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Low-risk meningioma: Initial outcomes from NRG Oncology/RTOG 0539

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Abstract

Background. Three- and five-year progression-free survival (PFS) for low-risk meningioma managed with surgery and observation reportedly exceeds 90%. Herewith we summarize outcomes for low-risk meningioma patients enrolled on NRG/RTOG 0539.

Methods. This phase II trial allocated patients to one of three groups per World Health Organization grade, recurrence status, and resection extent. Low-risk patients had either gross total (GTR) or subtotal resection (STR) for a newly diagnosed grade 1 meningioma and were observed after surgery. The primary endpoint was 3-year PFS. Adverse events (AEs) were scored using Common Terminology Criteria for Adverse Events (CTCAE) version 3.

Results. Among 60 evaluable patients, the median follow-up was 9.1 years. The 3-, 5-, and 10-year rates were 91.4% (95% CI, 84.2 to 98.6), 89.4% (95% CI, 81.3 to 97.5), 85.0% (95% CI, 75.3 to 94.7) for PFS and 98.3% (95% CI, 94.9 to 100), 98.3%, (95% CI, 94.9 to 100), 93.8% (95% CI, 87.0 to 100) for overall survival (OS), respectively. With centrally confirmed GTR, 3/5/10y PFS and OS rates were 94.3/94.3/87.6% and 97.1/97.1/90.4%. With STR, 3/5/10y PFS rates were 83.1/72.7/72.7% and 10y OS 100%. Five patients reported one grade 3, four grade 2, and five grade 1 AEs. There were no grade 4 or 5 AEs.

Conclusions. These results prospectively validate high PFS and OS for low-risk meningioma managed surgically but raise questions regarding optimal management following STR, a subcohort that could potentially benefit from adjuvant therapy.

Key Points

1. Surgery results in favorable outcomes for patients with newly diagnosed WHO grade 1 meningioma, with 5-year PFS 89.4% (95% CI: 81.3 to 97.5), and 94.3% (95% CI, 86.6 to 100) following GTR.
2. After STR 5-year PFS was 72.7% (95% CI: 45.9 to 99.5).

Importance of the Study

This is the first cooperative group trial reporting outcomes for patients with low-risk meningioma managed with surgery and observation and includes centrally reviewed pathology and imaging.

Meningioma has become the most frequently reported primary intracranial neoplasm,[1] the majority being benign. In the past, using early World Health Organization (WHO) standards or various institutional grading standards, approximately 90% were characterized as benign (grade 1).[2] However, with 2007, 2016, and 2021 WHO criteria, grade 1 is identified in approximately 70–75% of newly diagnosed intracranial meningiomas, grade 2 in about 20–25%, and grade 3 in 1–3%.[3,4]

A variety of management options are available for meningioma patients including observation, resection, external beam radiation therapy (RT), and stereotactic radiosurgery.[4] Given a wide variety of clinical presentations, institutional preferences, individualized patient circumstances, and a lack of level 1 evidence, approaches toward WHO grade I meningioma vary, adding relevance to a cooperative group trial with uniform entry criteria.

This analysis is the first publication of the low-risk cohort from a successfully completed international cooperative group trial. The intermediate- and high-risk subgroups have been published previously.[5,6] For purposes of the protocol, low-risk was defined as a unifocal, newly diagnosed WHO grade 1 meningioma whether gross totally or subtotally resected.

Materials and Methods

Institutional Review Board Approval

This cooperative group protocol was approved by the institutional review boards at each participating study site, and documentation was received at NRG Oncology. Each patient signed an approved informed consent prior to trial enrollment. This protocol, NRG Oncology RTOG 0539, is registered with ClinicalTrials.gov: (https://clinicaltrials.gov/ct2/show/NCT00895622?term=ROG+0539&rank=1). The ClinicalTrials.gov identifier is NCT00895622.

