Infradentate Approach to the Fourth Ventricle

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BACKGROUND: The use of minimally invasive transcranial ports for the resection of deep-seated lesions has been shown to be safe and effective for supratentorial lesions. The routine use of this surgical modality for posterior fossa masses has not been well established in the literature. In particular, fourth ventricular tumors are not the typical target for neuro-port surgery because of potential injury to the dentate nucleus.

OBJECTIVE: To describe the use of a tubular retractor system to reach the fourth ventricle while sparing the cerebellar vermis and the dentate nucleus. Three cases illustrations are presented.

METHODS: Surgical access to the fourth ventricle was developed sparing the cerebellar vermis and the dentate nucleus. The authors reviewed 3 cases to illustrate the feasibility of minimal access transcerebellar port surgery for the resection of these lesions using an infradentate access.

RESULTS: None of the patients developed new neurological deficits and the pathology was successfully resected in all cases. There were no major complications related to surgery and no mortalities.

CONCLUSION: The infradentate approach obviates the need for traditional approaches to the fourth ventricle, thus making this challenging target in the posterior fossa more accessible to neurosurgeons. The authors observed successful removal of lesions involving the fourth ventricle while avoiding any associated morbidity or mortality.

KEY WORDS: Fourth ventricle, Infratentorial, Posterior fossa tumors, Transcerebellar, Port surgery, Telovelar approach, Minimally invasive, Vermis, Dentate nucleus

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Untoward injury to the deep cerebellar nuclei, particularly the dentate, can increase morbidity associated with the surgical management of cerebellar and fourth ventricular tumors. Furthermore, resection of these masses can be complicated by cerebellar mutism in the postoperative period. The incidence of this complication is most common in the pediatric population after surgical treatment of medulloblastoma; however, this syndrome is not unique to this population.[1,2] Many authors believe that splitting of the vermis places patients at risk for this type of mutism, which is characterized by its typical self-limited course and possible persistent dysarthria.[3] In order to avoid this morbidity, the authors describe their use of a minimally invasive port technique to access the fourth ventricle without transgressing the vermis or the dentate nuclei.

ABBREVIATIONS: EVD, external ventricular drain; **MRI,** magnetic resonance imaging; **PICA,** posterior inferior cerebellar artery

Vermis

The vermis is posterior to the fourth ventricle. It is formed by 4 structures oriented from superior to inferior: the folium, tuber, pyramid, and the uvula as well as the nodule, which is found anterior to the uvula. The prepyramidal fissure splits the vermis into superior and inferior halves between the tuber and pyramid. The fastigial nucleus rests in the anterior portion of the pyramid forming the apex of the fourth ventricle roof. The dentate is located in the superolateral portion of the fourth ventricle. Historically, neurosurgeons accessed the fourth ventricle by removing a segment of the cerebellar hemisphere or dividing the vermis[3]. As a result of the morbidity related to these approaches, strategies that maintain the integrity of these structures have developed.

Dentate Nucleus

Because the dentate receives afferent connections from the supplemental motor area, this nucleus is involved with the coordination, initiation, and timing of volitional movement as well as balance and posture.[4] Additionally, connections have been discovered between the dentate nucleus and the premotor, oculomotor and posterior parietal areas of the cerebral cortex.[4] The vermis has dorsal and ventral components related to motor and nonmotor functions, respectively.

The vermis and the cerebellar peduncle bundle encompass the dentate and have important associations. The pyramid's extension laterally to the superolateral recess is a reliable surgical landmark that leads to the dentate nucleus. The inferior cerebellar peduncle has fibers that pass anteriorly and superiorly to the dentate and carry dorsal spinocerebellar, cuneocerebellar, olivocerebellar, and vestibulocerebellar pathways.[4] The middle cerebellar peduncle has 2 sets of fibers that pass over the dentate. The first group is the pontocerebellar fibers that run parallel to the dentate and the second group is the corticocerebellar fibers that travel parallel to the midline.[4] The superior cerebellar peduncle connects the dentate to the red nucleus via the dentatorubrothalamic tract, decussates, and ultimately projects to the ventrolateral thalamus; disruptions of these connections are thought to cause the symptoms of cerebellar mutism.[4] In order to avoid neurological morbidity, the surgeon must take every precaution to respect the integrity of the vast network of white matter tracts that run along the dentate.

The neurosurgeon should understand the relationship of the dentate to readily identified structures along the suboccipital surface. The medial aspect of the dentate is approximately 10.9 mm superior from the tip of the tonsil; the supratonsillar area where the tonsil is attached to the cerebellum is 0.6 mm lateral to the dentate.[4]

SURGICAL APPROACHES TO THE FOURTH VENTRICLE

Telovelar Approach

The telovelar approach is favored to access tumors of the fourth ventricle because it provides a corridor spanning from the obex to the aqueduct of Sylvius and between the paired foramina of Luschka, while avoiding injury to the deep cerebellar nuclei. The first step of this approach is directed through the cerebellomedullary fissure, which is the cleft that allows access to the vermis and the roof of the fourth ventricle after the medial tonsillar surfaces are lateralized. After the tonsils are retracted laterally, the pyramid and uvula of the vermis are visualized in the midline overlying the roof. The inferior half of the fourth ventricle's roof is formed by 2 membranes: the inferior medullary velum superiorly and the tela choroidea inferiorly.

When opening the roof of the fourth ventricle, the surgeon should locate the ostium in the caudal, midline sagittal plane of the tela choroidea, which is the foramen of Magendie. The opening of the fourth ventricle begins at the foramen of Magendie and extends laterally through the tela choroidea towards the lateral recess rather than superiorly toward the inferior medullary velum in order to avoid disconnecting the nodule from the flocculus.

At the level of the fastigium, the inferior medullary velum blends medially into the superior medullary velum, which forms the medial portion of the rostral half of the fourth ventricle roof. The lateral portion of the superior fourth ventricle roof is formed by the superior and inferior cerebellar peduncles.[3] Opening the superior medullary velum further exposes the floor and lateral recess of the fourth ventricle; the nuclei for the sixth and eighth cranial nerves are embedded in the floor at this level. The dentate nucleus forms an impression in the superolateral recess of the roof, known as the dentate tubercle, which is found superior and lateral to the superior vestibular nucleus.

