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ORIGINAL ARTICLE

Trans-cerebellomedullary fissure approach with special reference to lateral route

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Abstract The trans-cerebellomedullary fissure (CMF) approach provides good exposure of the fourth ventricle without splitting the inferior vermis. The popularly utilized trans-CMF approach is performed in the midline suboccipital approach. However, the trans-CMF approach actually has two routes: medial and lateral. The lateral route is the trans-CMF approach through a lateral foramen magnum approach such as the transcondylar approach, opening the CMF from the lower unilateral side. We studied the surgical anatomy of the CMF and fourth ventricle. Based on the anatomic findings, we adopted the lateral route of the trans-CMF approach for four patients, each with a tumor near the jugular tubercle extending into the fourth ventricle through the CMF. Our study demonstrated that the lateral route of the trans-CMF approach enables sufficient exposure of not only unilateral cerebellopontine cistern but also of the lateral part of the fourth ventricle. A tumor is safely removed by this approach with easy feeder or tumor bed controls, especially if it is anchored at the lateral part of the CMF as is the jugular tubercle meningioma.

Keywords Cerebellomedullary fissure · Fourth ventricle · Lateral recess · Lateral route · Transcondylar fossa approach

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Introduction

The trans-cerebellomedullary fissure (CMF) approach [10, 12, 18] provides good exposure of the fourth ventricle without splitting the inferior vermis, which occasionally results in the so-called postoperative vermian split syndrome [3, 4, 8]. Precise dissection and opening of the CMF, which is the entrance of the ventricle, offer a sufficient operative view not only of the medial region of the ventricle but also of the lateral part of the fissure and the deep area toward the cerebral aqueduct. The popularly utilized trans-CMF approach is performed in the midline suboccipital approach. However, the trans-CMF approach actually has two routes: medial and lateral. The medial route is the trans-CMF approach in the midline suboccipital approach, opening the CMF from the lower medial portion. On the other hand, the lateral route is the trans-CMF approach through the lateral foramen magnum approach such as transcondylar fossa [5, 9, 11, 15, 16, 22] and transcondylar [1, 2, 21, 24] approaches, opening the CMF from the lower unilateral side. We operated on four patients through the lateral route of the trans-CMF approach. We report these cases with a study of the surgical anatomy and discuss the efficacy of the lateral route of the trans-CMF approach.

Materials and methods

We studied the surgical anatomy of the CMF using formalin-fixed cerebellar specimens. We also examined appropriate surgical approaches for lesions involving the fourth ventricle and surrounding neural and vascular structures. Based on our findings, we adopted the trans-CMF approach through the lateral route for four patients, each with a tumor near the jugular tubercle extending into the fourth ventricle through the CMF.

Results

Microsurgical anatomy of fourth ventricle

The fourth ventricular floor has a rhomboid shape. The rostral two thirds of the floor are posterior to the pons, and the caudal one third is posterior to the medulla. Its cranial apex is at the level of the cerebral aqueduct; its caudal tip, the obex, is located at the rostral end of the remnant of the spinal canal, anterior to the foramen of Magendie, and its lateral angles open through the lateral recesses and foramina of Luschka into the cerebellopontine angles. The stria medullaris crosses the floor at the level of the lateral recess. A line connecting the orifices of the lateral recesses is located at the level of the junction of the caudal and the middle third of the length of the floor and also at the level of the junction of the pons and the medulla.

The inferior portion of the roof slopes sharply ventral and slightly caudal from the fastigium to its attachment at the inferolateral borders of the floor. The ventricular and cisternal surfaces are formed by the same structures, the tela choroidea and the inferior medullary velum, except in the rostral midline, where the ventricular surface is formed by the nodule and the cisternal surface is formed by the uvula. The choroid plexus projects from the ventricular surface of the tela choroidea into the fourth ventricle. The line of attachment of the inferior medullary velum to the tela choroidea, the telovelar junction, extends from the nodule into each lateral recess. The tela choroidea sweeps inferiorly from the telovelar junction around the superior pole of each tonsil to its attachment at the inferolateral edges of the floor along narrow white ridges, the tenia, which meet at the obex.

The lateral recesses are narrow, curved pouches formed by the union of the roof and the floor. They extend laterally below the cerebellar peduncles and open through the foramina of Luschka into the cerebellopontine angles. The rostral wall of each lateral recess is formed by the caudal margin of the cerebellar peduncles. The caudal wall is formed by the tela choroidea, which stretches from the lateral part of the tenia to the peduncle of the flocculus. The biventral lobule is dorsal to the lateral recess. The flocculus is superior to the outer extremity of the lateral recess. The rootlets of the glossopharyngeal and vagus nerves rise ventral to and the facial nerve rises rostral to the lateral recess. The fibers of the vestibulocochlear nerve cross the floor of the recess (Fig. 1a).