Selection Criteria

Adults 18 years of age or older with a unifocal, histologically documented intracranial meningioma were eligible. Extracranial involvement was specified as a condition for ineligibility. Patients must have had a Zubrod performance status of 0–1 without severe, active comorbidity, and without any history of cranial RT. Histology, including WHO 2007 tumor grade and subtype, was confirmed for each patient via central pathology review by one of the authors (A.P.). Following central confirmation of meningioma and based upon institutional assessments of resection extent based upon surgeon's assessment of Simpson grade confirmed on post-operative MRI, patients were enrolled into one of three study cohorts: Group I (low risk), Group II (intermediate risk), or Group III (high risk), as shown in Figure 1. This analysis focuses on Group I as Groups II and III have been previously published.[5,6]

Protocol Registration

Registration was a two-step process. Step 1 included submission of pathology specimens for central review. Following central confirmation of meningioma and WHO grade, step 2 registration proceeded with protocol group assignment and management, which for patients assigned to Group 1 was observation.

Tumor Grade and Resection Extent

Enrollment in the low-risk cohort (Group 1) was available only to patients with a newly diagnosed WHO grade 1 meningioma, whether gross totally or subtotally resected. Initial registration and central pathology review must have been completed within 24 weeks of surgery. This interval was designed to permit post-operative imaging at 2 to 3 months to confirm resection extent, and to permit additional surgery, when desired, to obtain a more thorough resection.

Resection extent based upon the neurosurgeons' assessment was classified according to Simpson criteria.[7] Gross total resection (GTR) was Simpson grades I–III, and subtotal resection (STR) Simpson grade IV or V. This categorization was chosen because it corresponds well with post-operative MRI findings, which were used for confirmation of resection extent. The enrolling institutions' imaging assessments were used for protocol group assignment, although imaging was also centrally reviewed [by B.D. (see Acknowledgements), and by authors J.M.M., or A.M.A.].

