Stereotactic Radiosurgery of the Brain: LINAC

Overview

Radiosurgery uses high-energy rays to destroy tumors and other diseases. Beams of radiation are aimed at the brain by a machine outside your body. Radiosurgery uses very high dose beams meant to kill all the cells in the target area. The beams are tightly focused and accurate in order to avoid damaging healthy cells. It is often given in a one-time therapy in a single day, or it can be broken into 2 to 5 treatments given over a week. Radiosurgery may be used as an alternative to traditional open brain surgery.

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, 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 the razor-sharp precision, computer image-guided technology is used to plan and carry out the procedure. The method of targeting an object by taking all three dimensions into account is called stereotaxis.

Radiosurgery may be given as a one-day session or divided into 2 to 5 treatments given over a week (hypofractionation). Delivering a fraction of the total radiation dose allows normal cells time to repair themselves between treatments and may reduce side effects. Doctors may advise radiosurgery as a standalone treatment or in combination with surgery, chemotherapy or immunotherapy. Radiation may be given before surgery to shrink a tumor or AVM or after surgery to stop the growth of tumor cells that remain.

The main radiosurgery technologies are:

- Gamma Knife uses cobalt-60 gamma rays
- Linear accelerator systems (LINAC) use high energy x-rays; the Novalis, TrueBeam or Cyberknife
- Proton beam therapy uses accelerated protons

Each technology has unique characteristics, but all accomplish the same goals:

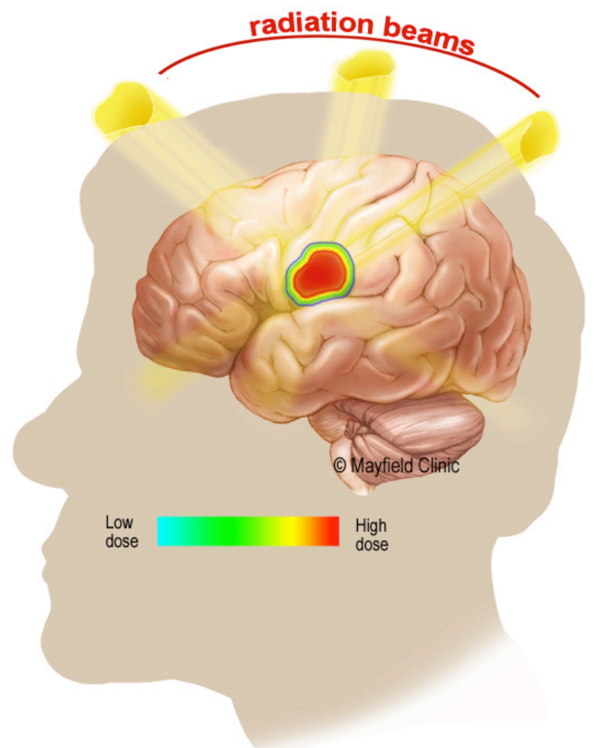

Figure 1. Radiosurgery shapes the radiation beams to match the exact outline of the tumor and minimize exposure of healthy brain. The beams come from numerous angles and intersect at the tumor to produce a high dose. The red ring shows the maximum dose and each outer ring represents lower and lower doses.

What's the difference?

RadioSURGERY 1-5 fractions	Delivers radiation at very high doses, a few times, to a highly focused area. There is a rapid fall-off, resulting in a lower dose to the surrounding normal brain.
RadioTHERAPY 6-33 fractions	Delivers radiation at lower doses, over multiple days, and to larger areas. Treats a "margin" of brain tissue around tumors.

Linear accelerator (LINAC)	A single beam, always focused on the tumor, rotates around the patient multiple times. The patient is held in position with either a head frame or facemask.
Gamma Knife	192 beams are precisely targeted on the tumor, with each beam originating from a slightly different point. The patient is held in position with a head frame.

1. Precisely locate the target (tumor, lesion)
2. Hold the target still
3. Accurately aim the radiation beam
4. Shape the radiation beam to the target
5. Deliver a specific radiation dose

Who is a candidate?