There are situations that the telovelar approach is not possible due to anatomic variations or peculiarities. For example, a branch of the posterior inferior cerebellar artery (PICA) can divide early to supply the vermis. This branch can hinder the possibility of full exposure of the fourth ventricle by obstructing visualization of the tela choroidea. Patients who have had previous surgery or radiation can have prohibitive scar overlying the foramen of Magendie limiting direct dissection into the forth ventricle as well.

Minimally Invasive Port Surgery

Port technology has been promoted in order to reduce potential operative morbidity related to the resection of intra-axial lesions. This modality has been in existence since the 1980s when cylindrical retractors were used instead of retractor blades because less damage was done to the surrounding cortex.[5] This technique has since gained popularity, particularly for accessing deep-seated lesions.[6] The port approach for infratentorial pathologies is not well established in the literature. However, there are published cases describing the use of ports for the resection of tumors from the cerebellar peduncles.7

In the authors' opinion, the main advantage of the cannulated tubular system is the cylindrical shape of the port that allows for tissue to be displaced around the tubes. The minimal disruption of brain tissue using this system has been supported by postoperative magnetic resonance imaging (MRI) findings, which show minimal radiographic changes; similar findings are seen in the described cases.[6]

Infradentate Port Approach to the Fourth Ventricle

The premise of this approach is to maintain the integrity of the vermis as well as critical structures that border the fourth ventricular floor. Optimum patient positioning and accurate navigation ensure the integrity of the cerebellum. Three illustrative cases are described in Table .

After general endotracheal anesthesia is induced and necessary neuromonitoring leads are placed, the patient's skull is placed in

TABLE . Demographic Characteristics of Three Patients, Who Underwent Infradentate Approach, and Pathologies

Case Number	Age at presentation (yr)	Gender	Tumor size (mm)	Tumor pathology	Preoperative symptoms	Postoperative results on MRI at latest follow-up	Complications, morbidity, and mortality
1	29	M	26 × 32 × 53 cephalo-caudal	WHO grade II epenymoma	Dizziness, headaches, nystagmus, blurry vision at baseline, and nausea	Postsurgical changes, stable small areas of residual constrast enhancing foci in R Lateral recess and cisternal space lateral to medulla minimal FLAIR signal along margin of surgical defect	Stable neuro deficits: Nystagmus with diplopia, blurry vision, chronic daily nausea
2	25	M	32 × 29 × 26	1. Recurrent /residual epidermal inclusion cyst with acute and chronic inflammation 2. Fibrovascular tissue with acute and chronic inflammation and fragment of epidermal cyst epithelium 3. Pseudomonas aeruginosa cultured from tissue	Seizure, nystagmus, and L dysmetria Dependence on EVD, compression of left ventricular outflow track from cerebellar abscess, and hydrocephalus	Diffusion restriction postoperative infarct in margin of surgical cavity, persistent significant mass effect of ponto-medullary junction stable T2 FLAIR signal in cerebellar hemisphere, L middle and superior cerebellar peduncles	Stable neuro deficits: Horizontal nystagmus, slow gait, L dysmetria (R anacusis which developed after intrathecal tobramycin for meningitis)
3	24	F	8 × 8 cavernoma; 35 × 35 × 30 hemor-rhagic mass	Cavernoma with hemorrhage	TMJ pain with mastication, cerebellar hemorrhage with ataxia, and gait instability	Postsurgical changes, residual hemosiderin staining along surgical tract	Neurologically intact

L, left; R, Right; TMJ, temporomandibular joint

a 3-pin fixation system. The patient in positioned in the lateral decubitus position according to the side of the lesion. The head is flexed and rotated contralateral in order to allow for optimum exposure of the suboccipital region. The patient is supported by a beanbag, secured to the bed, and all pressure points, joints, and potential sources for postoperative neuropathy are padded.

The patient is then registered to the neuronavigation system. The vermis, dentate, and tumor are all visualized on the MRI relative to the fourthe ventricle. The authors then measure a distance of approximately 11 mm from the tip of tonsil closest to the tumor as well as 5 mm lateral from the ipsilateral lateral recess of the fourth ventricle. The surgical target and entry point are planned so that port will be placed below the deep nuclei and lateral to the pyramid. By staying below and slightly medial with a trajectory towards the fourth ventricle, the authors have experienced no untoward injury to the deep cerebellar nuclei. Although diffusion tensor imaging would be useful in these cases, this imaging modality was not available for posterior fossa lesions at the time of surgery.

The surgery begins with a paramedian, linear incision behind the ear. Once the suboccipital bone is exposed, computed tomography bone refinement is performed using the navigation probe in order to increase the accuracy of the image guidance system; a fine-cut computed tomography scan is obtained preoperatively for this purpose. A suboccipital craniotomy overlying the lateral cerebellum is completed and the dura is opened in a standard manner; the authors prefer to open the dura in a cruciate fashion.

The navigation probe is then brought into the field to assess for accuracy. The preoperative plan is confirmed in order to ensure

