# Long-term Results of Stereotactic Radiosurgery for Skull Base Meningiomas

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## Introduction

Gamma knife radiosurgery (GKRS) is well-established in the management of inaccessible, recurrent, or residual benign skull base meningiomas. Most series report clinical outcome parameters and complications in the short - intermediate period after radiosurgery. Reports of long-term tumor control and neurological status are still lacking. We report the presentation, treatment, and long-term outcome of skull base meningiomas after GKRS.

**TABLE 1. Patient-Related Parameters[a]**

| Parameter | Value |
|---|---|
| Cohort size | 135 |
| Males:females sex | 54.1/45.9% (n = 73/62) |
| Age (median) at the time of GKRS, y | 54 (range 19-80) |
| Median KPS at the time of GKRS | 80 (range 50-100) |
| Pre-GKRS functional status | |
| KPS at the time of GKRS | |
| ≤50 | 5.2% (n = 7) |
| 60-80 | 65.9% (n = 89) |
| 90-100 | 28.9% (n = 39) |
| Preexisting neurological deficit | |
| Yes | 88.1% (n = 119) |
| None/minor | 11.9% (n = 16) |
| Tumor volume (median) at time of GKRS | 4.7 cm$^3$ (range 0.5-23) |
| Tumor location | |
| Parasagittal[b] | 17% (n = 23) |
| Cerebellopontine angle | 17% (n = 23) |
| Clivus | 15.6% (n = 21) |
| Falx | 14.8% (n = 20) |
| Tentorial | 9.6% (n = 13) |
| Petroclival | 9.6% (n = 13) |
| Petroclinoid | 8.1% (n = 11) |
| Petrous | 5.9% (n = 8) |
| Clinoid | 2.2% (n = 3) |
| Tumor abutting/invading venous structures | 6.7% (n = 9) |
| Peritumoral edema | |
| Absent | 54.8% (n = 74) |
| Present | 45.2% (n = 61) |
| Number of previous surgeries | |
| Median | 1 (range 0-4) |
| 0 | 36.3% (n = 49) |
| 1 | 54.1% (n = 73) 63.7% (n = 86) |
| 2 | 8.1% (n = 11) |
| ≥3 | 1.5% (n = 2) |
| Tumor resection grade (Simpson) at time of last surgery before GKRS | 63.7% (n = 86) |
| 1 | 8.1% (n = 11) |
| 2 | 34.8% (n = 47) |
| 3 | 5.2% (n = 7) |
| 4 | 13.3% (n = 18) |
| 5 | 2.2% (n = 3) |
| Previous embolization | 43% (n = 58) |
| Median margin dose, Gy | 15 (range 7.5-36)[c] |
| Median maximal dose, Gy | 34 (range 20-65)[c] |
| Median isodose line, % | 40 (range 28-80) |
| Median no. of isocenters | 5 (range 1-25) |

## Methods

From a prospectively collected IRB approved database, we selected patients with a WHO grade I skull base meningioma treated with a single-session GKRS and a minimum of 60 months follow up. 135 patients, 54.1% males (n=73) form the cohort. Median age was 54 years (19-80). Median tumor volume was 4.7 cm3 (0.5-23). Median margin dose was 15 Gy (7.5-36). Median follow up was 102.5 months (60.1-235.4). Patient and tumor characteristics were assessed to determine predictors of neurological function and tumor progression.

**TABLE 2. Outcome Parameters**

| Parameter | Value |
|---|---|
| Cranial nerve deficits (all causes) | 22 |
| Post-GKRS craniotomy due to tumor growth | 8.1% (n = 11) |
| Adverse radiation effects (AREs) | 7.4% (n = 10) |
| Median time to peak AREs (mo) after initial GKRS | 12 (range 6-36) |
| GKRS-induced complications | |
| Intermittent headache | 34.8% (n = 47) |
| Cranial deficit | 14.8% (n = 20) |
| Dizziness | 15.6% (n = 21) |
| Weakness | 11.1% (n = 15) |
| Encephalopathy | 3.7% (n = 5) |
| Pain | 1.5% (n = 2) |
| New or worsening seizures | 0.7% (n = 1) |
| GKRS-induced cranial nerve (CN) deficit | |
| Trigeminal (CN-V) | 10.4% (n = 14) |
| Vestibulocochlear (CN-VIII) | 7.4% (n = 10) |
| Optic (CN-II) | 6.7% (n = 9) |
| Facial (CN-VII) | 5.9% (n = 8) |
| Hypoglossal | 2.2% (n = 3) |
| Oculomotor (CN-III) | 2.2% (n = 3) |
| Vagus (CN-X) | 1.5% (n = 2) |
| Abducens (CN-VI) | 0.7% (n = 1) |
| Post-GKRS neurological preservation or improvement | 61.5% (n = 83) |
| Tumor control | 88.1% (n = 119) |
| Tumor progression | 11.9% (n = 16) |
| Median change in KPS last follow-up | +10 (range −30 to +30) |
| Favorable outcome (tumor control and neurological preservation/improvement) | 60.8% (n = 79) |
| KPS at last follow-up | |
| Median | 90 (range 40-100) |
| ≤50 | 3.7% (n = 5) |
| 60-80 | 31.9% (n = 43) |
| ≥80 | 64.4% (n = 87) |
| Follow-up | |
| Median (mo), range | 102.5 (range 60.1-235.4) |