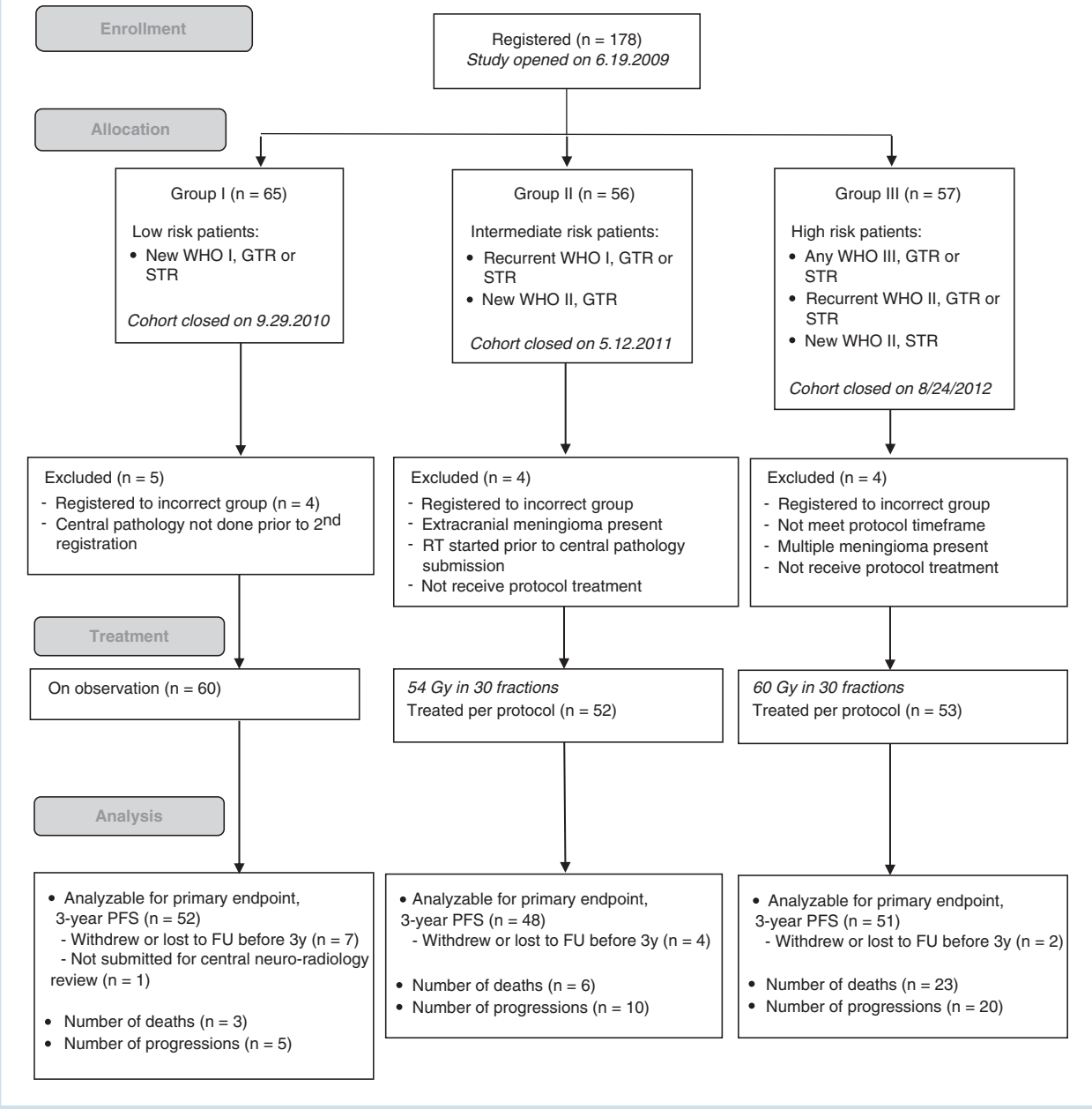

Fig. 1 NRG Oncology/ RTOG-0539 CONSORT diagram.

Patient Assessment and Management

Each Group 1 patient underwent surgery, then was observed. None received adjuvant therapy. Preoperative and postoperative MRIs were required. The initial postoperative MRIs must have been completed within 12 weeks of surgery. Postoperative evaluations included a history and physical with neurological examinations, adverse event (AE) evaluations, and brain MRIs at 6 months for 3 years, then at least annually for 10 years. Completion of the Mini Mental Status Exam as well as corticosteroid and other hormonal agent use followed the same schedule.

Progression was defined on imaging as an increase in measurable tumor greater than 20% in any diameter or as new nodular enhancement in patients with no measurable tumor on initial postoperative imaging. Suspected imaging progression less than 5 mm maximum diameter must have been confirmed on two successive follow-up MRIs at a minimum 3-month interval.

Statistical Methodology

The primary endpoint of each of the three study groups was to estimate the 3-year progression-free survival (PFS) rate. At the time of study development, no prospectively collected cooperative group data was available on these patient groups. A sample size of 50 patients per risk group

would allow a 95% CI around the estimate 3-year PFS rate to be no greater than ±14% using a binomial distribution. Target accrual was thus set at 55 patients per risk group to allow for up to 10% ineligibility and/or loss to follow-up.

Secondary endpoints included: (1) concordance between central and parent institution histopathologic diagnosis, grading, and subtyping; (2) incidence of prospectively scored grade 2+ acute and late AEs as measured by CTCAE version 3; (3) histopathologic correlates of PFS; (4) imaging (MRI) predictors of progression via central neuroradiology review; (5) molecular correlative studies; and (6) overall survival (OS). For this Group 1 evaluation, we report the primary endpoint (PFS) and secondary endpoints of OS and AEs. Central neuro-radiology review began with Dr. Bruce Dean (see Acknowledgments) and proceeded with two co-authors (J.M.M. and A.M.A.). Findings regarding pathologic concordance have been published separately.[8] To determine the concordance within Group 1, similar methods were employed including Cohen's κ in which $\kappa \leq 0$ indicates no agreement and 1.0 indicates complete agreement.[9]

PFS was measured from the date of study entry to the date of progression or death, or otherwise the date of the last follow-up on which the patient was reported alive and progression-free. OS was measured from the date of study entry to the date of death, or otherwise the date of the last follow-up on which the patient was reported alive. PFS and OS were estimated using the Kaplan-Meier method. Time to tumor progression was calculated using the cumulative incidence function, with death without progression treated as the competing risk. The effects of tumor features, including greatest single dimension (continuous variable measured in millimeters [mm]), edema, homogeneous enhancement, calcification, hyperostosis, and brain invasion, on OS and PFS were assessed with Cox proportional hazards models. As specified by the protocol, Groups 1–3 were considered in composite to increase statistical power for analyses of the prognostic impact of tumor features. Additionally, a Cox model was used to determine if meningioma location impacted PFS. Chi-square tests compared the distribution of location by resection status. Due to the limited number of events, subgroup analyses could not be conducted. AEs were graded with NCI's Common Terminology Criteria for AEs version 3. The incidence rates of treatment-related AEs for dermatology/skin, neurology, and ocular/visual (excluding alopecia) for all eligible patients who received protocol treatment (surgery) were of interest. Treatment-related was defined as definitely, probably, or possibly related to protocol treatment.

