Tonsilllobiventral fissure approach to the lateral recess of the fourth ventricle

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OBJECTIVE Surgical access to the lateral recess of the fourth ventricle (LR) is suboptimal with existing transvermian and telovelar approaches because of limited lateral exposure, significant retraction of the cerebellar tonsil, and steep trajectories near brainstem perforator arteries. The goal in this study was to assess surgical exposure of the tonsilllobiventral fissure approach to the LR, and to describe the relevant anatomy.

METHODS Two formaldehyde-fixed cerebella were used to study the anatomical relationships of the LR. Also, the tonsilllobiventral fissure approach was simulated in 8 specimens through a lateral suboccipital craniotomy.

RESULTS The pattern of the cerebellar folia and the cortical branches of the posterior inferior cerebellar artery were key landmarks to identifying the tonsilllobiventral fissure. Splitting the tonsilllobiventral fissure allowed a direct and safe surgical trajectory to the LR and into the cerebellopontine cistern. The proposed approach reduces cervical flexion and optimizes the surgical angle of attack.

CONCLUSIONS The tonsilllobiventral fissure approach is a feasible and effective option for exposing the LR. This approach has more favorable trajectories and positions for the patient and the surgeon, and it should be added to the armamentarium for lesions in this location.

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Abbreviations
CMF, tCMF = cerebellomedullary fissure, transcerebellomedullary fissure; LR = lateral recess of the fourth ventricle; PICA = posterior inferior cerebellar artery.

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Methods

Two extracted brain specimens were prepared with standard embalming solution to study the regional anatomy of the LR and design the surgical approach. In addition, 4 human heads (8 specimens) were prepared for surgical simulation at the University of California, San Francisco’s skull base and cerebrovascular laboratory, using our previously reported method. The tonsillobiventral fissure approach and the tCMF approach to the LR were performed as previously reported elsewhere. A photographic report was performed to depict the surgical trajectory and key anatomical landmarks. A descriptive comparative analysis, including a description of the limits of the surgical exposure, surgical corridor and trajectory, and vessels at risk was undertaken to assess the surgical feasibility of the tonsillobiventral fissure approach to the LR.

Results

Anatomical Relationships of the LR

The LR is a triangular space in the lateral corner of the rhomboid fossa (Fig. 1A). It is limited ventrally by the brainstem and dorsally by the cerebellum. The inferior cerebellar peduncle sits in the lateral aspect of the dorsal surface of the medulla. It forms the ventral wall and floor of the LR, merging dorsally into the cerebellum (Fig. 1A and B). The dorsal wall and floor of the LR are formed by the lateral continuation of the tela choroidea and the inferior medullary velum (the telovelar membrane). The tela choroidea is a thin semitransparent layer of tissue from which the choroid plexus protrudes into the fourth ventricle (Fig. 1C). The tela is attached to the teniae—an elevated ridge along the inferolateral borders of the rhomboid fossa. The dorsal surface of the fourth ventricle (also referred to as the caudal half of the roof of the fourth ventricle) is formed by the tela caudally, and the inferior medullary velum cranially. The inferior medullary velum—a thin layer of neural tissue—connects the nodule to the folliculus, which protrudes into the cerebellopontine cistern through the foramen of Luschka (Fig. 1C). The horizontal arm of the choroid plexus is attached to the tela and spans the length of the LR from medial to lateral, until it emerges through the foramen of Luschka in the cerebellopontine cistern. The CMF runs between the medulla and the cerebellar tonsil and reaches the LR superiorly (Fig. 1D and E).

The cerebellar tonsil is attached to the rest of the cerebellar tissue through a peduncle, located superolaterally. Anteriorly, the tonsil is separated from the medulla by the telovelar membrane (Fig. 1C). From the tCMF approach, the LR may be accessed after opening the CMF, which is accomplished by elevating the anterior surface of the tonsil from the dorsal surface of the medulla and dividing the tela (Fig. 1D and E).

The tonsil is related superolaterally to a portion of the cerebellar hemisphere called the biventral lobe. The fissure between the tonsil and the biventral lobe is called the tonsillobiventral fissure. This fissure runs inferiorly and laterally from the valley between the tonsil and the vermis to the lateral part of the CMF (Fig. 1F). When split and followed caudally, the tonsillobiventral fissure opens into the LR (Fig. 1G). The CMF is continuous with the tonsillobiventral fissure around the superior pole of the tonsil. The posterior inferior cerebellar artery (PICA) emerges from this fissure to continue its cortical course (P₂–P₃ transition) (Fig. 1F).

