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Surgical management of foramen magnum meningiomas: Clinical insights and outcomes

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Abstract

Aim: This retrospective study aimed to provide a comprehensive analysis of the surgical management of foramen magnum meningiomas (FMMs), focusing on patient characteristics, surgical approaches, complications, and postoperative outcomes.

Materials and Methods: The study included 23 patients diagnosed with anterior or anterolateral FMMs who underwent surgical treatment between 2014 and 2022. The study encompassed clinical records, neurological assessments, radiological findings, and surgical approaches, with a focus on the far lateral approach (FLA). Evaluation of outcomes included Karnofsky Performance Scale (KPS) scores and The Neck Disability Index (NDI) scores. Surgical approaches and postoperative care strategies were detailed. The study also examined the relationship between tumor location and surgical techniques.

Results: The analysis revealed that patients with FMMs presented with various clinical symptoms, including lower cranial nerve deficits, pyramidal tract syndrome, and sensory disturbances. The retrocondylar far lateral approach was predominantly utilized, resulting in various Simpson resection grades. Postoperative complications were observed, including cranial nerve deficits, cerebrospinal fluid leakage, and infections. Also, the study found patient KPS scores remained stable, and NDI scores showed no significant increases before and after surgery.

Conclusion: Surgical management of FMMs is a complex task requiring meticulous planning, individualized approaches, and close attention to neurovascular structures. The study emphasized the diverse clinical presentations and surgical techniques associated with FMMs and highlighted the importance of ongoing research and collaborative efforts to enhance patient care in this challenging field.

Introduction

The foramen magnum region plays a vital role as a passageway that connects the brain to the spinal cord [1]. It serves as the exclusive route for numerous arteries, veins, lymphatics, and peripheral nerves, making it a primary site for certain nervous system tumors [1,2]. The intricate anatomical complexity in this region presents considerable challenges during surgical procedures. Numerous anatomical and clinical investigations have been documented regarding the treatment of lesions at the foramen magnum [3,4]. The far lateral approach (FLA) represents an enhanced and expanded iteration of the traditional retrosigmoid approach [1]. Its main goal is to attain the best possible visibility and access to the anterior of the medulla oblangata and spinal cord, covering the extensive area from the C2 to clivus. This approach enables a comprehensive assessment of the tumor's contiguity with the primary structures in this area and the cervical spinal cord from a posterolateral perspective. Importantly, it eliminates the requirement to retract essential structures like the medulla oblangata and spinal cord for effective excision of foramen magnum meningiomas (FMMs) [2]. Nonetheless, the practical use of this technique is considerably limited by the complex interplay of crucial neurovascular structures, the increased risk of serious complications, the deep-seated location of the lesions and the extended recovery period.

To acquire a more profound understanding of the typical progression and manifestation of this specific tumor, we conducted a retrospective analysis of cases that had undergone surgical intervention within our healthcare facility. Our primary objective was to establish a comprehensive

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strategy for the management of FMMs.

Materials and Methods

Materials and Methods We conducted a comprehensive study that encompassed patient characteristics, demographic features, anatomical, and surgical assessments of 23 patients diagnosed with FMMs. These patients underwent surgical treatment between 2014 and 2022 at the Ankara Bilkent City Hospital and at Ankara Numune Training and Research Hospital in Ankara. This research received approval from the Institutional Review Board (Ankara Bilkent City Hospital No. 1 clinical research ethics committee, issue number E1-23-3862, approval date 16.08.2023), and written informed consent was acquired from each participating patient.

The study encompassed individuals aged 18 and above who had received a diagnosis of foramen magnum meningioma with an anterior or anterolateral location, as confirmed through compatible findings in imaging techniques between 2014 and 2022. Inclusion in the study was contingent upon patients providing informed consent for their data to be utilized for research purposes. Patients with foramen magnum meningiomas situated in posterior or posterolateral positions, and those who were younger than 18 years, exhibited craniocervical junction malformations, had prior surgeries involving the craniocervical junction, or had undergone radiotherapy treatment in the same region were excluded from participation in the study.