Results

Patient Characteristics and Follow-up

The trial was activated on June 19, 2009, and accrual to Group 1 (the present low-risk cohort) completed on September 29, 2010. Among the 65 patients enrolled within Group 1, five (7.7%) were found ineligible: four registered to the wrong group, and one was absent the required submissions for central pathology review. Of the remaining 60 evaluable patients, 56 (93.3%) were reported as GTR and 4 (6.7%) as STR by the enrolling institution. Sufficient imaging for central confirmation of resection extent was available for 48 patients. By central review, GTR was identified in 35 (72.9%) and STR in 13 (27.1%). There was an only fair agreement between the institution and central reviews ($\kappa = 0.26$, 95% CI, 0.02 to 0.54). No patient in Group 1 had a recurrence prior to registration.

Median follow-up for the 60 evaluable patients was 9.0 years (range 0.6–10.4 years) and for the 57 surviving patients, 9.1 years (range 0.6–10.4 years). Table 1 depicts pretreatment characteristics of the 60 evaluable patients.

PFS

For the 60 eligible patients, five (8.3%) withdrew without progression and two (3.3%) were lost to follow-up without progression before reaching 3 years. Data for an additional patient (1.7%) were not submitted for central neuroradiology review. These 8 were censored before 3 years. For the 52 evaluable patients, three (5.8%) progressed within 3 years, and one (1.9%) died within 3 years without disease progression. Estimated 3-year PFS was 91.4% (95% CI, 84.2 to 98.6), 5-year PFS was 89.4% (95% CI, 81.3 to 97.5), and 10-year PFS was 85% (95% CI, 75.3 to 94.7). Figure 2A displays Kaplan-Meier PFS for the entire cohort. Median PFS was not reached since only 8 (13.3%) patients progressed or died.

Assessing resection extent according to central review of the initial post-operative MRI, following GTR estimated 3-year and 5-year PFS rates were 94.3% (95% CI, 86.6 to 100), and 10-year 87.6% (95% CI, 76.2 to 99.1). After STR, estimated 3-year PFS was 83.1% (95% CI, 61.5 to 100), and 5-year and 10-year PFS 72.7% (95% CI, 45.9 to 99.5). Figure 2B shows PFS Kaplan-Meier curves comparing PFS following GTR and STR. Due to the small number of events (<10), no statistical test was conducted.

Meningioma Location and Resection Status

Anatomic location (grouped as convexity, parasagittal, and skull base) was analyzed against resection extent (Table 2). Among the 60 evaluable patients, 35 (58.3%) had a tumor of convexity/parasagittal origin, 19 (31.7%) skull base, and 6 (10.0%) tentorial/posterior fossa. According to central review, GTR was accomplished in 20 (83.3%) of the convexity/parasagittal meningiomas, 12 (66.7%) skull base, and 3 (50.0%) of the tentorial/posterior fossa, as compared to STR in 4 (16.7%) of the convexity/parasagittal, 6 (33.3%) of the skull base, and 3 (50.0%) of the tentorial/posterior fossa meningiomas.

Progression

Figure 2C is a graphic representation of time to progression for the full cohort. Progression was in each case local, after STR within the residual enhancing meningioma and after GTR within or immediately abutting the resection bed. Two patients experienced local failure within year 1, four within 3 years, and five within 5 years. There were no additional failures out of 10 years. For the entire cohort, the 3-year progression rate was 6.9% (95% CI, 2.2 to 15.4), 5-year 8.9% (95% CI, 3.2 to 18.2), and 10-year 8.9% (95% CI, 3.2 to 18.2). When

Table 1. NRG/RTOG 0539 Patient and Tumor Characteristics for All Eligible Patients in Group I

