Radiosurgery & Radiotherapy of the Head

Overview

Radiation therapy uses high-energy rays to treat tumors and other diseases of the body. Radiation works by damaging the DNA inside cells and making them unable to divide and reproduce. The benefits of radiation are not immediate but occur over time. Aggressive tumors, whose cells divide rapidly, typically respond more quickly to radiation. Over time, the abnormal cells die and the tumor may shrink. Normal cells can also be damaged by radiation, but they can repair themselves more effectively than abnormal cells. The goal of radiation treatment is to maximize the dose to abnormal cells and minimize the exposure to normal cells.

What is radiation therapy?

Radiotherapy is often given with the intent of destroying the tumor and curing the disease. However, not all disease or cancer can be cured with radiation. Sometimes radiation is used to relieve symptoms, such as pain or seizures. Sometimes it is used to prevent tumors from developing or spreading. Radiation may be used alone or in combination with other treatments such as surgery, chemotherapy, or immunotherapy.

Radiation can be delivered internally or with external beams. Internal radiation (brachytherapy) is delivered from inside the body. A surgeon places radioactive material sealed in catheters, seeds, or balloons directly into the tumor cavity during surgery. External beam radiation is delivered from outside the body by a machine that aims high-energy x-rays or gamma rays at the tumor.

All types of external radiation therapy follow these principles:

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 radiation dose that damages abnormal cells yet spares normal cells

The exact location and border of a tumor within normal tissue are not always clear on diagnostic scans. Doctors use a technique called stereotaxis to precisely locate targets, especially those that are small and deep within the brain. First, a stereotactic frame or mask is attached over the target area. Next, a CT and/or MRI scan is taken and interpreted by computer software. The stereotactic frame serves as a reference on the scan, allowing the computer to plot the exact coordinates (on the x, y and z axis) and to create a 3D reconstruction of the tumor or malformation (Fig. 1).

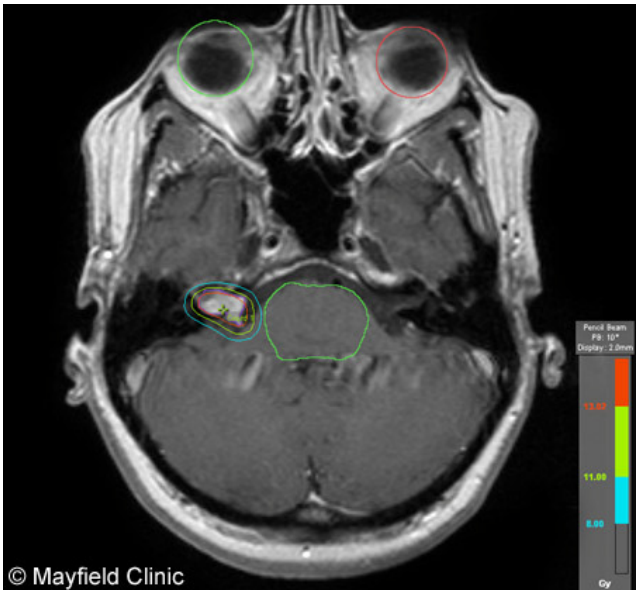

Figure 1. A radiotherapy treatment plan is designed to shape the radiation beam to the exact shape of the tumor, in this case an acoustic neuroma, and minimize exposure to normal brain tissue, in this case the brainstem (green circle). The colored rings represent the radiation dose level.

Types of radiation therapy

- **Stereotactic radiosurgery** (SRS) delivers a high dose of radiation during a single session. Because a single radiosurgery dose is more damaging than multiple fractionated doses, the target area must be precisely located and completely immobilized with a stereotactic head frame or mask.
- **Fractionated stereotactic radiotherapy** (FSRT) delivers a lower dose of radiation over multiple visits. A repositionable face mask, along with laser, x-ray, and infrared positioners, are used to precisely locate the target and accurately reposition the patient for each treatment session. FSRT offers the precision of stereotaxy for those who have

lesions near critical structures (the brain stem and optic and acoustic nerves) that cannot tolerate high doses. Patients first have a treatment planning visit where the stereotactic mask is constructed and imaging is obtained. Later, the radiotherapy treatment is planned. Patients then return daily over 1 to 7 weeks to receive the complete radiation dose.