## Results

At last follow up, tumor volume control was achieved in 88.1% (n=119). Post-GKRS clinical improvement or stability was reported in 61.5%. The 5, 10, and 15 years actuarial progression free survival rates are 100%, 95.4%, and 68.8%, respectively. Favorable outcome (both tumor control and clinical preservation/improvement) was attained in 60.8% (n=79). Pre-GKRS performance status (KPS) was shown to influence tumor progression (p=0.0001) and post-GKRS clinical improvement / preservation (p=0.003).

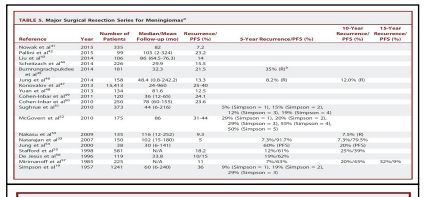
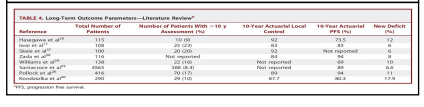


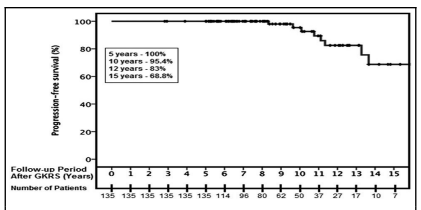
**TABLE 3. Outcome Parameters—Multivariate Regression[a,b]**

| Admission Parameters | Outcome Parameters: Tumor Progression | Post-GKRS Clinical Improvement or Stability | Favorable Outcome[c] |
|---|---|---|---|
| Sex | 0.713 | 0.088 | 0.069 |
| Age at GKRS | 0.219 | 0.325 | 0.462 |
| Tumor location | 0.341 | 0.446 | 0.869 |
| Tumor volume at GKRS | 0.131 | 0.334 | 0.592 |
| Perilesional edema | 0.171 | 0.074 | 0.057 |
| Margin dose | 0.617 | **0.036** | **0.018** |
| Pre-GKRS KPS | **0.0001** | **0.003** | **0.002** |

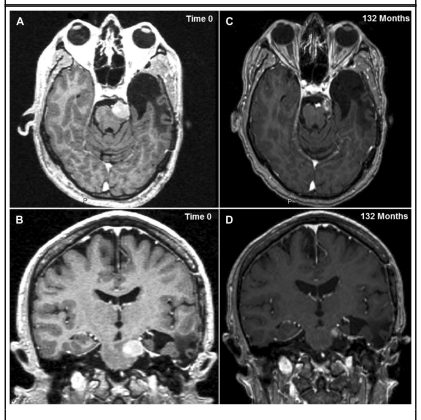


## Conclusions

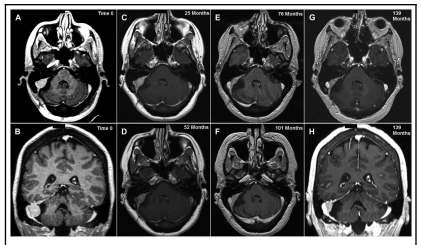
GKRS offers a highly durable rate of tumor control for WHO-I skull base meningiomas, with an acceptably low incidence of neurological deficits. KPS at the time of radiosurgery serves as a reliable long-term predictor of overall outcome.



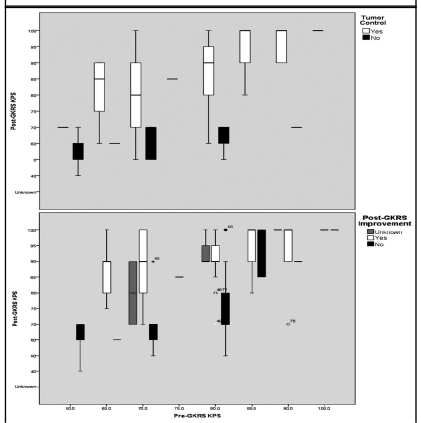

Kaplan-Meier curve presenting actuarial progression-free survival.




Sixty-year-old male patient treated for a left tentorial petroclival meningioma abutting the midbrain



44-year-old female treated for a right posterior fossa meningioma. Treatment volume 5.2 mL, given 15 Gy to the50%isodose line.




The correlation between pre-GKRS KPS and post-GKRS KPS grouped according to tumor control (1-tumor progression) andpost-GKRS improvement. GKRS, Gamma knife radiosurgery; KPS, Karnofsky Performance Scale.