Quantitative analysis of the Kawase versus the modified Dolenc-Kawase approach for middle cranial fossa lesions with variable anteroposterior extension

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OBJECT The surgical corridor to the upper third of the clivus and ventral brainstem is hindered by critical neurovascular structures, such as the cavernous sinus, petrous apex, and tentorium. 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. Due to interindividual variability, sometimes this area proves to be insufficient as a corridor to the posterior cranial fossa. The authors describe a modification to the technique of the extradural anterior petrosectomy consisting of additional transcaavernous exploration and medial mobilization of the cisternal component of the trigeminal nerve. This approach is termed the modified Dolenc-Kawase (MDK) approach.

METHODS The authors describe a volumetric analysis of temporal bones with 3D laser scanning of dry and drilled bones for respective triangles and rhomboid areas, and they compare the difference of exposure with traditional versus modified approaches on cadaver dissection. Twelve dry temporal bones were laser scanned, and mesh-based volumetric analysis was done followed by drilling of the Kawase triangle and MDK rhomboid. Five cadaveric heads were drilled on alternate sides with both approaches for evaluation of the area exposed, surgical freedom, and angle of approach.

RESULTS The MDK approach provides an approximately 1.5 times larger area and 2.0 times greater volume of bone at the anterior petrous apex compared with the Kawase's approach. Cadaver dissection objectified the technical feasibility of the MDK approach, providing nearly 1.5–2 times larger fenestration with improved view and angulation to the posterior cranial fossa. Practical application in 6 patients with different lesions proves clinical applicability of the MDK approach.

CONCLUSIONS The larger fenestration at the petrous apex achieved with the MDK approach provides greater surgical freedom at the Dorello canal, gasserian ganglion, and prepontine area and better anteroposterior angulation than the traditional Kawase approach. Additional anterior clinoidectomy and transcaavernous exposure helps in dealing with basilar artery aneurysms.

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KEY WORDS Kawase; Dolenc; petrous; cadaver; quantitative; petrosectomy; skull base

FOR decades, the petrous part of the temporal bone has haunted skull base neurosurgeons and continues to do so. The depth of lesions, difficulties of approaches, and challenging neurovascular structures, e.g., brainstem and cranial nerves, have frightened neurosurgeons for decades, causing this area to have a reputation of a “No Man’s Land.”^{17,18,22}

Operative approaches to this area include clivectomy af-

ter transcervical, transoral, extended transoral, subfrontal, transsellar-transcaavernous, transsylvian, combined transsylvian and anterior subtemporal, and combined transsylvian and transpetrosal approaches. Approaches vary from pure extradural to intradural and combined ones.^{1,2,5} The variety of approaches proves that none is adequate for the various lesions in this area. The neurosurgical world owes Professor Takeshi Kawase for making us familiar

ABBREVIATIONS CN = cranial nerve; GSPN = greater superficial petrosal nerve; MDK = modified Dolenc-Kawase; MMA = middle meningeal artery.

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with the anterior petrous bone with his extradural subtemporal transtentorial anterior petrosectomy approach, which avoids aerodigestive tract contamination and provides better exposure of the posterior cranial fossa.^{16,17} This approach provided an extradural corridor interposed between cranial nerve (CN) V and the CN VII/VIII complex, minimizing brain retraction.^{7,16} Various surgeons have developed several modifications of the Kawase approach in a variety of permutations and combinations.^{16,17}

Few studies are available for quantitative comparison of areas exposed by different operative approaches.^{6,7,14,20,21} We hereby describe a technique of the modified Dolenc-Kawase (MDK) approach, incorporating the surgical benefits of Dolenc's⁸ and Kawase's¹⁶ approaches, practiced by the senior author (A.S.). The MDK approach provides a larger area of exposure at the anterior petrous apex, maneuverability at Dorello's canal and the prepontine area with greater surgical freedom, and angulation via an extradural approach. This study is unique in that it uses 3D laser scanning of dry bones and quantitative mesh analysis of scanned polygonal data. The validity of the MDK approach is substantiated by computerized volumetric analysis of temporal bones and cadaver dissection, comparison with the Dolenc and Kawase approaches, and evaluation of clinical applications in 6 patients with a variety of lesions. This approach is helpful for large sphenopetroclival lesions with variable anteroposterior extension and basilar artery aneurysms.⁹

