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ORIGINAL ARTICLE

Exposure of the wide interior of the fourth ventricle without splitting the vermis: importance of cutting procedures for the tela choroidea

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Abstract In recent years, new procedures for fourth ventricular surgeries have been developed with good results. In particular, the trans-cerebellomedullary fissure approach, which exposes the fourth ventricle without splitting the inferior vermis, has proven successful. For optimum results, specialized techniques should be employed in order to effectively open the roof of the fourth ventricle and obtain a wide exposure of its interior. These techniques include the following steps: (1) placement of an incision over the teania extending from the foramen of Magendie to the ventricular entrance of the lateral recess; (2) lateral extension of the incision to the roof of the lateral recess to facilitate its exposure; (3) implementation of the same procedure on the contralateral side. Upon completion of these steps, the bilateral cerebellar tonsils can be easily retracted superolaterally; this eventually exposes a wide interior of the ventricle. In order to ensure successful surgeries, explicit and accurate descriptions of technique are vital. In this article, we employ detailed illustrations to precisely demonstrate the operative procedures and techniques for fourth ventricular surgeries.

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Introduction

Since the introduction of the trans-cerebellomedullary fissure approach (trans-CMF app) [9–11, 14, 15, 23], surgical procedures that do not require splitting of the inferior vermis to expose the fourth ventricle have been studied using cadaver specimens [1, 6, 8, 21, 25]. Achieving good results, these procedures are gaining popularity among the available surgeries for fourth ventricular tumours [2, 5, 8, 12, 13, 16–18, 22, 24, 26, 27]. One key benefit of these approaches is the avoidance of common complications such as cerebellar mutism, which is caused by the incision of the inferior vermis through the trans-vermian approach [3, 8, 16, 18, 23]. Furthermore, these procedures, which include the trans-CMF, CMF, and the telovelo approaches [8, 11, 14, 16, 21], are suitable for complete removal of fourth ventricular tumours by use of the lateral extension technique extending laterally into the cerebellomedullary cistern [9–11, 13, 15, 17, 18, 22, 24]. The conceptual framework of these approaches is well documented. However, adequate resources that explain, in detail, the technique of opening the roof of the ventricle are not available. Previous research has documented a few differences in the use of the CMF for exposing the fourth ventricle. In this article, with the inclusion of precise illustrations, we provide a thorough explanation of the actual operative procedures and techniques required to employ the medial route of the trans-CMF app. In addition, we emphasize the importance of sufficient

opening of the lateral recess to achieve adequate superolateral retraction of the cerebellar tonsils.

Basic knowledge of anatomy necessary before employing approaches that avoid splitting of the vermis

An overview of the anatomical landscape of the fourth ventricle will serve to clarify the surgical approach to the area. CMF is the fissure between the cerebellar hemisphere and the posterior surface of the medulla oblongata and the roof of the fourth ventricle (Fig. 1a). The floor of the fissure also serves as the inferior part of the roof of the ventricle, which is formed cranially by the nodule and inferior medullary velum and caudally by the tela choroidea. The tela choroidea is inferolaterally attached to the medulla oblongata by the taeniae, thus forming a V-shaped pattern (Fig. 1b). Rostrally, the taenia extends to the ventricular entrance of the lateral recess. The rhomboid lip of the lateral recess extends laterally from the rostral point of the taenia. The roof of the lateral recess is majorly composed of the tela choroidea and the choroid plexus with a small contribution from the inferior medullary velum.

The inferior vermis is sandwiched between the cerebellar tonsil, which is one of the major obstacle in accessing the ventricle. The greater part of the tonsil is free from the surrounding anatomy and is attached only at the superolateral portion; this attachment is referred to as the peduncle [20]. The uvulotonsillar space is present medial to the tonsil, whereas the medullotonsillar space lies inferior to it [16].

Classification of the methods used to expose the interior of the fourth ventricle through the trans-CMF app

In the trans-CMF app the opening portion of the fissure and roof of the ventricle depends on the target location and extent of required exposure. We have previously reported on the opening methods for the fissure via the medial route of the trans-CMF app [11, 16]. These methods are of three types: an extensive type (aqueduct type), a lateral wall type and a lateral recess type (Fig. 2). In subsequent research, we added the lateral route of the trans-CMF approach to the medial route [7, 19]. The medial route offers the widest exposure and is thus frequently used. We therefore demonstrate the technique of performing this opening method in the two cases described below with the help of detailed illustrations.

Illustrative cases

Case 1: cavernoma of the pons

The first case was that of a 66-year-old male patient who presented to us with a complaint of vomiting and drowsiness. Neurological examination revealed palsy of the sixth, seventh and ninth cranial nerves of the right side as well as left hemiparesis and cerebellar ataxia. His modified Rankin Scale score was 5. Computed tomography revealed haemorrhaging in the pons and upper medulla oblongata (Fig. 3a). Additionally, magnetic resonance imaging (MRI) indicated a mass that was suggestive of a cavernoma (Fig. 3b, c). In this case, the tumour majorly occupied the pons.