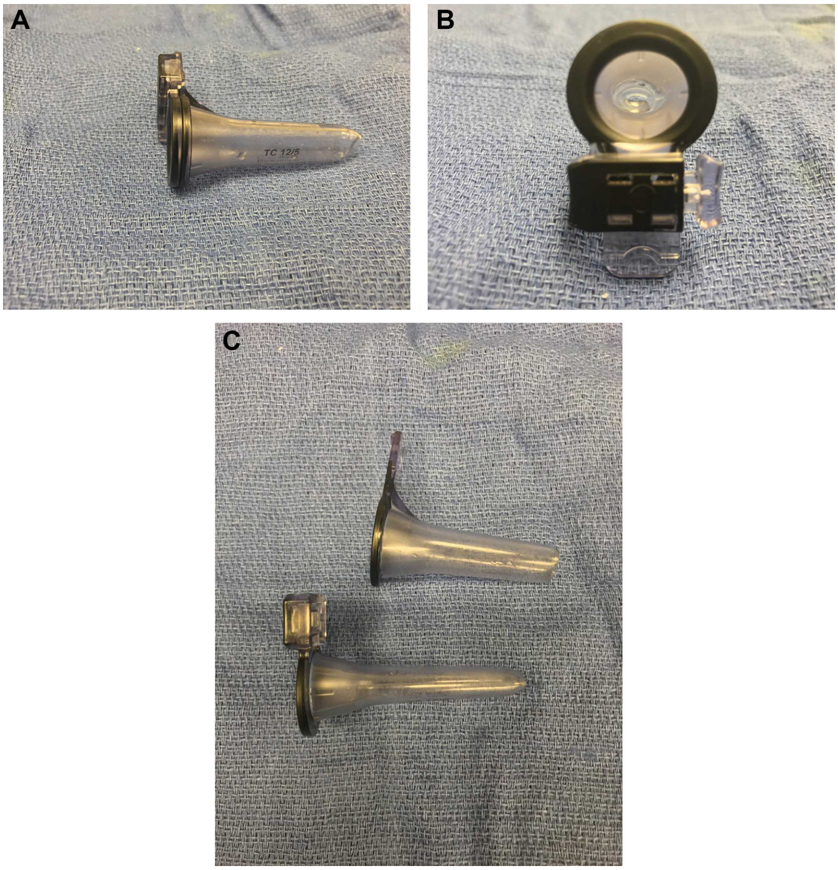

FIGURE 1. **A**, *Vycor Port 12 mm × 8 mm × 5 cm.* **B**, *Direct view down the barrel of the port with the introducer surrounding the port; this is how the port is setup for introduction into the parenchyma.* **C**, *Port on left, introducer on right.*

that the trajectory allows for the port to dock lateral to the vermis and inferior to the dentate nucleus. The entry point is then changed if needed in order to allow for orthogonal passage of the port to the target through at least a 3 mm corticectomy.

After the corticectomy is complete, the navigation probe is placed into a peel-away introducer, which is then advanced under image guidance towards the target in order to prepare and expand the path for the port. The introducer is then removed. Then, a 12 mm × 8 mm × 70 mm Viewsite Brain Access System port (Vycor Medical Inc, Boca Raton, Florida; Figure 1) is brought into the field. The choice of port size is dependent on the surgeon's preference and the lesion's dimensions; however, the authors favor using smaller ports when feasible. The navigation wand is then placed into the inner sheath of the port and secured with bone wax. The port is then advanced with navigation assistance towards the lateral aspect of the fourth ventricle, below the dentate (Figures 2 and 3). Once at the target, the tubular retractor is held in position by a flexible arm fixed to the skull clamp. The inner sheath is then removed. Once the lesion is encountered under microscopic visualization, it is removed using standard microsurgical technique. After the port docks on the tumor it can be manipulated and translated in any anatomic direction or angle to accommodate the 3-dimensional volume of the tumor; the port is quite maneuverable.

ILLUSTRATIVE CASES

Case 1

A 29-yr-old male presented with a primary complaint of dizziness. Imaging revealed a large fourth ventricular mass with extension through the foramen of Luschka. A telovelar approach was attempted in order to remove the tumor in its entirety, but a loop of the PICA was tethering the tonsil, preventing safe, gross total resection (Figure 4A and 4B). A subtotal resection that removed the extraventricular portion of the tumor was achieved (Figures 4C, 4D, and 5). The tumor pathology was a WHO grade II ependymoma. The residual tumor was located exclusively

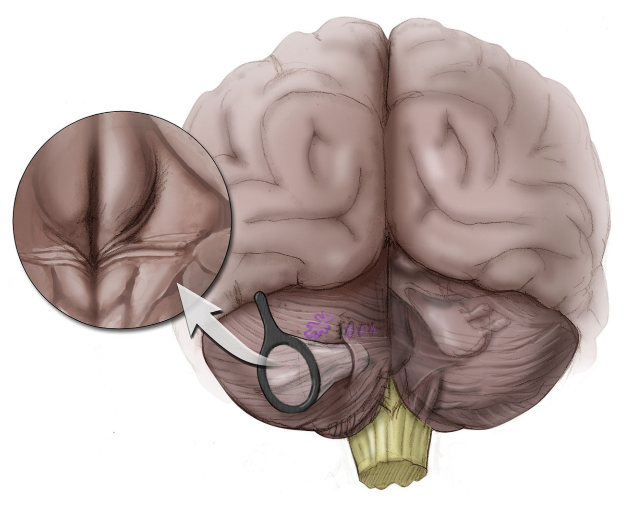

FIGURE 2. *This artist rendering demonstrates the surgical port cannulating the cerebellum and advancing below the dentate nucleus, lateral to the vermis, and towards the fourth ventricle. Once the port reaches its target it can be angled in any orientation and readjusted to obtain optimal visualization of the lesion and surrounding structures.*

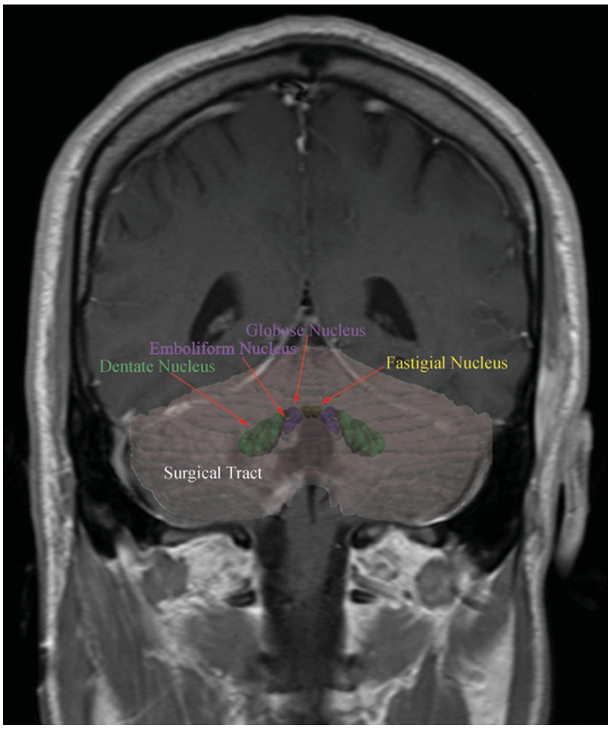

FIGURE 3. *T1 coronal MR image postcontrast postport procedure. Overlaid is a cartoon schematic demonstrating approximate locations of deep cerebellar nuclei. The surgical tract enters the right side of the fourth ventricle, inferior to the dentate nucleus.*

