Gamma Knife Stereotactic Radiosurgery (framed)

Overview

Gamma Knife radiosurgery uses high-energy rays to treat tumors and other diseases. Beams of radiation are aimed at the brain by a machine outside your body. Hundreds of low-dose beams come together at a single point to kill all the cells in the target area while avoiding damage to nearby healthy cells. When a small tumor is being treated, a single dose of radiation is given in a single session using a rigid frame.

What is stereotactic radiosurgery?

Radiation damages the DNA inside cells, making them unable to divide and grow. The benefits of radiation are not immediate but occur with time. Aggressive tumors, whose cells divide rapidly, tend to respond quickly to radiation. Over time, the abnormal cells die and the tumor may shrink. Benign tumors or other lesions, whose cells divide slowly, may take several months to a year to show an effect.

Pinpoint accuracy is critical so that the lethal dose is applied only to the target itself and not to surrounding healthy tissue or critical structures (Fig. 1). To achieve this razor-sharp precision, computer image-guided technology is used to plan and carry out the procedure. The method of targeting an object in three dimensions is called stereotaxis.

When a tumor less than 3 centimeters in diameter is being treated, radiosurgery is given in a single session that lasts 15 minutes to 3 hours. Your doctors may recommend radiosurgery as a stand-alone treatment or in combination with surgery, chemotherapy, or immunotherapy. If you first undergo removal of a tumor, your doctor may prescribe radiation to stop the growth of microscopic tumor cells that remain after surgery.

Gamma Knife technology allows your physician team to treat brain tumors of any size or shape, and in any location, with accuracy to .3 millimeters. Tumors that are close to critical brain structures or sensitive areas can be safely targeted.

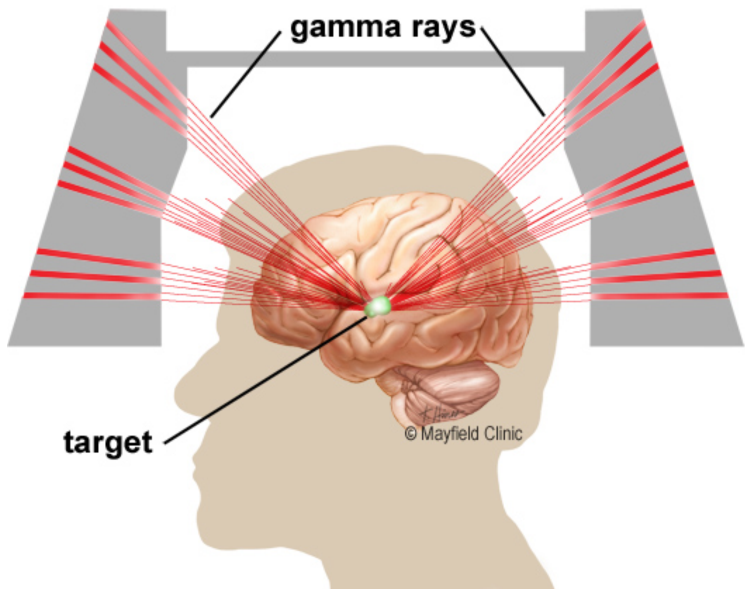

Figure 1. Gamma Knife utilizes 192 low-dose beams of radiation that intersect at the tumor to produce a high dose while minimizing exposure to nearby healthy brain.

The goals of Gamma Knife radiosurgery are to:

1. Precisely locate the target (tumor, lesion)
2. Hold the target still
3. Accurately aim the 192 radiation beams at the target
4. Deliver radiation at the specified dose that conforms to the shape of the tumor.

Who is a candidate?

You may undergo radiosurgery if you have a:

- Metastatic tumor or tumors that have spread to the brain from the lung, breast, or skin (melanoma)
- Benign brain tumor (acoustic neuroma, meningioma, craniopharyngioma, pituitary adenoma, hemangioblastoma, glomus tumor)
- Trigeminal neuralgia
- Glioblastoma (GBM), an aggressive brain cancer
- Arteriovenous malformation (AVM), a tangle of blood vessels
- Essential tremor

Who performs the procedure?