The research involved a thorough examination of clinical records and imaging studies. Neurological function status was assessed using the Karnofsky Performance Scale (KPS) and The Neck Disability Index (NDI) both before and after surgery. Additionally, we examined lower cranial nerve dysfunction, which includes conditions such as dysphagia, hoarseness, and the gag reflex. The lesion size was assessed using the equivalent diameter calculation (abc)/3, where "a," "b," and "c" denote the respective diameters measured on axial, sagittal, and coronal magnetic resonance images (MRI). Our research received approval from the Institutional Research Ethics Committee.

The 10-item NDI was published to monitor the level of disability and functional impairment experienced by individuals with neck pain or neck-related conditions [5]. The NDI scores range from 0 to 50 points, with corresponding percentages. A score of 0 to 4 points (0-8%) indicates no disability, signifying that the individual's neck pain has a minimal impact on their daily life. Scores in the range of 5 to 14 points (10-28%) represent mild disability, reflecting a relatively low level of functional impairment [5]. For scores falling between 15 to 24 points (30-48%), the classification is moderate disability, indicating a more substantial impact on daily activities. A score of 25 to 34 points (50-64%) corresponds to severe disability, suggesting a significant hindrance to normal functioning. The highest range, 35 to 50 points (70-100%), signifies complete disability, reflecting a severe limitation in daily life due to neck-related issues [5].

Neuroimaging studies played a pivotal role in our investigation. Before the surgical procedure, all patients underwent assessments with both contrast-enhanced MRI scans and computed tomography (CT) scans (Figure 1). In certain instances, particularly for large and laterally positioned tumors, comprehensive evaluations that include the visualization of blood vessels through methods such as CT angiography mostly used, digital subtraction angiography (DSA) and/or MRI angiography were conducted prior to surgery. These assessments aimed to assess the tumor's blood supply and determine the extent of encasement and constriction of the vertebral artery (VA). A prolonged T2 signal on the brainstem surface suggested the possibility of blood-brain barrier disruption or potential tumor invasion/adherence.

