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Microsurgical Management of Fourth Ventricle Lesions Via the Median Suboccipital Keyhole Telovelar Approach

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Abstract: In this 2-year retrospective analysis, 13 patients with fourth ventricle lesions who underwent microsurgical resection via the midline suboccipital keyhole telovelar approach were analyzed. This is the first study to investigate the surgical outcome and complications of using this approach to resect various types of lesions in the fourth ventricle. We aimed to clarify whether this approach has met its promise of lesion dissection. Three patients (23.1%) had intraoperative extraventricular drains. There were no immediate postoperative deaths. Gross total resection was achieved in 84.6% of the cases. The Fisher exact test showed there was no statistically significant correlation between lesion location, lesion size, brainstem invasion, and extent of resection. About two third (69.2%) of the cases were free of complications. New or worsening gait/focal motor disturbance (15.4%) was the most common neurological deficit in the immediate postoperative period. One patient (7.7%) had worse gait disturbance/motor deficit following surgical intervention. Two patients (15.4%) developed meningitis. Two patients (15.4%) required postoperative cerebrospinal fluid diversion after tumor resection, of these 2 patients, 1 (7.7%) eventually needed a permanent shunt. There were no cases of cerebellar mutism and bulbar paralysis. The median suboccipital keyhole telovelar approach provides relative wide access to resect most fourth ventricle tumors completely and with satisfactory results. In contrast, this requires the appropriate patient selection and skilled surgeons.

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Currently, lesions of the fourth ventricle continue to represent a surgical challenge. Adjacent cranial nerve (CN) nuclei in the ventricle floor, cerebellar peduncles, dentate nuclei in the ventricle roof, and critical vascular relationships are issues that increase the degree of surgical complexity.[1,2] In 1992, Matsushima et al[3] first described the microsurgical anatomy of the cerebellomedullary fissure and the use of the telovelar approach in 9 patients. Since then, an increasing number of anatomic reports[1,2,4–10] and clinical series[11–21] have proved that the telovelar approach has the potential to become the standard treatment for most lesions of the fourth ventricle.

The median suboccipital keyhole procedure was first described in 1970 by Krayenbuhl and Yasargil.[22] Surgical mortality and morbidity could be successfully minimized. In particular, a precise dissection within the subarachnoid spaces of the posterior fossa and the possibility of approaching the fourth ventricle through anatomic pathways offered a significant development in surgical results.

This is the first study to evaluate the surgical keyhole approach and the clinical results in a consecutive series of patients with various types of fourth ventricle lesions. All of them were treated in our institution. We aimed to clarify whether this technique could achieve the dissection of the lesions. We also compared the rates of extent of resection (EOR) and surgical complications between this keyhole approach and the traditional median suboccipital approach.

MATERIALS AND METHODS

Clinical Data

Patients were enrolled in the Department of Neurosurgery of the Affiliated Hospital of Qingdao University, China. The inclusion criteria involved all those presenting fourth ventricular lesions. All patients who underwent microsurgical resection via the midline suboccipital keyhole telovelar approach from September 2018 to October 2020 were identified. Operative and follow-up clinical notes were reviewed for demographic details, pathological and radiographic tumor characteristics, the EOR, and neurological outcome and complications. Every subject received continuous intensive monitoring for respiratory and cardiovascular complications and, after surgery, was symptomatically treated on the first day after the operation. Tracheostomy was often required in patients with shortness of breath and expectoration. All patients had at least 1 year of postoperative follow-up.

Surgical Technique

Intraoperative cerebrospinal fluid (CSF) diversion in the form of an extraventricular drain (EVD) had to be performed in patients with obstructive hydrocephalus before craniotomy. In all surgical procedures, the patients were in a three quarter prone position and had their heads anteroflected about 30° to 45°, which was fixed in a Mayfield head-holder. Special care was taken not to compress the ventilation tube and the larynx. Mediolaterally situated lesions require a further slight rotation of 5° to 15°. The skin incision was placed median extending from the line between the tips of the bilateral mastoid to 3 cm upwards and 1 cm downwards (Fig. 1A). After the skin incision, soft tissue dissection and separation of the suboccipital muscles were then strictly conducted in the midline through the ligamentum nuchae. An osteoplastic craniotomy with a diameter of about 2.0 cm was performed using a 2-mm high-speed craniotome (Fig. 1B).