inside the IV ventricle. A second stage was planned and performed a few weeks later. The tumor was completely removed using the image-guided transcerebellar, vermian sparing, and microscope assisted infradentate approach (Figure 6). The integrity of the PICA was maintained and gross total resection was achieved. The patient remained neurologically intact postoperatively and has had over 2 yr of follow-up without radiographic recurrence (Figure 4E-4H).

Case 2

A 25-yr-old male presented with a seizure and was found to have a posterior fossa epidermoid tumor causing outflow obstruction and associated hydrocephalus. He had an external ventricular drain (EVD) placed and he underwent subtotal resection of this mass via a midline suboccipital approach at an associated facility. He had a prolonged intensive care unit stay due to respiratory failure, bacteremia and ventriculitis requiring dependency on cerebrospinal fluid diversion. In addition, postoperatively, he developed left sided dysmetria, horizontal nystagmus, and anacusis, the latter of which was related to tobramycin administration. During his hospital stay, he again developed fourth ventricular outflow tract compression due to a cerebellar abscess and residual tumor. His case was presented to the senior author for a redo posterior fossa craniotomy for excision of the tumor and abscess (Figures 7A, 7B, and 8A).

The patient underwent the image-guided, paravermian infradentate approach. Upon opening the dura, there was significant arachnoiditis from the patient's history of meningitis and ventriculitis, which would have made a telovelar approach more challenging. Due to the severe arachnoiditis and impossibility of cisternal dissection, the tumor was encountered after the port was placed with navigation guidance in a trajectory inferior to the dentate nucleus. The tumor was removed with blunt microdissectors in a piecemeal fashion. After removal of the residual epidermoid, the trajectory of the port was changed without totally removing the port in order to visualize the abscess, which was positioned lateral to the tumor. Once encountered, its capsule was coagulated and the abscess was removed (Figures 7C-7D, and 8B-8C). The patient had a long recovery and his EVD could not be successfully weaned; ultimately, a ventriculoperitoneal shunt was placed. At follow-up 2 yr later, the patient has stable deficits as compared to immediately after his first surgery, and he continues to be monitored with serial radiographs (Figure 7E and 7F).

Case 3

A 24-yr-old female with a history of adenoid cystic carcinoma of the parotid gland presented with worsening temporomandibular joint pain with mastication. Routine imaging done for this symptom revealed a hemorrhagic lesion concerning for a cavernoma in the left cerebellum and another area of hemorrhage near the superior cerebellar peduncle with associated minimal enhancement (Figure 9A and 9B). While awaiting routine follow-up, her cerebellar cavernoma hemorrhaged generated a large

