

Early Pain Relief following Gamma Knife Radiosurgery for Trigeminal Neuralgia: Impact of Biologically Effective Dose

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ABSTRACT

This work aimed to evaluate our radiosurgical experience with trigeminal neuralgia treatment, with emphasis on short term pain relief and the influence of biologically effective dose (BED).

We retrospectively reviewed consecutive patients with trigeminal neuralgia treated at a single institution between 2020 – 2023 with a prescribed dose of 85 Gy. The BED was calculated using A9 formalism. Outcomes were evaluated using the Barrow Neurological Institute pain intensity scale before and at 3 month follow up after the GK treatment. Spearman' rank coefficient was calculated to determine the relationship between the BED and improvements in BNI score (Pre GK BNI – Post GK BNI) as well as facial numbness.

At 3 months follow-up, 37 of 44 patients (84%) demonstrated improvement in the BNI scale. A weak correlation (Spearman's rank $\rho=0.1$) was observed between higher BED and improvement in BNI score. GKRS demonstrated effective early pain relief for trigeminal neuralgia, with BED evaluation indicating a potential relationship with BNI pain outcomes. Further research into optimizing BED parameters could improve treatment effectiveness.

INTRODUCTION

- GK SRS delivers highly precise radiation from 192 Co-60 sources to intracranial targets (brain mets, vestibular schwannoma, AVM, meningioma, trigeminal neuralgia, pituitary adenoma) with sub-mm accuracy.
- Current planning relies solely on physical dose (Gy), ignoring time-dependent radiobiological effects arising from GK's multi-isocenter delivery.
- Same physical dose $\neq$ same biological effect. The true biological impact on target and normal tissue varies significantly between and within patients.
- Dose-rate effects are the key driver: sequential delivery across isocenters, with variable beam-on times and repositioning intervals, allows sublethal DNA damage repair between deliveries.
- Longer treatment time / lower effective dose rate $\rightarrow$ reduced biological effect, even at constant physical dose.
- Growing clinical evidence (2020–2025) links BED to GK outcomes across multiple disease sites, supporting the need for biologically-informed planning.
- The purpose of this work was to evaluate our radiosurgical experience with trigeminal neuralgia treatment, with emphasis on short term pain relief and the influence of biologically effective dose (BED).

METHODS AND MATERIALS

Design: Retrospective review of consecutive trigeminal neuralgia patients treated with GKRS at a single institution (2020–2023).

Target/technique: Dorsal root entry zone targeted using a single 4 mm shot, no sector blocking; prescribed dose of 85 Gy.

BED calculation: Biologically Effective Dose computed using the AGA9 (A9) formalism. Treatment duration: Ranged from 33.39 to 64.42 minutes across patients.

Outcome measure: Pain response assessed via Barrow Neurological Institute (BNI) pain intensity scale, recorded pre-GK and at 3-month follow-up.

Secondary endpoint: Presence or absence of post-treatment facial numbness recorded.

Statistical analysis: Spearman's rank correlation coefficient used to assess relationship between BED and (a) BNI score improvement (Pre-GK BNI – Post-GK BNI) and (b) facial numbness occurrence.

RESULTS

Key Results

- A total of 44 patients underwent GKRS. The mean follow-up was 48 weeks, with a median follow-up of 14 weeks.
- BED ranged from 1945.5 Gy to 2282.9 Gy (**Figure 1**). At 3 months follow-up, 37 of 44 patients (84%) demonstrated improvement in the BNI scale.
- No improvement was reported in 7 patients. Overall, 12 patients achieved complete pain relief (BNI I or II) and 22 patients achieved adequate pain relief (BNI III).
- A weak correlation (Spearman's rank $\rho=0.1$) was observed between higher BED and improvement in BNI score.
- The average maximum dose to the brainstem was 47.2 ± 4.8 Gy. Any facial numbness following treatment was observed in 21/44 (48%) cases.
- No correlation (Spearman's rank $\rho=0.009$) was found between the BED and facial numbness.