Microsurgical anatomy of cerebellomedullary fissure

The slit space between the tonsil and the medulla oblongata is the CMF, which has been called the posterolateral fissure. The fissure extends rostrally to the fastigium and laterally into the cerebellomedullary and cerebellopontine cisterns. The trans-CMF approach to the fourth ventricle has two routes: medial and lateral (Fig. 1b). When the tonsil and part of the biventral lobule are removed, the floor of the fissure is visible (Fig. 1c). The floor of the fissure, which is also the roof of the fourth ventricle, is composed of the tela choroidea and the inferior medullary velum. The tela choroidea is attached to the medulla oblongata inferolaterally by the tenia and extends laterally to form the roof of the lateral recess. The anterior wall of the lateral recess is formed by the flocculus and the middle cerebellar peduncle. The lower cranial nerves run anteriorly to the lateral recess (Fig. 1d).

Lateral surgical route to fourth ventricle; transcondylar fossa approach

A patient is set in the prone or lateral recumbent position. Skin and muscles are cut together in the shape of a horseshoe and are entirely reflected posteriorly from the suboccipital surface. The posterior condylar emissary vein is coagulated and cut above the vertebral venous plexus. A unilateral suboccipital craniotomy is performed. The craniotomy extends from the midline superomedially to the sigmoid sinus laterally and along the foramen magnum across the midline to the opposite side inferiorly. The condylar fossa superior to the posterior condylar canal, which is the posterior portion of the jugular tubercle, is extradurally drilled and removed, in sight of the canal as an anatomic landmark. Finally, the jugular tubercle located above the hypoglossal canal is drilled away (Fig. 2a–c). No stabilization procedure is needed after the completion of the drilling.

This approach provides a sufficient operative view of lesions situated around the jugular foramen and lateral part of the medulla oblongata. The operative space is wide, and the lesion is close to the surgeon. With a slight retraction of cerebellum after the lateral part of the CMF is dissected, the entire courses of the ninth and tenth cranial nerves and lateral recess of the fourth ventricle are visible (Fig. 2d). More dissection of the CMF provides a view of the tenia and the foramen of Magendie from the lateral side.

Our clinical experience

Patient 1 (left jugular tubercle meningioma) A 58-year-old woman was hospitalized because ataxic gait had gradually worsened in the previous 3 months. Magnetic resonance image (MRI) with contrast enhancement showed a round homogeneously enhanced tumor attached to the left jugular tubercle. The tumor extended into the left CMF and compressed the medulla oblongata (Fig. 3a). The patient underwent surgical treatment. The patient was set in the semiprone park bench position. The tumor attached to the

