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The Anterior Transpetrosal-Transtentorial Approach (Kawase Approach)

An Anatomic Description and Clinical Applications

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Learning Objectives: *After reading this article, the participant should be able to:*
1. Describe the surgical steps involved in the anterior transpetrosal-transtentorial (Kawase) approach.
2. Explain the specific advantages of the Kawase approach.
3. Recall the arguments supporting the current approaches for retrosellar and retroclival lesions.

Historical Perspective

It is difficult to gain access to retrosellar and retroclival lesions located in or close to the midline. In 1965, Drake proposed the subtemporal transtentorial approach for vertebrobasilar aneurysm. Drawbacks include possible damage to the temporal lobe due to forced retraction and, eventually, sacrifice of the vein of Labbé. Furthermore, the lower part of the basilar artery cannot be reached due to the petrous ridge, which impedes access to this region.

Bochenek and Kukwa first described an extradural subtemporal approach combined with drilling of the petrous bone, called the extended middle fossa approach, in 1975. It originally was used for the removal of acoustic neurinomas. This extradural subtemporal approach minimizes the risk of damage to temporal bridging veins. By drilling the petrous bone, 10 mm of extra space can be gained below the level of the superior petrous sinus. In the extended middle fossa approach, drilling is continued posteriorly, opening the semicircular canals and so jeopardizing hearing function on the ipsilateral side.

In 1985, Kawase et al. described a modification of the extended middle fossa approach for the treatment of low-lying basilar aneurysms. Drilling of the petrous bone was restricted to the petrous apex, which contains no neurovascular structures. The superior petrous sinus was divided, and 10 mm of the adjoining lateral aspect of the tentorium was incised, increasing the surgical field. This resulted in a bone defect about 20 mm wide and 10 mm deep giving access to the prepontine region between the level of the trigeminal nerve and the facial nerve.

The Kawase approach has been used for pathologic entities located in the petrous apex (e.g., cholesteatoma, cholesterol granuloma, chordoma, chondrosarcoma, petrous apicitis); the retrosellar/retroclival area (e.g., vertebrobasilar trunk aneurysms, trigeminal neurinomas, petroclival meningiomas, prepontine epidermoids); and for intrinsic lesions in the lateral pons (e.g., cavernomas).

Description of the Kawase Approach

Extradural Steps

The patient is placed in a supine position with a small pad under the ipsilateral shoulder. A lumbar spinal catheter for perioperative drainage of cerebrospinal fluid is optional. Cranial

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Category: Surgical approach

Key Words: Cranial base, Kawase approach, Anterior subtemporal approach, Basilar artery, Aneurysm, Petroclival meningioma, Clivus, Anterior petrosectomy

nerve monitoring is advisable, depending on the pathology. The head is rotated 90 degrees, and the vertex slightly tilted toward the floor to facilitate gravitational temporal lobe retraction. A U-shaped skin incision is made above the level of the external auditory canal, and the skin flap is retracted downwards. A vascularized fascia flap is prepared from the temporalis muscle to cover the floor of the temporal fossa at the end of the operation. A temporal craniotomy is performed, and the basal temporal bone is drilled to the level of the floor of the temporal fossa. Accidentally opened mastoid air cells should be obliterated with bone wax.

An alternative is to make a curved frontotemporal incision such as the one used for the standard pterional approach and remove the upper rim of the zygomatic arch, or to cut the zygomatic arch anteriorly and posteriorly and pull it downward with the masseter muscle still attached, to gain more space for the temporal muscle to be reflected downward. In this case the craniotomy can be expanded anteriorly, eventually opening the cavernous sinus when needed.

Under microscopic magnification the dura is peeled away from the floor of the temporal fossa. The middle meningeal artery, located posterolateral to the foramen ovale, is divided at the level of the foramen spinosum. The artery should not be divided too close to the foramen, because the proximal part could retract in the foramen and, when not properly coagulated, may cause bleeding, which could be difficult to manage. The dura is peeled away from posterior to anterior, avoiding traction on the geniculate ganglion via the greater superior petrosal nerve (GSPN), which runs from the geniculate ganglion to the pterygopalatine ganglion as the vidian nerve, together with branches from the carotid sympathetic plexus, and is responsible for lacrimation.

