

Introduction

World Health Organization (WHO) grade II and III meningiomas account for approximately 15–20% of meningiomas and are associated with substantially higher recurrence rates and worse outcomes compared with grade I disease.^{1,2}

Extent of resection (EOR) is a key determinant of tumor control, with gross total resection associated with improved recurrence-free survival.³ However, aggressive resection must be balanced against the risk of neurological morbidity, particularly for skull base and eloquent tumors.

Adjuvant radiotherapy (RT) is commonly recommended following subtotal resection and is increasingly considered after gross total resection, although its benefit remains uncertain and may reflect treatment selection for higher-risk disease.^{4,5}

Objective: To evaluate the association of EOR and adjuvant RT with recurrence-free survival in a population-based cohort of WHO grade II–III meningiomas.

Methods and Materials

Retrospective population-based cohort of adults with histologically confirmed WHO grade II–III meningiomas undergoing surgical resection in Saskatchewan, Canada (January 1, 2007 – December 31, 2017).

Extent of resection classified as:

- Gross total resection (GTR; Simpson I–III)
- Subtotal resection (STR; Simpson IV–V)

Additional variables recorded: age, sex, WHO grade, adjuvant radiotherapy, skull base location, brain invasion, and tumor necrosis.

Primary outcome: recurrence-free survival (RFS), defined as time from surgery to radiographic or clinical recurrence.

Baseline characteristics compared using Welch two sample t-tests and Fisher's exact tests.

Survival analysis performed using Kaplan–Meier methods with log-rank testing.

Multivariable Cox proportional hazards modeling used to identify independent predictors of recurrence.

Table 1. Baseline demographic, clinical, and tumor characteristics stratified by extent of resection (GTR vs STR).

Characteristic	GTR (Simpson 1–3) n = 81	STR (Simpson 4–5) n = 5	p-value ²
Age	60 ± 17 ¹	47 ± 13 ¹	0.092
Sex			>0.9
Female	44 (54%)	3 (60%)	
Male	37 (46%)	2 (40%)	
WHO grade			0.4
Grade II	73 (90%)	4 (80%)	
Grade III	8 (10%)	1 (20%)	
Skull base location	12 (15%)	3 (60%)	0.035
Tumor location			0.036
Convexity	52 (64%)	1 (20%)	
Falcine	4 (5%)	0 (0%)	
Olfactory groove	2 (2%)	1 (20%)	
Parasagittal	10 (12%)	0 (0%)	
Posterior fossa	5 (6%)	1 (20%)	
Sphenoid wing	8 (10%)	2 (40%)	
Adjuvant radiotherapy			>0.9
No RT	67 (83%)	4 (80%)	
Received RT	14 (17%)	1 (20%)	
Brain invasion	34 (42%)	3 (60%)	0.6
Tumor necrosis	47 (58%)	2 (40%)	0.6

¹Mean ± SD; n / N (%)

²Welch Two Sample t-test; Fisher's exact test

Results

Cohort Characteristics

A total of 86 patients were included, comprising 81 (94%) who underwent GTR and 5 (6%) STR. The mean age was 60 years and 54% were female.

STR was more common in skull base tumors (60% vs 15%, p = 0.035) (Table 1).

Recurrence-Free Survival (Unadjusted)

Twenty-five recurrences were observed. Five-year recurrence-free survival (RFS) was 70% (95% CI 61–81) after GTR and 60% (29–100) after STR, with no significant difference on Kaplan–Meier analysis (log-rank p = 0.56) (Figure 1).

