A Comparison between the Kawase and Extended Retrosigmoid Approaches (Retrosigmoid Transtentorial and Retrosigmoid Intradural Suprameatal Approaches) for Accessing the Petroclival Tumors. A Cadaveric Study

Mayur Sharma¹ Sudheer Ambekar¹ Bharat Guthikonda¹ Anil Nanda¹

¹ Department of Neurosurgery, Louisiana State University Health Science Center, Shreveport, Louisiana, United States

Address for correspondence Dr. Anil Nanda, MD, MPH, FACS, Department of Neurosurgery, Louisiana State University Health Science Center, 1501 Kings Highway, Shreveport, LA 71130-3932, United States (e-mail: ananda@lsuhsc.edu).

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Abstract

Background The aim of our study was to compare the area of exposure at the ventral brainstem and petroclival region offered by the Kawase, retrosigmoid transtentorial (RTT), and the retrosigmoid intradural suprameatal (RISA) approaches in cadaveric models.

Methods We performed 15 approaches (five each of the Kawase, RISA, and RTT approaches) on silicone-injected adult cadaver heads. Ventral brainstem and petroclival areas of exposure were measured and compared.

Results The mean ventral brainstem area exposed by the Kawase approach was $55.00 \pm 24.1 \text{ mm}^2$, significantly less than that exposed by RTT ($441 \pm 63.3 \text{ mm}^2$) and RISA ($311 \pm 61 \text{ mm}^2$) ($p < 0.05$). The area of ventral brainstem exposure was significantly more via RTT than through RISA ($p = 0.01$). The mean petroclival area of exposure through the Kawase approach was significantly smaller than that obtained through the RTT and RISA approaches ($101.7 \pm 545.01 \text{ mm}^2$, $696 \pm 57.7 \text{ mm}^2$, and $716.7 \pm 51.4 \text{ mm}^2$, respectively).

Conclusion Retrosigmoid approaches provide a greater exposure of the brainstem and petroclival areas. The Kawase approach is ideally suited for lesions around the Meckel cave with an extension into the middle fossa. These approaches can be used in conjunction with one another to access petroclival tumors.

Keywords

- Kawase
- retrosigmoid
- transtentorial
- suprameatal
- petroclival tumors.

Introduction

Meningiomas originating in the Meckel cave and trigeminal nerve schwannomas are the two most frequently encountered petroclival tumors.^{1,2} These tumors usually extend into both the middle and posterior fossa with a major portion of the tumor into either of these compartments and thereby pose a significant challenge to the neurosurgeon. Their large size at presentation and proximity to the critical neurovascular structures add to the complexity of their surgical management. A

variety of surgical approaches such as middle fossa (Kawase and extended middle fossa), retrosigmoid, retrosigmoid intradural suprameatal approach (RISA), and combined subtemporal-presigmoid and transpetrosal approaches have been described to access the petroclival region.^{3–12} Given the morbidity associated with the surgical resection of these tumors, two-staged resection or maximal safe resection with or without adjunct radiosurgery has also been described.^{8,13–17}

The Kawase approach is a well-established middle fossa approach to access the tumors in the petroclival region.^{8,9}

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RISA was described as an extension of the retrosigmoid approach to access the lesions around the Meckel cave and those with an extension into the middle fossa.^{4,18} Another novel approach, the lateral supracerebellar transtentorial approach, has been described for petroclival tumors with minimal extension into the Meckel cave or middle fossa.¹⁹ There are few quantitative studies comparing the exposure obtained by the Kawase and retrosigmoid approaches.¹³ The aim of our study was to compare the area of exposure of the ventral brainstem and petroclival region obtained by the Kawase and both the retrosigmoid (RISA and retrosigmoid transtentorial [RTT]) approaches in cadaveric models.

Clinical Materials and Methods

We performed 15 approaches (five each of the Kawase, RISA, and RTT approaches) using standard microsurgical techniques under $\times 3$ to $\times 40$ magnification on embalmed and silicone-injected adult cadaver heads with no known brain pathology. The Kawase and RISA approaches were performed using the described techniques.^{4,7–10,18} The cadaver heads were fixed using a table-mounted Mayfield head clamp. Microscope, electric drill, and microsurgical instruments were used in all dissections. Morphometric measurements were performed between the key anatomical landmarks.

