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Local Control and Toxicity Outcomes Following IMRT or VMAT in Postoperative Benign Brain Tumors: A Single Institution Retrospective Study

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Abstract: ***Introduction: Benign brain tumors such as meningiomas, pituitary adenomas, craniopharyngiomas, and schwannomas, though histologically non-malignant, may be life-threatening due to their critical intracranial location. Modern radiotherapy techniques, including Intensity-Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT), allow high-precision treatment while sparing adjacent structures. Aims and Objectives: The primary aim was to evaluate tumor response and local control one year after radiotherapy. Secondary objectives included assessing radiation-induced toxicities and correlating outcomes with histological subtypes. Materials and Methods: A retrospective study was conducted at Medical College Kolkata between January 2023 and August 2024. Thirty patients with histologically confirmed benign brain tumors were enrolled post-surgery and treated with IMRT or VMAT. Doses ranged between 50.4 and 54 Gy in 1.8 Gy per fraction. Patients were followed every three months for one year. Tumor response was assessed radiologically, and toxicities graded using CTCAE v5.0. Statistical analysis included Chi-square testing, with p_value < 0.05 considered significant. Results: The majority of patients showed positive response following radiotherapy, with excellent local control and no statistically significant association between tumor histology and treatment response. Acute and late toxicities were manageable, and no severe adverse events were reported. Conclusions: IMRT and VMAT provide effective and safe treatment for benign brain tumors, offering durable local control with minimal toxicity. Outcomes were favorable across tumor histologies, suggesting that modern radiotherapy techniques are valuable in managing benign intracranial tumors post-surgery.***

Keywords: meningiomas, pituitary adenomas, craniopharyngiomas, schwannomas, IMRT, VMAT

1. Introduction

Benign brain tumors comprise a heterogeneous group of neoplasms, including meningiomas, pituitary adenomas, craniopharyngiomas, and schwannomas. Although histologically nonmalignant, these tumors may result in significant morbidity and even mortality because of their critical intracranial location and their proximity to vital neural and vascular structures [1,2]. Depending on their size and location, they can cause raised intracranial pressure, visual disturbances, cranial neuropathies, or endocrine dysfunction, thereby necessitating timely diagnosis and effective management.

Surgical resection is generally considered the primary treatment modality. However, gross total resection is often not feasible in tumors that encase or abut critical structures such as the optic nerves, optic chiasm, brainstem, and hypothalamus. In such cases, subtotal excision or biopsy is performed, which increases the likelihood of residual or recurrent disease[3,4]. To address this limitation, radiotherapy (RT) plays an important role as an adjuvant treatment, improving long-term local control while minimizing neurological complications.

Conventional RT techniques such as two-dimensional radiotherapy (2D-RT) and three-dimensional conformal radiotherapy (3D-CRT) were associated with considerable late toxicities, including hypopituitarism, neurocognitive decline, and cranial neuropathies. These limitations reduced their appeal in treating benign conditions where long-term survival is expected [1,2]. The development of advanced precision RT, particularly Intensity-Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT), has allowed highly conformal dose delivery to the target volume while sparing organs at risk (OARs), including the optic chiasm, cochlea, hippocampus, and brainstem. These advances have led to improved outcomes with reduced treatment-related morbidity [1,2,3].

Accumulating evidence supports the effectiveness of precision RT in benign brain tumors. Minniti et al. demonstrated excellent long-term tumor control in large skull base meningiomas treated with fractionated stereotactic conformal radiotherapy, while Pollock et al. confirmed the durable benefits of stereotactic radiosurgery in WHO grade I meningiomas [4,5]. Brada et al. reported high tumor control rates with combined conservative surgery and RT in pituitary adenomas, highlighting the importance of adjuvant RT in functional preservation [6]. Similarly, Stapleton et al. found that both stereotactic radiosurgery and fractionated RT provided effective control in craniopharyngiomas, and Kaul et al. documented favorable outcomes in vestibular schwannomas treated with fractionated stereotactic RT [7,8]. These studies collectively validate the role of modern RT in achieving tumor stability while limiting toxicity across different benign histologies.

