)

RE VA	
LE VA	
RE VF	
LE VF	

AUDIOMETRY (DD/MM/20YY)

PTA L	
PTA R	
Speech Discrimination score	

MR IMAGING (DD/MM/20YY)

Residuum extent	
Edema (grade)	
Volume of tumor residue	
Tumour removal	Total/ Near (90%)/ Partial (70%)/ < 50%
Maximal Dimension	
Venous infarcts	Yes/ No
Haematoma	Yes/ No
Arterial infarcts	Yes/ No

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INTRODUCTION

The anterior petrous apex has been considered as a gateway to the posterior cranial fossa. The anterior petrosectomy as described by Kawase converts this deep narrow operative corridor into wider shallower exposures, improves manoeuvrability and minimizes retraction. It comprises of a sub-temporal craniotomy followed by extradural drilling of the petrous apex to reach the posterior fossa. The traditional Kawase approach provides a 10×5 mm fenestration at the petrous apex of the temporal bone between the 5th cranial nerve and internal auditory canal and the greater superficial petrosal nerve. Complications of this approach include palsies of facial, trigeminal and abducent nerve, CSF leak, hearing loss, injury to vein of Labbe, etc. The aim of this study is to calculate amount of bone resected in an anterior petrosectomy done in this institute and with this knowledge, quantify the differential variations used in each surgery while achieving adequate exposure with respect to the local complications will provide a better understanding of this approach. The study ought to define minimal safe resection for a lesion with best local outcome while preserving the adequacy of exposure.

REVIEW OF LITERATURE

As skull base surgeries advanced, the surgical corridors have become narrower, deeper but with improved manoeuvrability, minimum retraction and superior outcomes (1–3). Critical structures inside the cranium are protected by skull especially the skull base. Access to such areas need adjuncts in the standard craniotomies such as clinoidectomy and mastoidectomy. Similarly, anterior petrosectomy is performed by drilling off the Kawase triangle at the petrous apex. Anterior petrosectomy helps approach the upper clivus, upper petroclival area, medial cere

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

Institutional Ethics Committee

(IEC Regn No. ECR/189/Inst/KL/2013)

SCT/IEC/1147/DECEMBER-2017

18.12.2017

Dr. Mohamed Amjad Jamaluddin
Senior Resident
Department of Neurosurgery
SCTIMST, Thiruvananthapuram

Dear Dr. Mohamed Amjad Jamaluddin,

Thank you for submitting documents related to your proposal titled "PROSPECTIVE OBSERVATIONAL STUDY OF PATIENTS UNDERGOING ANTERIOR PETROSECTOMY" (IEC/1147) to the IEC for review.

List of Documents

1. Covering letter addressed to the Chairperson, IEC, SCTIMST dated 17.11.2017 with check list
2. Forwarding Letter from HOD
3. TAC Approval Letter
4. IEC Application Form
5. Project Proposal
6. Questionnaire
7. Patient Information Sheet and Informed Consent Form in English and Malayalam
8. CV of Principal Investigator and Co-Principal Investigators

IEC Recommendations

1. Correct the patient information sheet and consent form and separate the two in both English and Malayalam versions
2. Instead of relative (bandhu) in the consent form, use the word 'witness'(sakshi)

One set of all the documents including those revised may be submitted. The covering letter should indicate the revisions made.

Sincerely,

Mala Ramanathan
Member Secretary, IEC