Methods

Volumetric Analysis of Temporal Bones

This approach includes laser scanning and volumetric analysis of intact bone followed by reanalysis after drilling the bones for the Kawase triangle and later by additional drilling of the MDK rhomboid. Twelve dry temporal bones were randomly selected from the bone bank of the De-

partment of Anatomy (All India Institute of Medical Sciences) (Fig. 1 D1). These bones were laser scanned using Scanworks (Halyard Drive) (Fig. 1 L1). Three-dimensional scanned bone data were obtained in the form of point clouds. Geomagic Studio converts these point clouds into triangulated meshes. Fine processing of meshes was done with the aid of Autodesk Maya (Autodesk, Inc.) and ZBrush (Pixologic Inc.) (Fig. 1 M1). These meshes were evaluated for area and volume with the aid of MeshLab (version 1.3.2, Visual Computing Lab ISTI-CNR) (Table 1, Mesh 1).

The boundaries of the Kawase triangle were defined by the following landmarks: 1) the junction of the greater superficial petrosal nerve (GSPN) with the lateral border of the mandibular division of the trigeminal nerve (V3), 2) the lateral margin of the porus trigeminus, and 3) the anteromedial margin of the arcuate eminence (Fig. 1 D2, Fig. 2). The Kawase triangle was drilled using an electric diamond drill with the aid of a 3D microscope (OPMI Vario, Carl Zeiss; and 3D high-definition microscope camera, Sony) at uniform magnification (Fig. 1 D2). Drilled bones were rescanned (Fig. 1 L2), and volumetric analysis of the remaining bone was done as mentioned above (Table 1, Mesh 2) (Fig. 1 M2). The comparative evaluation of Mesh 1 and Mesh 2 provided the area and volume of the drilled portion of the bone (i.e., Kawase triangle) (Table 2).

The same bones (D2) were re-marked and drilled for the proposed rhomboid area (Fig. 1 D3), whose boundaries were defined as 1) the lateral margin of V3 after medial mobilization of the trigeminal nerve; 2) the bony surface, just lateral to petroclival ligament; 3) the arcuate eminence; and 4) the intersection of a line drawn along the axes of the GSPN and the arcuate eminence (Fig. 1 D3, Fig. 2). These bones were rescanned (Fig. 1 L3) and analyzed for area and volume (Fig. 1 M3) (Table 1, Mesh 3). The comparative evaluation of Mesh 1 and Mesh 3 provided the volumetric details of the drilled part of the bone (i.e., MDK rhom-

FIG. 1. Intact temporal bone (D1), corresponding laser scan (L1), and meshwork image (M1). Temporal bone after drilling of the Kawase triangle (D2), corresponding laser scan (L2), and meshwork image (M2) showing the drilled triangular part. Temporal bone after drilling of the MDK rhomboid area (D3), corresponding laser scan (L3), and meshwork image (M3). Arrows depict the sequential laser scanning and meshwork of the bone. D = dry bone; L = laser-scanned bone; M = meshwork. Figure is available in color online only.

TABLE 1. Area and volume of intact temporal bone (Mesh 1), remaining bone after drilling of Kawase's triangle (Mesh 2), and remaining bone after drilling of MDK rhomboid (Mesh 3)

Specimen No.	Intact Dry Temporal Bones (Mesh 1)		Temporal Bones After Drilling of Kawase's Triangle (Mesh 2)		Temporal Bones After Drilling of MDK Rhomboid (Mesh 3)	
	Area (mm ²)	Vol (mm ³)	Area (mm ²)	Vol (mm ³)	Area (mm ²)	Vol (mm ³)
1	12,594.606	96,866.102	12,400.056	96,192.554	12,036.646	94,687.316
2	15,301.513	129,188.734	15,164.803	128,704.728	14,831.553	127,544.823
3	12,907.796	101,742.586	12,719.166	101,186.807	12,385.666	100,080.641
4	14,709.261	126,224.195	14,413.121	125,370.967	14,006.481	124,071.684
5	13,340.863	105,108.383	13,084.133	104,312.414	12,805.203	103,360.086
6	14,821.771	126,969.266	14,517.671	125,630.618	14,289.041	125,189.324
7	14,022.294	113,722.547	13,734.974	112,930.782	13,262.984	111,462.477
8	16,521.176	149,546.203	16,095.026	148,467.615	15,480.746	146,629.854
9	16,223.099	145,045.938	15,849.349	144,281.776	15,385.108	142,841.501
10	12,042.714	91,733.883	11,790.814	90,991.685	11,454.554	89,876.364
11	13,557.831	113,621.258	13,333.121	112,959.172	12,950.181	111,689.021
12	12,878.767	109,653.892	12,589.637	108,801.44	12,499.917	108,397.307
Mean	14,076.807	117,451.916	13,807.656	116,652.547	13,449.007	115,485.867

boid) (Table 2). All the markings and drilling were done by the senior author (A.S.) to remove surgeon's error. All data were statistically analyzed using the Fisher exact test.