Nonetheless, late effects of cranial irradiation remain a concern, particularly radiation induced endocrine dysfunction. Hypopituitarism has been documented following cranial RT, even in non-pituitary tumors, due to

incidental irradiation of the hypothalamic–pituitary axis. This emphasizes the need for careful long-term follow-up and hormonal surveillance in these patients.

In this context, the present study was conducted to evaluate tumor response and local control following IMRT or VMAT in patients with benign brain tumors after surgery. The study also aimed to assess acute and late treatment-related toxicities, with particular emphasis on endocrine dysfunction, and to determine whether histological subtype influences treatment outcomes.

2. Materials and Methods

Study Design and Setting

This was a retrospective study conducted in the Department of Radiotherapy in a Tertiary Care Centre in Kolkata from January 2023 to August 2024 and all patients were followed up till August 2025. Departmental records of each patient has been assessed for statistical analysis as mentioned below.

Study Population

Thirty patients with histologically proven benign brain tumors were included from departmental records, following maximal safe surgical resection. Patients were selected based on the following criteria:

Inclusion criteria:

- Age > 10 years and < 70 years
- Post-operative patients with histologically confirmed benign brain tumors
- ECOG performance status 0–1
- Normal hematological, renal, and hepatic function

Exclusion criteria:

- Low-grade gliomas or malignant tumors
- Patients not meeting inclusion criteria

Since this is a retrospective study, the Ethical Clearance has been waved off.

Treatment Protocol

All patients were treated with advanced radiotherapy techniques, either IMRT or VMAT, following surgical resection. Treatment was delivered using linear accelerators with image guidance.

- Dose prescription: 50.4–54 Gy in 1.8 Gy per fraction
- Fractionation: Daily fractions, five days per week, without treatment breaks
- Target definition: Clinical target volume (CTV) included post-operative tumor bed with margin; planning target volume (PTV) generated with 3–5 mm expansion
- Organs at risk (OARs): Brainstem, optic nerves, optic chiasm, cochlea, and hippocampus were contoured and dose constraints respected

Follow-up and Assessment

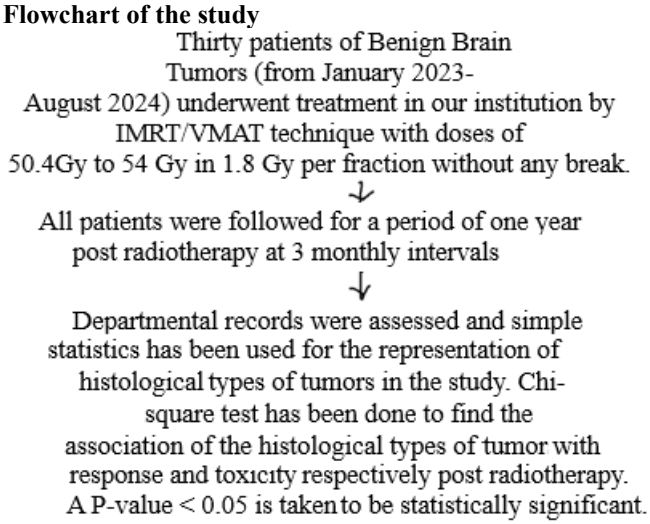
Patients were followed every three months for one year post-radiotherapy. Assessments included:

- Clinical evaluation: Neurological examination and toxicity assessment
- Imaging: MRI brain with contrast at 6 months and 12 months
- Toxicity grading: Using Common Terminology Criteria for Adverse Events (CTCAE) v5.0

Statistical Analysis

Tumor histological subtype distribution was analyzed descriptively. The Chi-square test was used to assess the relationship between histology and treatment outcomes. A p-value < 0.05 was considered statistically significant.

Flowchart of the study



3. Results

A total of 30 patients with benign brain tumors were included in this study. The cohort consisted of patients with meningiomas, pituitary adenomas, craniopharyngiomas, and schwannomas (Figure 1). Most patients were in the 30–60 year age group, and the male to female ratio was approximately balanced.