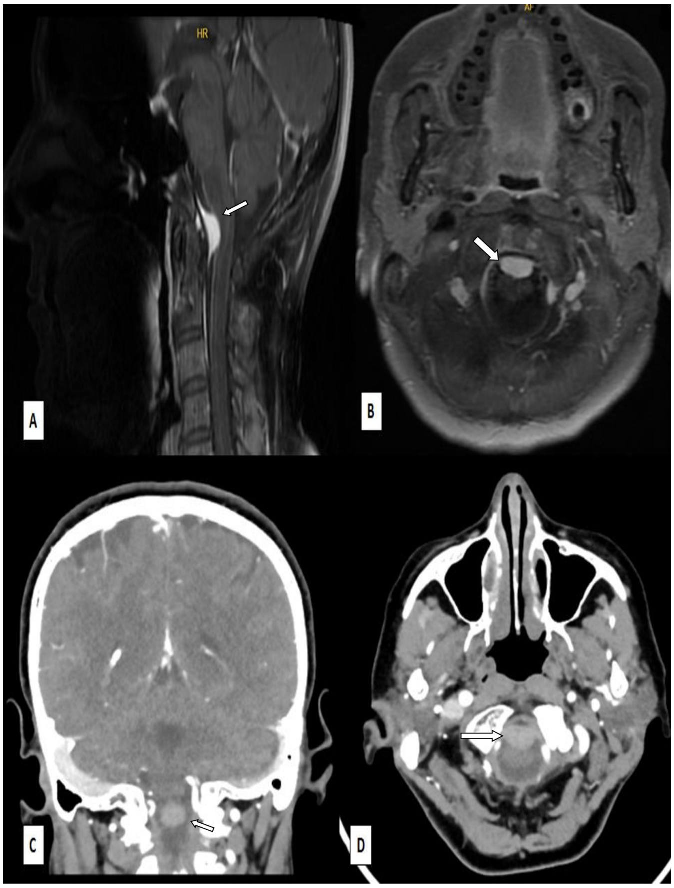

Figure 1. A 52-year-old woman was operated for an anteriorly located FMM. a) contrast-enhanced sagittal T1 MRI image, b) contrast-enhanced axial T1 MRI image, c) preoperative CT angiography of the same patient, coronal section, showing the relationship with the vertebral artery, d) preoperative CT angiography, axial section. The white arrows indicates the location of the tumor.

For classification purposes, FMMs were divided into three distinct groups, according to the classification established by George et al. [6,7]: 1) Anterolateral tumors were situated on the anterior and lateral rim of the foramen magnum, resulting in a posterolateral displacement of the brainstem and spinal cord (Figure 2); 2) Anterior tumors were attached to the anterior rim of the foramen magnum, leading to a posterior displacement of the brainstem;

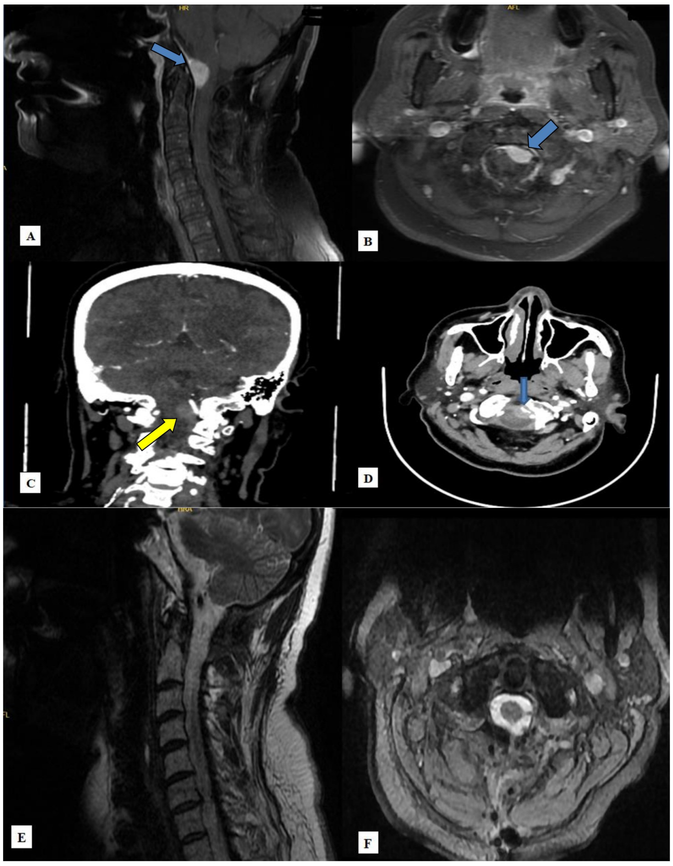

Figure 2. A 55-year-old woman was operated for an anterolaterally located FMM. a-b) preoperative contrast-enhanced T1 sagittal and axial MRI images, c-d) preoperative CT angiography images, coronal and axial images, showing the relationship with the vertebral artery, e-f) postoperative MRI images, showing total resection. (The blue arrows indicate the presence of the tumor, while the yellow arrow illustrates the relationship between the tumor and the vertebral artery).

3). Posterolateral tumors caused an anterolateral displacement of the brainstem and spinal cord.

The assessment of tumor removal extent occurred objectively within two weeks after the surgery through MRI scans. The categorization was done as either total, subtotal, or partial, corresponding to Simpson Grade 1-2, Simpson Grade 3-4, or Simpson Grade 5, respectively.

Surgical procedure

All patients were operated on while in the prone position, with their heads securely immobilized using a Mayfield 3-pin head holder and with their necks hyperflexed.