(*n* = 60)	
Patient characteristics	
Age (years)	
Median	56
Min–Max	31—79
Q1–Q3	46–64
≤ 49	21 (35.0%)
50–59	16 (26.7%)
60–69	15 (25.0%)
≥ 70	8 (13.3%)
Sex	
Male	12 (20.0%)
Female	48 (80.0%)
Race	
American Indian/Alaska Native	2 (3.3%)
Asian	1 (1.7%)
Black or African American	6 (10.0%)
White	50 (83.3%)
Unknown or not reported	1 (1.7%)
Ethnicity	
Hispanic or Latino	2 (3.3%)
Not Hispanic or Latino	55 (91.7%)
Unknown (individuals not reporting ethnicity)	3 (5.0%)
Clinical characteristics	
Zubrod performance status	
0	44 (73.3%)
1	16 (26.7%)
Neurologic function	
No symptoms	36 (60.0%)
Minor symptoms	16 (26.7%)
Moderate symptoms	8 (13.3%)
Current status of tumor	
initial diagnosis only	60 (100.0%)
Extent of resection (Simpson grade)	
Initial–grade I	36 (60.0%)
Initial–grade II	15 (25.0%)
Initial–grade III	5 (8.3%)
Initial–grade IV	4 (6.7%)
Lateralization of tumor	
Right	27 (45.0%)
Left	28 (46.7%)
Bilateral	4 (6.7%)
Unknown	1 (1.7%)
Location of tumor	
Skull base	19 (31.7%)
Convexity/parasagittal	35 (58.3%)
Tentorial/posterior fossa	6 (10.0%)
Preoperative imaging features on all groups	
Greatest single dimension (mm)	(*n* = 148)
Median	42.7
Minimum–maximum	4.2–144.4
Q1–Q3	28–57.6
Edema	(*n* = 114)
No	38 (33.3%)
Yes	76 (66.7%)
Homogeneous enhancement	(*n* = 116)
No	28 (24.1%)
Yes	88 (75.9%)
Calcification	(*n* = 27)
No	21 (77.8%)
Yes	6 (22.2%)
Hyperostosis	(*n* = 40)
No	23 (57.5%)
Yes	17 (42.5%)
Brain invasion	(*n* = 30)
No	29 (96.7%)
Yes	1 (3.3%)

Q1, first quartile; Q3, third quartile.

assessed by central review determined extent of resection, the rate of progression was 2.9% (95% CI, 0.2 to 12.9) at 3, 5, and 10 years following GTR, whereas after STR 3-year progression was 16.9% (95% CI, 2.3 to 43.3), while 5-year and 10-year progression rates were each 27.3% (95% CI, 5.6 to 55.8). Additional management for the five patients who experienced progression was surgery alone for one patient, surgery and radiosurgery for one, radiosurgery for one, and observation for two. Due to the small number of progression events (<10), no statistical test was conducted.

OS

Among the 60 evaluable patients, one (1.7%) died within 3 years. Of the three deaths that occurred within the follow-up of 0.6 to 10.4 years (median 9.0 years), 2 were due to this disease and one due to other neurological disease. Figure 2D shows the Kaplan-Meier estimated OS for the entire cohort. Median survival has not been reached. Kaplan-Meier 3-year and 5-year OS rates were 98.3% (95% CI, 94.9 to 100), and 10-year OS 93.8% (95% CI, 87 to 100). By central review determined extent of resection, GTR provided 3-year and 5-year rates of OS of 97.1% (95% CI, 91.6 to 100), and a 10-year rate of 90.4% (95% CI, 80 to 100). After STR, all patients survived through 10 years.