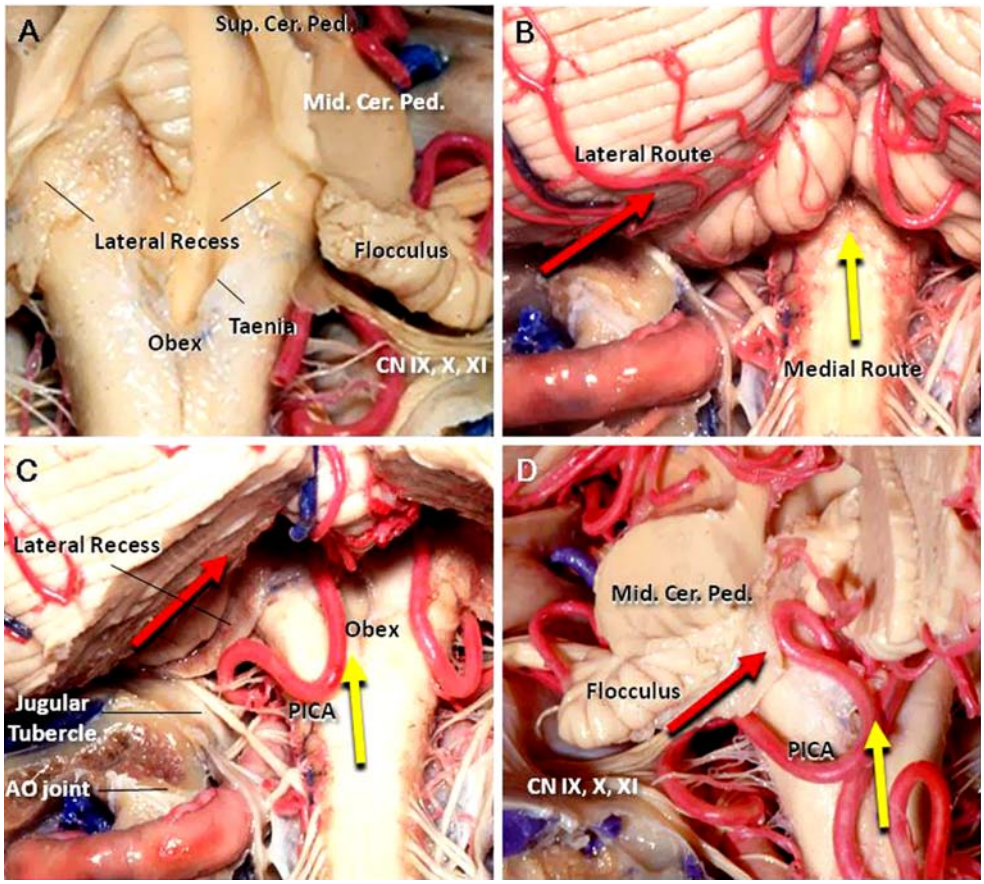

Fig. 1 **a** Anatomy of fourth ventricular floor. **b** Medial (*yellow arrow*) and lateral (*red arrow*) routes of the trans-cerebellomedullary fissure approach in a cadaveric specimen. **c** Lower part of the cerebellum is removed. The medial route (*yellow arrow*) accesses the floor of the fourth ventricle through the obex; whereas, the lateral route (*red arrow*) accesses it through the lateral recess. **d** The left cerebellar hemisphere is removed. The lateral (*yellow arrow*) and medial (*red arrow*) routes to the fourth ventricular floor are clearly visualized. *AO* atlanto-occipital, *Cer.* cerebellar, *CN* cranial nerve, *Mid.* middle, *Ped.* peduncle, *PICA* posterior inferior cerebellar artery, *Sup.* superior

left jugular tubercle was safely detached through a left transcondylar fossa approach by drilling the left condylar fossa and jugular tubercle. The medial part of the tumor, which extended into the left CMF and unilateral part of the fourth ventricle, was completely removed through a lateral route of the trans-CMF approach by opening the lateral part of the left CMF and lateral recess (Fig. 3b–d). The tumor was totally removed. Postoperative course was uneventful.

Patient 2 (left recurrent jugular tubercle meningioma) A 56-year-old man suffered from difficulty walking due to cerebellar ataxia that occurred 12 years before. MRI revealed a huge left cerebellopontine angle meningioma. The tumor was subtotally removed through a left lateral suboccipital approach during the first operation. The patient had right hemiparesis and symptoms related to cranial nerves V-X postoperatively, all of which gradually disappeared. A second operation for recurrent meningioma was performed through the lateral suboccipital approach 10 years after the first operation. Only a part of the tumor was removed. The patient had severe dysphagia and cerebellar ataxia postoperatively. During the follow-up period, a second recurrence was observed on the MRI 1.5 years after the second operation (Fig. 4a, b). The tumor extended into the fourth ventricle through the left CMF. Therefore, we applied the lateral route of the trans-CMF approach. The tumor in the fourth ventricle was completely removed through the lateral route of the trans-CMF approach (Fig. 4c, d). Postoperative course was uneventful.

Patient 3 (right cerebellar ependymoma) A 1-year-and-10-month-old boy was hospitalized because of headache, vomiting, and difficulty walking. MRI showed a hypointensity mass on a T1-weighted image, which was mainly located in the right cerebellomedullary and cerebellopontine cisterns and compressed the medulla oblongata to the left (Fig. 5a). The tumor also extended into the fourth ventricle through the right CMF, and extension of the tumor was confirmed during surgery (Fig. 5b). The mass was located mostly in the right cerebellomedullary and cerebellopontine cisterns, but it originated from the wall of the fourth ventricle near the right lateral recess. The tumor filled the right lateral recess connecting the ventricular interior and the cistern (Fig. 5c, d). The tumor was subtotally removed, and the histopathological diagnosis was ependymoma. Postoperative course was uneventful.

Patient 4 (left hypoglossal neurinoma) A 32-year-old woman had a sudden onset of vertigo and nausea 2 months before admission to our hospital. The left side of her tongue showed mild atrophy. MRI with contrast enhancement