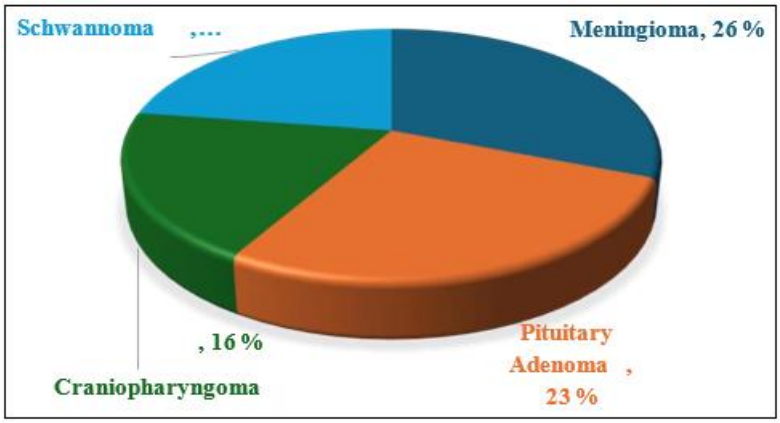


Figure 1: Distribution of benign brain tumors

Treatment Response

The majority of patients demonstrated a favorable response to radiotherapy at one year post treatment (Figure 2). Local control rates were high across all histological subtypes.

- Complete response / Stable disease: Observed in most patients
- Progression: Noted in a small minority of cases

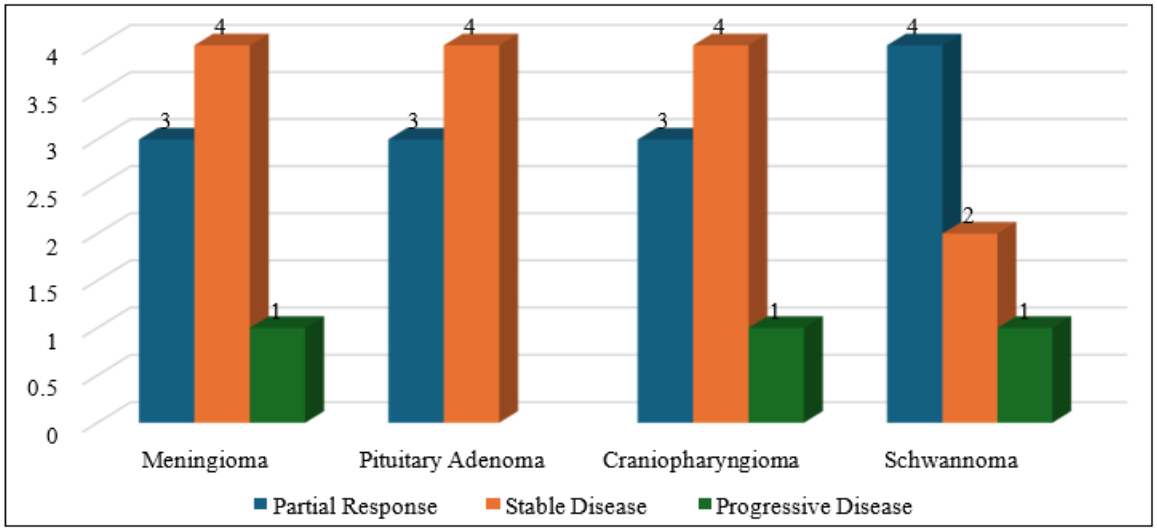


Figure 2: Response according to RECIST Criteria 1.1

There was no statistically significant association between tumor histology and treatment response ($p > 0.05$). No patients experienced severe acute or late toxicities requiring hospitalization or treatment discontinuation. (Figure 3)

- Acute toxicities: Mild to moderate headache, fatigue, and nausea, which were conservatively managed
- Late toxicities: Minimal and included mild memory impairment or fatigue in a few patients
- Severe adverse effects: None reported
- Overall, IMRT and VMAT were effective and safe, with favorable toxicity profiles.