- **Whole brain radiotherapy** (WBRT) delivers a radiation dose to the entire brain. It is often used to treat multiple brain tumors and metastases. A stereotactic frame or mask is not required for this treatment.

LINAC vs. Gamma Knife

Two kinds of machines can deliver radiotherapy: a linear accelerator (LINAC) and Gamma Knife. The machines have many similarities, but also important differences. LINAC machines use a single radiation beam that is delivered in multiple arcs around the target. They can perform radiosurgery on small and large tumors and can fractionate these treatments over several weeks. In contrast, Gamma Knife does not move around the target. Rather, the patient is placed in a helmet unit that allows the target to be placed exactly in the center of 201 converging beams. The ability of Gamma Knife to treat large tumors is limited, and it does not allow fractionated treatments.

Who is a candidate?

You may be a candidate for radiosurgery or fractionated radiotherapy if you have a:

- Benign tumor: acoustic neuroma, pituitary adenoma, meningioma, craniopharyngioma, glomus tumor
- Malignant tumor: glioma, glioblastoma, astrocytoma, lymphoma
- Metastatic tumor
- Arteriovenous malformation (AVM)
- Cavernoma
- Trigeminal neuralgia

Radiotherapy may be used alone or in combination with other treatments such as surgery, chemotherapy, or immunotherapy. It can be used when a tumor or malformation is first diagnosed or has recurred after previous treatment; or it can be used as a supplement to other treatments. If used before surgery, radiotherapy will shrink the tumor to make it easier to remove. If used after surgery, radiotherapy will destroy tumor cells that may have been left behind.

Who performs the procedure?

Radiation oncologists are doctors who have special training in treating cancer and other diseases with radiation. Their role is to evaluate the patient and determine the treatment plan, also called the prescription. The radiation oncologist works with a team that includes a surgeon, medical physicist, dosimetrist, radiation therapist, and oncology nurse. The surgeon and radiation oncologist decide what techniques to use to deliver the prescribed dose. The physicist and the dosimetrist then make detailed treatment calculations and set up the equipment. The radiation therapists are specially trained technologists who deliver the treatments.

What happens before treatment?

The neurosurgeon and radiation oncologist will work together to choose the best type of radiotherapy for your particular tumor or lesion, will explain the treatment process, and will describe possible side effects. Once you decide to proceed with treatment, you will sign consent forms.

You will be advised to arrive at the hospital or outpatient center at the appointment time and to check in with the receptionist. You may bring a friend or a relative with you for company. If you are having radiosurgery, please arrange for a family member or friend to drive you home after the treatment.

What happens during treatment?

The nurse or radiation therapist will escort you to a patient holding room, where you may need to change into a gown.

Step 1: attach stereotactic mask or frame

Depending on the target's size and location, either a stereotactic face mask or head frame will be used to immobilize your head during treatment.

- A stereotactic mask is custom-made to fit your face exactly and is used during each treatment session. First, a cream is applied to your face. Next, you will lie with your head on a cradle of mesh stretched between a U-shaped frame (Fig. 2). Thermoplastic mesh is dipped into a warm water bath, making the mesh very

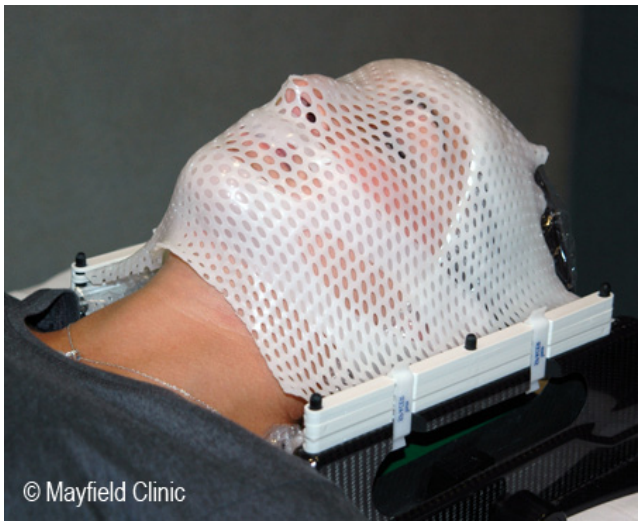

Figure 2. A stereotactic mask is made of thermoplastic mesh and custom-fit to the contours of your face. The front and back pieces of mesh are secured to a U-shaped frame that attaches to the treatment table to hold the head still.

flexible. The mesh is placed over your forehead, nose, and chin, and gently molded to conform to your face (you can easily breathe The mesh dries quickly. Creation of the mask takes about 30 minutes.