The dura was opened in a reverse U-shaped fashion and extended towards the foramen magnum. In young children, hemoclips or sutures could be used for hemostasis because of venous channels and marginal sinus. Sufficient drainage of CSF was then achieved by opening arachnoid sheets. After opening and retraction of the arachnoid, the bilateral cerebellar tonsils and vallecula were visible. The posterior inferior cerebellar artery was commonly observed at this point, which disappears into the cerebellomedullary fissure (Fig. 1C). The cerebellar tonsil was then retracted to the most extent after dissection of the uvulotonsillar and medullotonsillar spaces (Fig. 3A). The inferior aspect of a large tumor was usually evident protruding through the foramen of Magendie, with the tela choroidea and inferior medullary velum stretched thinly over its surface (Fig. 3B). The tela choroidea was bilaterally dissected from the taenia of the medulla oblongata. The inferior medullary velum and the vermis were gently retracted superiorly, providing a broad view of the fourth ventricle. For larger or laterally extended lesions, the inferior medullary velum was further opened, and the cerebellar vermis gently lifted to fully expose the cranial part of the fourth ventricle and its surrounding structures. This way, the fourth ventricle floor was identified and protected. The lesions were then dissected using a microsurgical technique (Fig. 3C). The aqueduct was inspected and its patency was verified at the end of the tumor resection (Fig. 3D).

Postoperative Evaluation

The extent of the resection was determined by postoperative magnetic resonance imaging (MRI) after 3 days and 3 months.

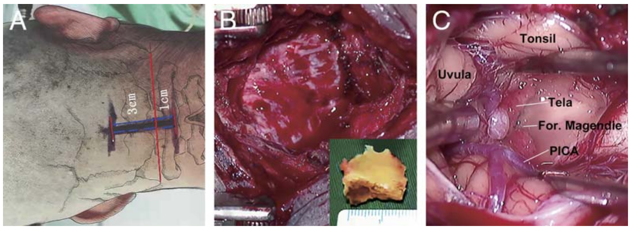

FIGURE 1. Midline suboccipital keyhole craniotomy for lesions of the fourth ventricle. (A) The skin incision was placed median extending from the line between the tips of the bilateral mastoid to 3 cm upwards and 1 cm downwards. (B) An osteoplastic craniotomy with a diameter of nearly 2.0 cm was performed using a 2-mm high-speed craniotome. (C) The bilateral cerebellar tonsils, uvula, posterior inferior cerebellar artery (PICA), foramen of Magendie, and tela choroidea could be observed after opening and retraction of the arachnoid.

Gross total resection (GTR) was defined as complete tumor resection with no residual viable tumor under the operating microscope and no evidence of residual tumor on postoperative MRI. Postoperative outcomes were evaluated by the Karnofsky Performance Status (KPS) scores. Both new and worsening deficits were counted as complications. Postoperative complications mainly included gait disturbance, deficits of the motor, speech, swallowing, and/or CN kind, visual impairment, hydrocephalus, and other medical alterations. Finally, we analyzed the clinical and radiologic factors that could potentially affect EOR using Fisher exact test.

RESULTS

Patient and Tumor Characteristics

Details about the 13 surgical patients are shown in Supplemental Table 1 (Supplemental Digital Content 1, http://links.lww.com/SCS/E363). General results involved a slight male preponderance (61.5%), an overall mean age of 30.8 years, and a majority of adult patients (61.5%). The most common symptoms were headaches (53.8%), gait difficulties (38.4%), nausea and vomiting (30.8%), and dizziness (30.8%). Only 2 patients (15.4%) had bulbar symptoms with preliminary speech problems. Several patients presented multiple symptoms.