You may undergo radiosurgery if you have a:

- Benign tumor: acoustic neuroma, meningioma, pituitary adenoma, craniopharyngioma, hemangioblastoma, glomus tumor
- Metastatic tumor: lung, breast, melanoma, or other cancer that has spread to the brain
- Primary brain tumor, such as malignant glioma
- Arteriovenous malformation (AVM)
- Cavernoma
- Trigeminal neuralgia

Who performs the procedure?

The radiosurgery team consists of a neurosurgeon, radiation oncologist, medical physicist, oncology nurse, and sometimes a dosimetrist and radiation therapist. The neurosurgeon and radiation oncologist are responsible for prescribing radiosurgery, for determining the correct target and radiation dose, and for approving the treatment plan. The medical physicist and the dosimetrist are involved in the treatment planning and set up the equipment. The radiation therapist positions the patient in the machine and monitors the treatment while under the supervision of the physicians and physicist. The nurse manages the medications and any side effects.

What happens before treatment?

Consultation

Your first appointment is a consultation with a neurosurgeon or radiation oncologist. Your doctor will perform a physical exam and reconfirm your diagnosis based on the imaging studies (CT, MRI) and pathology reports. Your doctor will discuss with you 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.

What happens next varies, depending on whether your treatment involves a facemask or a head frame. A facemask and imaging (Steps 1-3) are performed 1 to 2 weeks prior to radiosurgery. If a head frame is used, all steps occur in one day.

What happens during treatment?

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

Depending on the target's size and location, either a facemask or head frame will be used to hold your head completely still during treatment.

Step 1: facemask or head frame

A stereotactic facemask is custom-made to fit your face exactly. It will be used during imaging and treatment to hold your head perfectly still. You will lie with your head on a cradle of mesh stretched between a U-shaped appliance. Strips of stretchy plastic are then placed across your forehead, under your nose, and over your chin. You will be asked to bite a small piece of plastic with your front teeth. Next, thermoplastic mesh is dipped into a water bath, making the mesh very flexible. The mesh is placed over the face and allowed to conform (Fig. 2). You will be able to easily breathe. Cold mitts help the mesh cool and harden. Creation of the mask takes about 30 minutes.

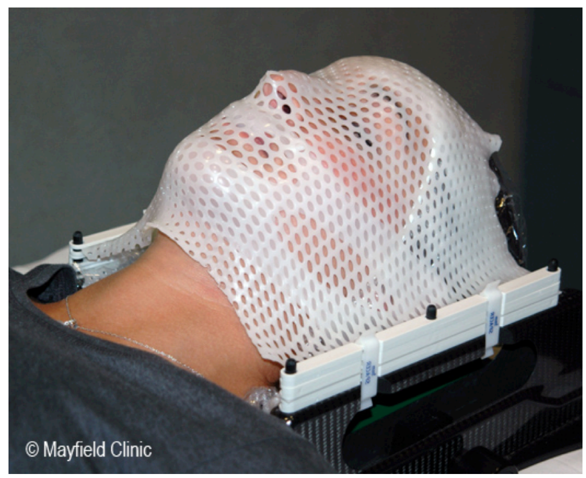

Figure 2. A thermoplastic mask is custom-fit to the contours of your face. The front and back pieces of mesh are secured to a U-shaped appliance that attaches to the treatment table to hold the head still.

Figure 3. Reflective balls are placed on the facemask prior to CT scanning. Markers are seen on the CT scan and help pinpoint the exact coordinates of the tumor or lesion.

It may be necessary to use a stereotactic frame attached to your head with small pins. If so, you will receive intravenous sedation to minimize discomfort. 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. You may receive a light sedative to minimize discomfort. You may feel some pressure as the pins are tightened. Placement of the head frame takes about 30 minutes and is well tolerated.

Step 2: imaging
Next you will undergo imaging scans while wearing the facemask or head frame. Reflective balls are placed on the facemask and worn during the CT scan (Fig. 3). These markers appear on the scan and help pinpoint the exact three-dimensional coordinates of the target in the brain. It may be necessary to obtain a new MRI scan.