Tonsillobiventral Fissure Approach to the LR

Access to the LR was achieved by splitting the tonsillobiventral fissure (Fig. 1G). After completion of a lateral suboccipital craniotomy and opening of the dura mater, the tonsillobiventral fissure was recognized and opened. Key landmarks for efficient exposure of the tonsillobiventral fissure were the vertical direction of the tonsillar folia relative to the folia of the biventral lobe (coursing diagonally) as well as the emergence of at least 1 major branch of the PICA. The dorsal and cranial aspects of the LR were exposed after continued microsurgical arachnoid dissection in an inferolateral trajectory. The contents of the LR, namely the telovelar membrane, the choroid plexus, and the rhomboid lip covering the choroid plexus, were accessed via the tonsillobiventral fissure approach (Fig. 1G). During opening of the tonsillobiventral fissure to reach the LR, no traversing of neural tissue was required and arachnoid dissection in an inferolateral trajectory led to the LR.

Because of the anatomical features of the tonsillobiventral fissure, the surgical trajectory of the tonsillobiventral approach was almost perpendicular to the axis of the brainstem (Fig. 2). Also, this approach enabled exposure of the most lateral extent of the LR all the way to the cerebellopontine cistern without transgressing neural tissue (Fig. 1G).

Since we published our report on the supratonsillar approach, we have operated on 9 cases of cavernous malformations of the cerebellum, using the tonsillobiventral fissure as the sole surgical corridor. Our anatomical research as well as clinical experience with the tonsillobiventral fissure inspired its use for LR access. Although our clinical applications are limited to cerebrovascular lesions— and cavernous malformations in particular—due to the subspecialty focus of the senior author (M.T.L.), the large exposure and optimal trajectory to the LR provided by the tonsillobiventral fissure approach justify its use for tumors as well. Choroid plexus tumors, ependymomas, neuromas of the caudal cranial nerves, and epidermoid tumors infiltrating the LR can also be addressed via this approach.

Case Illustration

A 24-year-old man presented with headaches related to heavy weight lifting. An MRI study of the brain revealed a lesion in the right LR that raised our concern for cavernous malformation. After discussing treatment options, the patient decided to pursue resection. A tonsillobiventral approach was performed and the lesion was resected en bloc (Fig. 3). The patient remained symptom free 3 months after the operation.

Discussion

This report shows that the tonsillobiventral fissure approach provides an optimal trajectory to the LR through the tonsillobiventral fissure. We observed and identified several
advantages of the proposed approach compared with its alternatives, the tCMF and transvermian approaches.

One of the major advantages of the tonsillobiventral approach is its ergonomic angle of attack, which allows a more comfortable operation for the surgeon and safer positioning for the patient. The tonsillobiventral fissure has a vertical trajectory relative to the brainstem compared with the CMF (Fig. 2). This anatomical feature facilitates surgical access to the LR by lessening the need for hyperflexion of the patient’s head when in the prone position, and by eliminating the need for a C-1 laminectomy. In the transvermian and tCMF approaches, the angle of attack is almost parallel to the brainstem axis and requires maximal neck flexion. Also, in such approaches, the steep angle of attack causes the cervical musculature and the C-1 lamina to obstruct the line of sight to the LR. These problems are virtually absent when the LR is accessed through the tonsillobiventral fissure. A slight rotation of the patient’s head toward the side of the lesion brings the tonsillobiventral fissure into the line of sight of the surgeon and improves surgical trajectory.

The tonsillobiventral approach requires minimal cerebellar retraction to reach the LR. The tonsillobiventral fissure leads directly to the LR (Fig. 1D, E, and G). During this approach, the tonsil is gently mobilized inferomedially, while the biventral lobule is retracted superolaterally (tonsillobiventral fissure split). The relatively vertical approach to the LR, and the reduced retraction of cerebellar tissue, both allow maximal protection of the neural tissue, which might minimize the risk of cerebellar mutism after this approach.17

Although it shares a common surgical corridor, the tonsillobiventral fissure approach to the LR is different from the one in our previous report on the supratonsillar approach to the inferior cerebellar peduncle in several ways.7 Because the inferior cerebellar peduncle sits superior to the LR, the trajectories to these 2 targets are different: inferolateral for the LR, and superolateral for the inferior cerebellar peduncle. As described in our previous work, accessing the inferior cerebellar peduncle invariably requires a far-lateral approach, in which the head is turned contralateral to the lesion and the neck is flexed. This position aligns the surgical view to the inferior cerebellar peduncle along the axis of the tonsillar peduncle. On the other hand, the LR can be accessed following an inferolateral trajectory, and the prone position with moderate neck flexion is sufficient to align the LR with the surgical view. The extreme neck flexion and the three-quarter
The prone position needed for accessing the inferior cerebellar peduncle are not required for exposing the LR through the tonsillobiventral approach, because there is no need to look “upward” to see the peduncle. Another difference between the supratonsillar approach to the inferior cerebellar peduncle and the tonsillobiventral approach to the LR is C-1 laminectomy. A C-1 laminectomy may be necessary to access the inferior cerebellar peduncle by providing a steeper angle of attack, but an inferolateral trajectory to reach the LR is not hindered by the lamina of C-1 and therefore does not require a C-1 laminectomy (Fig. 2F).