Anatomic Landmarks for Petrous Apex Resection

Important landmarks during the extradural phase of the Kawase approach are the arcuate eminence, covering the superior semicircular canal, which is the posterior border of the area of the petrous apex to be drilled (the Kawase triangle or rhomboid; Figure 1). The vestibule lies lateral to the superior semicircular canal, and the tegmen tympani can be identified more laterally, lateral to the lateral semicircular canal. The tegmen tympani is a thin layer of bone covering the structures of the middle ear—the head of the malleolus, the incus, and the tympanic segment of the facial nerve. The lateral border of the Kawase triangle is the pregasserian portion of the petrous carotid artery, in the foramen lacerum, and the smaller and GSPNs running close to the carotid artery. Drilling should not be extended lateral to the carotid artery, because the eustachian tube might be inadvertently opened or the overlying tensor tympani muscle could be damaged. The geniculate ganglion forms the connection between the GSPN and the labyrinthine portion of the facial nerve. From the geniculate ganglion, the facial nerve runs to the level of the stapes and from that point further downward, below the lateral semicircular canal, becoming the mastoid segment of the facial nerve. Some authors have pointed out the risk of facial nerve palsy due to traction on the geniculate ganglion, even when the GSPN is handled very carefully and a

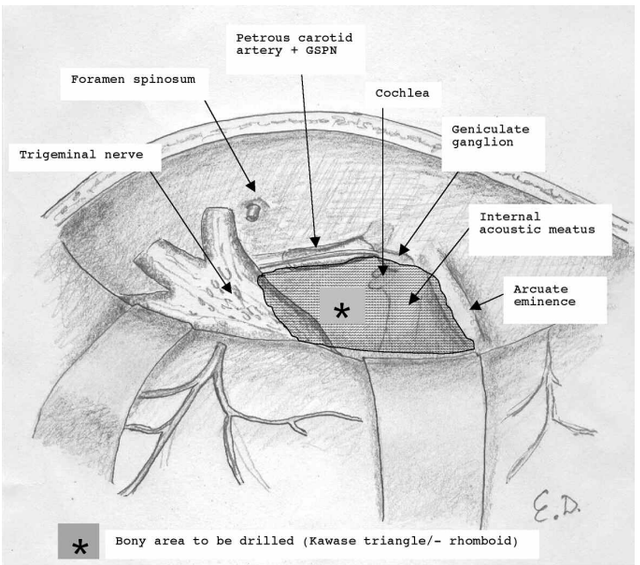

Figure 1. Surgical view after the extradural steps of the Kawase approach have been completed, depicting the rhomboid shaped area to be drilled. GSPN, greater superior petrosal nerve.

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small strip of periosteum is left on the nerve. It has been proposed that the GSPN be divided. Although this leads to a temporary diminishment of lacrimation of the ipsilateral eye, it usually is compensated for within a few months. The risk of damage to the facial nerve is increased in the 15% of cases where the geniculate ganglion is not covered by bone. The cochlea is located just medial to the geniculate ganglion and deeper in the temporal bone, posterosuperior to the lateral genu of the petrous carotid artery. The cochlea is separated from the petrous carotid by about 2.1 mm (range, 0.6–10.0 mm) of bone. The frontal border of the Kawase triangle is formed by the third division of the trigeminal nerve. Drilling can be continued under the trigeminal impression downward to the entrance of the abducent nerve in Dorello's canal. This landmark is, on average, 7 mm anteroinferior to the trigeminal impression (range, 5–9 mm) and also is the level of the inferior petrosal sinus in the petroclival fissure, which forms the deepest point of petrous apex removal. The medial border of the Kawase triangle or rhomboid is formed by the superior petrosal sinus (SPS). The internal auditory meatus (IAM) can be found by two methods, the Fisch and the House techniques. In the House technique, the GSPN is followed toward the geniculate ganglion, from which point the labyrinthine portion of the facial nerve is followed to the internal acoustic meatus. In the Fisch method, two virtual lines are drawn, one line representing the course of the GSPN and another line representing the arcuate eminence. The angle between these lines is 120 degrees. This angle is divided in two equal angles of 60 degrees, and the resulting virtual line represents the course of the IAM. The Fisch method is considered the safer one. The roof of the IAM, which is, on average, 5 mm thick (range, 3–7 mm) is drilled carefully from medial to lateral, leaving the dural sheath intact. In the lateral part of the IAM, the cochlear and inferior vestibular nerves are separated by a transverse bony crest from the facial nerve and superior vestibular nerve, and the facial nerve and the superior vestibular nerve are separated by a vertical bony crest.