The most common tumor types were medulloblastoma (30.8%) and choroid plexus papilloma (23.1%). Other lesion reports were 2 cases of metastases from tumors outside the brain, 1 case of epidermoid, 1 case of ependymoma, 1 case of hemangioblastoma, and 1 case of liponeurocytoma. The lesions of our enrolled patients were all located in the fourth ventricle without extending beyond the confines of the ventricle. Lesions in the inferior two third were the most frequently observed, occurring in 92.3% of the cases (there were 2 cases with the whole ventricle length covered), while some lesions with brainstem invasiveness appeared in 46.2% of cases. There were 3 cases of lesions whose maximum diameter was > 5 cm (23.1%).

Surgical Outcome

Three patients (23.1%) had intraoperative CSF diversion in the form of an EVD. There were no immediate postoperative deaths. Gross total resection was achieved in 84.6% of cases. There was no statistically significant correlation between lesions location ($P = 0.423$, Fisher exact test), lesion size ($P = 0.423$, Fisher exact test), brainstem invasion ($P = 1$, Fisher exact test), and EOR. Postoperative Karnofsky Performance Status (KPS) scores were documented in all cases. Compared with their preoperative function, 3 patients (23.1%) had worsening KPS scores immediately after surgery, while 2 (15.4%) had improvement. In 8 subjects (61.5%), no change was reported.

Neurological Morbidity

About two third (69.2%) of the cases were free of complications (Supplemental Table 2, Supplemental Digital Content 2, http://links.lww.com/SCS/E364). Two patients (15.4%) had new or worsening CN palsies after lesion resection; in one of these cases (7.7%), 2 CN were affected. Another patient suffered deficit in 1 CN. The most commonly affected nerve was CN VI, followed by CN VII. One patient (7.7%) had worse gait disturbance/motor deficit following surgical intervention. In contrast, infectious complications were slightly more common. Two patients (15.4%) developed meningitis, whereas 2 others (15.4%) required postoperative CSF diversion after tumor resection. Among the latter 2, 1 (7.7%) eventually received a permanent shunt.

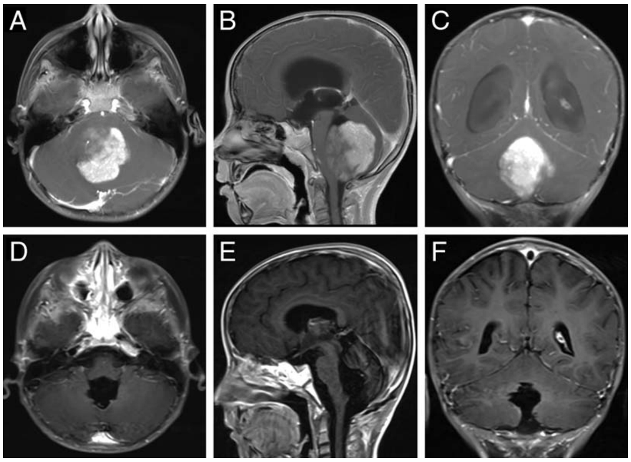

FIGURE 2. Preoperative and postoperative enhanced magnetic resonance imaging in a typical case. (A–C) Preoperative magnetic resonance imaging revealed a mass in the fourth ventricle with obstructive hydrocephalus. (D–F) Postoperative magnetic resonance imaging demonstrated successful gross total resection of the tumor.