Cadaver Dissection

The ethics committee of the All India Institute of Medical Sciences approved the cadaver dissection work. Five fresh cadaver heads with no known brain pathology

were dissected on both sides (10 specimens). All dissections were performed and recorded using a 3D microscope (OPMI Vario and 3D high-definition microscope camera). The drilling was done under fixed magnification (magnification factor 1.0; magnification $\times 7.08$). Each head was first treated via a traditional Kawase approach on one side and an MDK approach on the contralateral side. The ventral prepontine area was chosen as an area of interest

FIG. 2. A: Bony landmarks for the Kawase triangle and MDK rhomboid. B and C: Surface landmarks showing comparative areas of the Kawase triangle (B) and the MDK rhomboid (C). F = foramen; III = CN III; VI = CN VI; V1, V2, and V3 = ophthalmic, maxillary, and mandibular divisions of the trigeminal nerve. Figure is available in color online only.

TABLE 2. Area and volume of Kawase's triangle and MDK rhomboid

Specimen No.	Drilled Kawase's Triangle		Drilled MDK Rhomboid	
	Area (mm ²)	Vol (mm ³)	Area (mm ²)	Vol (mm ³)
1	194.55	673.548	363.41	1505.238
2	136.71	484.006	333.25	1159.905
3	188.63	555.779	333.50	1106.166
4	296.14	853.228	406.64	1299.283
5	256.73	795.969	278.93	952.328
6	304.10	1338.648	532.73	1779.942
7	287.32	791.765	471.99	1468.305
8	426.15	1078.588	614.28	1837.761
9	373.75	764.162	464.24	1440.275
10	251.90	742.198	336.26	1115.321
11	224.71	662.086	382.94	1270.151
12	289.32	852.452	378.85	1256.585
Mean	269.13	666.614	408.09	1349.272

because the Kawase exposure of the brainstem is focused between trigeminal nerve and the CN VII/VIII complex. The fenestration obtained at the anterior petrous apex, surgical freedom at the Dorello canal, and angulation of the approaches were compared on both sides (Figs. 3 and 4).

Dissection Technique: MDK Rhomboid

The dissected cadaver head was fixed on a 6-pin fixator in the supine position with 45° rotation to the opposite side with slight extension (surgeon standing on vertex side). The technique is described as follows (Video 1).

VIDEO 1. Cadaver dissection using the MDK approach. Copyright Ashish Suri. Published with permission. Click here to view with Media Player. Click here to view with Quicktime.

- 1) A curvilinear incision was started 1 cm anterior to the tragus, extending superiorly and anteriorly toward the ipsilateral midpupillary line. Interfacial dissection of the temporalis fascia was done to preserve the frontal branch of the facial nerve. Sharp subperiosteal dissection of the temporalis fascia was done at the upper border of the zygoma.
- 2) A temporal craniotomy and zygomatic osteotomy were performed, and the temporalis muscle was retracted infe-

FIG. 3. Operative surgical steps for the MDK approach. **A:** Sacrifice of the orbitomeningeal artery at the middle cranial fossa floor. **B:** Extradural dissection of the temporal dura. **C:** Sacrifice of the MMA at the foramen spinosum. **D:** Orbital deroofing via an extradural anterior clinoidectomy. **E:** Interdural dissection at the lateral wall of the cavernous sinus. **F:** Sharp dissection over the greater superficial petrosal nerve. **G:** Exposure of the trigeminal nerve after interdural dissection. **H:** Exposure of the MDK rhomboid. **I:** Medial mobilization of the mandibular division of the trigeminal nerve (V3). **J:** Exposed rhomboid after mobilization of the gasserian ganglion. **K:** Drilling over the MDK rhomboid. **L:** Exposure of the posterior fossa dura. **M:** Opening of temporal dura. **N:** Division of tentorial dura behind trochlear nerve. **O:** Division of the superior petrosal sinus. **P:** Exposure of the posterior cranial fossa. Figure is available in color online only.