Electrophysiological monitoring was systematically utilized in all procedures to protect the lower cranial cranial nerves, which involved monitoring brainstem auditory evoked potentials (BAEP) and somatosensory evoked potentials (SEP).

Most of the patients with anterior and anterolateral tumors, the preferred surgical approach was the FLA retrocondylar approach. This approach involved initiating a midline linear skin incision, starting above and extending to the superior nuchal line, then continuing down to the region between the spinous processes of C2 and C3. Identifying the VA positioned above C1 was essential to safely excise the C1 posterior arch, and the extent of laminectomy, whether at C1 or involving C2, was customized according to the tumor's caudal extent within the upper cervical spinal canal.

In patients with tumors exhibiting VA encasement or having small anterior tumors, a surgical excision was performed on a section of the medial margin of the occipital condyle, particularly involving up to one-third of the rim. In cases where FMMs extended into the superio region, an extended FLA was adopted. This approach involved unroofing the sigmoid sinus inferiorly, following it to the jugular foramen.

When assessing the dural incision, a "C"-shaped incision that commenced inferolaterally to the operating field was the preferred choice. The incision curving towards the superolateral corner at a median level was done. This approach took into consideration the denticulate ligament and the tumor's relationship with the vertebral artery (VA) and lower cranial nerves. The tumor was meticulously devascularized and then removed with great care, piece by piece. The extent of resection was assessed using the Simpson grade, in conjunction with postoperative contrast MRI images.

Following FLA approach surgery for FMM, postoperative care was tailored to the specific operative procedure. After the surgery, patients were transferred to the Neurosurgery Care Unit (NSCU). Before extubation, a thorough assessment of the cough and gag reflex was conducted. In cases where there was an increased risk of severe aspiration pneumonia or if patients experienced breathing difficulties, a tracheotomy was performed to ensure respiratory stability. For patients with dysphagia, nasogastric feeding was initiated to provide necessary nutritional support.

Radiosurgery was planned for patients who either experienced tumor recurrence or had undergone subtotal resection during their initial surgery. Follow-up data were collected through clinical examinations and imaging procedures at the 3rd months, 6-month and 1-year postoperative intervals.

Statistical analysis

Statistical analysis was carried out using the software package: IBM SPSS 25.0 (Armonk, NY: IBM Corp.). Descriptive statistics, including mean, median, frequency, standard deviation, percentage, and minimum-maximum values, were computed to summarize the data. In our statistical analysis, we utilized several hypothesis testing methods, each with its own set of assumptions. Chi-Square tests were employed for comparing qualitative data, assuming independence of observations and expected cell frequencies greater than 5, with Fisher's Exact Test as an alternative when this assumption was violated. The Mann-Whitney U test was utilized for comparing two independent groups with non-normally distributed data, assuming independence of observations, random sampling, and measurement on at least an ordinal scale. Spearman's rho Correlation test was applied to explore relationships between variables, assuming independence of observations and a monotonic relationship between variables rather than a linear one. These methods were selected based on the nature of our data and the assumptions they entail to ensure robust statistical analysis. The normality of data distribution was assessed using the Smirnov test, graphical techniques and skewness-kurtosis analysis such as histograms and Boxplots. The Mann-Whitney U test was employed for non-normally distributed data. Spearman's rho Correlation test was used for exploring the relationship between variables. A statistical significance level of $p<0.05$ was considered for all analyses.

Results

In the analysis, a total of twenty-three patients were included (Table 1), with a mean follow-up period of 33.5±12.3 months, ranging from 14 to 62 months. The average age at presentation was 59±13 years, ranging from 33 to 77 years. Notably, there was a predominance of female patients, accounting for 60.8% (14 patients) of the cohort. The locations of the lesions were categorized as anterior, anterolateral, and lateral, representing 47.9%, 21.7%, and 30.4% of the patients, respectively.

