Lateral inferior cerebellar peduncle approach to dorsolateral medullary cavernous malformation

Clinical article

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Object. Brainstem cavernous malformations (BSCMs) present a unique therapeutic challenge to neurosurgeons. Resection of BSCMs is typically reserved for lesions that reach pial or ependymal surfaces. The current study investigates the lateral inferior cerebellar peduncle as a corridor to dorsolateral medullary BSCMs.

Methods. In this retrospective review, the authors present the cases of 4 patients (3 women and 1 man) who had a symptomatic dorsolateral cavernous malformation with radiographic and clinical evidence of hemorrhage.

Results. All patients underwent excision of the cavernous malformation via a far-lateral suboccipital craniotomy through the foramen of Luschka and with an incision in the inferior cerebellar peduncle. On intraoperative examination, 2 of the 4 patients had hemosiderin staining on the surface of the peduncle. All lesions were completely excised and all patients had a good or excellent outcome (modified Rankin Scale scores of 0 or 1).

Conclusions. This case series illustrates that intrinsic lesions of the dorsolateral medulla can be safely removed laterally through the foramen of Luschka and the inferior cerebellar peduncle.

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KEY WORDS • cavernous malformation • inferior cerebellar peduncle • dorsolateral medulla • surgical technique

EXCISION of brainstem cavernous malformations (BSCMs) is typically reserved for lesions that have a pial or ependymal presentation and have shown prior hemorrhage. Safe access routes, such as the middle cerebellar peduncle,⁷ have been described for deep-seated lesions. Lesions at the dorsolateral medulla adjacent to the floor of the fourth ventricle pose unique challenges because of the limited safe surgical routes. A surgical route through the floor of the fourth ventricle is discouraged because of the predominance of cranial nerve nuclei and the high risk for postoperative deficits.²⁶ Medial approaches to the dorsal medulla and inferior cerebellar peduncle have been described and include the transvermian, telovelar, and supratonsillar approaches.²⁵⁶ In this report, we describe the cases of 4 patients who underwent excision of a dorsolateral medullary cavernous malformation via a novel lateral inferior cerebellar peduncle (ICP) approach.

Abbreviations used in this paper: BSCM = brainstem cavernous malformation; CN = cranial nerve; ICP = inferior cerebellar peduncle.

Methods

Four patients with a cavernous malformation located at the dorsolateral medulla were identified from a prospective database. There were 3 women and 1 man whose mean age was 52.5 years (range 37–77 years). The patients presented clinically with some of the following symptoms: dizziness, diplopia, dysphagia, contralateral weakness/numbness, and gait imbalance. All the patients had clinical and radiographic evidence of hemorrhage. All patients underwent resection via a far-lateral suboccipital craniotomy or a retrosigmoid craniectomy and through the lateral inferior cerebellar peduncle (Table 1).

Results

Follow-Up and Outcomes

There were no deaths. Two patients had postoperative
temporary worsening of symptoms that lasted 3–4 weeks (Cases 1 and 2, Table 1). The mean follow-up period was 5.75 years (range 1–10 years). All patients had multiple follow-up MRI scans that showed no evidence of recurrence (Figs. 1–4). The modified Rankin Scale score was 0 in 2 patients (Cases 1 and 2) and 1 in 2 patients (Cases 3 and 4) (Table 1).

### Illustrative Cases

#### Case 2

**Clinical Presentation.** A 37-year-old woman presented with progressive left hemiparesis and facial dysesthesia. Neurological examination revealed mild hoarseness, left-sided V₃ numbness, left-sided upper- and lower-extremity weakness (Grade 4/5), and mild truncal ataxia. Brain MRI demonstrated a BSCM located at the dorsolateral medulla (Fig. 5).

