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Foramen magnum meningiomas: Surgical approaches and outcomes from a single-center series

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Abstract

Background: Foramen magnum meningiomas (FMMs) are rare skull base tumors whose surgical management is challenging due to their relationship with the brainstem, lower cranial nerves, and vertebral arteries.

Methods: We retrospectively analyzed 14 patients who underwent microsurgical resection of FMMs between 2014 and 2024. Data included demographics, tumor location, surgical approach, extent of resection, complications, and functional outcomes.

Results: The mean age was 51 years (range 29-82), with a female predominance (9/14). Tumors were anterior (15%), anterolateral (35%), lateral (35%), and posterior (15%). All patients were operated in the prone position, with a posterolateral suboccipital approach in four cases (28.5%). Gross total resection (Simpson III) was achieved in 85%. Complications included transient cranial nerve deficits (14%) and cerebrospinal fluid fistula (14%). No permanent deficits occurred. One patient (7.1%) died of postoperative complications. Mean Karnofsky Performance Score improved from 75 preoperatively to 90 at last follow-up.

Conclusion: Tailored microsurgical approaches, guided by dural attachment and neurovascular configuration, enable safe and effective resection of FMMs with high rates of tumor control and favorable functional outcomes.

Keywords: Meningioma; Foramen Magnum; Skull Base; Microsurgery; Treatment Outcome

1. Introduction

Meningiomas constitute 14–19% of intracranial tumors, yet only 1.8–3.2% occur at the foramen magnum (FM). Despite their rarity, they represent nearly 70% of benign FM lesions [2,16]. These tumors typically grow slowly, producing subtle and progressive symptoms that often delay diagnosis until they reach considerable size. Surgical management is technically demanding due to the confined space and intimate relationship with the vertebral artery (VA), lower cranial nerves (CN), and brainstem. Optimal outcomes depend on the choice of surgical approach, the extent of bone resection, and meticulous neurovascular preservation [14–6].

This study aims to analyze surgical outcomes, complications, and recurrence risk factors in a consecutive series of 14 patients with FM meningiomas

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2. Materials And Methods

This is a retrospective, single-center case series including patients who underwent surgery for foramen magnum meningiomas (FMMs) between January 2014 and December 2024 at the University Hospital of Fez, Morocco.

Inclusion criteria were patients with radiologically and histologically confirmed FMMs who underwent microsurgical resection and had at least 12 months of follow-up. Exclusion criteria included patients with incomplete medical records, histology other than meningioma, prior craniovertebral surgery, or follow-up shorter than 12 months.

The following parameters were assessed: demographic features (age, sex), clinical presentation (cranial nerve deficits, pyramidal signs, other symptoms), tumor location (anterior, anterolateral, lateral, posterior), surgical approach, and extent of resection according to Simpson grade.

Functional outcomes were evaluated using the Karnofsky Performance Status (KPS) scale, recorded preoperatively, immediately postoperatively, and at last follow-up. Postoperative complications were categorized as cranial nerve deficits, cerebrospinal fluid (CSF) leak, hydrocephalus, infection, or death. Potential confounding variables included tumor size, dural attachment, neurovascular encasement, and surgical approach.

Data were analyzed using SPSS v.26. Continuous variables were expressed as mean ± standard deviation (SD) or median with range, while categorical variables were presented as counts and percentages. Group comparisons were performed using Student's t-test for continuous variables and chi-square or Fisher's exact test for categorical variables. A p-value < 0.05 was considered statistically significant. Comparisons between groups (Simpson I vs. Simpson II-III, anterior vs. anterolateral/posterior tumors, recurrence vs. No recurrence) were performed using the chi-square test or Fisher's exact test for categorical variables, and the Mann-Whitney U test for continuous non-normally distributed variables (age, follow-up). A two-tailed pvalue < 0.05 was considered statistically significant

To contextualize our findings, we performed a literature review of studies published during the same period. PubMed and LILACS databases were searched using combinations of the terms "meningioma," "foramen magnum," and "skull base."

3. Results

A total of 14 patients underwent microsurgical resection of foramen magnum meningiomas.

The mean age was 53.7 ± 13.4 years (range 29-82). No significant difference was observed in mean age between patients with anterior/anterolateral vs posterior/lateral tumors ($t(12) = 1.12$, $p = 0.28$).

Female predominance was observed (71.4%), but gender distribution did not differ significantly between tumor locations ($\chi^2(1) = 0.87$, $p = 0.35$).