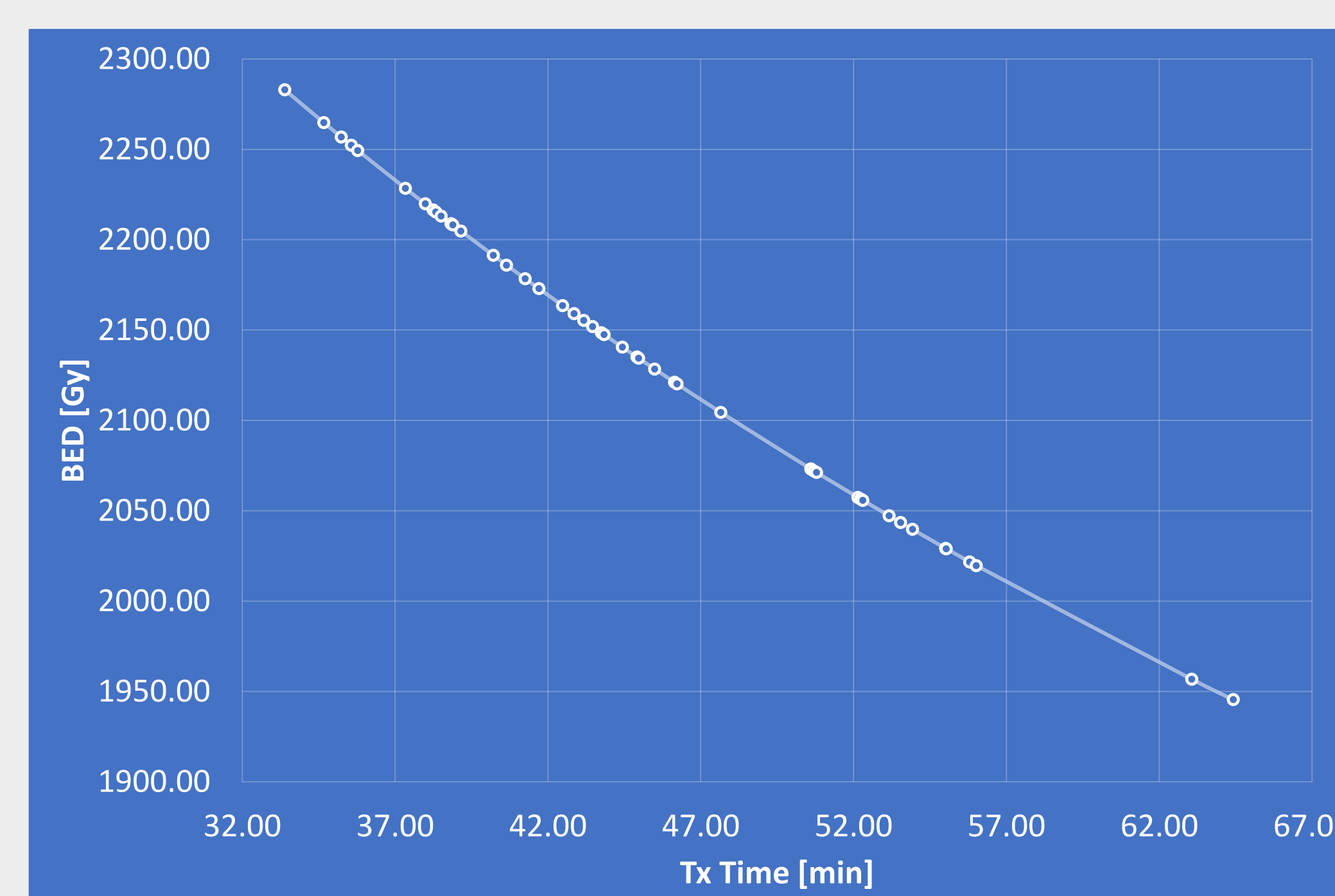


Figure 1. Relationship between treatment (Tx) time and Biologically Effective Dose (BED) for trigeminal neuralgia patients treated with GKRS