After the scan, you will be taken to a private room and given a light snack while the doctors plan the radiation prescription for later the same day. Your family and friends may keep you company. If you had a head frame attached, it will remain in place until treatment is completed.

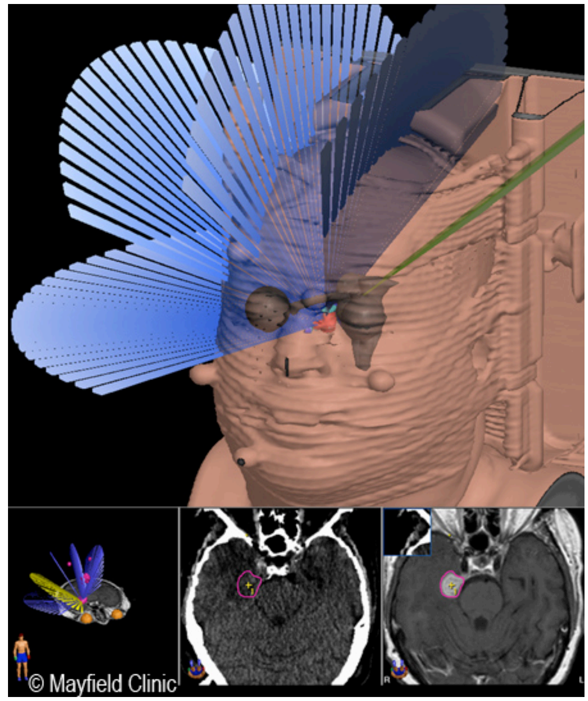

Figure 4. The computer creates a 3D view of your anatomy. A treatment plan determines the number and angle of beams, the size and shape of the radiation beams, and the radiation dose.

Step 3: treatment planning
Information about the tumor's location, size, and closeness to critical structures is gathered by the CT or MRI scan. Advanced computer software creates a 3D view of your anatomy and the tumor (Fig. 4). Using the software, the neurosurgeon, radiation oncologist, and physicist work as a team to determine the:

- appropriate target(s)
- radiation dose
- number and angle of treatment beams
- size and shape of the beams to exactly match the tumor or target

Each individual beam is too weak to damage the healthy brain as it passes through on its way to the target. But at the intersection of all the beams, the energy dose is strong enough to destroy the tumor.

Step 4: position the patient
After the radiation machine is calibrated and prepared for your specific treatment plan, you will lie on the table. The mask is placed over your face and secured to the table. If you have a head frame, it is secured to the treatment table.

Alignment lasers and x-rays position you correctly. Stereoscopic x-rays are taken and compared to the treatment plan. Any misalignments are corrected before treatment.

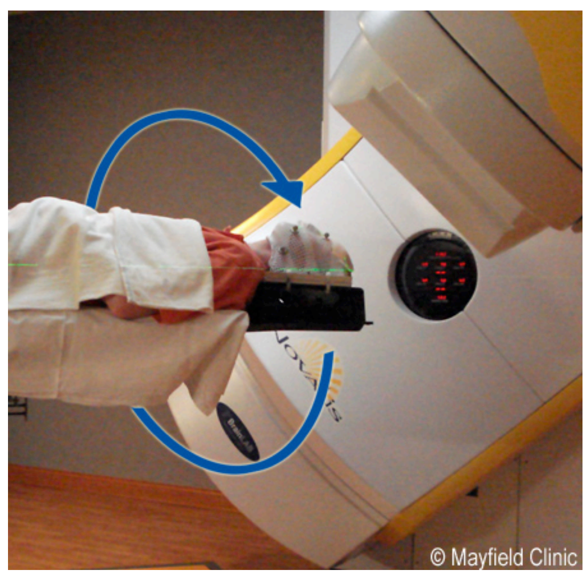

Figure 5. The facemask is secured to the treatment table and holds the patient's head perfectly still and positioned in the treatment field. The LINAC machine rotates around the patient, aiming radiation beams at the tumor.

Step 5: deliver the radiation
The therapist leaves the room and operates the machine from the control room. The team watches you through video monitors and speaks to you over an intercom. The machine and treatment table move every so often to deliver radiation beams from one or more directions (Fig. 5).