Midline suboccipital craniotomy with partial C1 laminectomy was initiated with the patient in the prone position. The medullotonsillar and uvulotonsillar spaces were partially dissected after exposing the cerebellar hemispheres, and the medulla oblongata, following which the right tonsil was detached from the medulla oblongata and uvula for adequate retraction (Fig. 4a, b). Following retraction, the posterior portion of the roof of the fourth ventricle became visible. The taenia was then incised from the foramen of

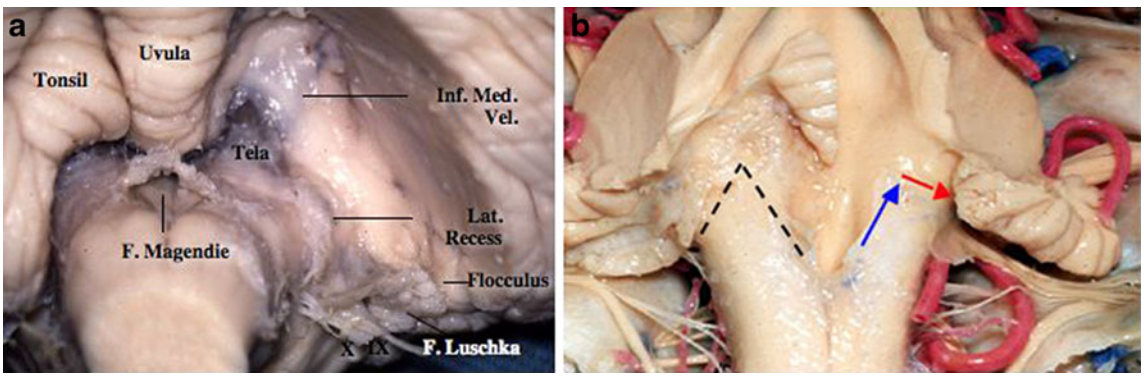


Fig. 1 The anatomy of the cerebellomedullary fissure. **a** The cerebellomedullary fissure. The right tonsil and a part of the biventral lobule have been removed. The cerebellomedullary fissure can be seen with the roof of the fourth ventricle forming its floor. The roof is formed rostrally by the inferior medullary velum and caudally by the tela choroidea. **b** The inferior half of the roof of the ventricle. The tela choroidea is attached to the medulla oblongata by the teaniae, and laterally extends to form the roof of the lateral recess. The *dot line* and *arrows* demonstrate an incisional line and its turns for opening of the roof

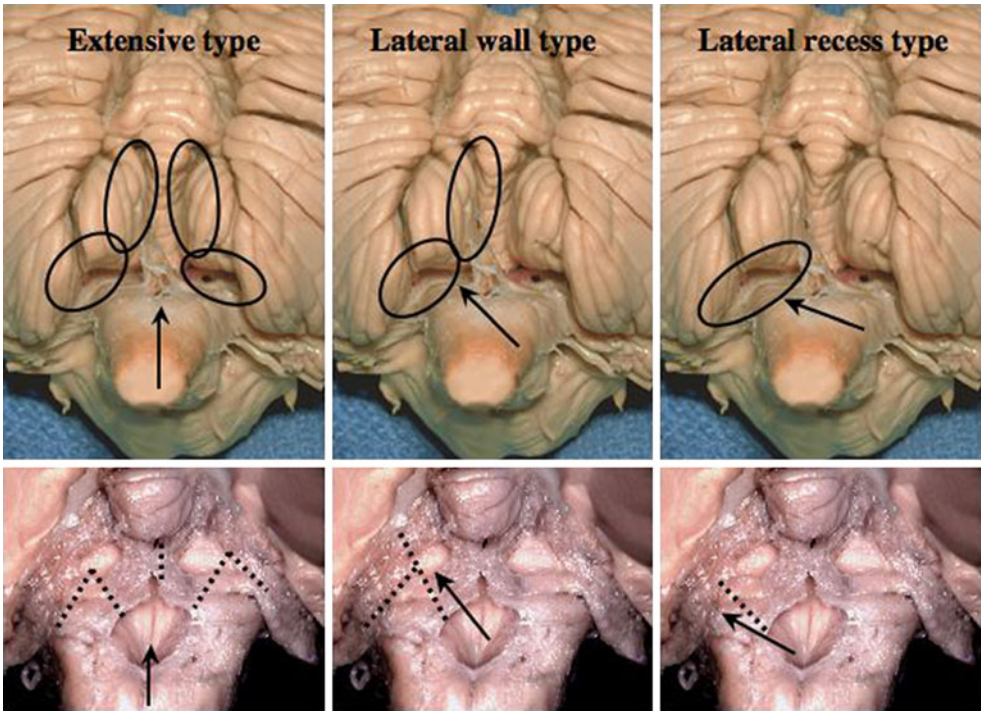


Fig. 2 Classification of the opening methods employed during the medial route of the trans-CMF app (from Matsushima et al. [16]). Three types of opening methods: extensive, lateral wall and lateral recess types

Magendie to the ventricular entrance of the lateral recess on the right side (Fig. 4c). This incision along the taeniae exposed the ventricular entrance of the lateral recess. Next, the cutting line was deviated laterally to the posterior margin of the lateral recess (Fig. 4d), which was also almost completely exposed. These steps made it possible for the ipsilateral tonsil to be retracted adequately in a superolateral direction. The inferior medullary velum was not incised. Those procedures were then repeated on the contralateral side. Ultimately, when the bilateral tonsils were retracted, nearly the entire floor of the fourth ventricle was exposed. The bulging hematoma was identified just superior to the facial colliculus in the upper right pons (Fig. 4e). When the right suprafacial triangle was incised, a haemorrhagic cavity and cavernoma were found. The