riorly. The zygomatic osteotomy was performed from the lateral margin of the orbit anteriorly to the temporomandibular joint posteriorly. Removing part of the zygoma reduces the degree of temporal lobe retraction and allows a superiorly angled approach beneath the temporal lobe. (Although a zygomatic osteotomy is not done in traditional Kawase's approach,¹⁶ we added it for standardization in both procedures.) 3) The temporal base and sphenoid ridge were drilled to the middle cranial fossa floor until the orbitomeningeal artery (Fig. 3A). The temporal dura was elevated from the posterior-to-anterior and lateral-to-medial directions (Fig. 3B). 4) Subtemporal extradural dissection was done with sacrifice of the middle meningeal artery (MMA) after drill dilation of the foramen spinosum (Fig. 3C and D). 5) A sharp incision with a No. 11 surgical knife was made on the outer wall of the lateral cavernous sinus, i.e., the dura propria (Fig. 3E). Interdural dissection (be-

tween the membranous dura and dura propria) was performed on the lateral wall of the cavernous sinus, exposing 3 divisions of the trigeminal nerve, without violating the inner dural layer. 6) Sharp dissection was done along the inferior margin of the greater petrosal groove to preserve the GSPN (Fig. 3F and G). Interdural dissection exposed the trigeminal nerve from the superior orbital fissure anteriorly to the gasserian ganglion posteriorly (Fig. 3H and I). It facilitated additional medial mobilization of V3 exposing a larger rhomboid area (Fig. 3J). 7) Surface landmarks (i.e., the tegmen tympani, AE, and GSPN) were identified from lateral to medial. The boundaries of the MDK rhomboid were delineated. Drilling with a diamond drill in this area exposed a larger fenestration of 20 × 18 mm (Fig. 3K and L). Drilling proceeded in a posterior direction with no neurovascular structure in its way. 8) The posterior fossa dura and temporal dura were cut along with division of the

Kawase's Approach		MDK Rhomboid Approach	
1. Temporal craniotomy		1. Temporal craniotomy with zygomatic osteotomy
2. MMA sacrifice		2. Drill dilation of foramen spinosum and MMA sacrifice (to prevent retraction of MMA)
3. GSPN: ± division		3. Sharp dissection over GSPN: posterior to anterior
4. Dural elevation posterior to V3 and GG: Extradural exposure of Kawase's triangle		4. Interdural dissection over lateral wall of cavernous sinus (V1, V2, V3, GG)
5. Exposure of Kawase's triangle		5. Exposure of MDK rhomboid with medial mobilization of V3
6. Drilling over Kawase's triangle		6. Drilling over MDK rhomboid
7. Opening of Meckel's cave from same dural incision on temporal side (if needed)		7. Dural incision on both sides of SPS and larger exposure of prepontine area

FIG. 4. Comparison of the Kawase and MDK approaches. AE = arcuate eminence; gang. = ganglion; GG = gasserian ganglion; GSPN = greater superficial petrosal nerve; KT = Kawase triangle; MMA = middle meningeal artery; SPS = superior petrosal sinus. Copyright Manjul Tripathi. Published with permission. Figure is available in color online only.

superior petrosal sinus and tentorium, providing access to the infratentorial posterior cranial fossa (Fig. 3M and N). The exposure achieved extends from the basilar bifurcation superiorly to the CN VII/VIII complex inferiorly (Fig. 3 O and P).

Custom Tailored MDK Rhomboid Approach

For lesions extending into the anterior cavernous sinus and orbit, an extradural anterior clinoidectomy and fronto-temporal zygomatic osteotomy with orbital deroofing may be added to the MDK approach (Video 2).

VIDEO 2. Custom-tailored addition of an extradural anterior clinoidectomy and orbital deroofing for the MDK approach. Copyright Ashish Suri. Published with permission. Click here to view with Media Player. Click here to view with Quicktime.

The lesser wing of the sphenoid was drilled from lateral to medial, and the tentorial duplicature was cut at the anterior clinoid process. Orbital deroofing was done, followed by an extradural anterior clinoidectomy (Fig. 3D) and anterolateral cavernous dissection through the far-lateral and Parkinson triangles. This exposure provides access to lesions extending into the anterior part of the cavernous sinus, from the superior orbital fissure anteriorly to the gasserian ganglion posteriorly.