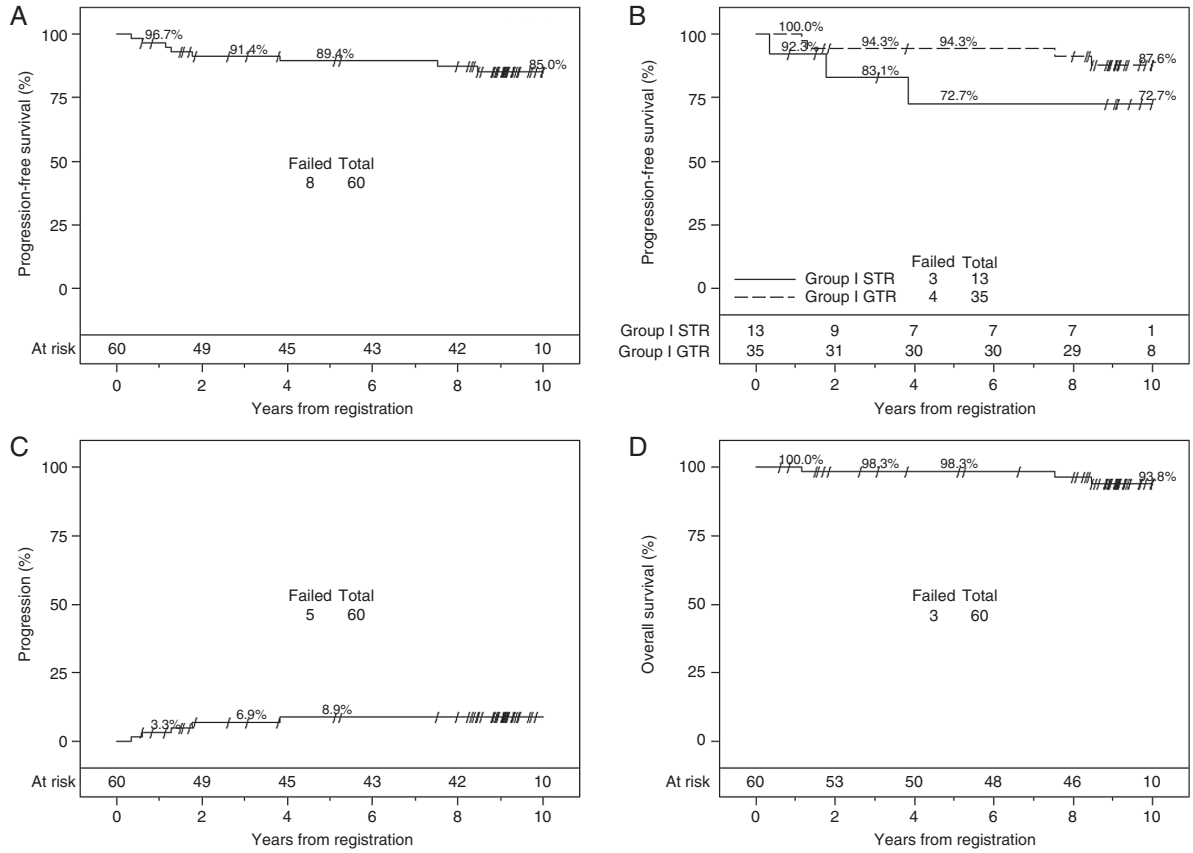

Fig. 2 (A) PFS for the entire low-risk cohort. The listed percentages are the Kaplan-Meier PFS estimates at 1, 3, 5, and 10 years, respectively. (B) PFS by resection status. The listed percentages are the Kaplan-Meier PFS estimates at 1, 3, 5, and 10 years, respectively. (C) Time to progression (local failure). The listed percentages are the cumulative incidence estimates at 1, 3, and 5 years, respectively. D: OS. The listed percentages are the Kaplan-Meier OS estimates at 1, 5, and 10 years, respectively. GTR, gross total resection; PFS, progression-free survival; STR, subtotal resection; OS, overall survival.

Table 2. Meningioma Location by Resection Status

	Skull base ($n = 18$)	Convexity/parasagittal ($n = 24$)	Tentorial/posterior fossa ($n = 6$)	Total ($n = 48$)
Gross total resection	12 (66.7%)	20 (83.3%)	3 (50.0%)	35 (72.9%)
Subtotal resection	6 (33.3%)	4 (16.7%)	3 (50.0%)	13 (27.1%)

P-value (Fisher's Exact Test) = 0.16.

Prognostic Factors

As measured via central review and inclusive of all three study cohorts, the median greatest single tumor dimension on pre-operative MRI was 42.7 mm, range 4.2–144.4 mm. We found that increasing tumor size was associated with significant worsening of PFS (hazard ratio [HR] = 1.03; 95% CI, 1.01 to 1.05, $P = 0.003$,) as well as OS (HR = 1.03; 95% CI, 1.00 to 1.05; $P = 0.021$), indicating that a 3% relative worsening of PFS and OS per 0.01 mm tumor size (Table 3). This was the only finding with statistically significant impact. We also examined cerebral edema (66.7%), homogeneous enhancement (75.9%), calcification (22.2%), and hyperostosis (42.5%).