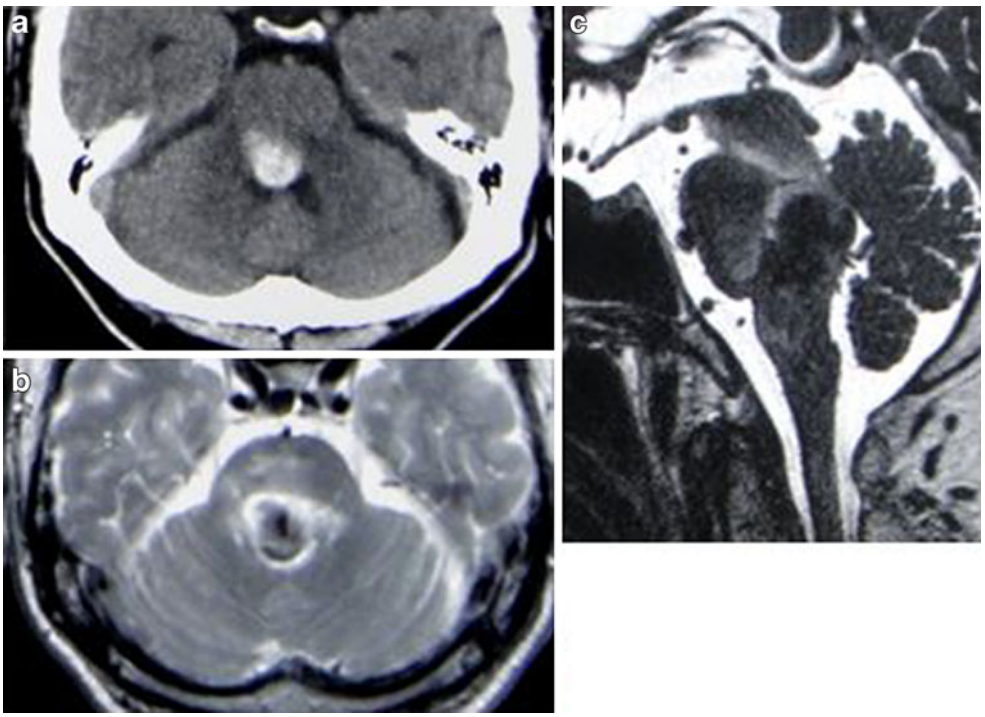


Fig. 3 Preoperative images in Case 1. **a** Plain CT demonstrating the haemorrhage in the pons. **b** MRI, T2-WI, axial view demonstrating a cavernoma with the haemorrhage. **c** MRI, T2-WI, sagittal view showing the posterior bulging of the pons and medulla oblongata into the fourth ventricle