Results

Volumetric Analysis: Dry Temporal Bones

The average lengths of the edges of Kawase's triangle of the dry temporal bones were 21.71 ± 0.79 mm $\times$ 17.11 ± 0.40 mm $\times$ 13.05 ± 1.01 mm. With the traditional Kawase approach, a triangle was obtained at the anterior petrous apex of the area ranging from 136.71 mm² to 426.15 mm² (mean 269.13 mm²). The corresponding volume of drilled bone ranged from 484.01 mm³ to 1338.65 mm³ (mean 666.614 mm³).

The average lengths of the margins of the rhomboid with the MDK approach were 13.15 ± 0.84 mm $\times$ 24.53 ± 1.77 mm $\times$ 12.54 ± 0.94 mm $\times$ 14.69 ± 1.16 mm. The area of the rhomboid was 278.93 to 614.28 mm² (mean 408.09 mm²), and the corresponding volume was 952.328 to 1837.761 mm³ (mean 1349.272 mm³). The areas and volumes obtained by MDK rhomboid exposure were 1.5 times and 2 times larger, respectively, than those obtained with the traditional Kawase approach, which was statistically significant ($p < 0.001$) (Table 2).

Exposed Area With Direction of Drilling: Cadaver Dissection

The MDK approach provided a fenestration of 20 $\times$ 18 mm at the anterior petrous apex, which was significantly larger than fenestration achieved using the Kawase approach (10 $\times$ 5 mm). Medial mobilization of V3 provided increased extension with significant surgical freedom at the Dorello canal and CN VI maneuverability. Interdural dissection and medial mobilization of the trigeminal nerve helps in lesser retraction over the temporal lobe. The added advantages are greater surgical freedom with increased anterolateral angulation (Figs. 3–5).

Clinical Application

For the last decade we have surgically treated all vari-

FIG. 5. Comparative view of the area exposed at the anterior petrous apex and anteroposterior angulation obtained with the MDK approach (dotted area between Arrows 1 and 3) and traditional Kawase approach (hatched area between Arrows 2 and 3). Figure is available in color online only.

eties of middle cranial fossa pathologies using the MDK approach.¹⁰ We prefer this technique because of its better angulation and exposure, which allow increased surgical ease (Fig. 6).

Discussion

The anterior petrous apex has been considered as a gateway to the posterior cranial fossa. Walter Dandy must be pleased to see that after decades of practice, the radical approach of aggressive skull base procedures has forced the surgical fraternity to change the philosophy to access lesions of the petroclival region. However, the aim remains the same (i.e., maximum removal with minimal morbidity). The middle cranial fossa approach was introduced by House et al. for vestibular nerve section in cases of intractable vertigo.¹⁵ It is beyond doubt that advances in microneurosurgical techniques, better magnification, and instrumentation have improved the margin of safety for approaching lesions in the sphenopetroclival and prepontine regions.³ After the modification of House et al., several modifications followed, with slight variations to the approaches, skull base dissections, and preservation of the vestibulocochlear apparatus.⁴ The need for better exposure in this region remains obvious, as the brainstem cannot be retracted and CNs do not tolerate excessive manipulation.²⁰

Comparison With Other Surgical Approaches to the Petroclival Region

The Kawase approach provides access to traditionally difficult lesions, such as large sphenopetroclival meningiomas and basilar trunk aneurysms. This technically de-

S No.	Age (years), Sex	Clinical Presentation	Preoperative Image	Diagnosis (Clinical and Pathological)	Postoperative Image	Surgical Results	Postoperative Course
1	15, M	Raised ICP, visual deterioration		Rosai Dorfman Disease (B/L tentorial, petroclival, cavernous sinus extension)		GTR in staged surgeries (6 weeks apart)	Prolonged hospital stay
2	35, M	Facial hypoesthesia, Extraocular nerves impairment, and 5 th nerve involvement, Long tract signs		Right Trigeminal Schwannoma, Type C		GTR	Uneventful, Improved cranial nerve functions, Motor improvement to 4/5
3	42, F	Headache, facial hypoesthesia, ataxia, long tract signs		Rt Petroclival Meningioma		GTR	Transient 3 rd nerve paresis
4	53, F	Headache, extraocular nerve paresis, ataxia, somatosensory deficits		Rt Petroclival Meningioma		STR	3 rd nerve paresis, Improvement in ataxia
5	50, M	Ruptured aneurysm with SAH and IVH		Basilar Tip Aneurysm		Aneurysm clipping	Uneventful, Transient 3 rd nerve paresis
6	54, F	Hemifacial spasm, Trigeminal neuralgia, Long tract signs		Middle and Posterior Fossa Epidermoid		GTR	Aseptic Meningitis, Prolonged hospital stay