**Intervention.** After discussing alternatives with the patient, she agreed to undergo a resection. The patient was taken to the operating room. She was placed supine and underwent a left retrosigmoid craniotomy. The dura was opened and reflected anteriorly. Sharp microsurgical dissection of the cisterns was performed, and CSF was released for cerebellar relaxation. The flocculus and choroid plexus protruding through the foramen of Luschka were also identified. The foramen of Luschka was opened, and the cavernous malformation was localized with intraoperative neuronavigation. The location of the ICP was identified within the foramen of Luschka. There was hemosiderin staining of the peduncle. A small incision was made in the ICP, and the cavernous malformation was entered. The lesion was dissected with microsurgical techniques and removed. Following excision of the cavernous malformation, the venous anomaly was identified and preserved. The field was irrigated and dura was closed.

**Postoperative Course.** The patient was discharged to home on postoperative Day 3. Her neurological status remained stable after surgery, with mild left hemiparesis and facial numbness. Her hoarseness was transiently worse but resolved within a few days. At 6 years after surgery, the patient remains neurologically asymptomatic and has had no radiographic evidence of recurrence (Figs. 4 and 6).
Dorsolateral medullary cavernous malformations

Case 4

Clinical Presentation. A 42-year-old man presented with acute onset of vertigo, nausea, vomiting, and dysphagia. Head CT showed a hemorrhage in the dorsolateral medulla (Fig. 1). Head MRI demonstrated a 9-mm-diameter rounded hypointense focus on T1-weighted sequence (Fig. 2A) that showed prominent blooming on the gradient echo sequence (Fig. 2B). These findings suggested a cavernous malformation at the dorsolateral medulla. The lesion approached the floor of the fourth ventricle and the lateral dorsomedullary pial surface. An associated developmental venous anomaly was noted in the brainstem and cerebellum (Fig. 2C). A 3-month follow-up MR image again suggested a cavernous malformation with evolution of lesional blood products. The patient had only mild swallowing disturbance at this follow-up visit. He elected to undergo excision of the cavernous malformation. High-resolution preoperative MRI images were carefully reviewed and correlated with the literature on dorsolateral medulla sectional and surgical anatomy. A lateral approach through the inferior cerebellar peduncle was selected.

Intervention (Video 1). General anesthesia was induced, and somatosensory evoked potential and lower cranial nerve monitoring was performed. The patient was placed supine with his head turned laterally to expose the left retromastoid region. A linear incision was made in

![Fig. 2. Case 4. A: Axial T1-weighted image showing a hypointense lesion at the left dorsolateral medulla. B: Axial gradient echo sequence demonstrating prominent blooming suggestive of hemorrhage. C: Axial gradient echo sequence revealing the cavernous malformation and a prominent venous malformation.](image1)

![Fig. 3. Case 4. Postoperative axial T2-weighted MR image showing no obvious residual cavernous malformation.](image2)

![Fig. 4. Case 2. A: Axial T2-weighted image showing a small cavernous malformation at the left dorsal medulla. The patient underwent a left retrosigmoid craniectomy and cavernous malformation resection. B-D: Sagittal, coronal, and axial T1-weighted contrast-enhanced images showing no evidence of recurrence at 6-year follow-up.](image3)
the left retromastoid region. The lateral transverse sinus, transverse-sigmoid junction, and posterior aspect of the sigmoid sinus were exposed. The dural opening was fashioned to retract the sigmoid sinus anteriorly. The foramen of Luschka was opened and the origins of CNs IX and X were visualized. Using an image guidance system, the ICP and the point where the cavernous malformation approached the surface were identified. There was no pial presentation of the lesion. A small vertical incision was created inferior to the cochlear nuclei and posterior to the origin of CNs IX and X. A chronic hematoma was identified and evacuated. The cavernous malformation was then resected with sharp microsurgical dissection techniques using microscissors and microdissectors. After removal of the cavernous malformation, the surgical bed was carefully examined to confirm there was no residual malformation. Hemosiderin-stained tissue was not removed. The venous anomaly was not manipulated. There was no change in the patients’ neuromonitoring potentials. Details of the procedure are shown in Video 1.