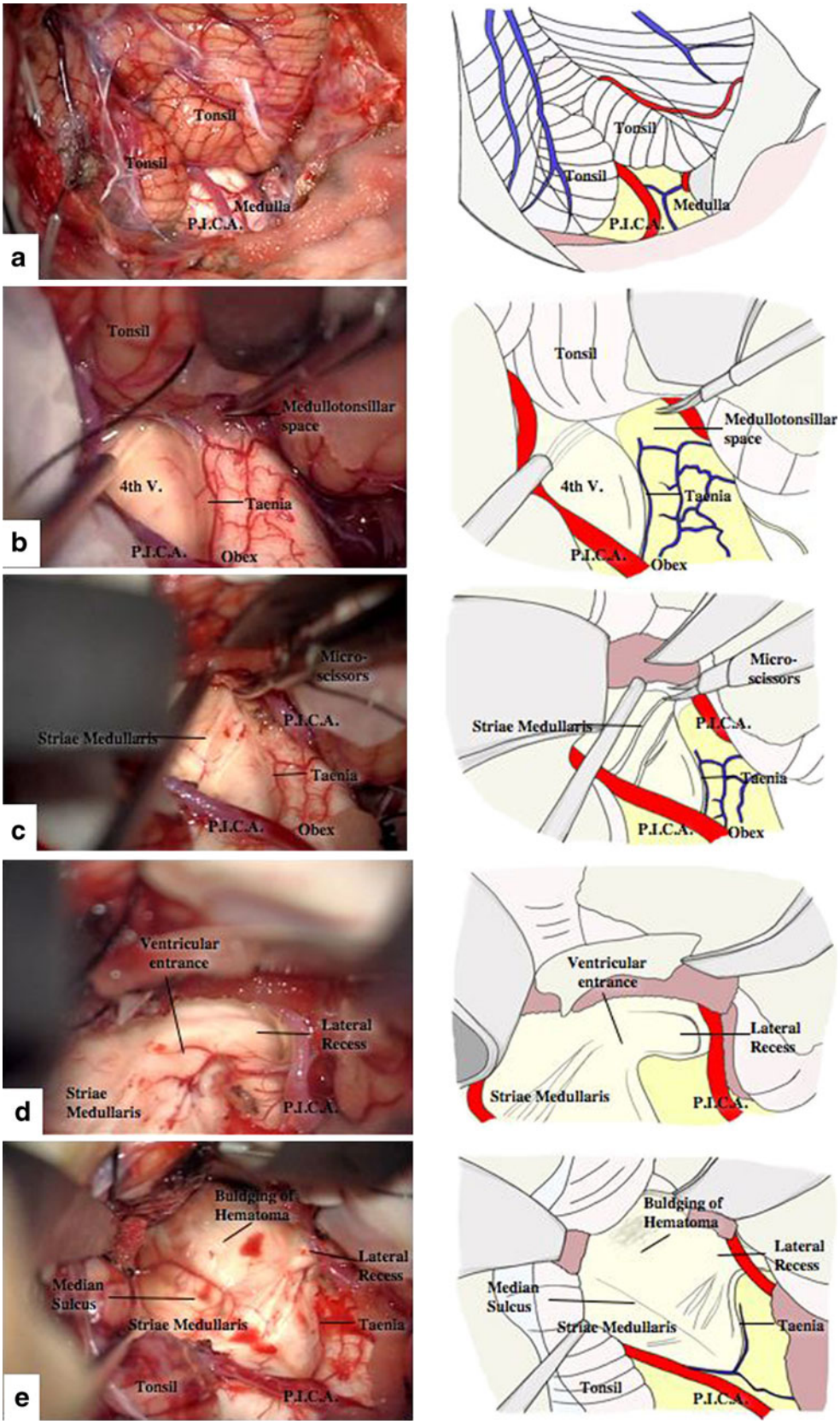


Fig. 4 Intraoperative photos of the step by step procedures employed in Case 1 along with their detailed illustrations. **a** The cerebellar hemispheres and medulla oblongata exposed after opening of the dura mater. **b** Separation of the medullotonsillar space on the right side. **c** Incision of the taenia to reach the ventricular entrance of the lateral recess on the right side. **d** Incision and opening of the roof of the lateral recess. The striae medullaris can be seen running into the lateral recess. **e** Exposure of the wide interior of the fourth ventricle with retraction of the tonsils on both sides. A bulging of the haemorrhage can be seen in the right suprafacial triangle of the floor

cavernoma was totally resected. Postoperative neurological findings were almost identical. Postoperative MRIs revealed a residual cavity consequential to the removal of the cavernoma and haemorrhage (Fig. 5). The inferior vermis was

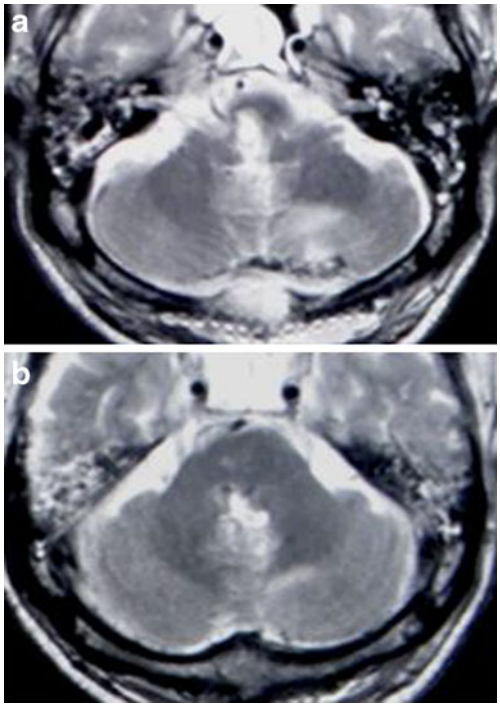


Fig. 5 Postoperative images in Case 1. **a** and **b** MRI, T2-WI, axial view demonstrating a postoperative cavity after removal of the cavernoma and the haemorrhage. The inferior vermis is intact

intact. The patient was discharged with a modified Rankin Scale score of 3.

Case 2: ependymoma of the fourth ventricle

The second case was that of a 34-year-old female patient who was referred to our department with a complaint of headache and ataxia. Neurological examination revealed cerebellar ataxia, and MRI revealed a mass in the fourth ventricle with obstructive hydrocephalus. The tumour was located mainly in the ventricle and extended inferiorly to the level of C2 and laterally to the left cerebellomedullary cistern (Fig. 6a, b, c).

Midline suboccipital craniotomy with partial C1 laminectomy was initiated with the patient in the prone position. The tumour was identified as a tongue-like protrusion from the ventricle that passed between the bilateral tonsils (Fig. 7a). First, the right medullotonsillar space was dissected to expose the cerebellomedullary fissure. The fibrous tissue in the space was cut to facilitate retraction of the right tonsil (Fig. 7b). At the same time, the right taenia was incised rostrally from the obex to the ventricular entrance of the right lateral recess (Fig. 7c). During these procedures, feeding arteries from the posterior inferior cerebellar artery (PICA) were coagulated and cut. In addition to PICA, the vein of the inferior cerebellar peduncle was visible in the space. When the ventricular entrance of the right lateral