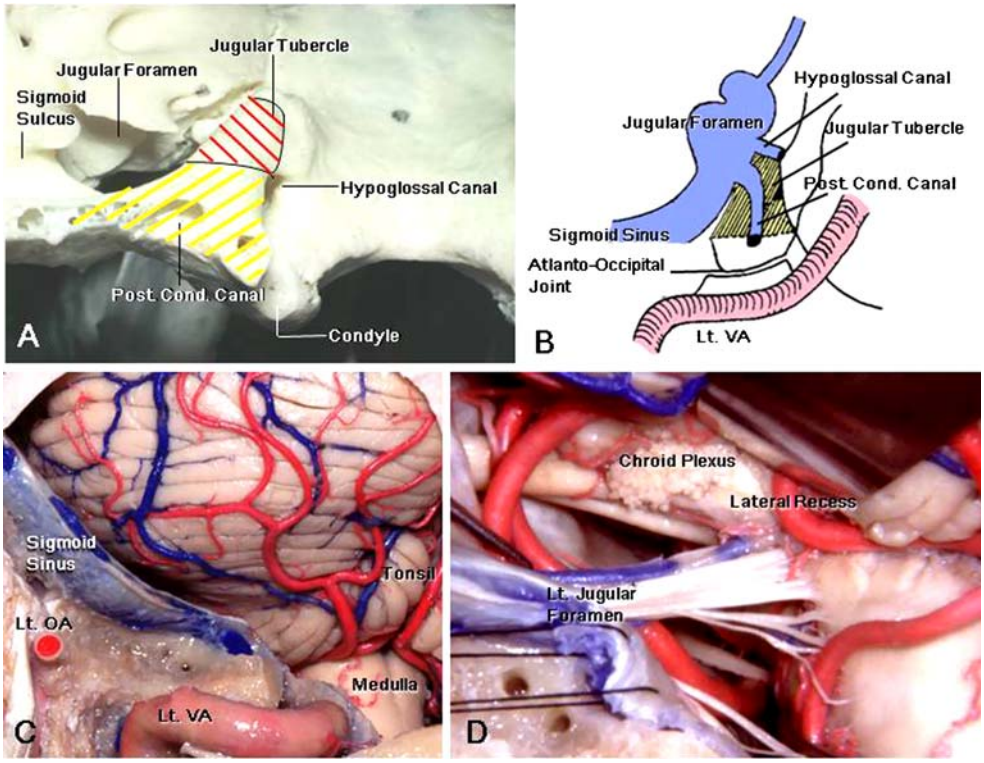

Fig. 2 Transcondylar fossa approach (*left side*). **a** The *yellow oblique lines* indicate the removal of the condylar fossa superior to the posterior condylar canal, which is the posterior portion of the jugular tubercle. Then, the jugular tubercle located above the hypoglossal canal is drilled away (*red oblique lines*). **b** A schematic illustration shows the basic amount of bone removed during the transcondylar fossa approach. The *oblique lines* indicate the removal of the posterior portion of the jugular tubercle in this approach, which is superior to the posterior condylar canal. The atlanto-occipital joint is thus kept intact. **c** A unilateral suboccipital craniotomy is performed. The condylar fossa superior to the posterior condylar canal is drilled extradurally and removed. The jugular tubercle located above the hypoglossal canal is drilled away. **d** The lateral portion of the fourth ventricle exposed through the lateral route. This approach provides a sufficient operative view of lesions situated around the jugular foramen and lateral part of the fourth ventricle. Opening the lateral part of the cerebellomedullary fissure enables a surgeon to access the fourth ventricle through the lateral route. *Lt.* left, *OA* occipital artery, *Post.* posterior, *VA* vertebral artery

showed a round, partially enhanced cystic tumor, which extended into the left CMF and compressed the medulla oblongata. The tumor was located in the intracranial and extracranial regions, showing a dumbbell shape, through the dilated left hypoglossal canal (Fig. 6a). The preoperative diagnosis was hypoglossal neurinoma. The patient underwent surgical treatment through a left transcondylar approach by drilling the left condylar fossa, jugular tubercle, and posterior condyle. The tumor, which extended into the extracranial part, was observed when the left hypoglossal canal was opened. The intracranial part of the tumor was located mainly in the left CMF (Fig. 6b). The origin of the tumor was the left hypoglossal nerve, which was observed on the surface of the tumor. The lateral part of the tumor was continuous to the left hypoglossal canal. Medial part of the tumor extended into the unilateral part of the fourth ventricle through the lateral recess (Fig. 6c). First, internal decompression was performed by removing the cystic content of the tumor. Then, the shrunk tumor was detached from surrounding structures including medulla oblongata, lateral recess of the fourth ventricle, lower cranial nerves, and vertebral artery and its branches. The medial part of the tumor was completely removed through a lateral route of the trans-CMF approach after the lateral part of the left CMF was opened. Finally, the intracranial part of the tumor was totally removed (Fig. 6d). The tumor located in the left hypoglossal canal was removed intra- and extradurally. The extracranial tumor was not treated at this time, which will be treated by an otorhinolaryngologist. The patient suffered from transient dysphagia postoperatively, which disappeared after a while.

