

# Long-Term Outcomes Using Frameless Immobilization in Upfront Gamma Knife Radiosurgery for Meningioma

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## Introduction

Traditional GKRS relies on rigid, pin-based stereotactic frames for immobilization, which can be uncomfortable and limit fractionated treatment.<sup>1</sup> The LGK Icon enables frameless, mask-based delivery with improved comfort, workflow, and support for fractionation.<sup>2,3</sup>

This represents the largest study to date evaluating long-term outcomes of frameless GKRS as upfront treatment for meningioma.

## Objective

The objective of this study was to evaluate oncologic outcomes from frameless, mask-based upfront Gamma Knife radiosurgery (GKRS) treatment for intracranial meningiomas.

## Methods and Materials

Patients were chosen from an IRB-approved prospective observational cohort and retrospectively analyzed. Patients with radiographically or histopathologically confirmed meningiomas treated with upfront Gamma Knife radiosurgery (GKRS) therapy using the frameless, mask-based fixation method were included in this study; a parallel frame-based cohort was analyzed for reference. Clinical, treatment, and outcome data were abstracted from the electronic medical record. Local control was defined as absence of in-field or marginal progression ( $\leq 2$  cm from the prescription isodose line). Progression-free survival (PFS) was measured from GKRS to intracranial progression or death and estimated using Kaplan-Meier methods. Secondary outcomes included treatment-related toxicities such as radiation necrosis, seizures, and visual complications.

**Table 1.** Baseline characteristics of patients undergoing fixation with the frameless mask-based and the frame-based techniques

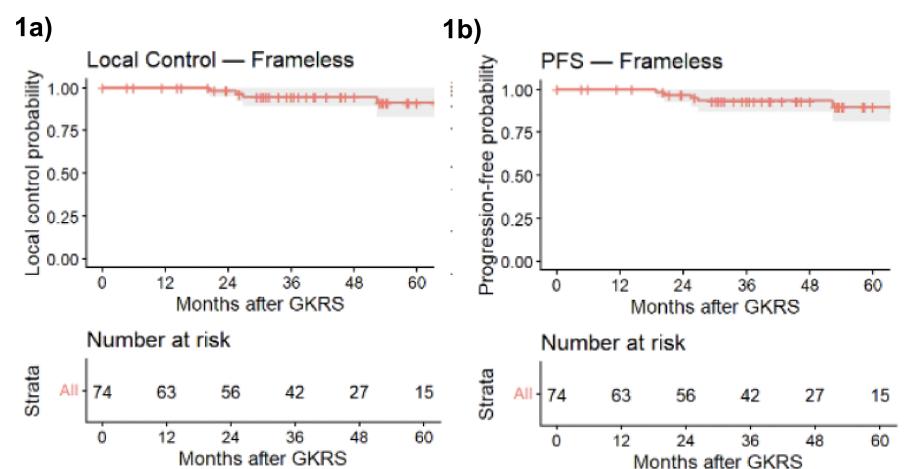
Variable	Frameless (N = 74) <sup>1</sup>	Frame (N = 62) <sup>1</sup>	Std diff <sup>2</sup>	p-value <sup>2</sup>
<b>Sex</b>				0.8
F	46 (72%)	34 (76%)		
M	18 (28%)	11 (24%)		
Age at GKRS (years)	65.6 [56.3, 73.0]	61.8 [56.2, 72.2]	2.2	0.3
<b>Tumor grade</b>				>0.9
WHO I	1 (20%)	3 (21%)		
WHO II	4 (80%)	11 (79%)		
WHO III	0 (0%)	0 (0%)		
Prior brain RT	4 (6.3%)	1 (2.3%)		0.6
Prior surgery (any)	3 (4.1%)	1 (1.6%)		0.7
Treatment volume (cc)	2.5 [1.4, 4.5]	2.4 [0.9, 4.6]	0.37	0.3
<b>Marginal dose (Gy)</b>				<0.001
11.5	1 (1.4%)	0 (0%)		
12	0 (0%)	2 (3.4%)		
14	50 (68%)	45 (78%)		
15	0 (0%)	1 (1.7%)		
16	5 (6.8%)	9 (16%)		
18	0 (0%)	1 (1.7%)		
25	18 (24%)	0 (0%)		
<b>Number of fractions</b>				<0.001
1	56 (76%)	58 (100%)		
5	18 (24%)	0 (0%)		
Follow-up (months)	41.6 [26.1, 56.8]	54.9 [26.6, 93.5]	-17	0.006
<b>Tumor location</b>				0.14
Non-skull base	28 (38%)	32 (52%)		
Skull base	45 (62%)	29 (48%)		

<sup>1</sup>n (%); Median [Q1, Q3]  
<sup>2</sup>Pearson's Chi-squared test; Wilcoxon rank sum test; Fisher's exact test; NA

## Results

- 74 lesions undergoing frameless mask-based fixation, and 62 lesions undergoing frame-based fixation were included
- Median follow-up time for the frameless cohort was 41.6 months and 54.9 months for the frame-based cohort
- 1-, 3-, and 5-year PFS was 100%, 93.2% and 89.8% respectively for the frameless cohort and 90.7%, 80.9%, 74.4% respectively for the frame-based cohort
- 1-, 3-, and 5-year local control was 100%, 94.8% and 91.2% respectively for the frameless cohort and 90.7%, 86.7%, 86.7% respectively for the frame-based cohort
- 1-, 3-, and 5-year overall survival was 100%, 98.4% and 98.4% respectively for the frameless cohort and 100%, 92.5%, 87.7% respectively for the frame-based cohort
- Toxicity rates were low and comparable between frame-based and frameless GKRS

**Figure 1.** Kaplan-Meier curves for frameless cohorts showing local control (1a) and progression free survival (1b)



**Table 2.** Summary of 1-, 3-, and 5-year outcomes after GKRS by fixation methods

Outcome	Cohort	1-year (%)	3-year (%)	5-year (%)
PFS	Frameless	100.0	93.2	89.8
PFS	Frame	90.7	80.9	74.4
Local control	Frameless	100.0	94.8	91.2
Local control	Frame	90.7	86.7	86.7
Overall survival	Frameless	100.0	98.4	98.4
Overall survival	Frame	100.0	92.5	87.7

**Table 3.** Toxicity profile after GKRS by fixation method

Toxicity	Frameless GKRS			Frame-based GKRS		
	Yes	No	Percent	Yes	No	Percent
Radiation Necrosis	0	64	0.0	1	30	3.2
New-onset Seizures	0	64	0.0	1	30	3.2
Optic Neuropathy	1	63	1.6	1	30	3.2
Visual Symptoms	1	65	1.5	1	29	3.3

## Conclusions

Frameless mask-based GKRS used as upfront treatment provides excellent local control and progression-free survival outcomes for intracranial meningiomas, with low toxicity rates comparable to traditional frame-based fixation. These findings support frameless GKRS as a safe, effective, and patient-centered upfront radiosurgical option, particularly given its workflow efficiencies and suitability for fractionated treatments.

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