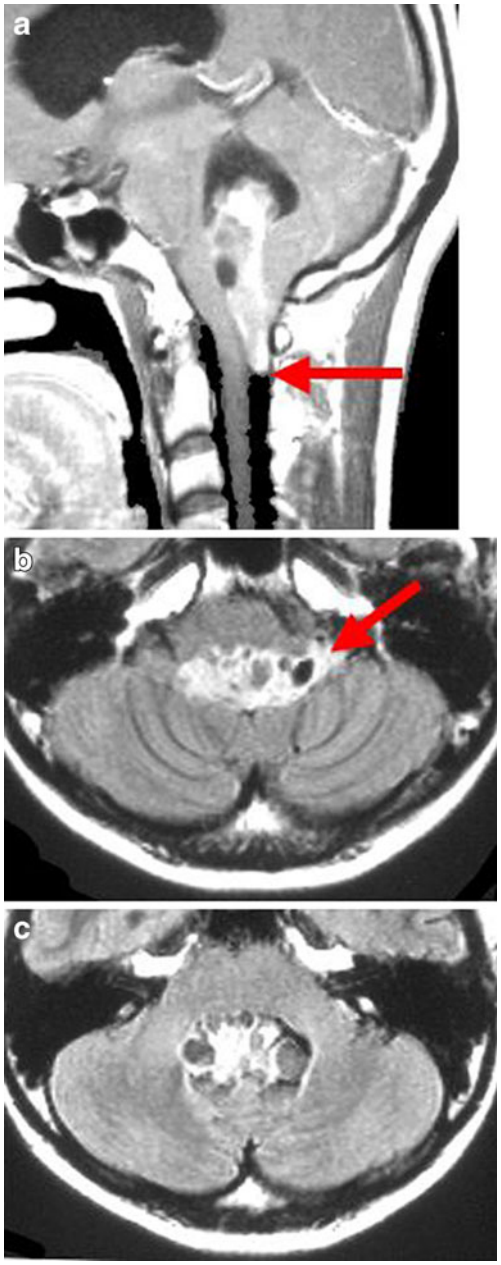


Fig. 6 Preoperative images in Case 2. **a** Enhanced MRI, T1-WI, sagittal view demonstrating a fourth ventricular tumour extending to the level of C2. **b** and **c** Enhanced MRI, T1-WI, axial views demonstrating the fourth ventricular tumour with the lateral extension through the cerebellomedullary fissure

recess was accessed, the cutting direction was deviated in a lateral direction along the lateral recess (Fig. 7d). The lateral recess, which was blocked by the tumour, was then opened; this facilitated further retraction of the tonsil. The lateral margin of the tumour extension was also confirmed (Fig. 7e). After incision of the left taenia, the tumour was detached from the ventricular wall and the main mass was removed without splitting the vermis (Fig. 7f). Consequently, the left lateral recess was exposed, and the residual tumour

was found to extend laterally into the cerebellomedullary cistern through the former. Upon this discovery, the tumour was totally removed macroscopically. This facilitated a view of the entire interior of the fourth ventricle and the dilated cerebral aqueduct. Postoperative MRI demonstrated successful removal of the entire tumour (Fig. 8a, b, c). Five years after surgery, the patient was leading a healthy life without any neurological deficits.

Discussion

In the early 1980s, during dissection studies of the fourth ventricle of cadavers, we noticed the presence of the big fissure, the CMF [20]. During subsequent surgeries on fourth ventricular tumours, we observed that the fissure was crucial for minimizing or avoiding the splitting of the vermis and for total removal of fourth ventricular tumours via the lateral extension technique. Consequently, in the early 1990s, we proposed the opening of the fissure instead of splitting the vermis during these surgeries [9–11, 15, 23]. As a result, we concluded that exposure of the lateral recess through the fissure to facilitate complete removal of tumours in the lateral recess was the key to a positive prognosis in cases of fourth ventricular tumours [4, 9, 13, 16]. We labeled this approach as the trans-CMF app [5, 14, 16]. Kellogg et al. also described an opening method for the fourth ventricle without splitting the vermis; they called it the CMF approach. [8]. In their method, an incision extending from the foramen of Magendie to the foramen of Luschka was placed in the tela choroidea; this was the same method used in our study [9, 11, 16]. Subsequent to these reports, the success of the approaches was verified by several other authors [2, 22, 24, 26, 27]. We also reported the surgical results of 19 cases where we employed the trans-CMF app [16].

While research in general confirms the effectiveness of the trans-CMF app, several differences in the description and employment of this method must be taken into account. In previous studies, several authors have described techniques of opening the CMF. They also clarified the part of the roof of the fourth ventricle that should be ideally incised [2, 8, 11, 16, 17, 21, 22, 24, 26]. However, each author had a different perspective on the method of exposing the