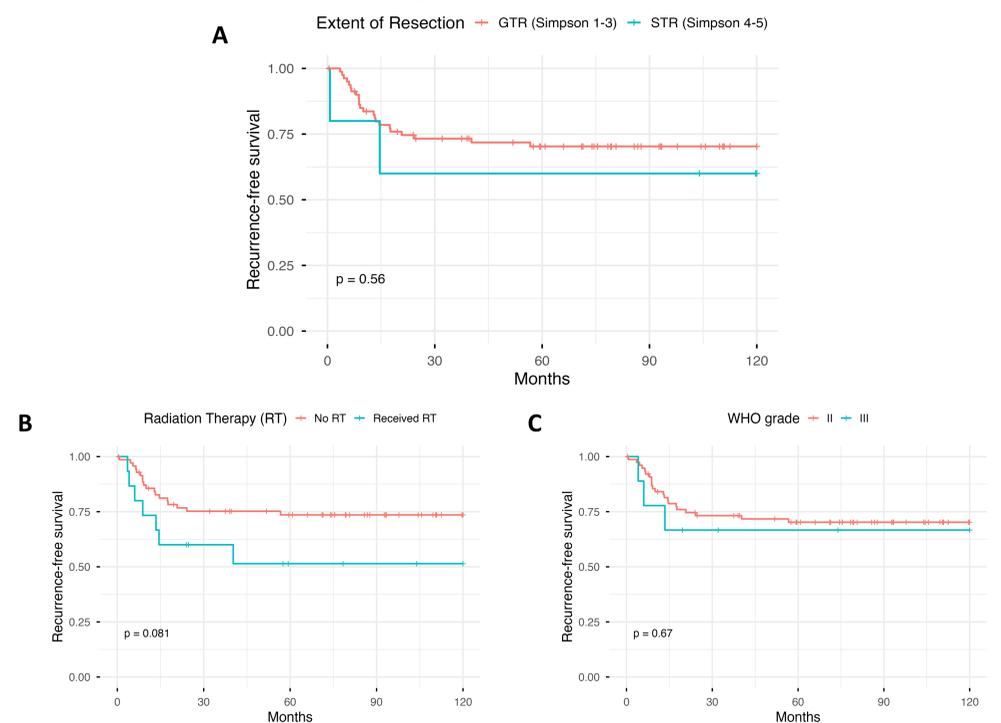
Multivariable Analysis

STR independently predicted recurrence (HR 12.7, 95% CI 1.10–146.1, p = 0.041).

Tumor necrosis was also associated with recurrence (HR 3.17, 95% CI 1.09–9.22, p = 0.03).

Adjuvant radiotherapy was associated with an increased recurrence risk (HR 3.23, 95% CI 1.03–10.1, p = 0.04).

Figure 1. Kaplan–Meier estimates of recurrence-free survival stratified by (A) extent of resection, (B) adjuvant radiotherapy, and (C) WHO grade.



Discussion

- In this population-based cohort of WHO grade II–III meningiomas, EOR emerged as the strongest predictor of recurrence, reinforcing the importance of achieving maximal safe resection.
- Although unadjusted analyses did not demonstrate a significant difference by EOR, STR was independently associated with a markedly increased recurrence risk after adjustment for tumor and treatment factors.
- Adjuvant RT was associated with worse recurrence-free survival, likely reflecting confounding by indication, with RT preferentially used in higher-risk tumors.
- WHO grade was not associated with recurrence-free survival, suggesting that tumor biology (e.g., necrosis) and surgical factors may be more important than grade alone for risk stratification.
- These findings support a treatment strategy focused on maximizing safe resection while improving risk stratification to guide postoperative radiotherapy decisions.

Limitations

- Retrospective design with potential for selection bias and unmeasured confounding.
- Small sample size, particularly in the STR group (n = 5), resulting in wide confidence intervals and limited statistical power.
- Association between adjuvant RT and recurrence likely reflects confounding by indication.
- Single-province cohort may limit generalizability to other practice settings.

Conclusions

- In this population-based cohort of WHO grade II–III meningiomas, extent of resection was the strongest predictor of recurrence.
- STR was independently associated with a markedly increased risk of recurrence, supporting the importance of maximizing safe resection.
- Adjuvant RT was associated with worse outcomes, likely reflecting treatment selection for higher-risk disease rather than a causal effect.
- Improved risk stratification incorporating tumor biology is needed to guide postoperative radiotherapy decisions.

Contact

Jasleen Saini, MD
 Division of Neurosurgery, Department of Surgery, University of Toronto
 Email: jas.saini@mail.utoronto.ca
 Phone: +1 (306) 514-3555



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