The machine is large and makes a humming noise as it moves around your head. Its size and motion may be intimidating at first. It may pass close to your body, but it will not touch you. You do not have to hold your breath—just breathe normally. Treatment may take 30 minutes or longer, depending on the number and complexity of targets.

What happens after treatment?

After treatment the therapist releases the facemask or head frame and helps you off the treatment table. If multiple treatments are planned, the facemask is stored at the center for your next session. You will return each day at your scheduled time to repeat steps 4 and 5 until all fractions of the complete dose are delivered. You may be prescribed medication for a few days or weeks after treatment.

If you had a head frame, the pins and frame are removed. You may have oozing from the pin sites and a mild headache. 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. Steri-strips or bandaids may be placed over the pin sites. Remove them the next day.
3. Swelling may occur around the pin sites for the first few days. Keep your head elevated and apply an ice pack to the area.
4. 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, dose delivered to the tumor, number of fractions, and 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). Radiation necrosis can happen anytime, but it most often occurs 6 to 12 months after radiosurgery. This dying tissue can become toxic to surrounding normal tissue, and swelling may occur. Radiation necrosis may look similar to tumor regrowth on an MRI scan. Specialized tests such as a PET scan or MR spectroscopy/perfusion may help differentiate between necrosis and tumor. Treatment for radiation necrosis may include:

- Medicines that reduce inflammation, 5-LOXIN (Boswellia serrata)..
- Hyperbaric oxygen therapy (treatment in an oxygen chamber) may be prescribed to help damaged brain tissue heal.
- A drug called bevacizumab (Avastin) may be given if other treatments are not effective.
- 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 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 metastatic tumors, the goal of shrinking or stopping the tumor's growth is achieved in 80%-90% of patients (Fig. 7).

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 or 800-325-7787.

Links
www.cancer.gov
www.irsa.org
www.abta.org

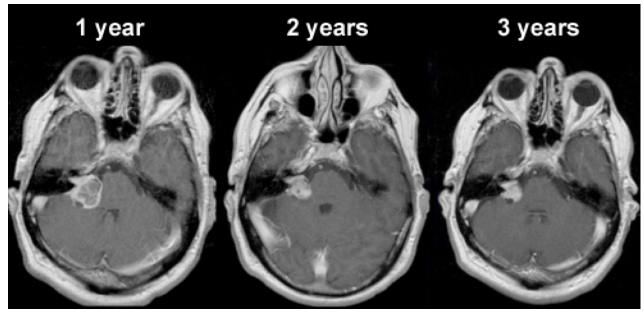

Figure 6. Following radiation, slow-growing (benign) tumors like acoustic neuroma shrink gradually over time.

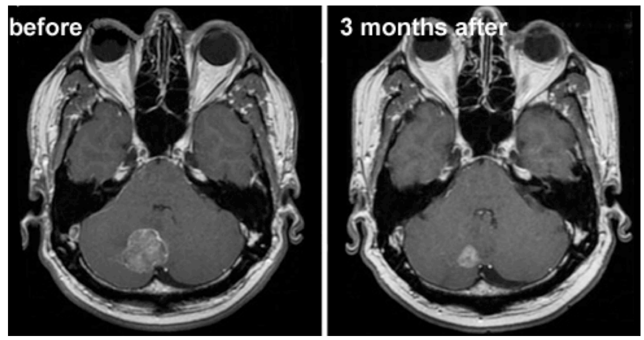

Figure 7. Fast-growing malignant tumors like metastatic lung cancer shrink rapidly after radiation. The tumor is shown before treatment and 3 months after treatment.

Glossary
benign: not cancerous.
fractionated: delivering the radiation dose over multiple sessions.
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.

updated > 7.2018
reviewed by > Ronald Warnick, MD, Mayfield Clinic, Cincinnati, Ohio

Mayfield Certified Health Info materials are written and developed by the Mayfield Clinic. We comply with the HONcode standard for trustworthy health information. This information is not intended to replace the medical advice of your health care provider. © Mayfield Clinic 1998-2018.