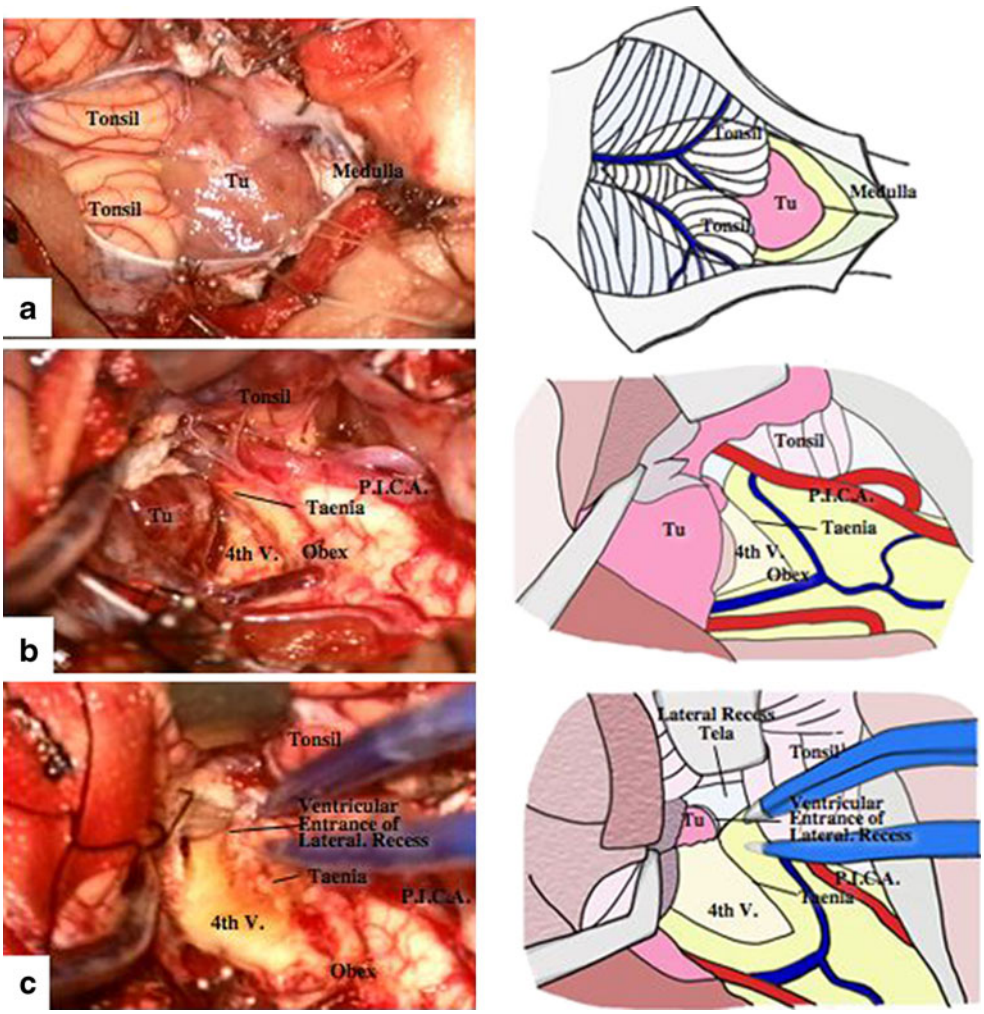
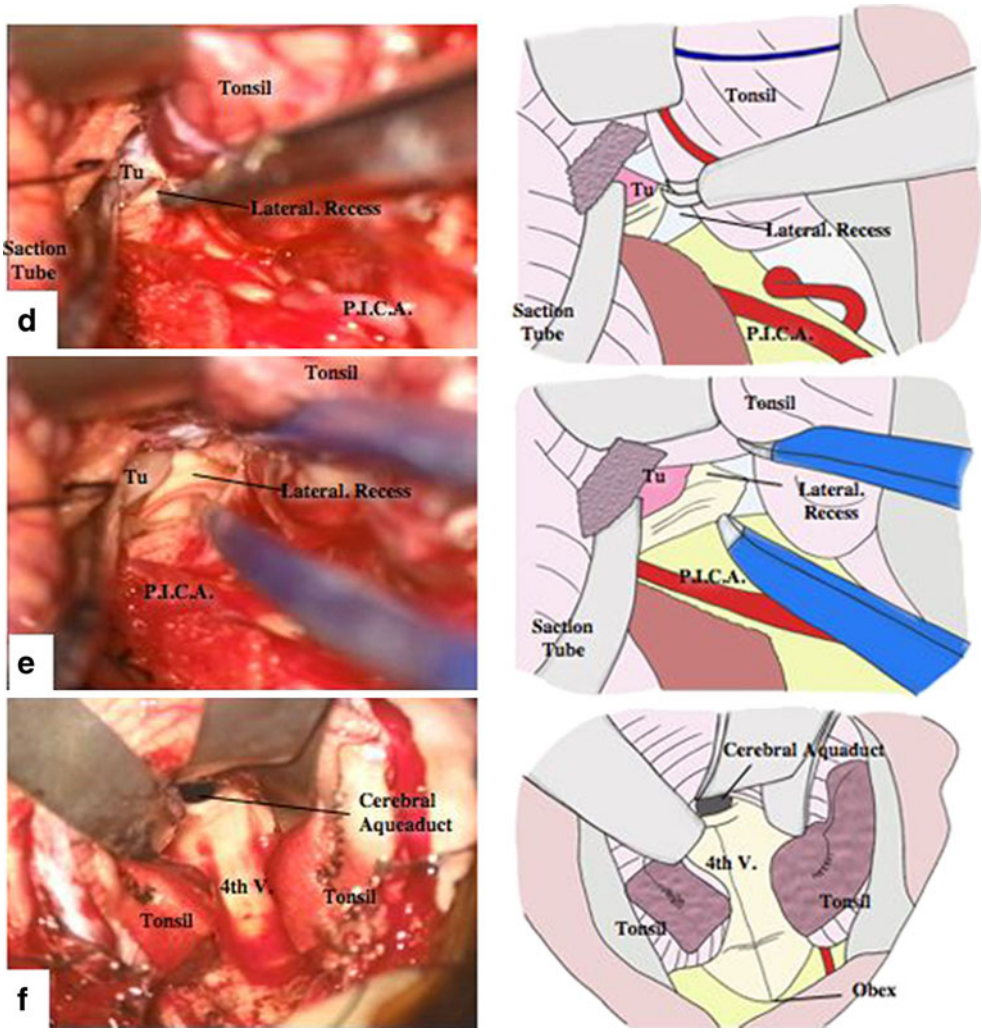