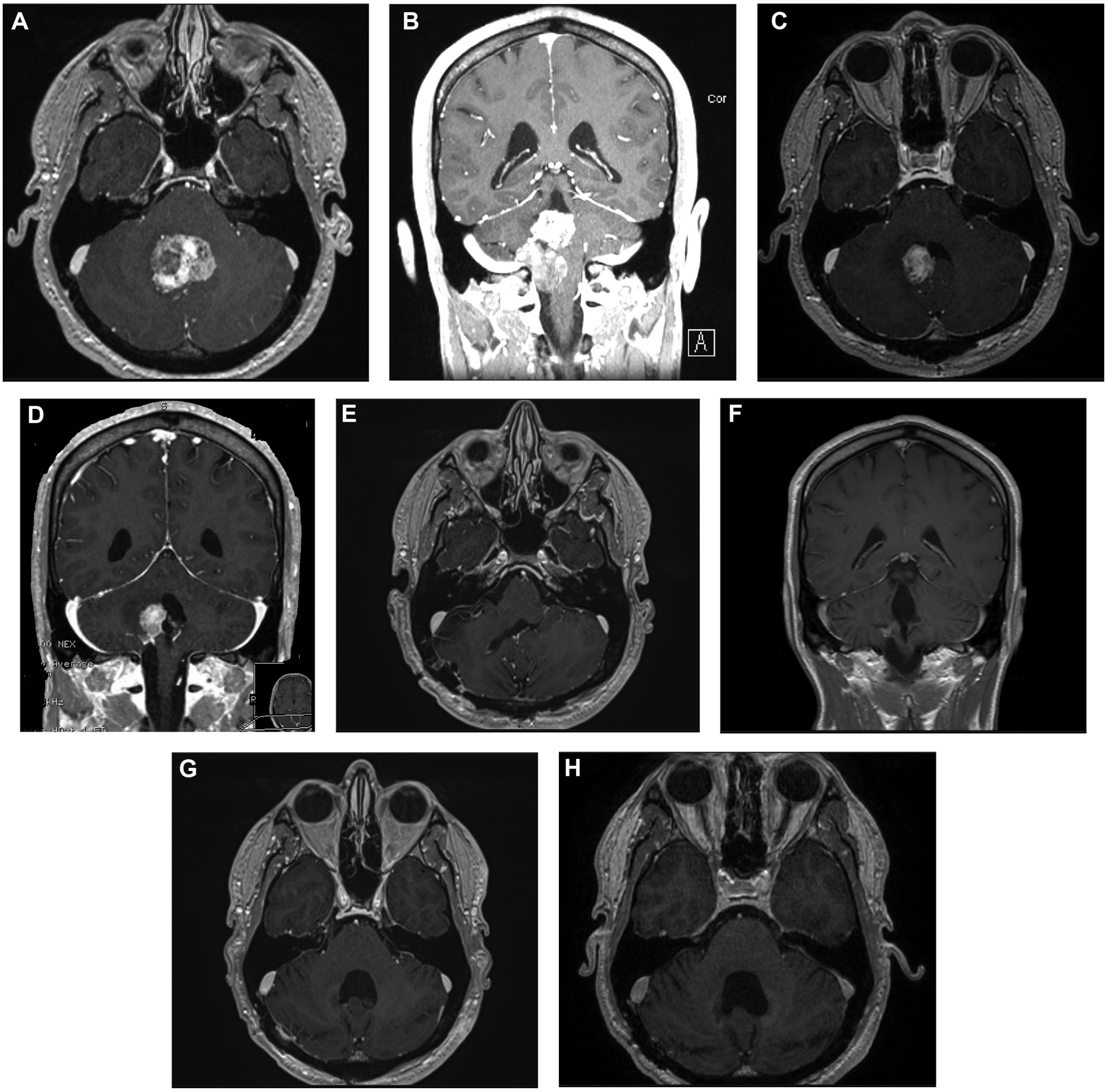

FIGURE 4. **A** *and* **B**, *T1 axial and coronal MR images with contrast before the telovelar approach and before the second stage port procedure.* **C** *and* **D**, *T1 axial and coronal, contrasted images after initial telovelar approach.* **E** *and* **F**, *T1 axial and coronal, respectively, MR images with contrast after telovelar approach and the second stage port procedure; E, also shows the majority of the port track through the right cerebellar hemisphere.* **G**, *T1 axial MRI with contrast at 6 mo postoperation and* **H**, *T1 axial MRI with contrast at 2 yr postoperation, shows no recurrent tumor.*

hematoma of the cerebellar peduncle that occupied the lateral aspect of the fourth ventricle.

The procedure began with the patient positioned in the lateral decubitus position with the head elevated and turned slightly to the right. She underwent a transcerebellar infradentate port approach. After the dura was opened, an 8 mm corticectomy along the folia was completed. The port was placed as described above. The lesion was encountered and evacuated using standard microsurgical technique.

At 2 yr follow-up she is neurologically intact. Unfortunately, because of end-stage renal disease and a resultant renal transplant, she is not able to receive contrast. Her most recent

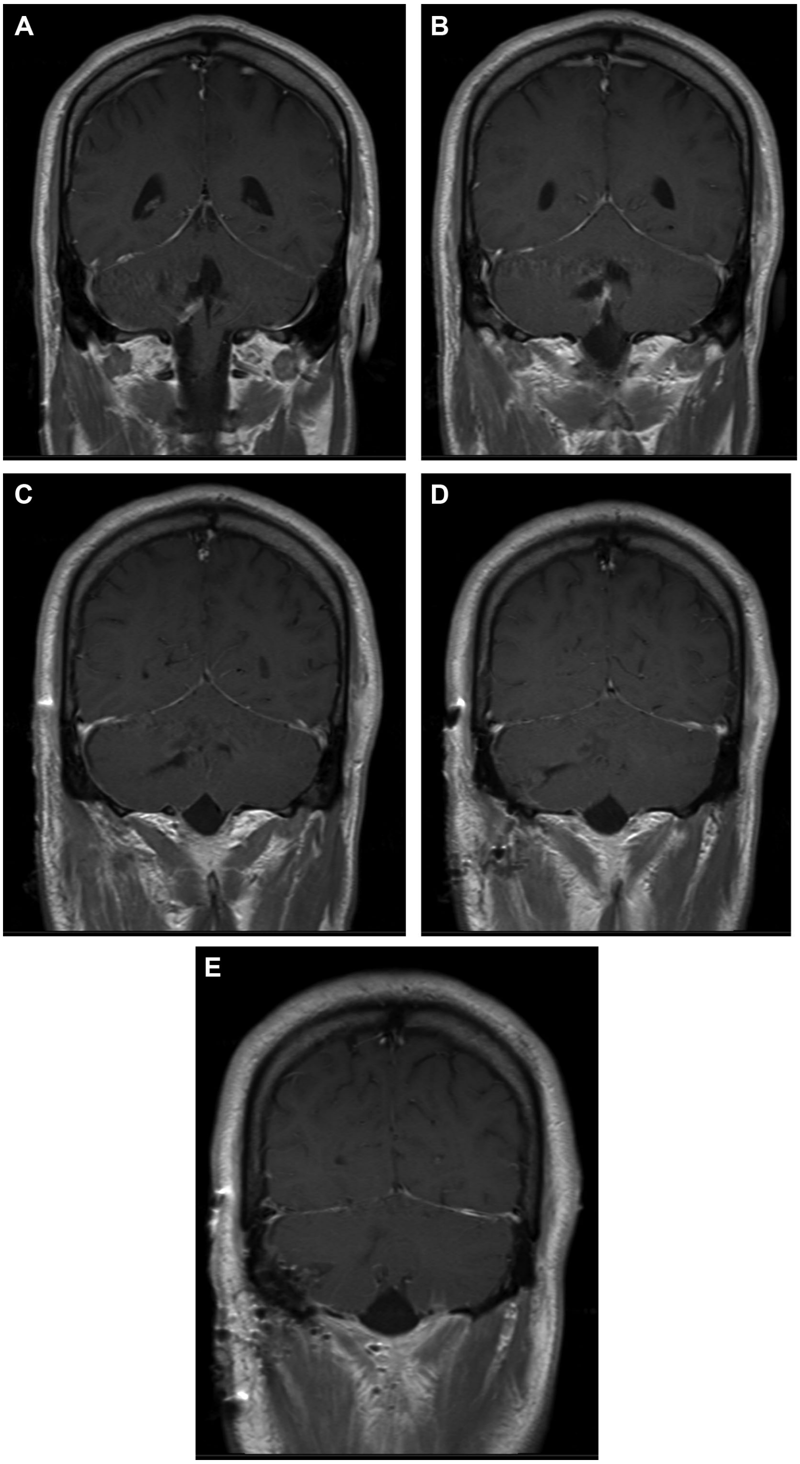

FIGURE 5. A *to* E, *T1 coronal postcontrast MR image postport approach. The port tract can be visualized in the anteroposterior direction from the lateral extent of the right cerebellar hemisphere, inferior to the dentate, and entering the fourth ventricle.*