The radiosurgery team consists of a neurosurgeon, radiation oncologist, critical care nurse, and medical physicist. The neurosurgeon places the stereotactic frame. The neurosurgeon and radiation oncologist are responsible for determining the correct target and radiation dose, and for approving the treatment plan. The medical physicist is involved in treatment planning and setting up the equipment. The critical care nurse assists in frame placement/removal and manages medications.

What happens before treatment?

Consultation

Your first appointment is a radiosurgery consultation with a neurosurgeon or radiation oncologist. Your doctor will perform a physical exam and confirm your diagnosis based on the imaging studies (CT, MRI) and pathology reports. Your doctor will discuss the best type of radiation treatment for your particular tumor or lesion, explain the treatment process, and discuss the potential benefits and possible side effects. Once you have decided to proceed with treatment, you will sign consent forms. Your doctor will also prescribe steroids (e.g., dexamethasone) and anti-seizure medication (e.g., Keppra).

What happens during treatment?

On the day of treatment, arrive at the center and check in with the receptionist. You may bring a relative or friend for company. Please arrange for someone to drive you home after treatment.

Step 1: head frame

Because you are being treated with a single high dose of radiation, a stereotactic head frame will be used to hold your head completely still during imaging and treatment. A nurse anesthetist will administer "twilight" anesthesia so that you are not aware of the procedure. The frame will be attached to your head with small pins (Fig. 2). While you are seated, the frame is temporarily positioned on your head with Velcro straps. The four pin sites are cleaned and injected with local anesthesia to numb the area. Placement of the head frame takes about 10 minutes and is well tolerated. Most patients awake with no recollection of the procedure.

Step 2: imaging

Even if you have had brain imaging done before, you will need to have it done again with the head frame so that the exact location, size, and shape of the target can be determined. A coordinate box is placed over the frame to provide reference points. Markers on the coordinate box appear on the scan and help pinpoint the exact three-dimensional coordinates of the target in the brain.

After the scan, you will be taken to a private room and given breakfast while the doctors develop the radiation plan for later the same day. Family and friends may keep you company. The head frame remains in place until treatment is complete.

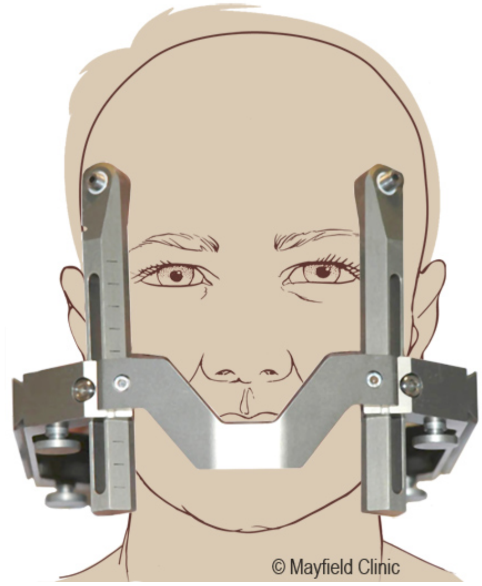

Figure 2. A stereotactic frame is secured to your head with 4 pins.

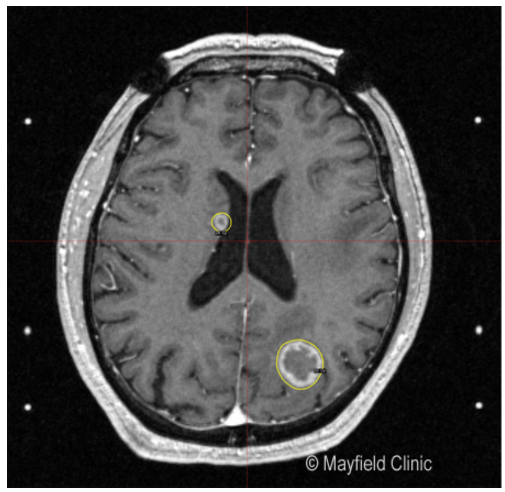

Figure 3. The computer creates a 3D view of your anatomy from the MRI/CT scans. The physicians determine the number and size of the radiation beams, as well as the radiation dose.