Nasal liquorrhea might occur when mastoid air cells, the tegmen tympani, or the Eustachian tube are accidentally opened. Defects should be carefully closed and covered. Deafness invariably occurs when the cochlea is opened, and it occurs in about 20% of cases when the semicircular canals are partially opened. Blue-lining of the cochlea and the superior semicircular canal offers the maximum space, but it also risks opening these structures and so jeopardizing hearing function. It is safer to drill until the consistency of the bone of the petrous apex changes from relatively soft to very hard. This thin shell of hard bone covers the structures of the inner ear. After drilling is completed, the dura under the level of the SPS is opened, exposing the posterior fossa.

Intradural Steps

The temporal dura is opened basally, parallel to the cranial base, two small retractors are placed under the temporal lobe, and the temporal lobe is gently retracted. The tentorial edge is identified, as well as the trochlear nerve in its subarachnoidal course, running parallel to the tentorial edge and entering the tentorium more anteriorly. A cut of about 10 mm is made in the tentorium medial and perpendicular to the SPS. The SPS is divided between two hemoclips as far posterior as possible to avoid damage to the trigeminal nerve. Care is taken to include

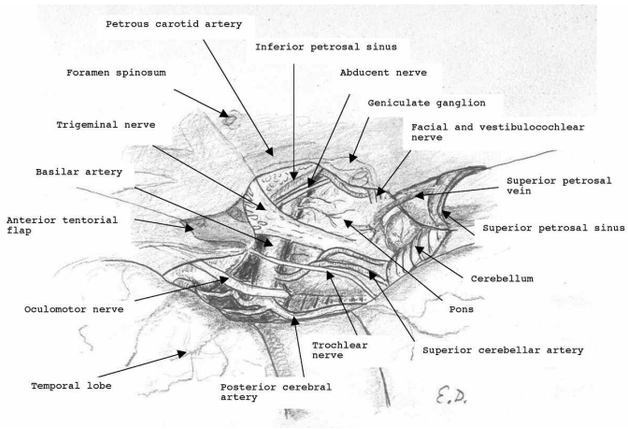

Figure 2. Surgical view after the extradural and intradural steps of the Kawase approach have been completed.

the superior petrosal vein (Dandy's vein) in the posterior part of the divided SPS. However, there is ample space to do this in only about 20% of cases. In other cases, the entry of the superior petrosal vein is at the level of Meckel's cave or at a point somewhere between Meckel's cave and the IAM. The risk of permanent vascular complications from sacrificing the superior petrosal vein probably is very low, so when the superior petrosal vein hinders visibility, it is best to coagulate and divide it. A later modification of the approach was to cut the tentorium from the tentorial edge medially, behind the entry point of the trochlear nerve, toward the SPS at the posterior level of the trigeminal nerve, and hold the two tentorium flaps aside with stitches. MacDonald et al. advised opening the dura in an inverted Y shape, pulling one dura flap down, so as to be able to put a retractor under the temporal lobe, flush to the temporal cranial base. Additional space is gained by cutting the tentorium twice: one cut starts just behind the entry of the trochlear nerve, traversing posterolaterally medial to the SPS and the petrous ridge; and one smaller cut is made perpendicular to the first in an anterolateral direction, running laterally to the trigeminal nerve and dividing the SPS just lateral to the trigeminal nerve. One tentorium flap containing the trochlear nerve can be retracted anteriorly with a stitch, and the posterior tentorium flap can be retracted posteriorly also with a stitch (Figure 2). If necessary, the parasellar region can be reached by opening the sylvian fissure.