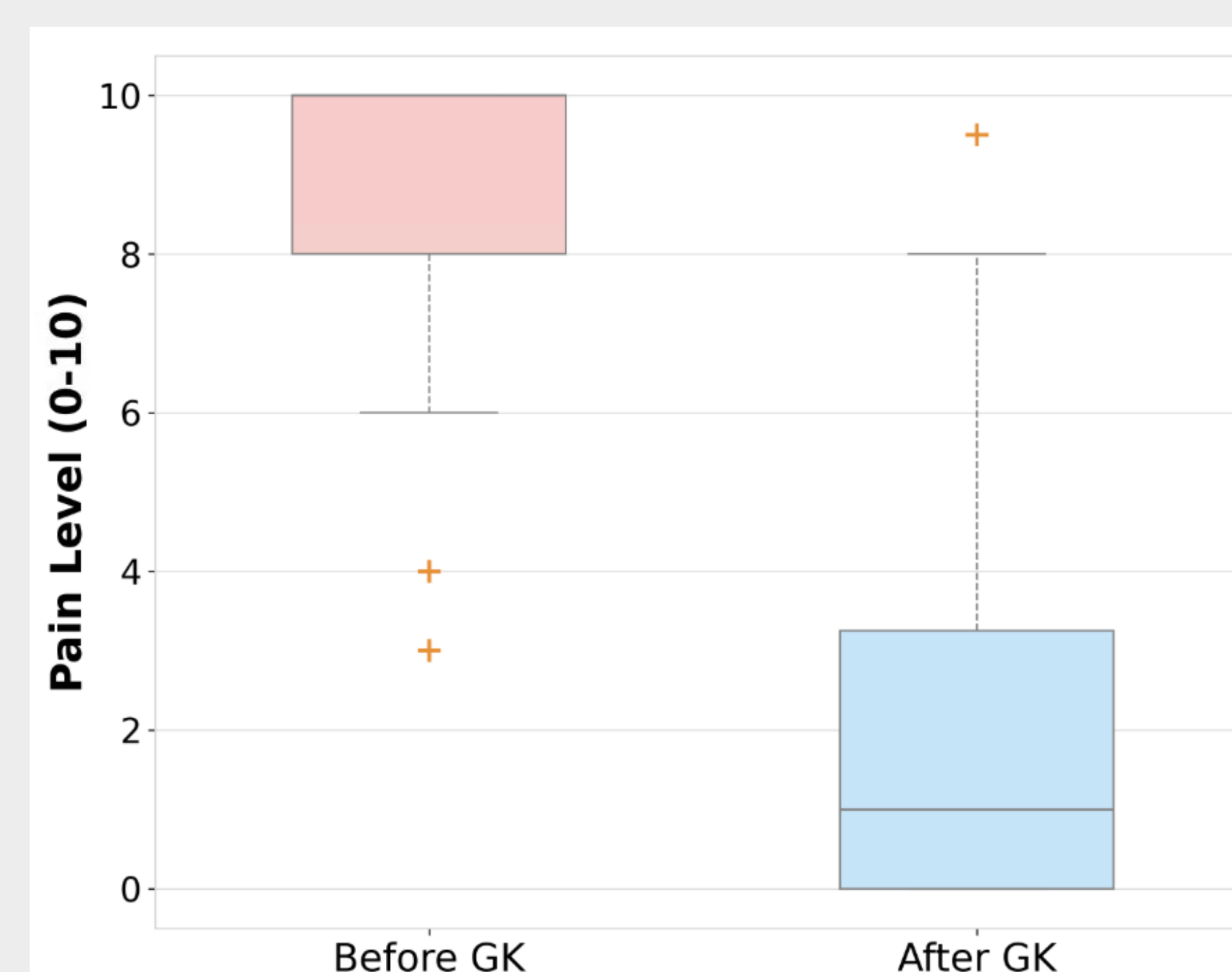


Figure 2. Box-and-whisker plot of pain intensity (0–10 scale) before and after Gamma Knife radiosurgery (GKRS) for trigeminal neuralgia.