Mean preoperative KPS was 77.1 ± 11.6 vs postoperative 80.7 ± 24.3, showing a nonsignificant improvement ($t(13) = 1.45$, $p = 0.17$)

All patients underwent surgery in the prone position. A midline suboccipital approach was used in ten cases and a posterolateral approach in four cases. In suboccipital cases, the incision was made along the midline from the occipital protuberance to C2, with exposure through the avascular plane. Bone removal was limited to the lower occipital bone and posterior arch of C1. The dura was opened in a T- or Y-shaped fashion. In posterolateral cases, positioning was identical, but the incision was curved laterally toward the mastoid to improve access to tumors extending laterally.

Simpson grades I, II, and III resections were achieved in 45%, 40%, and 15% of patients, respectively. No significant association was found between Simpson grade and tumor location ($\chi^2(2) = 2.14$, $p = 0.34$).

Postoperative outcomes were favorable in most cases: twelve patients had no new neurological deficits, two experienced transient worsening, and two developed cerebrospinal fluid leakage. One patient (7.1%) died from postoperative sepsis

Recurrence occurred in 2 patients (14.2%), both of whom had anterior tumors. The recurrence rate was significantly higher in anterior vs non-anterior locations ($\chi^2(1) = 4.52$, $p = 0.033$).

4. Discussion

Foramen magnum meningiomas represent a distinct surgical challenge due to their location at the craniovertebral junction. Anatomically, the FM is defined by the lower third of the clivus to the superior border of C2 anteriorly, the jugular tubercles and C2 laminae laterally, and the posterior margin of the occipital squama to C2 spinous process posteriorly [6,7].

FMMs are predominantly intradural (90%) and classified by dural attachment into anterior, lateral, and posterior subtypes. Most series report anterolateral predominance (70%), with anterior (15%), posterolateral (10%), and posterior (5%) lesions [2, 6, 14, 16]. In our cohort, tumor distribution was more balanced: anterior 15%, anterolateral 35%, lateral 35%, and posterior 15%.

Beyond dural attachment, neurovascular relationships critically influence surgical complexity. Gattozzi et al. proposed a classification system based on the spatial relationship between tumors and the neurovascular bundle: Type 1 (ventral), Type 2a-c (superior, inferior, splayed), Type 3 (dorsal), and Type 4 (encasement of cranial nerves and/or vertebral artery)

Type 4 lesions required meticulous dissection and prolonged operative times, whereas Types 1-3 allowed more straightforward resections.

All patients were operated in the prone position, which we favor over the sitting position due to lower risk of air embolism, reduced surgeon fatigue, and enhanced microscopic maneuverability. Posterolateral tumors were accessed via a lateralized suboccipital approach with an inverted L-shaped incision extending toward the mastoid, allowing optional contralateral craniotomy enlargement and obviating occipital condyle resection, thereby preserving craniovertebral stability. This strategy emphasizes the importance of tailoring the surgical approach to tumor location while minimizing morbidity.

Simpson resection grades I and II were achieved in 85% of patients, consistent with prior series. Transient lower cranial nerve deficits occurred in 10% of patients and resolved within three months, whereas CSF fistula occurred in 14%. No permanent neurological deficits were recorded, and mortality was 7%. These findings reinforce that meticulous microsurgical technique, guided by anatomical and neurovascular classifications, can yield high rates of complete resection with acceptable morbidity, even in complex FMMs.

When compared to previously published series, our outcomes are favorable. Gross total resection rates in prior studies ranged from 69.2% to 96%, with major complications including cranial nerve palsy (4-38.5%), CSF fistula (4-30.8%), hydrocephalus (4-20%), and mortality rates up to 7.5% [8-18]. Our series, though smaller, demonstrated a high Simpson I-II rate (95.7%) with only transient cranial nerve palsy and CSF leaks, and mortality within expected limits. These results underscore that meticulous microsurgical technique, guided by anatomical and neurovascular classifications, allows high rates of complete resection with acceptable morbidity, even in complex FMMs (Table 2).

Anterior location, bilaterality, and recurrence have been associated with worse prognosis. Our data corroborate this, as anterior lesions required more extensive exposure and carried greater risk of cranial nerve and brainstem complications. Compared with historical series, our cohort demonstrates a more balanced distribution of tumor location, high gross total resection rates, low permanent morbidity, and favorable functional outcomes.

This study has several limitations, including its retrospective single-center design, the relatively small sample size, and the absence of long-term neurocognitive outcomes. Moreover, the surgical techniques varied according to surgeon preference, which may have introduced bias. Despite these limitations, the study provides valuable insights into the surgical management of foramen magnum meningioma.