**VIDEO 1.** A left retrosigmoid craniotomy has been performed with exposure of the sigmoid sinus. This allows for dural retraction of the sigmoid to augment exposure. CSF is released at the cerebellopontine angle for cerebellar relaxation. A single retractor is placed to achieve exposure at the region of the foramen of Luschka. The tenia choroidea behind CNs IX, X, and XI were opened to reveal the dorsolateral medulla within the foramen. Using image guidance, a small incision is made in the brainstem below the level of the cochlear nuclei. The hemorrhage is encountered and the malformation is removed using microscissors and microforceps. The cavity is then inspected for residual lesion. Hemosiderin-stained tissue is left intact as is the venous malformation. Hemostasis is achieved and the retractor is removed. Copyright Providence Brain and Spine Institute. Published with permission. Click here to view with Media Player. Click here to view with Quicktime.

**Postoperative Course.** The patient’s swallowing function was slightly worse. Postoperative MRI showed no obvious residual malformation (Fig. 3). The patient was discharged 4 days after the procedure, tolerating solids. He had no postoperative complications. At the 2-week follow-up visit, he complained of a chronic cough and had decreased left palatal elevation similar to that seen on his preoperative examination. He also exhibited mild imbalance when walking, with mild left upper- and lower-extremity dysmetria. At 6-month follow-up, the patient’s swallowing function was normal and his cerebellar findings had resolved.

![Drawing of the ICP. Reproduced from: DeArmond SJ et al.: Structure of the Human Brain: A Photographic Atlas, 3rd Ed., 1989 (Fig. 44, p. 88). By permission of Oxford University Press, USA.](image-url)
Discussion

Symptomatic BSCMs are associated with an annual risk for hemorrhage estimated at 4%–11%. Lesions of the brainstem can be resected safely if they have pial or ependymal presentation. For lesions that are deep to the pia or ependyma, safe entry zones into the brainstem include the middle cerebellar peduncle and the lateral medullary sulcus, among others. We introduce an approach to intrinsic medullary lesions through the foramen of Luschka with an incision in the inferior cerebellar peduncle. The limits of the incision are the origin of cranial nerves (CNs) IX and X anteriorly, the dorsal and ventral cochlear nuclei and the junction of CNs VII and VIII with the brainstem rostrally, the floor of the fourth ventricle posteriorly, and the cuneate nuclei below the CNs IX, X, and XI origin inferiorly.

Surgical Anatomy of the Foramen of Luschka

The foramen of Luschka is the lateral aperture of the fourth ventricle. Its boundaries include the origins of CNs IX and X as well as the rhomboid lip anteriorly, the flocculus of the cerebellum superiorly, and the choroid plexus and tela choroidea laterally and inferiorly. The rhomboid lip and the tela choroidea form the true foramen of Luschka. The foramen of Luschka is postero-inferior to the junction of the facial and vestibulocochlear nerves with the brainstem. Choroidal branches of anteroinferior cerebellar artery supply the choroid plexus and tela choroidea in the lateral aspect of the foramen of Luschka. Branches of posteroinferior artery supply the choroid plexus and tela choroidea in the medial aspect of the foramen of Luschka.

Surgical Anatomy of the Dorsolateral Medulla Adjacent to the Foramen of Luschka

The ICP is located in the dorsolateral medulla posterior to the origin of CNs IX and X and is exposed by opening of the foramen of Luschka. The ICP is lateral to the floor of the fourth ventricle and ventral to the lateral recess (Figs. 5 and 6). At the lower part of the pons, the ICP forms the ventricular surface of the upper wall of the fourth ventricle. The lateral cuneate nucleus and the lateral vestibulospinal tract in the inferior vestibular nucleus are posterior to the ICP.

Surgical Anatomy of the Floor of the Fourth Ventricle at the Level of the Rostral Medulla

At the level of the rostral medulla, the floor of the fourth ventricle is lined by several important nuclei and tracts. From medial to lateral, these include the hypoglossal nucleus, the dorsal efferent nucleus of the vagus nerve,
the solitary nucleus, the medial vestibular nucleus, the inferior vestibular nucleus, and the lateral cuneate nucleus. From medial to lateral, important tracts include the dorsal longitudinal fasciculus, the solitary fasciculus, and the lateral vestibulospinal tract (Fig. 5 and 6). These important nuclei and tracts make an approach through the floor of the fourth ventricle treacherous.3,16