Fig. 7 Intraoperative photos of the step by step procedures employed in Case 2 along with their detailed illustrations. **a** State after opening of the dura mater. The cerebellar hemispheres are exposed and a fourth ventricular tumour protruding like a tongue between the hemispheres can be identified. **b** Separation of the medullotonsillar space on the right side. The tumour is present not only in the fourth ventricle but also in the cerebellomedullary fissure. The right PICA in the medullotonsilar space can be seen running parallel to the taenia. **c** Incision of the taenia. When the taenia is incised from the foramen Magendie, the ventricular entrance of the lateral recess can be accessed. The right lateral recess is almost completely occupied by the tumour. **d** Incision of the roof of the lateral recess. The roof of the lateral recess is incised from its ventricular entrance to the foramen of Lushka. **e** Exposure of the lateral margin of the tumour in the lateral recess. **f** State after total removal of the tumour. Almost the entire interior of the ventricle can be seen

Fig. 7 (continued)



ventricle without splitting the vermis. As a result, the preferred method for gaining access to the wide interior of the ventricle has not been definitively established; additionally, minor variations in techniques will be observed because of the unique nature, origin and size of each lesion.

Some authors have proposed the incision of the inferior medullary velum [2, 21, 26]. Mussi et al., who studied the approach using cadaver specimens, proposed the telovelo approach [21]. As suggested by the name itself, the incision in this technique is placed in the inferior medullary velum as well as in the tela choroidea. However, we did not feel the need to incise the inferior medullary velum in our patients; incision of the tela choroidea, which forms the posterior part of the inferior half of the ventricular roof, was sufficient. Moreover, the opening of the roof of the lateral recess, which was also formed by the tela choroidea, proved to be more important for adequate superolateral retraction of the tonsil. In an actual surgery, negotiating the tonsil is a primary challenge. Therefore, it is extremely helpful to understand the attachment of the tonsil to the cerebellar hemisphere.

Furthermore, the preferred methods for exposing the fourth ventricle also depend on the kind of tumour. Moreover, the approach may be modified depending on the origin of the tumour. For example, the opening method for a medulloblastoma is different from that for an ependymoma [13, 17, 18, 24]. In case of tumours originating from the vermis, such as medulloblastomas or astrocytomas, the incision of the inferior vermis can be minimized through the trans-CMF app; however, a partial incision may still be necessary in certain cases.

The original concept of the trans-CMF app is to open and pass through the fissure instead of incising the inferior vermis [8–11, 14]. However, there are fibrous adhesive tissues as well as numerous blood vessels in the fissure. Therefore, although the uvulotonsillar and/or medullotonsillar spaces are exposed to some extent, the part of the fourth ventricular roof that should be incised needs to be carefully considered. In an actual procedure, it is wise to incise the teania, which is the lateral margin of the tela choroidea. After the incision, the ipsilateral tonsil can be easily lifted up together with the incised tela choroidea. Moreover, this

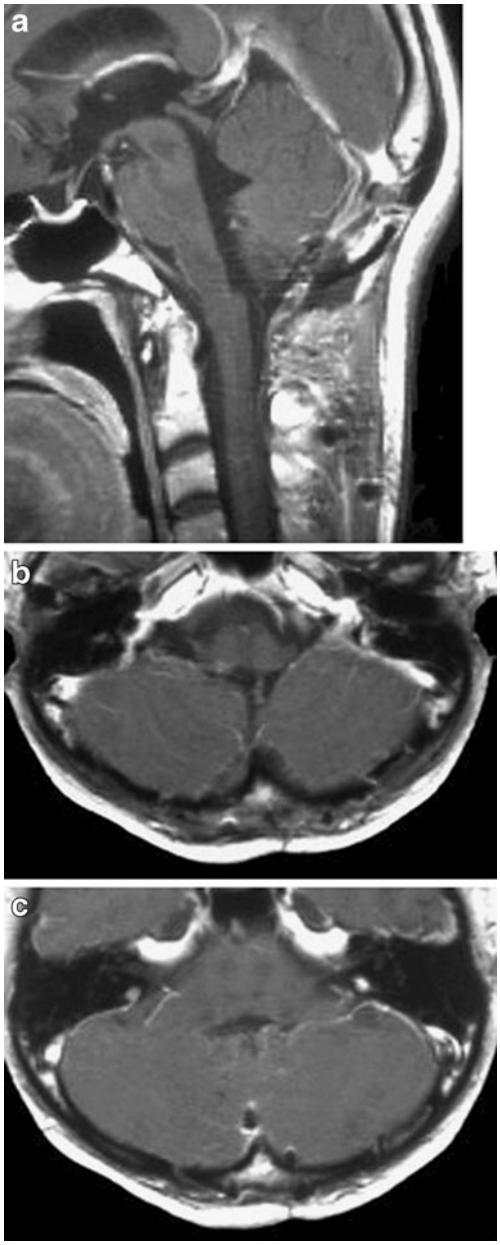


Fig. 8 Postoperative images in Case 2. **a**, **b** and **c** Enhanced T1-WI MRIs. The tumour was totally removed. The inferior vermis looks almost intact