FIG. 6. Clinical details in 6 patients who underwent surgery via the MDK approach. B/L = bilateral; GTR = gross-total resection; ICP = intracranial pressure; IVH = intraventricular hemorrhage; SAH = subarachnoid hemorrhage; STR = subtotal resection. Images in Cases 2, 4, and 5, copyright Ashish Suri. Published with permission.

manding procedure is popular because of the surgeon's familiarity with anatomy, years of successful practice, lesser parenchymal injuries, and temporal lobe retraction. With it, we get a triangular area at the petroclival region, medial to the internal auditory canal devoid of any significant neurovascular structures (Table 3).^{3,7,16,17} The fenestration of 10 × 5 mm sometimes proves insufficient for lesions with significant infratentorial and cavernous sinus extension. Individual temporal bones suffer from significant variability in morphometric parameters. Earlier studies have raised questions regarding the value of the Kawase approach; the size of the window in the petrous bone is significantly smaller, providing insufficient space as a corridor to the posterior fossa.⁷ Only a few authors have performed and described morphometric analyses of these approaches.^{3,6,7,14,19}

The tip of the petrous apex lies hidden under the lateral margin of the gasserian ganglion. Interdural dissection on the lateral wall of the cavernous sinus allows a wider area of exposure with some degree of medial mobilization of V3, which helps in better exposure of the pathological lesion. With added surgical exposure by the MDK approach, we get a larger fenestration due to removal of this hidden

tip of the petrous apex. This provides increased surgical access to CN VI at the Dorello canal, the upper two-thirds of the clivus, and the prepontine area (exposure of CNs II–VIII). We call this approach the modified Dolenc-Kawase approach, as it is an addition of the Dolenc approach (anterolateral cavernous dissection)⁸ to the Kawase approach (extradural subtemporal transtentorial approach) and provides a larger area at the anterior petrous apex.^{16,17} Anterior clinoidectomy and orbital derroofing are additional custom-tailored procedures with the MDK approach for lesions extending into the interpeduncular and suprasellar cisterns, orbit, oculomotor trigone, and cavernous sinus. An anterior clinoidectomy and a complete transcavernous approach significantly increase the working area and linear exposure of the basilar artery compared with abbreviated forms of the approach ($p < 0.05$).⁹

Clinical Implications of MDK Rhomboid Geometry in Comparison With the Kawase Triangle

Lesions at the petrous apex are notorious for expanding in every possible direction, namely the middle cranial fossa, para cavernous sinus, orbit, and posterior cranial fossa. Before Kawase introduced his approach, all middle fossa

TABLE 3. Comparison of various surgical techniques for petroclival region

Authors & Year	Procedure Performed	Fenestration at Petrous Apex	Pros	Remarks
Kawase et al., 1985; Kawase et al., 1991; Day et al., 1994	Subtemporal extradural transtentorial approach	10 x 5 mm	1) Straight access to anterior petrous; 2) familiarity among neurosurgeons	1) Traction to GSPN; 2) potential risk to vein of Labbé, cochlea, semicircular canals & ICA; 3) nontailored approach
Hakuba et al., 1988	Combined retroauricular preauricular transpetrosal transtentorial approach	10 x 5 mm	1) Extradural exposure of petrous bone; 2) minimal retraction injury to temporal lobe & cerebellum	1) Needs radical mastoidectomy & extensive bone removal; 2) sinus injury; 3) increased operative time; 4) risk of hearing impairment
Harsh & Sekhar, 1992; Day et al., 1994	Subtemporal anterior intradural transcavernous approach	10 x 15 mm	1) Lesser chances of injury to petrous ICA by intradural drilling; 2) larger fenestration	1) Resection of anterior 4 cm of inferior temporal gyrus (optional); 2) needs dural closure at skull base; 3) dissection of posterolateral cavernous sinus; 4) needs division & resuturing of trigeminal nerve; 5) injury to vein of Labbé
Gupta & Salunke, 2012	Transsylvian intradural anterior petrosectomy	Custom tailored	1) Tailored bone removal as per the lesion; 2) no pressure or traction on vein of Labbé; 3) early control of tumor vascularity; 4) tumors w/ orbital extension can also be removed	1) Needs FTOZ craniotomy; 2) needs meticulous dural closure at skull base; 3) potential need to sacrifice transsylvian temporal bridging veins
Gupta et al., 2006	MDK approach for subtemporal transcavernous extradural anterior petrosectomy	20 x 18 mm	1) Larger fenestration at anterior petrous apex; 2) straight approach to petrous apex; 3) surgical freedom at Dorello canal & prepontine space; 4) no dural breach; 5) lesser temporal retraction; 6) custom tailored for lesions in cavernous sinus & orbital extension	1) Optional anterior clinoidectomy & transcavernous exposure; 2) needs mobilization of V3; 3) increased operative time (30 mins)