Clinical Applications

Basilar Trunk Aneurysms

The Kawase approach is ideal for retrosellar and retroclival lesions in or near the midline. It can reach the area from the level of the sellar floor to the floor of the IAM. The distance from the sellar floor to the floor of the IAM, known as the K1 line, measures, on average, 18 mm (range, 15–22 mm). This makes the Kawase approach the only reasonable approach for basilar trunk aneurysms located within the K1 line, especially for posterior-pointing aneurysms.

Basilar Aneurysms in the Retrosellar Region

For basilar aneurysms in the retrosellar region, the transcavernous approach offers more advantages. However, drilling of a long posterior clinoid process up to the level

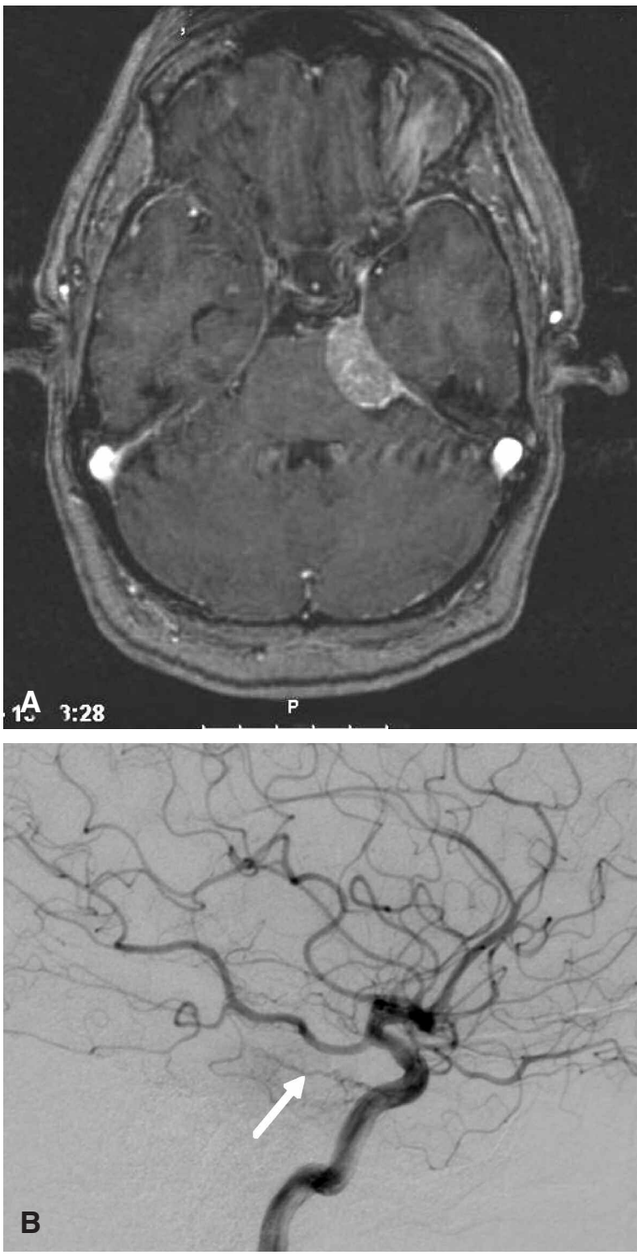

Figure 3. Patient 1. *A*, MRI scan showing tentorial type petroclival meningioma. *B*, Angiogram showing meningohypophyseal trunk (*arrow*) feeding the tentorial type petroclival meningioma.

of the sella floor can be difficult, with the length ranging from 6 to 10 mm, and bleeding from the retrosellar basilar venous plexus could be difficult to manage. The transcavernous approach may be combined with the Kawase approach in the event temporary clipping of the basilar artery is considered necessary and is not feasible via the transcavernous approach alone. For lesions below the K1 line, other cranial base approaches should be considered, such as the retrosigmoid approach, the presigmoid approach, or the transcondylar approach, eventually combined with drilling of the jugular tubercle.

Figure 4. Patient 1. Postoperative MRI scan showing the removal of the tumor. A very small remnant probably is left in the superior petrosal sinus.

