Gamma Knife radiosurgery

- Radiosurgery of benign intracranial lesions. Indications, results , and perspectives
- Upfront frameless hypofractionated gamma knife radiosurgery for large posterior Fossa metastases
- Patterns of Recurrence After Postoperative Stereotactic Radiotherapy for Brain Metastases
- The Role of Gamma Knife Surgery in the Treatment of Rare Sellar Neoplasms: A Report of Nine Cases
- Exploring the Role of ADCs in Brain Metastases and Primary Brain Tumors: Insight and Future Directions
- Prediction of Pituitary Adenoma's Volumetric Response to Gamma Knife Radiosurgery Using Machine Learning-Supported MRI Radiomics
- Temporal evolution of MRI findings and survival outcomes in patients with brain metastases after stereotactic radiosurgery
- Expanded analysis of vertebral endplate disruption and its impact on vertebral compression fracture risk

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Gamma Knife radiosurgery is a type of radiation therapy used to treat tumors and other abnormalities in the brain.

see also Fractionated Gamma Knife Radiosurgery

History

In 1951, using the Uppsala University cyclotron, Lars Leksell and the physicist and radiobiologist Borje Larsson, developed the concept of Radiosurgery. Leksell and Larsson first employed proton beams coming from several directions into a small area into the brain , in experiments in animals and in the first treatments of human patients. Thus, he achieved a new non-invasive method of destroying discrete anatomical regions within the brain while minimizing the effect on the surrounding tissues.

First prototype of Gamma Knife was installed in Sophiahemmet in 1968. Over the rest of his career, Leksell treated 762 patients with the “Gamma Knife”. Throughout this time he would propose improving radiosurgery with modern imaging modalities including CT, MRI and angiography, as is currently used. Today, Leksell's technique is used as an effective treatment for many conditions such as arteriovenous malformations, pituitary tumors, acoustic neuromas, craniopharyngiomas, Meningioma, Matastatic and skull base tumors, and primary brain tumors. The Gamma Knife is manufactured by Elekta Instruments, Inc.

see Leksell Gamma Knife Perfexion.

In Gamma Knife radiosurgery, specialized equipment focuses close to 200 tiny beams of radiation on a tumor or other target. Although each beam has very little effect on the brain tissue it passes through, a strong dose of radiation is delivered to the site where all the beams meet.

The precision of Gamma Knife radiosurgery results in minimal damage to healthy tissues surrounding the target. In some cases, Gamma Knife radiosurgery may have a lower risk of side effects compared with other types of radiation therapy. Also, Gamma Knife radiosurgery is often a safer option than is traditional brain surgery.

Gamma Knife radiosurgery is usually a one-time therapy completed in a single day.

Indications

Gamma Knife radiosurgery Indications.

Gamma Knife Radiosurgery (GKRS) Modalities

Gamma Knife Radiosurgery (GKRS) is a form of stereotactic radiosurgery used to deliver highly focused radiation to intracranial targets. Below is a classification of the main modalities used in GKRS.

1. Based on Treatment Delivery

a. Single-Fraction SRS

- **Definition:** Entire dose delivered in one session.
- **Indications:** Small brain metastases, vestibular schwannomas, trigeminal neuralgia.
- **Advantages:** Quick procedure, high precision, minimal invasiveness.

b. Hypofractionated SRS (HF-GKRS)

- **Definition:** Radiation delivered over 2–5 sessions.
- **Indications:** Large tumors, lesions near eloquent brain areas (e.g., optic pathways, brainstem).
- **Advantages:** Reduces risk of radiation necrosis in sensitive structures.

2. Based on Gamma Knife Platform

a. Gamma Knife Perfexion

- Modular collimator system.
- Allows automated repositioning.
- High efficiency and precision.

b. Gamma Knife Icon

- Includes cone-beam CT for adaptive planning.
- Enables frameless mask-based immobilization.
- Allows for hypofractionation.
- Real-time motion monitoring.

c. Older Models (4C, B, C)

- Rely on rigid frame-based fixation.
- Longer preparation time.
- No fractionation capabilities.