Surgical Procedure

Kawase Approach

The cadaver head was fixed to the table using the Mayfield clamp and rotated 90 degrees to the contralateral side ($\rightarrow$ Figs. 1 and 2. The vertex was tilted toward the floor, which facilitates the gravitational temporal lobe retraction. A horseshoe-shaped skin incision was made above the external auditory canal, and the temporal bone was exposed after dividing the temporalis muscle in layers. A 3 cm $\times$ 3 cm

Fig. 1 In the Kawase approach, the dura was peeled away from the temporal base, avoiding injury to the greater superficial petrosal nerve (GSPN; arrow). The Kawase triangle or rhomboid is formed by the third division of the trigeminal nerve anteriorly, petrous carotid artery anterolaterally, GSPN laterally, arcuate eminence posteriorly, and the superior petrosal sinus medially.

Fig. 2 Area of ventral brainstem exposed following drilling of the Kawase triangle. The star indicates the exposed brainstem.

temporal craniotomy was performed, and the inferior limit of the craniotomy was drilled to the level of the floor of the middle cranial fossa. The dura was separated from the temporal base from posterior to anterior, avoiding injury to the greater superficial petrosal nerve (GSPN) and retracted at a constant 1.5 cm above the base. The middle meningeal artery was divided at the level of the foramen spinosum. The Kawase triangle or rhomboid is formed by the third division of the trigeminal nerve anteriorly, petrous carotid artery anterolaterally, GSPN laterally, arcuate eminence posteriorly, and the superior petrosal sinus medially. The drilling was limited to this triangle to expose the ventral brainstem area, and measurements were made.

Retrosigmoid Transtentorial Approach

The surgical technique of RTT was described in detail in our previous study.²⁰ In brief, the cadaver head was fixed using the Mayfield clamp and rotated to the contralateral side ($\rightarrow$ Fig. 3). The long axis of the petrous bone was oriented along the visual axis by the anterior and lateral flexion of the head. A linear incision was made 2 cm behind the mastoid just above the transverse sinus below. The incision was deepened in layers, and a burr hole was made just below the asterion using a high-speed drill. A 3 cm $\times$ 3 cm craniotomy was made, and the dura was opened based on the transverse and sigmoid sinuses. The cerebellum was retracted at a constant 1.5 cm using a Greenberg retractor, and the cerebellopontine angle was visualized. The arachnoid over the cerebellomedullary cistern was dissected and opened. After inspecting the surrounding neurovascular complexes, the tentorium cerebelli was incised using a no. 11 blade, and brainstem surface measurements were taken.

Retrosigmoid Intradural Suprameatal Approach

The cadaver head position, skin incision, and craniotomy steps were similar to that used for the RTT approach ($\rightarrow$ Fig. 4). The dura was opened and the cerebellum was retracted at a constant 1.5 cm. The arachnoid covering the

Fig. 3 Exposure of the cerebellopontine angle after retracting the cerebellum and incising the tentorium during the retrosigmoid transtentorial approach. The cranial nerve V can be seen in the upper part of the cerebellopontine angle entering into the Meckel cave. The red arrow points to the probe into the area exposed after incising the tentorium. The asterisk indicates the suprameatal tubercle.

Fig. 4 Area of exposure after drilling the suprameatal tubercle during the retrosigmoid intradural suprameatal approach. Cranial nerve V can be seen traversing the superior portion of the cerebellopontine angle into the Meckel cave; nerve complex VII-VIII can be seen in the lower portion of the cerebellopontine angle.

cerebellomedullary fissure was opened, and the suprameatal tubercle was identified. The suprameatal tubercle was bounded by the tentorium and fifth nerve superiorly and internal auditory canal with seventh-eighth nerve complex posteroinferiorly. The tubercle was drilled using a high-speed drill up to the posterior and superior semicircular canals laterally. Subsequently, brainstem surface measurements were made.

Area of Exposure

The ventral brainstem area was chosen for comparison among all three approaches because the Kawase approach to the

posterior fossa primarily directs to the ventral portion of the brainstem between the fifth nerve and seventh-eighth nerve complex. The area of the ventral brainstem was determined by a trapezium construct based on four anatomical points, anterior to the line joining the origins of the fifth cranial nerve and seventh-eighth cranial nerve complex from the brainstem. The maximum superoventral point of exposure above the origin of the V nerve and inferoventral point of exposure below the origin of acousticofacial bundle was determined. Similarly, for the petroclival area of exposure the constant landmarks chosen were Meckel cave superiorly and internal auditory canal inferolaterally. The other two points were the maximum superoventral and inferoventral points of exposure through the gap between the fifth cranial nerve and seventh-eighth nerve complex.

Statistical Analysis

Statistical analysis was performed using SPSS v.20 (IBM Inc., Chicago, IL) and Microsoft Excel. Student *t* tests were used to compare the mean of the area of brainstem exposure. Comparisons were considered significant only if the *p* value was < 0.05 .