Function of the ICP

The ICP carries projections from the medulla and spinal cord to the cerebellum. Crossed olivocerebellar fibers constitute the bulk of the ICP. Other projecting brainstem and spinal cord nuclei include the lateral reticular nucleus, the accessory cuneate nucleus, the paramedian reticular nuclei, the arcuate nucleus, and the perihypoglossal nuclei.3 These projections are sent diffusely to the cerebellar hemispheres and to the deep cerebellar nuclei. The literature regarding isolated ICP injury is sparse. Several case reports and series have described injury to the inferior cerebellar peduncle in the dorsolateral medulla resulting in ipsilateral truncal ataxia, limb ataxia, dysmetria, dysdiadochokinesia, and axial lateropulsion.4,9,13 Many of the cerebellar findings in a Wallenberg’s syndrome may be related to ICP injury (Fig. 5).

Approaches to the Dorsolateral Medulla

Approaches to the dorsolateral medulla include lateral and medial approaches. Lateral approaches include the retrosigmoid and far-lateral transcondylar approach. Medial approaches include the transvermian, subtonsillar, and telovelotonsillar approaches. Recently, medial approaches through arachnoid clefts have gained favor because of dissection planes through natural clefts and wide exposure of the foramen of Luschka.11,12,17 Lawton et al. have described a supratonsillar approach to cavernous malformations located in the ICP.11 In their series, all patients had lesions in the peduncle and the cerebellum but not intrinsic within the medulla. The supratonsillar approach places the surgeon in a location and trajectory above the foramen of Luschka and above the level of the medulla. A lateral approach through the foramen of Luschka to the ICP for an intrinsic brainstem lesion has not been previously described. A medial telovelotonsillar approach can allow the surgeon to access the medial aspect of the foramen of Luschka, but accessing the lateral aspect of the foramen is a longer reach. Also, a medial approach may lead to an incision into the floor of the fourth ventricle. Entry through the floor of the fourth ventricle is discouraged because of the presence of the cranial nerve nuclei and tracts. For dorsolateral medullar lesion, the most direct route is laterally through the foramen of Luschka rather than medially. As demonstrated in this report, a small incision in the inferior cerebellar peduncle is tolerated well.

Advantages and Disadvantages of the Foramen of Luschka Approach

The positioning of the patient, supine with head turned, is easier for the surgical team than the prone position. The incision is linear, and the exposure does not require removal of the C-1 lamina. The anatomy of the retrosigmoid approach is more familiar and requires less arachnoidal dissection than the medial approaches. With a telovelar approach, the dorsolateral medulla is at the lateral-most extent of the exposure, and exposure may be limited.11 Minimal retraction is required for the lateral approach, and dynamic retraction with a suction device is frequently sufficient. The lateral transforaminal approach is a direct route to the ICP with no intervening structures (Fig. 6). In contrast, the medial approach threatens entry into the dorsal aspect of the fourth ventricular nuclei. The primary disadvantage of the lateral ICP approach is the potential for cerebellar dysfunction due to the brainstem incision. The patient in Case 1 had only mild ataxia immediately postoperatively, and this had resolved by the 6-week follow-up. A small, shallow, vertically oriented incision into the brainstem isolated to the ICP may have minimized the patient’s postoperative symptoms. Resection of dorsolateral medullary lesions can also worsen swallowing symptoms as seen in Cases 2 and 4. However, in both patients, this mild dysphagia was transient. The patient in Case 4 continues to have intermittent coughing episodes, but these are infrequent.

Conclusions

We introduce the lateral trans–foramen of Luschka ICP approach as a potential route to access intrinsic lesions of the dorsolateral medulla. This lateral approach has several advantages over medial foramen of Luschka approaches. Careful preoperative selection with high-resolution MRI and reliance on image guidance is crucial to a successful clinical outcome. Selection of a lesion close to the pial surface with a small and shallow brainstem incision minimizes the likelihood of postoperative cerebellar dysfunction.

Disclosure

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

Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: Deshmukh, Rangel-Castilla. Analysis and interpretation of data: Deshmukh, Rangel-Castilla. Drafting the article: Deshmukh, Rangel-Castilla. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Study supervision: Spetzler.

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