AEs

Treatment-related AEs were limited to grades 1 through 3. There were no grade 4 or 5 events. One grade 3 (infection), four grade 2 (neurologic, pulmonary, gastrointestinal, and pain), and five grade 1 (three neurologic, one occulovisual,

Table 3. Cox Proportional Hazards Model (Stratified by Group) With Central Neuroradiology Review of Tumor Size and Other Features ($n = 104$)

Variable	*P*-value	Hazard Ratio (95% CI)
Progression-free survival		
Greatest single dimension (continuous)	0.003	1.03 (1.01 to 1.05)
Overall survival		
Greatest single dimension (continuous)	0.021	1.03 (1.00 to 1.05)

Both models derived from stepwise selection.
Variable(s) not included in final models: edema and homogeneous enhancement (dropped out during the stepwise selection process), calcification, hyperostosis, and brain invasion were not included as covariates in this analysis due to too few patients with available data.

and one constitutional) events were reported from five patients. No Group 1 patient received postoperative adjuvant therapy; thus all events were attributed to surgery itself.

Discussion

The WHO updated its meningioma grading criteria in 2021.[10] The 2021 WHO criteria recognize rapidly evolving molecular discoveries which are adding constructively to subtype classification, grading, and prognostic determination. These presently include SMARCE1 associated with clear cell meningioma, BAP1 with rhabdoid and papillary subtypes, KLF4/TRAF7 with secretory, TERT, and CDKN2A/B with WHO grade 3, H3K27me3 loss and methylome profiling with aggressive behavior.[10] This arena is undergoing rapid evolution and will be part of ongoing investigations and publications within this trial.

Building upon prior 2000, 2007, and 2016 criteria, the new 2021 grading parameters are, from the microscopic and histopathologic viewpoint, very similar to those employed in this cooperative group trial. Using these modern grading criteria, other investigators have independently validated strong associations between meningioma grade, recurrence-free survival, and OS.[11–13] In concert with the present article, our prior publications of outcomes with intermediate- and high-risk meningioma subgroups from the same NRG/RTOG-0539 trial have been confirmatory.[5,6]

Surgery remains an important primary therapy for meningioma as numerous publications have demonstrated a strong relationship between resection extent and recurrence.[4] The characterization of surgical resection by Donald Simpson has remained the standard.[7] His report published in 1957 carefully described surgical outcomes with 256 patients based upon resection extent, which he categorized as grades I–V.[7] Although some contemporary surgical series have questioned the Simpson grading scheme's applicability to the present era,[14–16] the majority have confirmed lower meningioma recurrence risk with greater degrees of resection of the tumor, its adjacent dura, and any involved bone.[7] A large series by Hasseleid confirmed significant differences in PFS between Simpson grade I, grades II to III, and grades IV to V.[17]

We defined GTR as Simpson grades I-III. This was chosen because grades I–III would be difficult to impossible to differentiate on the basis of post-operative imaging, which was mandated and centrally reviewed within the trial. Interestingly, among the 60 low-risk (Group 1) patients observed on protocol, 56 (93%) were reported as GTR by the enrolling sites. In contrast, among 48 patients with sufficient imaging submitted for thorough central review, 35 (73%) were interpreted as GTR. Statistically, this represents fair agreement, although numerically there is a 20% discrepancy. The reasons for this remain to be clarified. Direct surgeon input, which was absent with central review, may perhaps have impacted radiographic interpretation at the enrolling site. Other investigators have noted that intraoperative Simpson grading may over-estimate resection extent in comparison with postoperative imaging.[18]

For a WHO grade 1 meningioma, GTR is considered definitive therapy, although it is well recognized that long-term local recurrence risk persists. Reports with extended follow-up have identified local recurrence in 7–27% at 5-years, 18–53% at 10-years, and 21–68% at 15-years.[13,14,19,20] With respect to our entire Group 1 cohort, following either GTR or STR, results are at the more favorable end of this spectrum. Per literature review, we estimated 3-year progression risk at 10% for the low-risk cohort. Our observed failure rate was 8.6%, thus within our outcome estimates. PFS at 3-years was 91.4%, at 5-years 89.4%, and at 10 years 85%. By resection extent, as anticipated, results were numerically superior following GTR, following which 3 and 5-year PFS rates were each 94.3%, and 10-year PFS 87.6%. Following STR, PFS rates were numerically inferior: 83.1% at 3-years, and 72.7% at 5 and 10-years, although there have yet been too few events for statistical comparison. For the entire cohort, OS was 98.3% at 3 and 5 years and 93.8% at 10 years.