Discussion

Evaluation of the fourth ventricle by a microscopic survey revealed detailed anatomical information for neurosur-

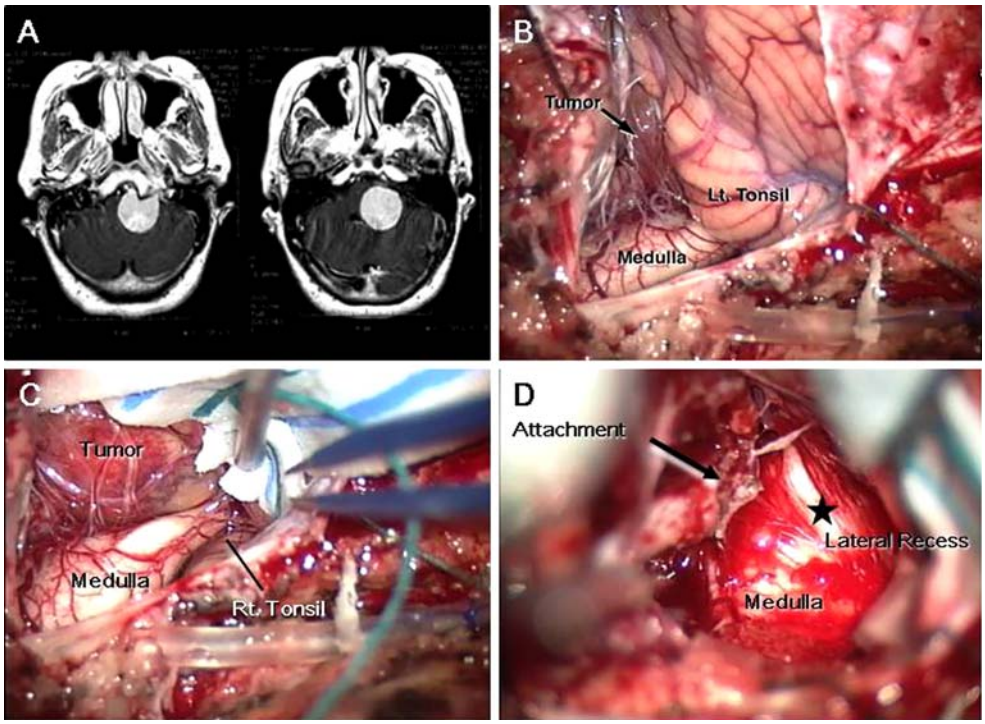

Fig. 3 A case of left jugular tubercle meningioma. **a** Magnetic resonance images with contrast enhancement. They show a round homogenously enhancing mass attached to the left jugular tubercle. The tumor extends into the left cerebellomedullary fissure (CMF) and compresses the medulla oblongata. **b** Intraoperative view 1. When the dura mater is opened, a mass is found in the cerebellomedullary cistern (*arrow*). **c** Intraoperative view 2. The meningioma attached to the left jugular tubercle extends into the left CMF. The right tonsil is visible. **d** Intraoperative view 3. The tumor was totally removed. The left lateral recess of the fourth ventricle (*asterisk*) seen through the lateral route. *Rt.* right

geons. One of the important anatomical structures for fourth ventricle surgery is the CMF, which is the only entrance or exit. The fissure is surrounded rostrally by tonsils and the biventral lobules and caudally by the medulla oblongata, tela choroidea, and lateral recess. The lower part of the cerebellum and brainstem can be easily separated by dissecting the entire CMF. The importance of this fissure and the approach using the fissure have been reported in cadaveric and clinical studies [7, 10, 12–14, 17–20, 25, 26].

The trans-CMF approach can avoid splitting the vermis on the suboccipital surface of the cerebellum, which is associated with development of cerebellar mutism [3, 4, 8].