FIG. 2. Schematic illustration and comparison of the CMF and tonsillobiventral fissure approaches to the LR. A and B: Patient positioning and craniotomy. C and D: Sagittal trajectory and manipulation of different segments of the PICA. E and F: Different trajectories in the operative view. G and H: Different trajectories from the inferior anatomical perspective. Copyright UCSF Skull Base and Cerebrovascular Laboratory. Published with permission. Figure is available in color online only.
In our previous work, we stated that after reaching the inferior cerebellar peduncle “no additional subarachnoid dissection is possible.” However, an inferolateral trajectory toward the LR allows subarachnoid dissection all the way to the cerebellomedullary cistern (Fig. 4 left). The most lateral limits of the LR can be accessed completely via the tonsillobiventral approach, which is a substantial improvement over traditional approaches (Fig. 1D, E, and G). The results of our analysis show that opening the tonsillobiventral fissure allows access to the choroid plexus of the cerebellopontine cistern (Fig. 1A). Such exposure could not be easily obtained via the tCMF approach without excessive retraction of the tonsil (Figs. 1D and 4 right).

Using a superolateral trajectory, the tonsillobiventral approach may also be used to access intracerebral cerebellar lesions (e.g., inferior cerebellar peduncle). However, exposure and resection of lesions within the LR do not involve traversing neural tissue, because following the arachnoid planes inside the tonsillobiventral fissure will directly expose the LR. Navigation planning and intraoperative guidance can help in selecting the proper trajectory to reach intracerebral lesions, especially when invasion of the white matter is present.
Avoidance of the telovelar segment of the PICA is another advantage of the tonsillobiventral approach. During the tCMF approach, the distal cisternal segments of PICA (i.e., tonsillomedullary [P3] and proximal telovelotonsillar [P4]) are exposed and require manipulation.\(^{10,14}\) These segments give rise to most medullary perforator arteries along the course of the PICA.\(^{13}\) Also, after opening of the LR, the PICA and its minute perforator branches remain within the working corridor during resection of the LR lesion. However, the tonsillobiventral approach exposes and follows the distal telovelotonsillar (distal P4) segment of the PICA to reach the LR (Fig. 1F). The distal P4 segment has fewer or no medullary perforators and therefore entails less risk of brainstem infarction. Nevertheless, it should be kept in mind that the tonsillobiventral approach does not eliminate the risk to PICA branches, although it carries less risk to brainstem perforators compared with the tCMF approach.

**Surgical Landmarks of the Tonsillobiventral Approach**

Although we did not find much variation in the specimens regarding landmarks for identification of the tonsillobiventral fissure, surgical identification of the tonsillobiventral fissure may not be straightforward.\(^{7,18}\) The inferior cerebellar peduncle arches over the LR from posterior to anterior. This structure forms a thin layer of white matter between the LR and the dentate nucleus (Fig. 5). Opening the arachnoid trabeculae requires utmost attention to identify the inferior cerebellar peduncle and deeper cerebellar nuclei. Because splitting the tonsillobiventral fissure provides a direct trajectory to the LR, addressing lesions concealed within the limits of the LR should not require removal of neural tissue.

Splitting the tonsillobiventral fissure can be technically challenging. Distal branches of the PICA and prominent supra- and retrotonsillar veins inside the fissure need to be identified and protected early during the subarachnoid dissection. Also, the fissure could be adherent and this may put distal PICA segments at risk.\(^{7}\) However, the technical difficulty of splitting the tonsillobiventral fissure may be overcome through correct patient positioning, meticulous microsurgical dissection, and protection of the pial planes that define the borders of the tonsillobiventral fissure. Table 1 summarizes the features of the tonsillobiventral approach compared with the tCMF approach.

**Conclusions**

The tonsillobiventral fissure approach, or supratonsillar approach, can be used to access the LR, even its most
lateral extent. Compared with transvermian and tCMF approaches, this approach has a more favorable trajectory that uses gravity retraction to naturally unfold the tonsillobiventral fissure, and it reduces fixed cerebellar retraction. Also, vital brainstem perforator arteries originating from the P4 and proximal P3 segments of the PICA are avoided during the tonsillobiventral fissure approach. Limitations of this approach include possible damage to the distal PICA branches, the inferior cerebellar peduncle, and the dentate nucleus, and difficulty in identifying the tonsillobiventral fissure. However, anatomical landmarks are reliable and meticulous microsurgical dissection of arachnoid planes inside the fissure with navigation guidance maximizes safety. This approach has been a useful addition to the surgical armamentarium for cavernous malformations inside the inferior cerebellar peduncle and those in the vicinity of LR, and may have additional application to vascular and tumor lesions in the LR.

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References


Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Conception and design: Benet, Tayebi Meybodi, Lawton. Acquisition of data: Benet, Tayebi Meybodi, Tabani. Analysis and interpretation of data: all authors. Drafting the article: Benet, Tayebi Meybodi, Tabani. Critically revising the article: Benet, Lawton, Tabani. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Benet. Statistical analysis: Benet, Tayebi Meybodi, Lawton. Administrative/technical/material support: Benet, Lawton. Study supervision: Benet, Lawton.

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