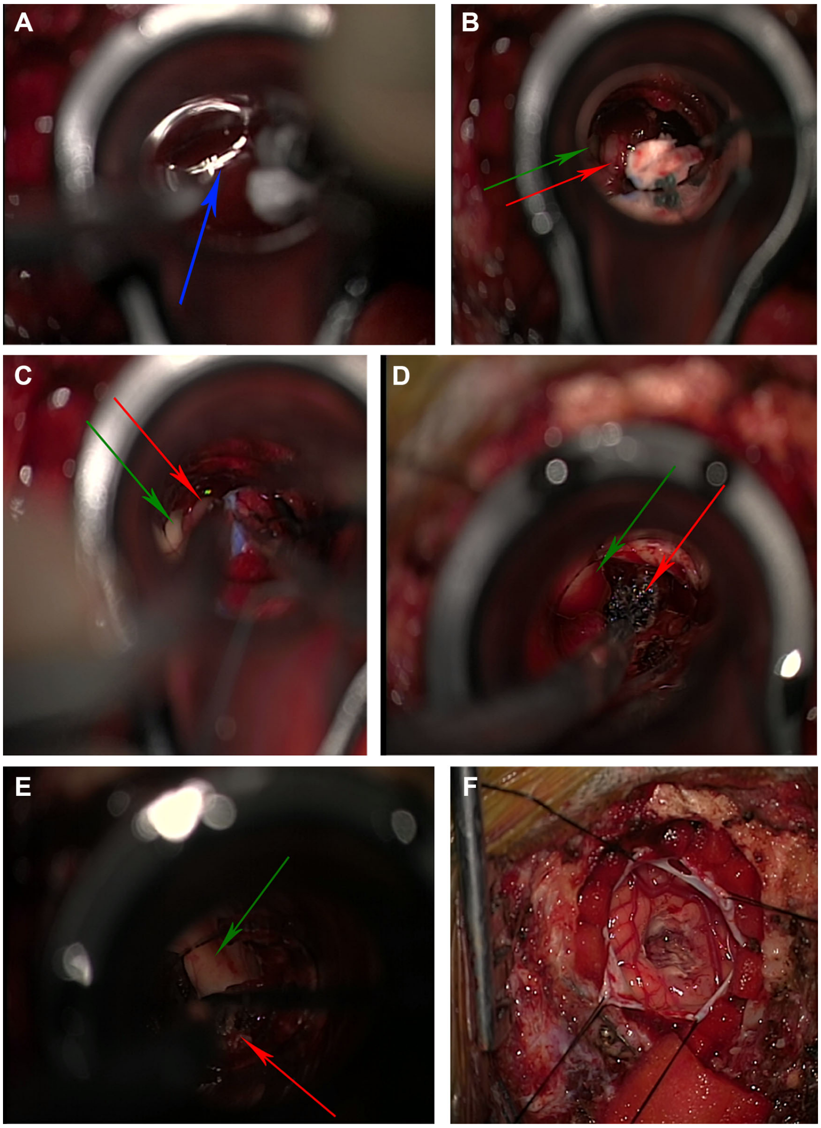

FIGURE 6. *Intraoperative photographs of intradentate transcerebellar port during dissection and removal of tumor.* **A**, *CSF (blue arrow) rising up the port tube once the tumor was manipulated and the port tip entered the fourth ventricle.* **B** *to* **D**, *Progressive dissection of tumor and circumferential plane. Green arrow is fourth ventricle; red arrow is tumor.* **E**, *Final piece of coagulated tumor (red arrow) under retraction exposing fourth ventricle (green arrow).* **F**, *Dural cruciate incision and port trajectory after tumor and port removal.*

noncontrast MRI shows evidence of a surgical track but no significant encephalomalacia or evidence of a new lesion (Figure 9C and 9D).

DISCUSSION

The vast fascicular network that originates in or traverses through the cerebellum towards higher cortical areas qualify the cerebellar peduncles and the deep nuclei as eloquent neural structures. Although the cerebellum is principally thought to control balance and coordinate volitional movement, it also plays a significant role in neuropsychological functioning and sensory processing.[8-11]

The telovelar approach has been described in order to avoid injury to the vermis and dentate.[3,4] When the dentate is damaged, patients can develop disequilibrium and intentional