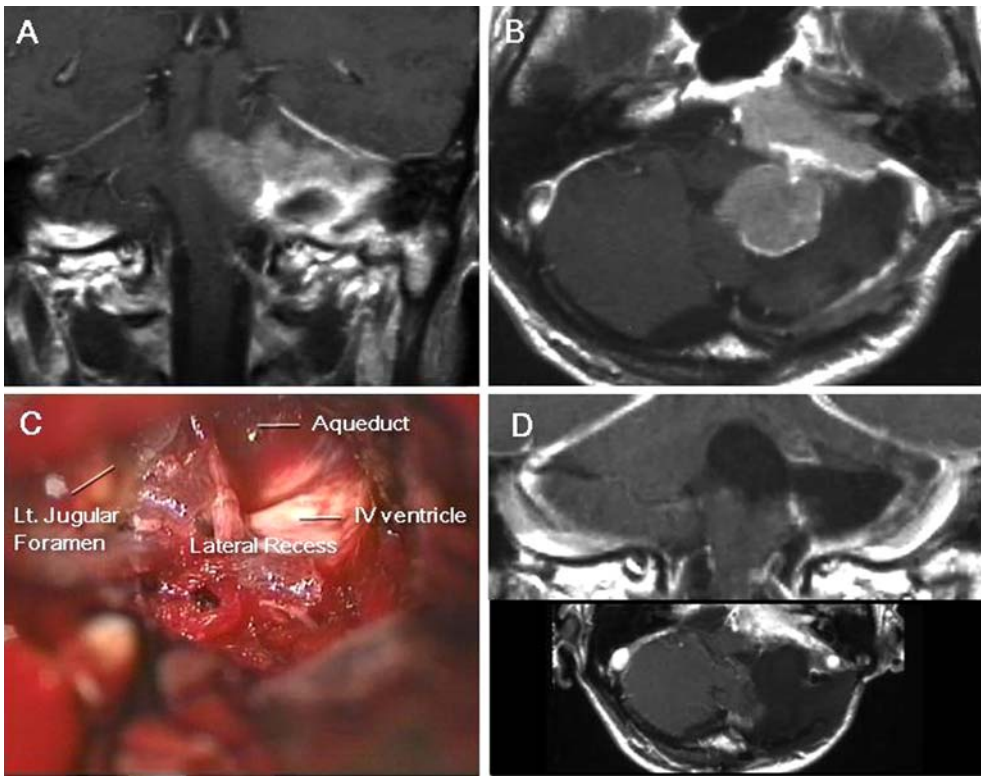

Fig. 4 A case of left recurrent meningioma. **a** and **b**. Magnetic resonance image (MRI) with contrast enhancement. It shows a papillary enhanced tumor, which extends into the left cerebellomedullary fissure (CMF) as well as the fourth ventricle. **c** The tumor, which extended into the left CMF and unilateral part of the fourth ventricle, was completely removed through a lateral route of the trans-CMF approach. **d** MRI with contrast enhancement shows complete removal of the recurrent tumor. *Lt.* left