At the time of presentation, patients exhibited various signs and symptoms, including lower cranial nerve deficits in 10 patients (43.5%), pyramidal tract syndrome in 9 patients (39.1%), dizziness in 5 patients (21.7%), motor deficits in 7 patients (30.4%), gait disturbances in 8 patients (34.7%), dysesthesia in 3 patients (13.0%), head and neck pain in 18 patients (78.2%), dysphagia in 3 patients (13.0%), hoarseness in 3 patients (13.0%), and one patient (4.3%) presented with Lhermitte's sign.

The extreme lateral approach was employed for all cases. Resection grades according to the Simpson classification were as follows: grade I in 21.7% of cases, grade II in 65.3%, and grade III in 13.0%.When assessing the patients' grades based on the WHO classification for central nervous system tumors, the histopathology results indicated Grade 1 in 19 patients, Grade 2 in 3 patients (including 2 patients with atypical findings and 1 patient with clear cell characteristics), and 1 patient was categorized as Grade 3 (anaplastic). Among the patients, 3 experienced a recurrence of their condition, prompting the implementation of radiosurgery for 5 patients in the postoperative period. Evaluation of preoperative imaging, which included MRI, CT angiography, or DSA, revealed complete encasement of the VA in 3 patients.

The mean preoperative KPS was 76.5±14.6%, while the postoperative KPS was 79.5±15.2%, and the follow-up KPS (postoperative 1st year) was 79.1±10.8. No statistically significant differences were observed between these groups ($p>0.05$). However, seven patients experienced a decrease from the preoperative KPS value due to complications after surgery. Upon NDI evaluation, the preoperative mean score averaged 13.17 ± 7.18, while the postoperative mean score was 10.65 ± 9.47. Importantly, there was no statistically significant difference between these scores ($p>0.05$) (Table 2).

Postoperative complications included neck and occipital numbness in 7 patients (30.4%), weak cough reflex, hoarseness, and choking while drinking water in 5 patients (21.7%), cerebrospinal fluid leakage in 1 patient (4.3%), pneumonia in 5 patients (21.7%), incision infection in one patient (4.3%), hydrocephalus (requiring a shunt in four patients), gastrostomy in 4.3% of cases, tracheostomy in 21.7%, and pulmonary thromboembolism in 4.3%.

Table 1. Patient demographic features and characteristics.

		n	%(Median, min-max)
Sex	Female	14	60.8
	Male	9	39.2
Age (years)*		59 ± 13	58.0 (33.0 – 77.0)
Neurologic status	No deficit	10	43.5
	Deficit	13	56.5
Comorbidity[a]	No	5	21.7
	Yes	18	78.3
	HT	13	56.5
	DM	9	39.2
	Other	4	17.4
	HT + DM	4	17.4
Tumor location	Anterior	11	47.9
	Lateral	7	30.4
	Anterolateral	5	21.7
Tumor size(mm)*		28.9±12.5 CI: (23.5- 34.2)	28.0(9.0-55.0)
Recurrence	No	20	87.0
	Yes	3	13.0
Simpson Grade	1	5	21.7
	2	15	65.3
	3	3	13.0
	4	0	0
	5	0	0
WHO Grade	1	19	82.6
	2	3	13.0
	3	1	4.4
KPS*	Preoperative	76.5±14.6 CI: (70.19- 82.81)	80.0 (50.0-100.0)
	Postoperative	79.5±15.2 CI: (72.93-86.07)	90.0 (40.0-100.0)
	Follow-up (after 1 year)	79.1±10.8 CI:(74.4- 83.7)	80.0 (50.0-100.0)
Radiosurgery	No	18	78.3
	Yes	5	21.7
Follow-up (months) *		33.5±12.3 CI: (28.1- 38.8)	33.0 (14.0-62.0)
Total VA encasement	No	15	65.3
	Yes	8	34.7

*: Mean ± Standard Deviation / Median (Min – Max). [a]: Some patients have multiple comorbid diseases; therefore. the sum of percentages may exceed 100%. This is reflective of the presence of multiple conditions in some individuals and should be considered in the interpretation of the data. HT:Hipertension. DM: Diabetus Mellitus. CI: Confidence Interval (95%). WHO: The 2021 World Health Organization Classification of Tumors of the Central Nervous System. KPS: Karnofsky Performance Score. VA: Vertebral Artery.