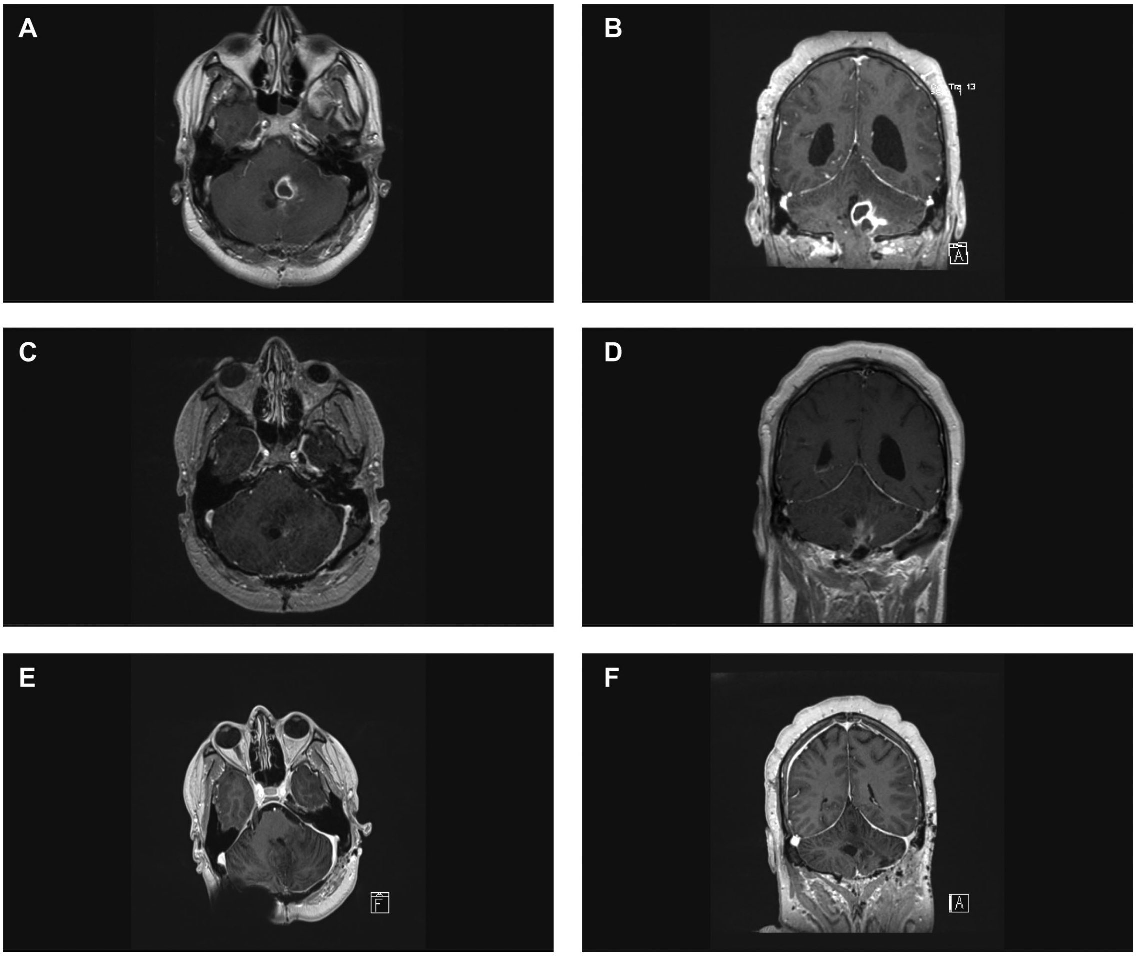

FIGURE 7. **A** *and* **B**, *T1 axial and coronal, MR images with contrast postoperative from a midline suboccipital surgery. There is rim-enhancing fluid collection with loculations in left middle cerebellar peduncle with mass effect and partial effacement of the fourth ventricle and hydrocephalus.* **C** *and* **D**, *T1 axial and coronal, MR images with contrast postoperative from transcerebellar port approach for resection of the cerebellar abscess and residual epidermoid cyst. There are several small foci of restricted diffusion in the surgical bed, and slight decrease in the ventricular size* **B**. **E** *and* **F**, *T1 axial and coronal, MR images with contrast 2 yr postoperative from transcerebellar port approach show continued effacement of the fourth ventricle.*

tremor that is more pronounced than with injury elsewhere in the cerebellum. Splitting the inferior cerebellar vermis may bring about the caudal vermis syndrome that causes truncal ataxia, nystagmus, imbalance, and head oscillation.[4] Incising the vermis and transecting the nodule may also induce cerebellar mutism, which is a well-known complication related to surgery of the fourth ventricle and thought to be related to damage of an outflow tract of the superior cerebellar peduncle—the dentatorubrothalamic fasciculus.[4,12-14]

White matter sparing has become a popular trend amongst neurosurgeons who manage intra-axial, subcortical/periventricular or intraventricular tumors.[11] The ultimate goal is to reduce retractor-induced parenchymal injury associated with the use of blade or ribbon systems.[15-17] These blades cause metabolic changes in the retracted parenchyma consistent with cellular damage.[18] Modern port systems have been developed in order to reduce this operative morbidity and have thus gained popularity amongst surgeons accessing deep-seated lesions.[6,19] Because these port systems can be used alongside frameless stereotaxy systems, surgeons can target tumors that can be accessed with minimal disruption of surrounding tissue.

In order to more reliably avoid the postoperative cerebellar insults that have been discussed above, diffusion tensor imaging studies that trace the white matter tracts that surround the dentate

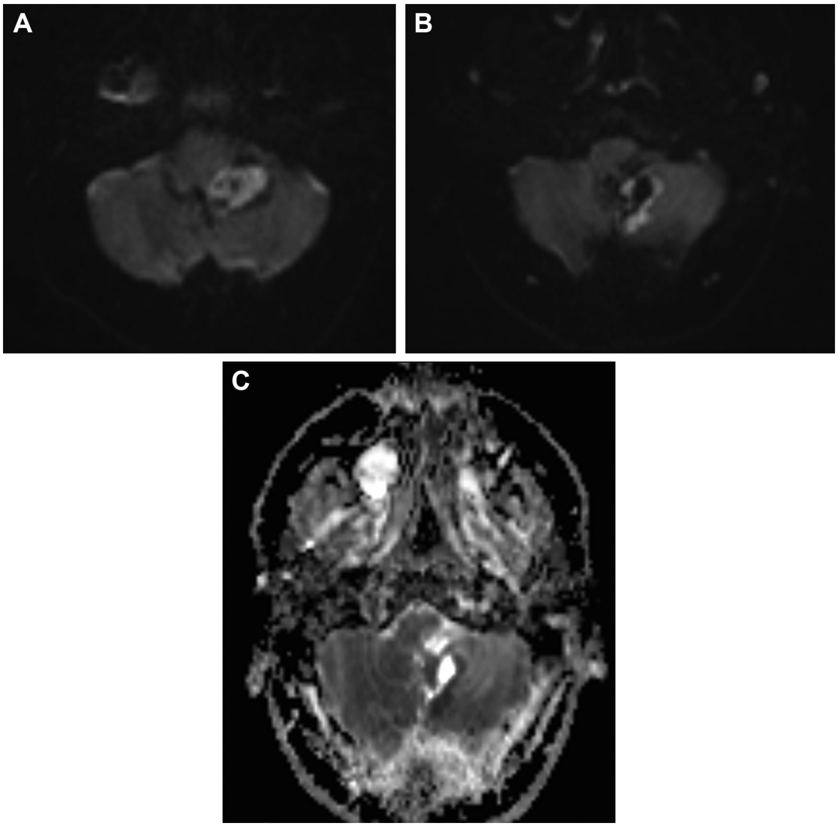

FIGURE 8. **A**, *shows diffusion weighted imaging before the port procedure. There is a hyperintensity in the left cerebellar hemisphere that indicates an abscess.* **B**, *Postport procedure diffusion weighted imaging with diffusion restriction around the margins of the surgical cavity. This likely represents postoperative changes.* **C**, *Apparent diffusion coefficient imaging with T2 shine through artifact in the surgical cavity, and hypointensity around the margin of the surgical cavity.*