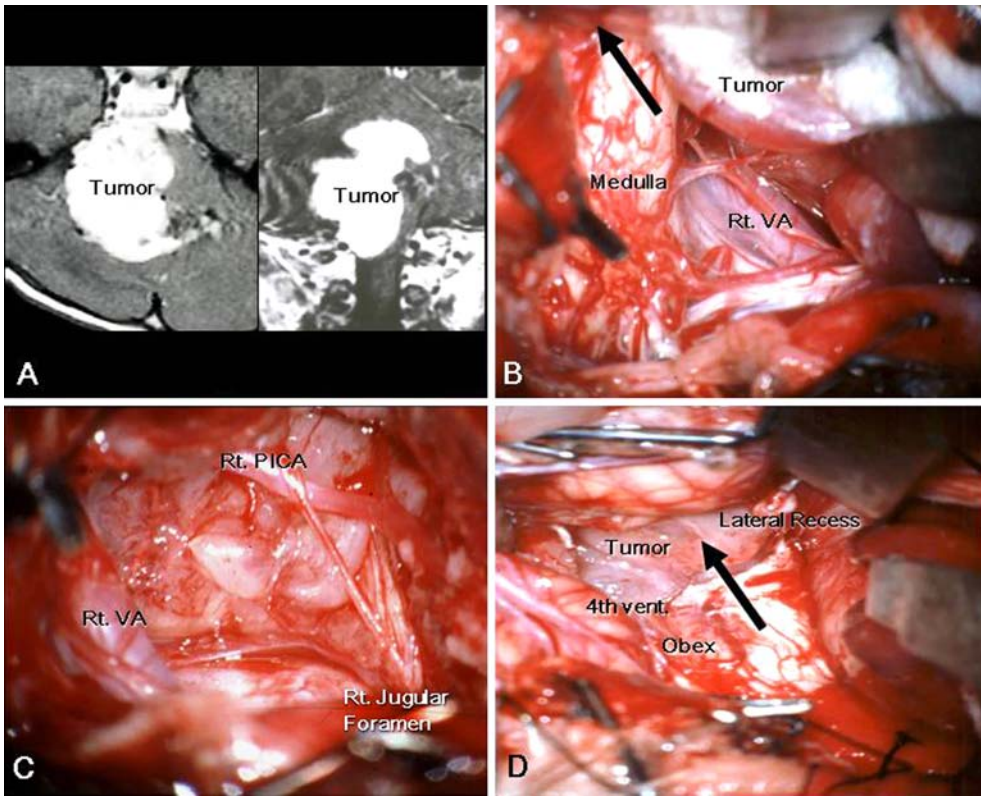

Fig. 5 A case of right cerebellar ependymoma. **a** Magnetic resonance image with contrast enhancement (axial and coronal images). It shows an enhanced mass, which is located in the right cerebellomedullary and cerebellopontine cisterns, and compresses the medulla oblongata to the left. **b** Intraoperative view 1. The tumor extends into the fourth ventricle through the right cerebellomedullary fissure (*arrow*). The right cerebellomedullary cistern and right vertebral are observed by retracting the tumor upward. **c** Intraoperative view 2. The tumor extends into the lateral part of the fourth ventricle beyond the lower cranial nerves. **d** Intraoperative view 3. The tumor originates from the wall of the fourth ventricle near the right lateral recess. The tumor extends from the fourth ventricle into the cerebellomedullary cistern through the lateral route (*arrow*). *Rt.* right, *Vent.* ventricle

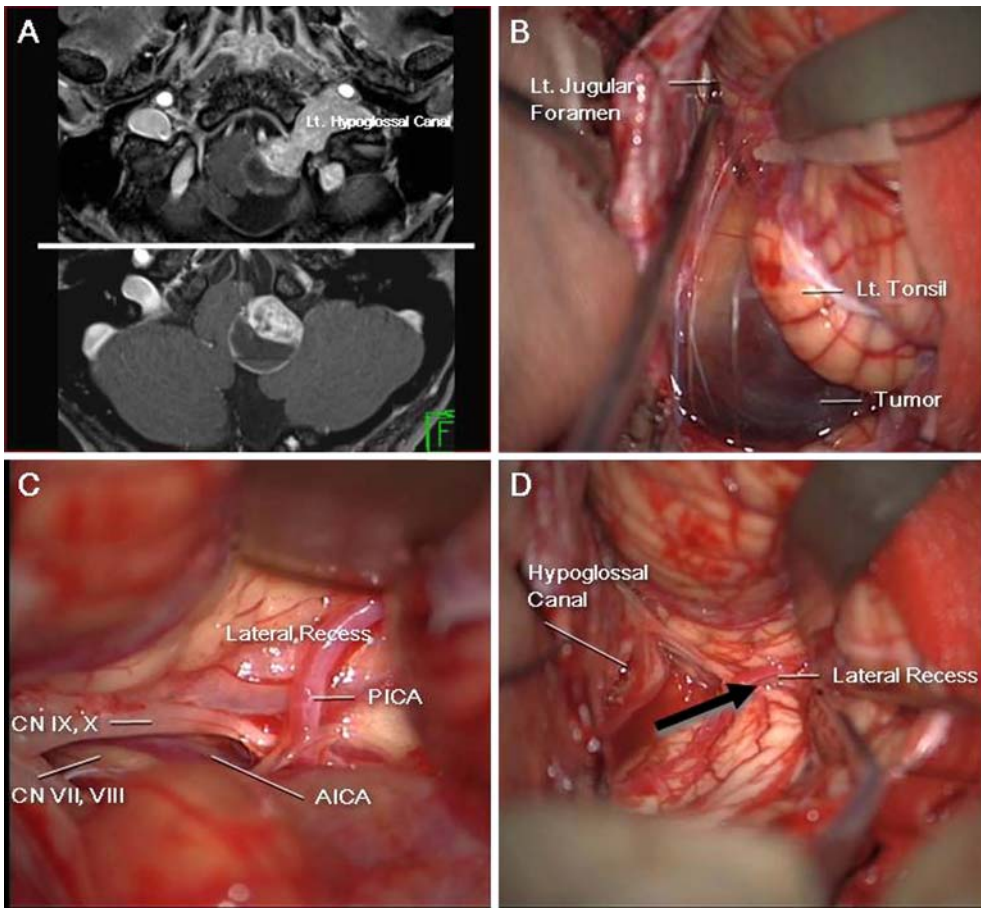

Fig. 6 A case of left hypoglossal neurinoma. **a** Magnetic resonance image with contrast enhancement. The tumor is located in the intracranial and extracranial regions, showing a dumbbell shape, through the dilated left hypoglossal canal. The tumor shows a round partially enhanced cystic tumor, which extends into the left cerebellomedullary fissure and compresses the medulla oblongata. **b** Intraoperative view 1. When the dura mater is opened, a cystic mass is found in the cerebellomedullary cistern. **c** Intraoperative view 2. The tumor extends into the left lateral recess of the fourth ventricle. **d** Intraoperative view 3. The tumor was totally removed. The lateral part of the fourth ventricle seen through the lateral route (*arrow*)