Table 2. Comparison of NDI and KPS scores in pre-operative and postoperative patients.

	Pre-operative	Post-operative	P value
NDI (mean±SD)[a]	13.17 ±7.18 CI: (10.07- 16.27)	10.65±9.47 CI: (6.55-14.75)	>0.05
KPS (mean±SD)[a]	76.5±14.6 CI: (70.19- 82.81)	79.5±15.2 CI: (72.93-86.07)	>0.05

[a]: Independent Samples t Test (Mean ± SD), NDI: Neck Disability Index, KPS: Karnofsky performance scale, SD: Standard Deviation, CI: Confidence Interval (95%).

Discussion

The foramen magnum accommodates numerous critical vascular and neuroanatomical structures that necessitate careful consideration by surgeons. Among these, meningiomas are the most prevalent benign tumors located at the foramen magnum, occurring three times more frequently than the next most common type, neurinomas [8,9]. The clinical manifestations of patients with lesions in the foramen magnum can exhibit a broad spectrum of symptoms and may resemble other neurological conditions such as amyotrophic lateral sclerosis, brainstem tumors, cervical spondylosis and multiple sclerosis [8,10]. These conditions tend to progress slowly, resulting in symptoms such as sensory disturbances, uneven motor deficits, unsteady gait, and, less commonly, cranial nerve impairments especially CN IX and X. For the diagnosis of FMM, MRI is the preferred modality. MRI provides precise information about the tumor's size, location, dural attachment site, and its relationship with vascular and neural structures. It also offers insights into the tumor's consistency and vascularity. Surgeons have access to a range of approaches for reaching the foramen magnum, including posterior, lateral, and anterior methods. The anterior approach, primarily conducted through the transoral method, is infrequently utilized for intradural lesions like meningiomas, mainly due to the challenges associated with dural repair, the risk of cerebrospinal fluid (CSF) leakage, and the potential for meningitis. Tumors situated in the posterior or posterolateral regions of the spinal cord or brainstem can be effectively excised using a posterior midline suboccipital approach in combination with C-1 laminectomy. For tumors located anteriorly, the FLA described by Heros [11] for vertebral artery aneurysms or the extreme lateral modification as described by George [7] may be employed. The most significant complications associated with these approaches include deficits in lower cranial nerves (especially CN IX and X) and injuries to the VA.

The decision to resect the occipital condyle in cases involving anterior and anterolateral FMMs can pose a complex challenge during surgical planning. Certain studies have investigated the dissection of 1/2 to 2/3 of the occipital condyle to establish a broader surgical pathway for tumor removal. These surgical techniques were initially explored through cadaver studies [12–14]. Arnautovic and colleagues stressed the importance of condyle drilling as a means to ensure a safe and comprehensive resection of anterior FMMs using a transcondylar approach [15]. They proposed the removal of approximately 1/3 to 1/2 of the condyle, with no observed craniocervical instability as a result. Conversely, certain neurosurgeons have endorsed the modified "retrocondylar" approach, asserting that resection of the occipital condyle is typically unnecessary for the majority of FMMs, except for specific small anterior tumors. Nanda and colleagues conducted anatomical studies and examined ten clinical cases, asserting that removing the occipital condyle was not required for the safe and complete resection of anterior intradural foramen magnum tumors [13]. In their initial examination of the first 10 cases involving anterior or anterolateral tumors, they drilled between one third to one half of the occipital condyle. Nevertheless, as their experience grew, they managed to accomplish the majority of anterior and anterolateral FMM resections effectively by utilizing a FLA retrocondylar approach, eliminating the necessity for occipital condyle resection [13]. Their study demonstrated that the removal of less than one-third of the occipital condyle proved to be adequate for managing anterior FMMs. It was noted that this approach offered sufficient and effective tumor exposure, particularly in the case of anteriorly located FMMs exhibiting bilateral growth [13].