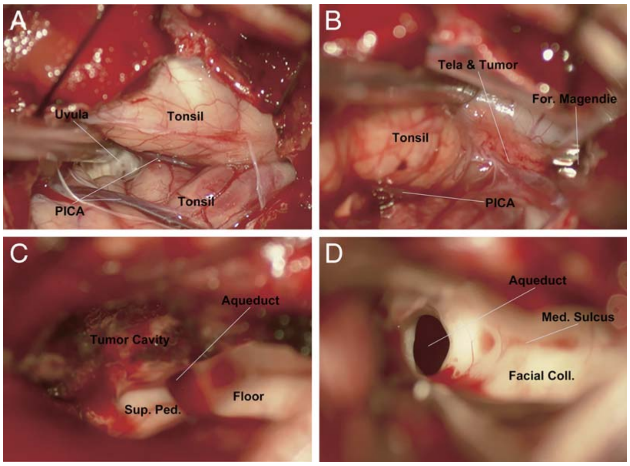

FIGURE 3. Intraoperative photos of a typical case. (A) The bilateral cerebellar tonsils, uvula, and posterior inferior cerebellar artery (PICA) could be observed after opening and retraction of the arachnoid. (B) By visualizing the inferior part of the tumor, its protrusion through the foramen of Magendie was evident, with the tela choroidea and inferior medullary velum stretched thinly over its surface. (C) After the retraction of the vermis and the inferior medullary velum, the entire tumor was exposed and totally resected piece by piece. (D) The aqueduct was inspected and its patency was verified at the end of the resection.

Typical Case

A 5-year-old male patient entered our department with a complaint of headache, vomiting, and ataxia. Neurological examination revealed cerebellar ataxia and partial bulbar paralysis. Magnetic resonance imaging revealed a mass in the fourth ventricle and obstructive hydrocephalus (Fig. 2A–C). An EVD was performed before midline suboccipital keyhole craniotomy. The bilateral cerebellar tonsils, uvula, and posterior inferior cerebellar artery were observed after opening and retraction of the arachnoid (Fig. 3A). Afterwards, the medullotonsillar and uvulotonsillar spaces were dissected to expose the cerebellomedullary fissure. By visualizing the inferior part of the tumor, its protrusion through the foramen of Magendie was evident, with the tela choroidea and inferior medullary velum stretched thinly over its surface (Fig. 3B). The tela choroidea was bilaterally dissected from the taenia of the medulla oblongata. Then, the vermis and the inferior medullary velum were retracted, and the entire tumor was subsequently exposed and totally resected piece by piece (Fig. 3C). The aqueduct was inspected and its patency was verified at the end of the resection (Fig. 3D). Postoperative MRI demonstrated successful GTR of the tumor (Fig. 2D–F). Two years after surgery, the patient was leading a healthy life without any neurological deficits.

DISCUSSION

In 1992, Matsushima et al[3] described for the first time the microsurgical anatomy of the cerebellomedullary fissure and the use of the telovelar approach in 9 patients. This method was further enhanced by Mussi and Rhoton,[1] as they introduced 3 key steps: opening the tela choroidea, incising the superior medullary velum, and cutting the tela between the tonsil and the medulla. The merits and limitations of this traditional approach are thoroughly discussed in the literature.[1,4,19] However, to our knowledge, there has only been a single publication available about the keyhole telovelar approach (focused only on astrocytoma) thus far. Hence, the present work is the first to report such a method to resect various types of lesions in the fourth ventricle.