With relatively few progression events with Group 1 alone, we evaluated imaging prognostic features among all three protocol risk groups. Extent of edema, homogeneous versus heterogeneous enhancement, hyperostosis, calcification, and tumor dimension (as a continuous variable) were considered. Except for tumor size (measured by greatest dimension), each variable dropped out of the model due either to its paucity or to statistical insignificance. With median greatest dimension 42.7 mm (range 4.2–144.4 mm), tumor size significantly impacted PFS ($P = .003$) and OS ($P = .021$). Whether this applies variably to different study cohorts remains an important question for future analysis. Although some investigators have not identified a correlation between meningioma size and recurrence risk,[21] the majority have,[18,22–25] including a recent meta-analysis.[26] Tumor size may play a larger role in recurrence risk, and possibly even survival, than has traditionally been attributed to it.

We compared a subcohort of Group 1 (centrally reviewed WHO grade 1, STR alone), with a subcohort of Group 2 patients (centrally reviewed WHO grade 2, GTR + RT).[5] At 5-years PFS was, respectively, 94.1% versus 83.1%, numerically superior for Group 2. There remain too few events for statistical analysis. However, noting that no AEs beyond grade 2 were encountered with Group 2 patients who received RT after GTR[5] this may raise questions regarding optimal management of patients with subtotally resected WHO grade 1 meningioma, who may benefit from secondary resection or RT.

As one might anticipate, STR (Simpson Grade IV and V) resulted in higher rates of progression than GTR in the majority of reports. Local progression following STR of WHO grade 1 meningioma has occurred in 37–63% of patients at 5-years, 52–100% at 10-years, and 70–91% at 15-years.[14,19,20,27,28] Furthermore, in one study cause-specific survival (CSS) was significantly decreased in patients receiving subtotal compared to GTR, with 15-year CSS 51% versus 88%, respectively.[14] Whether secondary surgery or early RT may be appropriate in this setting remains an important question for future investigation.

This publication represents the first clinical report of low-risk (newly diagnosed WHO grade 1 treated surgically) meningioma patients treated within a cooperative group trial. With PFS at 3, 5, and 10 years of 91.4, 89.4, and 85.0%, and 10-year OS 93.8%, the results prospectively validate surgery followed by observation for most low-risk patients, but raise possible questions regarding optimal management following STR, particularly for patients with a large meningioma.

Management algorithms now increasingly oblige fine tuning beyond our current appraisals of histopathologic grade, resection extent, recurrence status, tumor size, and tumor volume. As presently constituted, these result in overtreatment in as many as half of high-risk patients and undertreatment of a similar percentage of those ostensibly at lower risk. The identification of molecular fingerprints for those meningiomas most likely to recur or progress, and perhaps even those most likely to benefit from adjuvant therapy is underway. There is noteworthy evidence that DNA methylation, among other molecular fingerprints, may inform progression risk and help individualize management for patients with meningioma, the most common of primary intracranial tumors.[29–32] We are presently investigating methylation among patients on NRG/RTOG-0539 with a Moonshot grant. Additionally, there are plans for further molecular analysis built into the protocol once there have been sufficient events in support of such inquiry. These will be the topics for subsequent publication. It is expected that such investigations will advance our understanding of meningioma subtyping, grading, and treatment with improved identification of which patients stand to benefit from which management strategies.

Keywords

cooperative group trial | meningioma | observation | surgery | WHO grade 1 (benign)

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Previous Presentations

Society for Neuro-Oncology 25th Anniversary Scientific Meeting, Austin, Texas, November 2020 (meeting changed to virtual during COVID-19 pandemic). Limited early results presented at ASTRO, 58rd Annual Meeting of the American Society of Therapeutic Radiology and Oncology, Boston, Massachusetts, September 2016.

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