In his laboratory work concerning the microsurgical anatomy of the posterior fossa, one of our authors, Matsushima et al., reported that opening both the tela choroidea and inferior medullary velum and extending the lateral recess laterally toward the foramen of the Luschka expose the ventricle cavity from aqueduct to obex and laterally to the peduncular surface bordering the recess [10, 18]. Additionally, in their cadaveric and clinical studies related to lesions involving the fourth ventricle, Matsushima et al. also classified exposure to the fourth ventricle into three types: extensive opening, lateral wall opening, and lateral recess opening [12]. Tanriover et al. reported the microanatomy and exposures gained through the trans-CMF and transvermian approaches [23]. Both approaches provide access to the entire width of the floor of the fourth ventricle. The major difference between the two approaches is exposure of the lateral recess and the foramen of the Luschka. The trans-CMF approach, even in the midline suboccipital approach, exposes the lateral and superolateral recesses and the foramen of the Luschka. It allows observation of the lateral end of the fourth ventricular lesion. The trans-vermian approach, which offers an incision through at least the lower third of the vermis, affords a modest increase of the operator's working angle compared to the trans-CMF approach when accessing the rostral half of the fourth ventricle. The trans-CMF approach has the advantage of accessing the lateral part of the fourth ventricle [12, 23]. According to Ikezaki et al., lateral-type tumors arising from the vestibular area and/or the lateral recess showed a significantly lower 5-year cumulative survival rate and mean survival time (21% and 40 months) when compared to mid-floor-type tumors originating from the caudal half of the fourth ventricular floor beneath the striae medullaris (73% and 170 months) [6]. The importance of the entire exploration should be emphasized when lesions involving the fourth ventricle are treated surgically.

The trans-CMF approach is usually performed through the medial route, which starts between tonsils and the medulla oblongata toward the obex. On the other hand, in some cases, when the lesion is located mainly in the unilateral cerebellomedullary cistern and occupies the lateral part of the ventricle cavity partially, we use the trans-CMF approach through the lateral route after the lateral foramen magnum approach. This is quite natural when inferior and inferolateral extensions of the ependymomas through the CMF are considered. This approach is applied to tumors including epidermoid, ependymoma, neurinoma, and meningioma. Especially in cases of meningioma originating from the jugular tubercle and neurinomas originating from jugular foramen or hypoglossal canal, all of which are anchored at the lateral part of the CMF, the tumor can be totally removed only through this combined approach. It might be troublesome to treat such tumors by the trans-CMF approach through the medial route, making feeding artery or tumor bed control difficult. In none of these cases do we need bilateral tonsillouvular dissection. When the tumor extends into the unilateral cerebellomedullary cistern through the CMF, it frequently expands the unilateral CMF, which enables easy dissection. In every case, we first dissect the cistern followed by exploration of the unilateral lateral recess into the fourth ventricular floor. The trans-CMF approach through the lateral route provides not only unilateral exposure of the CMF around the jugular foramen but also midline exposure of the fourth ventricle.

The posterior inferior cerebellar artery and its branches might be engulfed or displaced by the tumor, which has to be taken into consideration during dissection and removal of the mass in the CMF. Damage to the lower cranial nerves and vertebral artery should also be avoided.

While avoiding damage to delicate structures, complete resection of the tumor and improving operative outcome depend on a clear knowledge of the microanatomical relationships between the tumor and surrounding structures that might be supplied by operative exposure. Our study demonstrates that the trans-CMF approach through the lateral route enables sufficient exposure of not only the unilateral cerebellopontine cistern but also the lateral part of the fourth ventricle.

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Comments

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Evandro de Oliveira, São Paulo, Brazil

The authors report their experience with the lateral route of the trans-CMF approach to the fourth ventricle. The approach was used for tumors occupying the region of the jugular tubercle and extending to the lateral portion of the fourth ventricle. The transcondylar fossa approach was used to access the region of the jugular tubercle. The lateral recess was exposed by dissecting the cerebellomedullary fissure and opening the tela choroidea. The authors show that dissection of the CMF exposes the lateral recess from the flocculus to the inferior cerebellar peduncle with no need of resection or sacrifice of parts of the cerebellum. This study reinforces the usefulness of the CMF to gain access to the fourth ventricle as described by one of the authors (Toshio Matsushima) in previous publications.

Niklaus Krayenbühl, Zurich, Switzerland

Kawashima et al report their experience with the transcerebello-medullary fissure approach in treating four patients with tumors in the region of the lateral recess of the fourth ventricle. The trans-cerebellomedullary fissure approach is usually used in medial approaches to the fourth ventricle and has been well described in earlier publications by Toshio Matsushima, one of the Co-authors. This well written article with its description of the surgical anatomy and pictures of cadaver dissections illustrates nicely the advantages of this technique, when dealing with challenging lesions situated in the very lateral part of the fourth ventricle like meningiomas of the jugular tubercle, ependymomas or neurinomas.