3. Based on Immobilization Method

a. Frame-Based Fixation

- Titanium stereotactic frame fixed to skull.
- Maximum precision.
- Preferred for functional and AVM cases.

b. Frameless Fixation (Mask-Based)

- Thermoplastic mask with image guidance.
- Available in Gamma Knife Icon only.
- Enables outpatient workflow and multiple sessions.

4. Based on Target Type

a. Tumoral

- Examples: Brain metastases, meningiomas, gliomas.
- Dose and fractionation depend on size, location, histology.

b. Vascular

- Example: Arteriovenous malformations (AVMs).
- Dose: 16–25 Gy.
- Gradual obliteration over 2–3 years.

c. Functional

- Examples: Trigeminal neuralgia, tremor, epilepsy.

- Very high precision required (e.g., 90 Gy for trigeminal root entry).

5. Summary Table

Modality	Platform	Fixation	Dose Scheme	Typical Indications
Single-fraction GKRS	All	Frame or mask	1 session (18–25 Gy)	Small metastases, schwannomas
Hypofractionated GKRS	Icon only	Mask	3–5 sessions	Large tumors, near critical structures
Functional GKRS	All (prefer frame)	Frame	1 session (up to 90 Gy)	Trigeminal neuralgia, essential tremor
AVM GKRS	All	Frame	1 session (20–25 Gy)	AVMs not suitable for surgery

Planning

The purpose of a study of Duggar et al. was to compare two methods of stereotactic localization in Gamma Knife treatment planning: cone-beam computed tomography (CBCT) or fiducial. While the fiducial method is the traditional method of localization, CBCT is now available for use with the Gamma Knife Icon. This study seeks to determine whether a difference exists between the two methods and then whether one is better than the other regarding accuracy and workflow optimization.

Cone beam computed tomography was used to define stereotactic space around the Elekta Film Pinprick phantom and then treated with film in place. The same phantom was offset known amounts from center and then imaged with CBCT and registered with the reference CBCT image to determine if measured offsets matched those known. Ten frameless and 10 frame-based magnetic resonance imaging (MRI) to CBCT patient fusions were retrospectively evaluated using the TG-132 TRE method. The stereotactic coordinates defined by CBCT and traditional fiducials were compared on the Elekta 8 cm Ball phantom, an anthropomorphic phantom, and actual patient data. Offsets were introduced to the anthropomorphic phantom in the stereotactic frame and CBCT's ability to detect those offsets was determined.

Cone beam computed tomography defines stereotactic space well within the established limits of the mechanical alignment system. The CBCT to CBCT registration can detect offsets accurately to within 0.1 mm and 0.5°. In all cases, some disagreement existed between fiducial localization and that of CBCT which in some cases was small, but also was as high as 0.43 mm in the phantom domain and as much as 1.54 mm in actual patients.

Cone beam computed tomography demonstrates consistent accuracy in defining stereotactic space. Since both localization methods do not agree with each other consistently, the more reliable method must be identified. Cone beam computed tomography can accurately determine offsets occurring within stereotactic space that would be nondiscernible utilizing the fiducial method and seems to be more reliable. Using CBCT localization offers the opportunity to streamline workflow both from a patient and clinic perspective and also shows patient position immediately prior to treatment [1).

Books

Berger A. Book Review: Recent Advances and Controversies in Gamma Knife Neurosurgery. Neurosurgery. 2022 Nov 21. doi: 10.1227/neu.0000000000002258. Epub ahead of print. PMID: 36409960.

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Duggar WN, Morris B, Fatemi A, Bonds J, He R, Kanakamedala M, Rey-Dios R, Vijayakumar S, Yang C. Gamma Knife(®) icon CBCT offers improved localization workflow for frame-based treatment. J Appl Clin Med Phys. 2019 Oct 6. doi: 10.1002/acm2.12745. [Epub ahead of print] PubMed PMID: 31587520.