Figure 4. Secured to the table, the head frame holds the patient's head perfectly still in the treatment field.

Figure 5. The table moves your head into the machine. Radiation is delivered through 192 openings in the Gamma Knife machine.

Step 3: treatment planning
Planning for your treatment is complex and vitally important. It is a team effort that can take from 1 to 3 hours. Information about the tumor's location, size, and closeness to critical structures is gathered by the CT or MRI scan. Advanced computer software fuses the scans together and creates a 3D view of your anatomy and the tumor (Fig. 3). Using the software, the neurosurgeon, radiation oncologist, and medical physicist work as a team to outline the tumor's borders and any critical structures nearby. Together, your team will determine the:

- appropriate target(s)
- contours of the target(s)
- radiation dose
- number of individual treatment beams, their diameter, and how long they will deliver radiation to the target(s)

Each individual beam is too weak to damage the healthy brain as it passes through on its way to the target. But at the focal point where all the beams merge, the energy dose is powerful and capable of damaging the tumor cells. This high-dose radiation corresponds to the shape of your tumor or tumors.

Step 4: position the patient
After the Gamma Knife machine is calibrated and prepared for your specific treatment plan, you will lie on the treatment table, and the head frame will be secured to the treatment table (Fig. 4).

Step 5: deliver the radiation
The physicians and medical physicist will leave the room and operate the machine from the control room. You will feel the treatment table moving so that your head is inside the Gamma Knife machine. The team will watch you through video monitors and speak to you over an intercom. The treatment table moves every so often to enable the delivery of radiation beams (Fig. 5).

You will hear some mechanical sounds as 192 radiation sources move into position. Your treatment will be completely painless. The treatment table will move your head into different positions through small, preprogrammed movements. You do not have to hold your breath; just breathe normally. Your treatment will last anywhere from 15 minutes to 3 hours.

What happens after treatment?

After treatment, the medical physicist and nurse release the head frame and help you off the table. The frame is then removed by the neurosurgeon and nurse. The pin sites are cleaned, and a tiny absorbable suture is placed at each pin site to prevent oozing. You will be observed for 30 to 60 minutes before you can go home. You may have a mild headache that requires Tylenol.

You will continue taking steroids and anti-seizure medications for 2-3 weeks after treatment. A nurse will provide medication instructions as well as instructions for tapering. You may then gather your belongings and go home. Follow these instructions for care of the pin sites:

1. If you have discomfort or tenderness around the pin sites, Tylenol may help.
2. Swelling may occur around the pin sites for the first few days. Keep your head elevated and apply an ice pack to the area.
3. Call the doctor if you have a fever greater than 101 degrees or have any drainage or sign of infection at the pin sites.

What are the risks?

Side effects of radiation vary, depending on the tumor type, the dose delivered, and the amount of healthy tissue in the target area. Some side effects are temporary, and some may be permanent. Ask your doctor about specific side effects that you may experience. General side effects may include:

Swelling (edema)
Radiation causes tumor cells to die. The body's natural response to cell death or injury is swelling. Edema is extra fluid, or swelling, within the tissues of the brain. If brain swelling occurs, it can cause headaches, weakness, seizures, confusion, or speech difficulty. It may also worsen the symptoms that were present before treatment. If you start to feel uncomfortable with headaches or any other symptoms, call your neurosurgeon or radiation

oncologist. Steroid medication (dexamethasone) may be given to reduce brain swelling and fluid within the tumor. Steroids should always be taken with food to protect your stomach and prevent nausea. Steroids can also affect the normal bacteria in your mouth and cause a yeast infection called thrush, which appears as whitish patches on the tongue. Do not abruptly stop taking steroids. A tapering schedule is required to avoid withdrawal.