Table 1 Summary of Clinical and Statistical Results

Parameter	Measure / Comparison	Mean ± SD / n (%)	Test Statistic	*p*-Value	Interpretation
Age (years)	Mean (range)	53.7 ± 13.4 (29–82)	—	—	—
Gender	Female / Male	10 (71.4%) / 4 (28.6%)	χ^2 (1) = 0.87	0.35	No significant gender difference by tumor location
Tumor location	Anterior / Anterolateral / Posterior-Lateral	5 / 5 / 4	—	—	—
Simpson grade I–II resection	Overall rate	13 (92.8%)	—	—	Gross total resection achieved in most cases
Simpson grade vs. tumor location	χ^2 test	—	χ^2 (2) = 2.14	0.34	No association between resection grade and location
Recurrence	Total / by location	2 (14.2%) — both anterior	χ^2 (1) = 4.52	0.033	Higher recurrence in anterior tumors
Preoperative KPS	Mean ± SD	77.1 ± 11.6	—	—	—
Postoperative KPS	Mean ± SD	80.7 ± 24.3	*t* (13) = 1.45	0.17	Non-significant improvement
Radiotherapy	Patients treated postoperatively	2 (14.2%)	—	—	Adjuvant RT used for grade II and recurrence cases
Follow-up (months)	Mean ± SD (range)	60.9 ± 33.8 (1–120)	—	—	Long-term follow-up available

Descriptive and statistical summary of the present series. Continuous variables were analyzed with Student's t-test, and categorical variables with chi-square (χ^2) or Fisher's exact test. Statistical significance was set at $p < 0.05$. KPS: Karnofsky Performance Scale; RT: radiotherapy; SD: standard deviation.

Table 2 Summary of selected FMM series and present cohort

Study (Year)	N	Location (A/AL/P)	Simpson I/II (%)	Major Complications	Mortality (%)
George et al., 1997 (12)	40	18/21/1	94 / 50	Death 7.5%	7.5
Arnautovic et al., 2000 (1)	18	16/0/0	75	CN IX–X palsy	NA
Goel et al., 2001 (13)	17	0/17/0	82.3	Lower cranial nerve lesion 5.8%	NA
Boulton & Cusimano, 2003 (5)	10	0/7/3	90	CSF fistula 10%, Brown-Séquard 10%, Neurocognitive 10%	NA
Pamir et al., 2004 (17)	22	0/20/2	95.5	Fistula 18%, Hydrocephalus 4.5%, CN palsy 9%, Vascular injury 4.5%	4.5
Bassiouni et al., 2006 (3)	25	8/14/3	96	CSF fistula 16%, CN lesion 4%	4

Borba et al., 2009 (4)	15	8/7/0	80	XII palsy 6.6%, Fistula 6.6%, Hydrocephalus 6.6%, Transient myelopathy 6.6%	NA
Wu et al., 2009 (18)	114	80/24/10	86	Dysphagia 55%, Tracheostomy 28.9%, Hydrocephalus 7.8%, CSF fistula 6.1%	1.8
Colli et al., 2014 (8)	13	4/9/0	69.2	CSF fistula 30.8%, Transient CN palsy 38.5%, Permanent CN palsy 7.7%	NA
Dobrowolski et al., 2016 (9)	24	3/19/2	83.3	Hydrocephalus 4.1%, CSF fistula 4.1%, Pneumonia 4.1%	NA
Li et al., 2017 (15)	185	122/49/14	83.2	CN palsy IX–X 21.6%, XII 10.8%, Tracheostomy 29.2%, Hydrocephalus 6.5%	NA
Fernandes et al., 2018 (10)	20	9/9/2	85	Hydrocephalus 20%, Gastrostomy 10%, Tracheostomy 25%, CSF fistula 5%, Brainstem ischemia 10%, Pulmonary embolism 5%, Rebleeding 5%	5
Current series	14	5/5/2	95.7	Transient CN palsy 14.2%, CSF leak 14.2%	7.14

Legends A: anterior; AL: anterolateral; P: posterior; CN: cranial nerve; MSO: midline suboccipital; Lat: far-lateral; NA: not available.

5. Conclusion

Management of foramen magnum meningiomas should be guided by dural attachment and neurovascular anatomy, with tailored approaches-especially the prone posterolateral corridor-enabling safe resection and craniovertebral stability. While our findings are limited by a small case series, they provide a framework for surgical planning, risk assessment, and patient counseling.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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