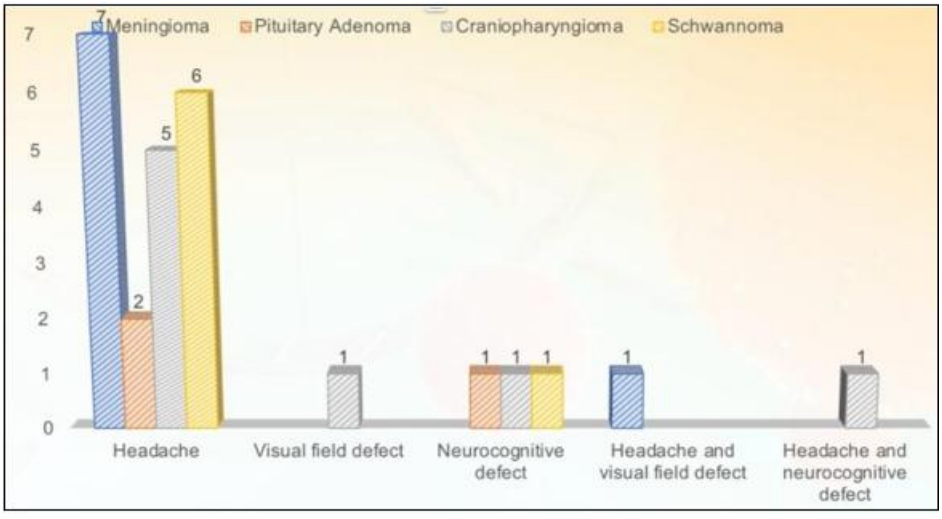


Figure 3: Distribution of the toxicities associated with the tumor types post radiotherapy. (P-value=0.246)

4. Discussion

This retrospective study evaluated local control and toxicity outcomes in benign brain tumors treated with advanced radiotherapy techniques (IMRT and VMAT) following surgery. Our findings demonstrate excellent tumor response and local control at one year, with no significant correlation between histological subtype and treatment outcomes. Toxicities were manageable and non-severe, highlighting the safety of modern precision radiotherapy in this patient group.

Scaringi et al. [1] emphasized that advances in RT delivery such as IMRT and VMAT have improved conformity and reduced the risk of long-term complications in benign brain tumors. Dissaux et al. [2] similarly demonstrated that fractionated RT provides durable tumor control with acceptable toxicity across different histological types. Albano et al. [3]confirmed that parasellar tumors respond favorably to RT, with good disease stabilization and functional preservation.

Meningioma management has been extensively studied in the context of RT. Minniti et al. [4]reported excellent local control with fractionated stereotactic RT in large skull base meningiomas, consistent with our findings. Pollock et al. [5] further showed that stereotactic radiosurgery (SRS) achieves durable control in WHO grade I meningiomas, underscoring the role of precision RT in long-term disease management.

For pituitary adenomas, Brada et al. [6] demonstrated that conservative surgery followed by RT offers high tumor control with acceptable toxicity. Our results align with these findings, as most patients with pituitary adenomas in our study tolerated RT well and maintained stable disease.

In craniopharyngiomas, Stapleton et al. [7]found that both SRS and fractionated RT achieve favorable outcomes, with high control rates and manageable toxicity. This supports our observation that histology does not significantly influence RT response when advanced techniques are employed.

Our study also included patients with vestibular schwannomas, who showed excellent outcomes with minimal late toxicity. Kaul et al. [8]reported similar findings, noting high control rates and preservation of neurological function after fractionated stereotactic RT in elderly patients.

Taken together, these studies and our findings confirm that modern RT techniques provide effective tumor control across benign intracranial tumor types. The lack of a significant correlation between histology and response in our study may be due to the uniformly high efficacy of precision RT. Larger studies with extended follow-up are warranted to assess long-term outcomes and late toxicity more comprehensively.

5. Conclusion

Postoperative IMRT and VMAT demonstrated high one year local control with minimal severe toxicity in benign brain tumors across histologies. These findings reinforce conformal radiotherapy as an effective adjuvant modality, though longer follow up and larger cohorts are required to validate long term endocrine and neurocognitive safety.

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