Ferguson et al[13] suggested that the unilateral opening of the inferior medullary velum could improve the visualization of the superior lateral recess and the aqueduct. They also inferred that reaching the Luschka foramen entails extending the opening to the uvulotonsillar fissure. In our series of patients, we first dissected the uvulotonsillar and medullotonsillar fissures, and then bilaterally dissected the tela choroidea from the taenia of the medulla oblongata. Because of the flexibility of the brain, retraction of the inferior medullary velum and vermis offered a wider corridor to access the aqueduct and the lateral recess. In our series, the opening of the inferior medullary velum was always necessary for the optimal exposure of the superior and lateral extension of the lesions. In general, the degree of telovelar opening varies from patient to patient and depends on the tumor size and location. Throughout our 13 patients, 11 subjects (84.6%) had GTR, while 2 subjects (15.4%) had subtotal resection. The latter was mainly due to brainstem involvement. For its part, Guowei et al[15] reported that GTR was achieved in 92% via the keyhole approach. To review other studies, GTR was 88.9% in the Tomasello and colleagues'[18,19] case series, 84.1% in the Atallah et al's[11] series, 82.0% in the Han et al's[16] series, and 75% in the Ferguson et al's[13] series (via traditional median suboccipital approach). Tomasello and colleagues[18,19] reported that tumors that are large or extend to the upper third of the fourth ventricle are more surgically challenging and increase the risk of both subtotal resection and postoperative hydrocephalus (shunt dependency). Conversely, we had no problems with the GTR of tumors that extended to the rostral third of the fourth ventricle via keyhole approach. This is probably because sufficient dissection of the medullotonsillar and uvulotonsillar fissures provide a wider corridor to access the aqueduct by retracting inferior medullary velum and vermis.

In our study, 3 patients (23.1%) had worsening KPS scores immediately after surgery, which is lower than the series by Ferguson et al[13] (51%). We also found that the incidence of complications after resection of fourth ventricle tumors was nearly 30.8%. In another telovelar keyhole approach study, only 1 in 12 cases suffered 2 neurological complications.[15] To review other studies, 45% of the patients experienced at least 1 neurological complication in the series by Ferguson et al,[13] 22.7% in those by Atallah et al,[11] and 11.2% in those by Tomasello and colleagues.[18,19] Here, 2 patients had their CN affected (15.4%) and 2 others (15.4%) suffered hydrocephalus and required postoperative CSF diversion following tumor resection. Between the latter 2 patients, 1 (7.7%) eventually needed a permanent shunt. In the present series, we did not record any cases of cerebellar mutism after bilateral telovelar opening via the keyhole procedure, which are similar results to Tomasello and colleagues.[18,19] To compare with other studies, the series by Atallah et al[11] found that 13.6% of the patients experienced cerebellar mutism. Another relatively common postoperative complication is bulbar paralysis, which affected 38% of postoperative patients in the series by Ferguson et al[13] but none in our study. Our results may be due to the relatively smaller lesions of our subjects, which did not extend beyond the confines of the ventricle.

Compared with the traditional telovelar approach, this keyhole approach offers some unique advantages: Patients have a better surgical experience that involves smaller incisions and faster recovery. The incision is performed without cutting off external occipital protuberance. This can reduce postoperative poor wound-healing complications.[15] The bone window does not require drilling the posterior arch of the atlas. Therefore, separation of the occipitoposterior muscle group (which reduces the effect on the stability of the craniocervical junction) can be avoided.[15] Bilateral opening of the cerebellomedullary fissure and adequate exposure of the aqueduct. In this regard, verification of both its patency and the increment of the cisterna magnae—fourth ventricle communication can reduce the incidence of hydrocephalus.[19]

Although telovelar access by endoscopy offers the advantage of minimizing retractions and injuries to the dentate nuclei,[23,24] there seems to be a more promising prospect if performed particularly by the keyhole approach. This method has not been used clinically; however, inspired by the work of Feletti et al,[25] we occasionally inspected patency and aspirated blood clots of the aqueduct and tumor residue in our series. Moreover, using endoscopy for access in the telovelar keyhole approach will be one of the main objectives of our future work.

This study could have been limited by its retrospective nature and the relatively small lesions of our enrolled patients, which did not extend beyond the confines of the ventricle.

In summary, fourth ventricle tumors represent a major clinical challenge for neurosurgeons. Our study focused on the keyhole telovelar approach to resect various lesions in the fourth ventricle. To our knowledge, our results are the first to be reported. Here, we show that this methodology could provide a relatively wide corridor of access to resect most fourth ventricle tumors completely and with satisfactory results. Certainly, this requires the appropriate patient selection and skilled surgeons. Larger scale research with longer follow-up periods is certainly needed to better assess this keyhole procedure.

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