Comprehending the connection between FMM and the VA is essential for formulating surgical approaches and foreseeing patient outcomes [16]. In our study, most FMMs were located below the VA, leading to variations in the extent of laminectomy until VA was located, to the lateral mass of C1 based on the tumor's location. Patients in this group displayed improved KPS scores during follow-up. Three patients in our study exhibited complete encasement of the VA. Managing such cases necessitates a meticulous and careful dissection. Nonetheless, there is always a possibility of VA injury during this phase of the operation. To mitigate this risk, in cases where tumor dissection around the VA was particularly challenging, we intentionally left some tumor residue surrounding the VA. For FMMs situated above the VA, surgical resection may require the removal of the occipital bone up to the sigmoid sinus to adequately expose the tumor. Patients with such tumor locations are at a higher risk of experiencing lower CN dysfunction post-surgery and should receive extra care. In cases where tumors encase the VA, safeguarding both the VA and lower CNs becomes of paramount importance. The drilling of the medial rim of the occipital condyle is essential for tumor removal involving the VA.

In this study, the retrocondylar FLA was chosen for the target group, which consisted of patients with anterior and anterolateral FMMs. This approach offers a comprehensive view of the ventral aspect of the brainstem and cervical spinal cord while minimizing the need for retraction of essential structures. Notably, in cases where FMMs extended into the middle clival region, an extended FLA approach was adopted. This versatility in surgical approaches allows for a tailored response to the tumor's location and characteristics. Patient outcomes were assessed using the KPS and NDI both before and after surgery. While there were no statistically significant differences in KPS scores, some patients experienced a decrease in KPS due to postoperative complications. The NDI scores showed no significant differences before and after surgery, indicating that, on average, patients did not experience a significant increase in disability due to the surgical intervention. Postoperative complications highlight the challenges and potential risks associated with surgical interventions in the foramen magnum region. Careful preoperative planning and vigilant postoperative care are essential to manage and mitigate these complications effectively.

This study has several limitations, including its retrospective design and relatively small sample size. Additionally, exploring the role of adjuvant therapies, such as radiosurgery, in preventing recurrence could provide valuable insights for improving patient care.

Conclusion

In conclusion, our study provides valuable insights into the surgical management and outcomes of patients with FMMs. By conducting a retrospective analysis of cases treated at our healthcare facilities, we aimed to establish a comprehensive strategy for managing these tumors. Our findings underscore the complex nature of surgical interventions in the foramen magnum region, where critical neurovascular structures pose significant challenges to successful tumor excision. We employed the FLA as a primary surgical technique, tailored to the individual characteristics and locations of the tumors. Through meticulous preoperative planning and careful intraoperative techniques, we aimed to achieve maximal tumor resection while minimizing complications. Our study contributes to the existing body of literature by providing insights into the surgical techniques and outcomes specific to FMMs. However, it is important to acknowledge the limitations of our study, including its retrospective design and small sample size. Future research endeavors should focus on prospective studies with larger cohorts to further elucidate optimal treatment strategies and long-term outcomes for patients with FMMs. Additionally, exploring the role of adjuvant therapies, such as radiosurgery, in preventing tumor recurrence could offer valuable insights into improving patient care and outcomes in this challenging clinical scenario.

Ethical approval

Ethical approval was received for this study from Ankara Bilkent City Hospital No. 1 Clinical Research Ethics Committee (Decision no: E1/3862/2023).

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