Results

Morphometric Analysis

The mean ventral brainstem area exposed by the Kawase approach was $55.00 \pm 24.1 \text{ mm}^2$. This exposed area was significantly less than that exposed by RTT approach ($441 \pm 63.3 \text{ mm}^2$) ($p < 0.05$) or RISA approach ($311 \pm 61 \text{ mm}^2$) ($p < 0.05$). On comparing RTT and RISA approaches, the area of ventral brainstem exposure was significantly more through RTT than through RISA ($p = 0.01$). The superoventral exposure of the ventral brainstem was more with the RTT and Kawase approaches compared with RISA ($\rightarrow$ Fig. 5).

Fig. 5 Bar graph shows the working area of the ventral brainstem exposed by all three approaches. The mean ventral brainstem area exposed by the Kawase approach was significantly less than that exposed by the retrosigmoid transtentorial approach (RTT) approach ($p < 0.05$) or retrosigmoid intradural suprameatal approach (RISA) approach ($p < 0.05$). The area of ventral brainstem exposure was significantly more through RTT than through RISA ($p = 0.01$).

The mean petroclival area of exposure through the Kawase approach was $101.75 \pm 45.01 \text{ mm}^2$, whereas that through the RTT and RISA approach were $696 \pm 57.7 \text{ mm}^2$ and $716.7 \pm 51.4 \text{ mm}^2$, respectively. The difference between the petroclival area of exposure through the Kawase and RTT approaches or through the Kawase and RISA approaches reached statistical significance using the Student *t* test ($p < 0.05$). However there was no difference in the area of petroclival exposure obtained by RTT and RISA ($p = 0.57$). The degree of surgical freedom medial to Meckel cave was more with the Kawase approach and RISA as compared with the RTT approach; however, objective measurements were not taken. The origin of the anterior inferior cerebellar artery was visualized through both the retrosigmoid and Kawase approach in all our specimens (—Fig. 6).

Discussion

Surgical resection of petroclival tumors is associated with a significant morbidity and mortality by virtue of their location, large size, bicompartamental extension, and proximity to the critical neurovascular structures. However, with the advances in skull base approaches, there has been a significant improvement in the resection rates of petroclival tumors and overall patient outcome.^{12,21–23} A variety of skull base approaches have been described to access the lesions involving the petroclival region.^{3–12} Although transpetrosal approaches provide a wider access to the petroclival region with minimal brain retraction and early access to the feeding vessels, they are often associated with significant surgical morbidity such as facial nerve injury, hearing loss, injury to the vein of Labbe, and cerebrospinal fluid leak.^{3,5,10,13,18} Therefore the optimal surgical approach to the petroclival tumors depends on the size, location of the tumor with its extension into the middle or posterior fossa, tumor consistency, and the surgical expertise available.

Charles Drake proposed the subtemporal transtentorial approach for the management of vertebrobasilar aneurysms

Fig. 6 Bar graph shows the working area of the petroclival region exposed by all three approaches. The petroclival area of exposure through the Kawase approach was significantly less than that exposed by both the retrosigmoid approaches (retrosigmoid transtentorial approach [RTT] and retrosigmoid intradural suprameatal approach [RISA]) ($p < 0.05$). However there was no difference in the area of petroclival exposure obtained by RTT and RISA ($p = 0.57$).

in 1965.²⁴ In 1975, Bochenek and Kukwa first described an extended middle fossa approach with drilling of the petrous bone for the excision of acoustic neurinomas.²⁵ Three years later, House et al described the transcochlear approach for the lesions arising anterior or medial to the internal auditory canal as well as for those arising directly from the clivus.⁵ Kawase et al described a middle fossa approach for the management of low lying basilar aneurysms and petroclival tumors in 1985 and 1991, respectively.^{7,9} Their technique involved drilling of the petrous apex (the Kawase rhomboid) with no neurovascular structures in it. The Kawase rhomboid was bounded by the mandibular division of the trigeminal nerve anteriorly, petrous carotid artery anterolaterally, GSPN laterally, arcuate eminence posteriorly, and the superior petrosal sinus medially. The superior petrosal sinus was divided and the lateral aspect of the tentorium was incised. This approach resulted in a bone defect ~ 20 mm wide and 10 mm deep to access the ventral brainstem between the fifth nerve and fascio-acoustic bundle. Therefore this approach is ideally suited for lesions near the Meckel cave with middle fossa extension.¹³ The major disadvantages of this approach are the risk of injury to the draining veins, especially the vein of Labbe on the dominant side, damage to the temporal lobe, and the prolonged operative time.¹³ In our study, the mean ventral brainstem area and petroclival area exposed by the Kawase approach was significantly less than that exposed by retrosigmoid approaches (RTT and RISA; $p < 0.01$), which is in concordance with the literature.¹³ In a study, the Kawase approach provided an increased surgical freedom at the trigeminal porus as compared with the standard retrosigmoid approach.¹³ Therefore, the Kawase approach is ideal for tumors with a predominant middle fossa extension than the posterior fossa, such as trigeminal nerve schwannomas or Meckel cave meningiomas.