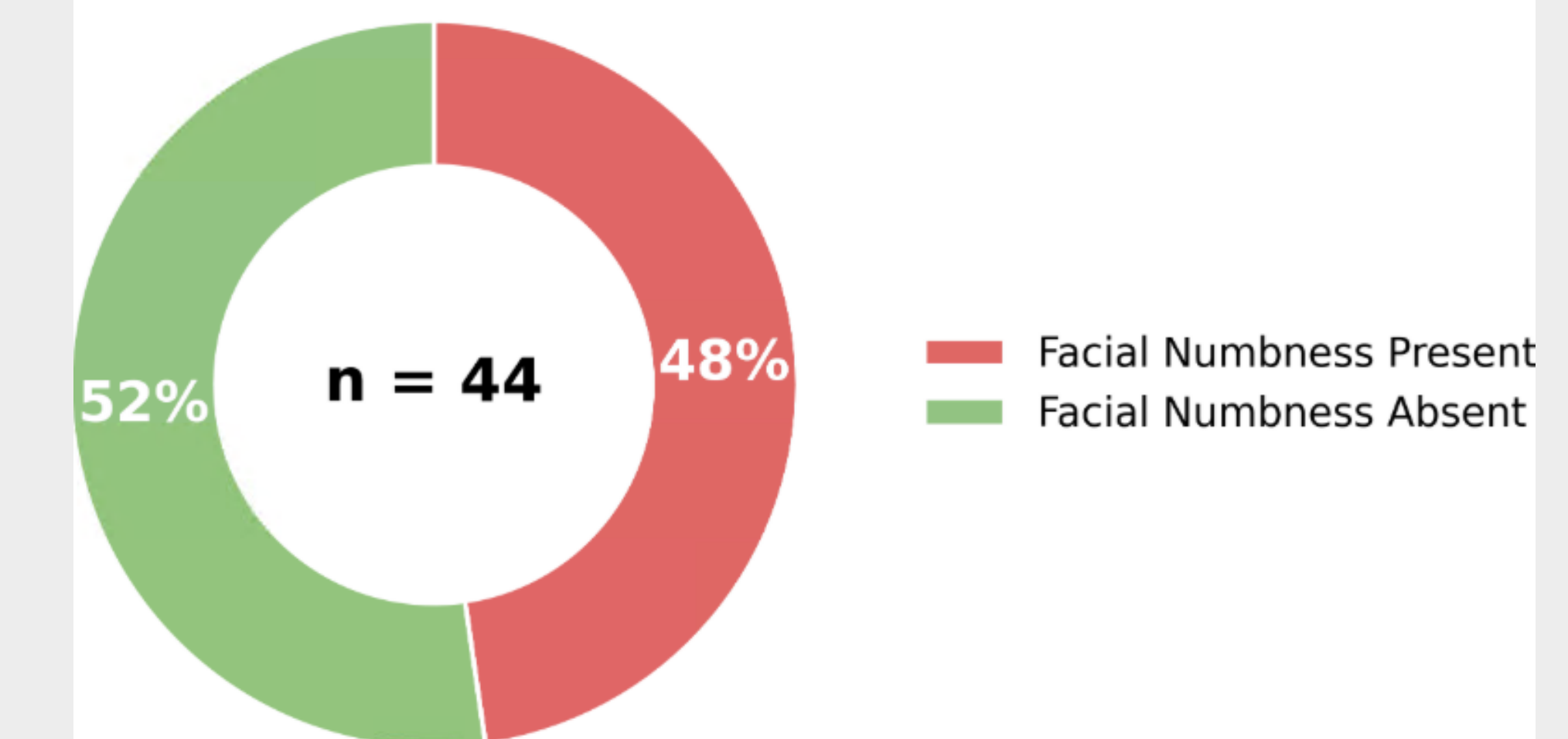


Figure 3. Distribution of post-treatment facial numbness following Gamma Knife radiosurgery for trigeminal neuralgia

CONCLUSIONS

- GKRS demonstrated effective early pain relief for trigeminal neuralgia, with BED evaluation indicating a potential relationship with BNI pain outcomes. Further research into optimizing BED parameters could improve treatment effectiveness.

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