manoeuvre can easily be continued to the next step, which involves opening the lateral recess. Not only the roof of the ventricle but also the roof of the lateral recess should be incised and opened. Opening the lateral recess and retracting the tonsil are very important for obtaining wide exposure of the ventricle; however, these steps have not been clearly understood or widely performed. When the lateral recess is opened, the tonsil can be retracted further superolaterally. As shown in the representative case of cavernoma, even if a lesion is located in the centre of the floor of the ventricle, we usually open the lateral recess at least on the lesion side. Minor variations in the procedure because of the various reasons documented in this paper should always be open to the observation and discretion of the surgical team. However, in the main, the description of the trans-CMF app as presented in our paper provides the most successful method to date for the surgical approach to fourth ventricular tumours.

In sum, this surgical technique for the removal of large fourth ventricular tumours offers several key advantages [8, 9, 16, 22]. First, we do not have to incise the tumour directly, and second, during the incision of the taenia, the feeding arteries to the tumour can be coagulated. Third, the lateral margin of the tumour can be confirmed after opening the lateral recess. Importantly, in our experience, the incision and opening of the lateral recess did not contribute to any neurological deficits. Therefore, we find this technique to be the most effective strategy for the total removal of fourth ventricular tumours.

Acknowledgements We would like to express our gratitude to Prof. Rhoton, University of Florida, for giving us the opportunity to study the microsurgical anatomy of the fourth ventricle and for his sustained attention to our work. We also thank Mrs. Takako Shiga and Mrs. Sumiko Matsushima for preparing the manuscript and illustrations.

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Comments

Ulrich Sure, Essen, Germany

The present paper is a very nice Technical Note on the exposure of the fourth ventricle by incision of the tela choroidea. The paper is nicely written and highly relevant for microneurosurgeons, because it nicely explains and demonstrates the various types and extensions of the telovelomedullary approach. It offers very instructive figures with its possible variations. Personally, I recommend to read the discussion. Here, it is correctly pointed out that an incision of the velum medullare posterior (inferior) is not necessary for a wide exposure of the fourth ventricle, even in very large tumors with an extension up to the aqueduct.

According to my personal experience, there is nothing to add to the authors' statements. In my opinion, the manuscript represented one of the rare occasions where even no further correction was necessary in its primary version. It deserved immediate publication. The authors have to be congratulated for this excellent and important contribution to the recent microsurgical literature.

Ernesto Coscarella, Miami, USA

My congratulations to the Dr. Matsushima and authors for this paper which shows well-done anatomical dissections and correct correlation to their surgical cases. I personally believe that detailed anatomical studies made in the skull base lab are very useful to better understand the anatomy we encounter in real surgery. It will improve our minimal surgical manipulations as well as we are going to achieve a better and safer exposure of the lesions.

As the authors admit in the introduction, the conceptual framework of these CMF approaches is well documented, but detailed anatomical studies of this complicated microsurgical anatomy is very important as well. Besides to improve our surgical manipulation techniques it will inspire the youngest neurosurgeons to use rigorous skull base lab experience in their daily practice as well.

Following my personal anatomy dissection experience in the lab, I agree that the cerebellar tonsils are mostly free structures and attached to the cerebellar biventral lobule only on the superior lateral surface of the upper pole. Therefore it is possible and intelligent to look for their mobilization in order to expose the floor of the IV ventricle.

Moreover, by looking straight at the tonsil and virtually removing it, we will expose on the same plane the lateral surface of the rhomboid fossa of the IV ventricle, particularly the junction of the superior (SCP), middle (MCP), and inferior (ICP) cerebellar peduncles. Therefore, their mobilization can definitely open small corridors to the surface entry points of these structures as well. A good example is for MCP cavernous malformations resection.

As the author mentioned, I agree that for high IV ventricle located lesions, like medulloblastomas or upper gliomas, limited vermis splitting is inevitable to better achieve total resection.

In conclusion, again my congratulations to Dr Matsushima and others for this well-done paper, hoping to see more similar works in the future as well.

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This article probably comes from a group that to my research has one of the largest operative experiences of fourth ventricular surgeries. This is a well-written and documented technical note that precisely demonstrates the operative procedures in the fourth ventricular region. The group around Matsushima et al. illustrates an operative technique

of the medial route for the trans-cerebellomedullary fissure approach. The authors distribute detailed illustrations about the operative procedures for this kind of fourth ventricular surgeries. Two very well-documented illustrative cases are included to visualize their very own methods. Neurosurgeons who are keen in fourth ventricular surgery, should gather this technical note as a must-have to learn from it. In my opinion, this technical note is a motivational framework to stimulate young neurosurgeons to participate in more lab time experience as well. At the end, this will help to improve surgical manipulation techniques to achieve superior resections in the fourth ventricular region.

In summary, again congratulations to Matsushima et al. for this convincing technical note, we hope to see related work in the near future.