FTOZ = frontotemporo-orbito-zygomatic; ICA = internal carotid artery.

approaches, such as the subtemporal transtentorial approach, were associated with complications, such as temporal lobe retraction injuries, especially venous infarcts.^{3,7,10} With the MDK approach, we were able to create an area larger than that described by Kawase by removing bone from the AE to the tip of the petrous apex, which unroofs the internal auditory canal 270° and increases surgical freedom.

Although it is clear that the exposure obtained is much greater than that obtained with the Kawase approach, the major determinants of tumor resection with preservation of critical structures is also determined by tumor consistency, arachnoid plane preservation, and degree of involvement of critical neurovascular structures.³ The senior author (A.S.) has practiced the MDK approach and has not encountered any retraction-related injury to temporal lobes. There were transient CN deficits in the postoperative period; otherwise, the complication rates were comparable with those associated with the Kawase approach, with increased surgical exposure and ease (Fig. 6)

Conclusions

The present paper describes a new technical modification of the traditional Kawase approach. Skull base procedures are complex and demand high competence and

proficiency by the treating surgeon. Extent, pathology, and preoperative neurological status of the patient guide the surgeon in choosing the appropriate approach. An ideal approach is one that provides maximum exposure with minimal bone dissection and injury to parenchyma and neurovascular structures. There is little space for tailored approaches for lesions in the petroclival region. The MDK approach is a custom-tailored extradural approach for middle cranial fossa lesions with variable extension into the anterior and posterior cranial fossae.

The complexities of the skull base anatomy and dissection must be understood in cadavers in the laboratory before the approaches are practiced in the operation room. In our report, cadaveric analysis is a validating factor to prove our volumetric findings. The contribution of our study is primarily in describing our philosophy of a larger exposed area at the anterior petrous apex with an entirely extradural approach that provides enhanced exposure of middle cranial fossa lesions for better excision.

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Author Contributions

Conception and design: Suri. Acquisition of data: Tripathi, Deo. Analysis and interpretation of data: Suri, Tripathi, Deo, Srivastav, Baby, Prasad, Paul. Drafting the article: Tripathi. Critically revising the article: Suri, Tripathi, Prasad. Reviewed submitted version of manuscript: Deo. Statistical analysis: Tripathi, Srivastav, Baby. Administrative/technical/material support: Suri, Kumar, Kalra, Banerjee, Prasad, Paul, Roy, Lalwani. Study supervision: Suri, Kalra, Banerjee, Roy, Lalwani.

Supplemental Information

Videos

Video 1, Media Player. http://mfile.akamai.com/21490/wmv/digitalwbc.download.akamai.com/21492/wm.digitalsource-na-regional/jns13-2876_video_1.asx.

Video 1, Quicktime. http://mfile.akamai.com/21488/mov/digitalwbc.download.akamai.com/21492/qt.digitalsource-global/jns13-2876_video_1.mov.

Video 2, Media Player. http://mfile.akamai.com/21490/wmv/digitalwbc.download.akamai.com/21492/wm.digitalsource-na-regional/jns13-2876_video_2.asx.

Video 2, Quicktime. http://mfile.akamai.com/21488/mov/digitalwbc.download.akamai.com/21492/qt.digitalsource-global/jns13-2876_video_2.mov.

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