Petroclival Meningiomas

The Kawase approach also can be used for petroclival meningiomas originating medially to the trigeminal nerve in the petroclival junction in the upper two thirds of the clivus. Four types of petroclival meningiomas can be distinguished:

- Upper clival type, in the midline, displacing the trigeminal nerve laterally;
- Cavernous sinus type or sphenopetroclival meningioma, extending in the cavernous sinus and encasing the carotid artery;
- Tentorial type, originating from the tentorium near the SPS and displacing the trigeminal nerve caudally, with high incidence of retrograde invasion of Meckel's cave; and
- Petrous apex type, originating from the dura of the petrous pyramid lateral to the trigeminal nerve and medial to the facial nerve, often extending into the IAM.

Meningiomas arising in the lower third of the clivus are foramen magnum meningiomas. The Kawase approach is indicated for medially extending petroclival meningiomas, not extending below the IAM. Another advantage is that the main feeders from the meningohypophyseal trunk can be eliminated in an early stage. If that patient has nonfunctional hearing, the petrous resection can be extended posteriorly by removing the superior and posterior semicircular canal and the mastoid, or a total petrosectomy could be considered. The transcavernous

Figure 5. Patient 2. MRI scan showing large left pontine cavernoma.

Figure 6. Patient 2. Postoperative MRI scan showing complete resection of the left pontine cavernoma.

approach is an alternative for tumors extending in the cavernous sinus. For large retroclival meningiomas extending below the K1 line, the Kawase approach can be combined with a posterior petrosal approach or a standard retrosigmoid approach.

Case Presentations

Patient 1

A 59-year-old woman underwent surgery for a tentorial-type petroclival meningioma fed by a hypertrophic tentorial branch of the meningohypophyseal trunk (Figure 3). Subtotal resection applying the Kawase approach was possible, probably leaving a small remnant in the posterior part of the SPS (Figure 4). Preoperatively, the patient had ipsilateral facial dysesthesia and pain, which resolved after the operation. She recovered uneventfully, with the exception of trochlear nerve palsy with some double vision, which was operatively corrected by the ophthalmologist. Histologic analysis showed a grade I meningioma.

Patient 2

A 54-year-old woman underwent surgery for a large cavernoma in the left side of the pons (Figure 5). She had reported ipsilateral facial numbness and mild ataxia, which resolved after the cavernoma was removed using the Kawase approach. She recovered uneventfully, with the exception of a period of diminished lacrimation of the ipsilateral eye for several months, although the GSPN had been left anatomically intact during the operation. A postoperative MRI scan showed complete removal of the cavernoma (Figure 6). Histologic analysis confirmed the diagnosis of cavernoma.

Conclusion

The Kawase approach is very useful for retroclival lesions extending from a line behind the level of the sellar floor to the floor of the IAM (K1 line). It is especially indicated for medially or paramedially located lesions and for intrinsic lesions in the petrous apex or lateral pons. In more extensive lesions, the approach can be combined with other cranial base approaches. Because of the complex anatomy of the temporal bone and of the extradural and intradural steps of the approach, the Kawase approach should first be practiced thoroughly in the laboratory on cadaveric heads and during hands-on courses before the surgeon uses it in patients.

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1. The superior petrosal vein usually enters the superior petrosal sinus at the level of the internal acoustic meatus or more posteriorly.

True or False?

2. The lowest point of the K1 line is at the level of the floor of the internal acoustic meatus.

True or False?

3. In approximately 85% of cases, the geniculate ganglion is not covered by bone.

True or False?

4. Opening of the semicircular canals always leads to deafness.

True or False?

5. The arcuate eminence covers the lateral semicircular canal.

True or False?

6. The Kawase approach is very useful for medially or paramedially located retroclival lesions within the K1 line.

True or False?

7. The transcavernous approach usually is the most appropriate choice for basilar aneurysms with the neck located in the retrosellar region.

True or False?

8. Traction on the greater superior petrosal nerve may cause deafness.

True or False?

9. For retroclival lesions located below the level of the floor of the internal acoustic meatus, a posterior petrosal approach or a transcondylar approach should be considered.

True or False?

10. Drilling lateral to the petrous carotid increases the risk of nasal liquorrhea.

True or False?