Radiation necrosis
In some cases, radiosurgery may cause the center of the tumor to become necrotic (dead). This dying tissue can become toxic to surrounding normal tissue, and swelling may occur. Radiation necrosis can happen anytime, but it most often occurs 6 to 12 months after radiosurgery. Radiation necrosis may look similar to tumor regrowth on an MRI scan. Specialized tests such as MR spectroscopy / perfusion may help differentiate between necrosis and tumor. Treatment for radiation necrosis may include:

- Medicines that reduce inflammation, such as 5-LOXIN (Boswellia serrata).
- A drug called bevacizumab (Avastin) may be given if other treatments are not effective.
- Hyperbaric oxygen therapy (treatment in an oxygen chamber) may be prescribed to help damaged brain tissue heal.
- In some cases, surgery may be needed to remove the necrotic tissue.

What are the results?

After radiosurgery, MRI scans will be taken periodically so that your doctors can look for signs of response. Several months may pass before the effects of treatment are visible. Some tumors or lesions may be completely eliminated with radiation. For others, the goal is to stop or halt the growth. In some cases the tumor is considered "controlled," even if it does not shrink.

For benign tumors, the goal is to stop or control the tumor's growth. About 60% of patients with an acoustic neuroma or meningioma show tumor shrinkage after radiosurgery, while about 30% of tumors remain the same (Fig. 6). Fewer than 10% of these tumors continue to grow.

For trigeminal neuralgia, the goal is to deaden the trigeminal nerve root to interrupt pain signals and keep them from reaching the brain. About 90% of patients will have good pain relief at 1 year. In about 30% of patients, pain recurs 3 to 5 years after treatment. Repeat radiosurgery can be effective; however, the risk of facial numbness is increased.

For metastatic tumors, the goal of shrinking or stopping the tumor's growth is achieved in 80-90% of patients (Fig. 7).

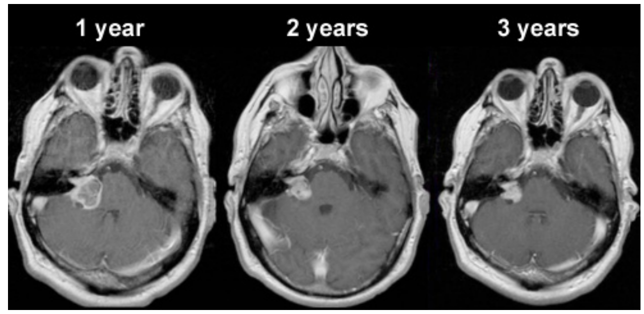

Figure 6. Following radiation, slow-growing (benign) tumors like acoustic neuroma shrink gradually over time.

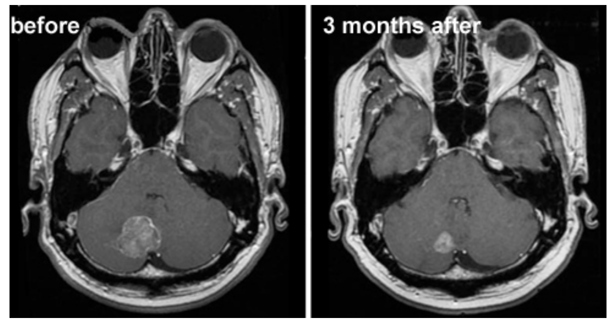

Figure 7. Fast-growing malignant tumors like metastatic lung cancer shrink rapidly after radiation.

For malignant primary tumors, results vary depending on the size, location, and type of tumor. Talk to your doctor about your specific prognosis.

For AVMs, the goal is to thicken the vessel walls and create scar tissue that will close off the blood supply. It may take up to 3 years for an AVM to completely close. Results are related to the size and flow rate of the AVM. Small AVMs (<3 cm) have a 90% success rate. Larger AVMs (>5 cm) may require multiple radiosurgery sessions, spaced 3 to 6 months apart.

Sources & links

If you have questions, please contact Mayfield Brain & Spine at 513-221-1100.

Links
www.cancer.gov
www.irsa.org
www.abta.org
www.elekta.com/patients/

Glossary

benign: not cancerous.
malignant: cancerous.
metastatic: a cancerous tumor that has spread from its original source (e.g., lung, breast).
stereotactic: a precise method for locating structures within the body through the use of 3-dimensional coordinates.
target: the area where radiation beams are aimed; usually a tumor, malformation, or lesion.

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