The RISA approach was first described by Samii et al in 1983, as an extension of the classical retrosigmoid approach to access the lesions around the Meckel cave with bicompartamental extension.^{4,18} This technique involves drilling of the portion of the petrous bone that is located anterior to and above the internal acoustic meatus. In contrast to the Kawase approach that involves drilling of the petrous bone from above and directed anteriorly, in the RISA approach the petrous bone is drilled from below and directed posteriorly.¹⁸ Semicircular canals (posterior and superior) and the surrounding neurovascular structures should be taken care of while drilling the petrous bone.¹³ The main advantages of this approach include an avoidance of the temporal lobe retraction with its associated complications, an early visualization of the cranial nerves, and the mobilization of the trigeminal nerve that improves visualization of the structures medial to the internal auditory canal, to the petrous apex, Meckel cave, and the posterior end of the cavernous sinus.^{4,18} Moreover, large tumors arising from the petrous apex increase the surgical corridor by displacing the fifth nerve upward and acousticofacial bundle downward, which facilitates their complete resection by this approach.¹⁸ In addition, the direction of displacement of these cranial nerves by large tumors might

help in choosing the appropriate surgical approach (Kawase or extended retrosigmoid), to minimize cranial nerve injuries, and to maximize tumor resection. However, compared with the standard retrosigmoid approach, the RISA approach does not increase the depth or angle of exposure as well as the visualization of the midline structures.⁴ Similarly, Chang et al reported that the working area at the ventral brainstem and the clivus exposed by the RISA approach was not significantly different than that exposed by the standard retrosigmoid approach.¹³ However, the addition of suprameatal extension to the standard retrosigmoid approach did improve surgical freedom at the trigeminal porus.¹³

In 2006, Kawamata et al first described the lateral supracerebellar transtentorial approach for petroclival meningiomas with minimal extension into the Meckel cave and middle fossa.²⁶ They described that the division of the tentorium can increase the exposure to the petroclival region without extensive bony resection associated with the RISA approach. Using this approach they achieved gross total resection of the petroclival meningiomas in 42% and subtotal resection in 38% of their patients with a permanent postoperative morbidity rate of 15%.¹⁹ The RTT approach is an extension of the classical retrosigmoid approach that involves incising the tentorium without extensive bony resection associated with the RISA or lateral supracerebellar transtentorial approach. In our study, the mean ventral brainstem area exposed by RTT was significantly more than that exposed by RISA ($p = 0.01$). However, exposure of the petroclival area did not show a significant difference between the two approaches (RTT versus RISA). The main advantage of this approach is avoidance of bone drilling and its associated complications. Superior petrosal vein and trochlear nerve are the two structures that should be taken care of while incising the tentorium. In most of the cases with petroclival meningiomas, the superior petrosal vein is either displaced or compressed, resulting in the formation of collateral veins, and therefore superior petrosal vein can be safely sacrificed in such cases.¹⁸ Therefore the RTT approach can be used prior to the drilling of the suprameatal tubercle, which can be added if there is an insufficient exposure with the RTT approach.

Limitations

Although our study provides an estimate of the area of exposure obtained by various surgical approaches, the accuracy of the exposure area and surgical freedom can be improved by using stereotactic measurements. Our cadaveric study may not take into consideration the anatomical distortions produced by the tumor and its relation to the surrounding neurovascular structures.

Conclusion

Based on this cadaveric study, the retrosigmoid approaches (RTT and RISA) provide a greater exposure of the ventral brainstem and the petroclival area compared with the Kawase approach. The RTT approach offers a greater exposure of

the ventral brainstem that that offered by RISA with no significant difference in the exposure of the petroclival area. The Kawase approach is ideally suited for lesions around the Meckel cave with a major extension into the middle fossa. These approaches can be used either in isolation or in conjunction with each other to access the petroclival tumors based on the extension of the tumor and the involvement of surrounding neurovascular structures.

Disclaimer

The authors have no conflicts of interest to disclose.

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