and fourth ventricle should be completed preoperatively. In so doing, the surgeon can properly plan the course for a port. The surgeon must aim to place the port along the long axis of the tract so that it courses parallel to the fascicles. In the authors' opinion, the main advantage of the tubular retractor system is that the beveled, tapered edge of the port allows for tissue to be displaced around the tubes rather than transecting or retracting vital white matter tracts with blades. The minimal disruption of brain tissue using this system has been supported by postoperative MRI findings, which show minimal FLAIR, T2, and ADC/DWI, changes; similar findings are seen in the above cases.[6,20]

In addition to decreasing surrounding cytotoxic injury and edema, the port allows for a feasible and reproducible transcortical approach to the fourth ventricle and its surroundings. Classic approaches to the fourth ventricle are not routine for general neurosurgeons and often the telovelar approach is not possible due to anatomic limitations specific to certain patients. In fact, 2 of the 3 patients in this series were undergoing redo posterior fossa surgery and an alternate route was critical to the successful removal of their lesions. The port can give surgeons access to tumors within the fourth ventricle without much subarachnoid dissection while allowing for total resection and minimizing operative morbidity.

Although these sorts of port cases have been described, they are not routine for all neurosurgeons. Therefore, comfort with these minimally invasive techniques in the supratentorial space is advised prior to tackling a posterior fossa lesion. The authors have found that the learning-curve is steep.

CONCLUSION

The transcerebellar, vermian sparing, and infradentate port approach to the fourth ventricle is a safe technique that can be used in situations where the telovelar approach is not suitable to completely expose the fourth ventricle. The infradentate port approach allows for direct exposure of lesions in the roof and

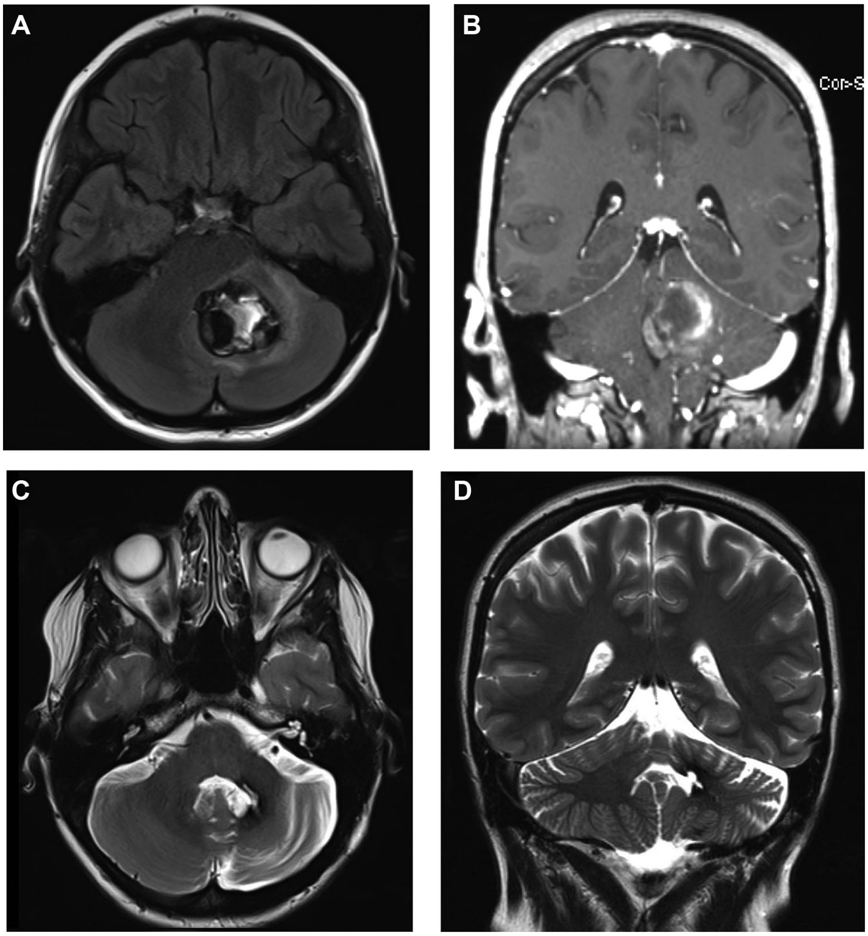

FIGURE 9. **A** *and* **B**, *Axial and coronal, T2 FLAIR and T1 with contrast, respectively, images preoperatively show a large hemorrhagic mass in the left middle cerebral peduncle with effacement and encroachment of the fourth ventricle, without hydrocephalus.* **C** *and* **D**, *T2 axial and coronal, MR images without contrast showing hemosiderin staining and encephalomalacia along the postoperative surgical tract, without evidence of residual cavernous malformation.*

floor of the fourth ventricle without the need for major cisternal dissection and avoiding deep cerebellar nuclei damage.

Disclosures

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COMMENTS

The authors describe a transcerebellar approach through a port in accessing fourth ventricular tumors. They demonstrate a mastery of the anatomy and application and have achieved excellent neurological and imaging outcomes in the 3 cases presented. I congratulate the authors on this elegant report. This approach should be in the armamentarium of the surgeon when the telovelar approach is not going to be possible or sufficient for certain tumors.

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I read with great interest this manuscript detailing a technique to remove deep cerebellar/fourth ventricle lesions while avoiding damage to the deep cerebellar nuclei. Admittedly, I have found the telovelar approach is typically sufficient for the lesions presented here. I was especially gratified to see the authors give recognition to Dr Pat Kelly who pioneered and described the technique of stereotactic guided resection of deep cerebral and cerebellar lesions via a tubular retractor system 30 years ago. I congratulate the authors on their excellent results.

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