- Occasionally, it is necessary to use a stereotactic frame attached to your head with small pins. 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 (Fig. 3). Placement of the head frame takes about 30 minutes.

Step 2: CT or MRI localization
You will then have an imaging scan, using either computed tomography (CT), magnetic resonance imaging (MRI), or both. A box-shaped localizing device may be placed over top of the mask or frame (Fig. 3). Markers in the box show up on the scan and help pinpoint the exact three-dimensional coordinates of the target within the brain. After the scan, the localizing box is removed.

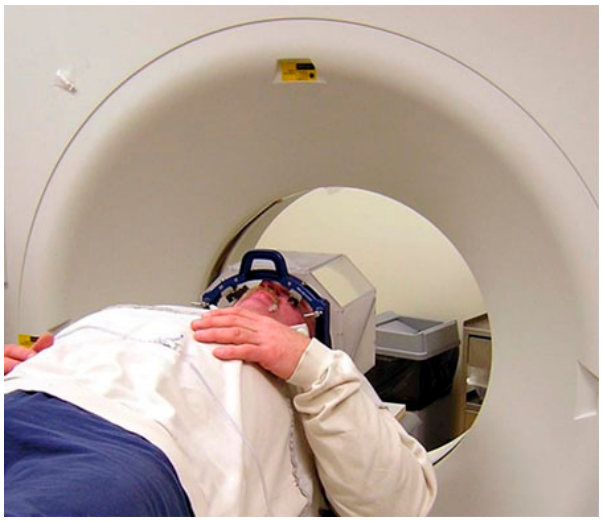

Figure 3. A box-shaped localizing device is placed on the frame or mask prior to CT scanning. Markers in the device are seen on the CT scan and help pinpoint the exact coordinates of the tumor or lesion.

Typically, patients go home after the localization scan. The doctors continue with step 3 (treatment planning), and the patient returns within a week or so to begin treatment. If a head frame has been attached for radiosurgery, patients are taken to a private room and given a light breakfast while they wait for the treatment plan to be determined so that radiation can be delivered on the same day.

Step 3: treatment planning
Information about the target's location, volume, and proximity to critical structures is gathered by the CT scan and transferred into the treatment planning computer system. In some cases MRI images also are sent electronically to the system. The software uses the CT or MRI images to form a 3D view of your anatomy and the target (Fig. 4). Using the software, the team (radiation oncologist, surgeon, and physicist) determine the radiation prescription:

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

It is crucial that the dose be delivered only to the target area. By using numerous beams, radiation of normal tissue is minimized. All beams meet at a single point, where the target is located. At the center, the single beams add up to a very high dose of radiation.

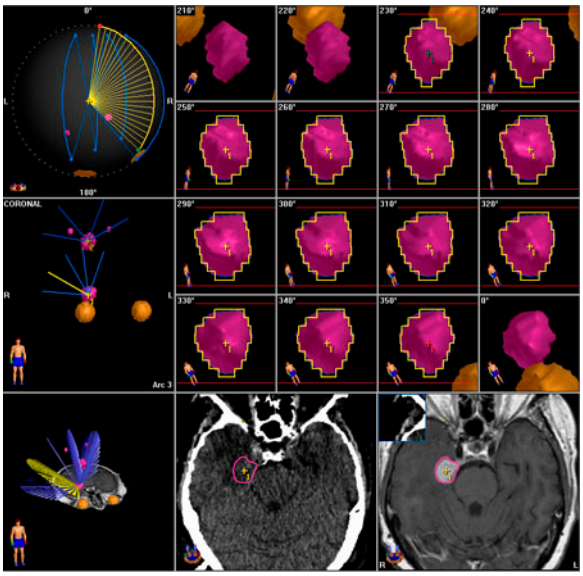

Figure 4. The computer system is used to develop a treatment plan of the number and angle of beams, the size and shape of the radiation beams, and the radiation dose.

Step 4: position the patient
Once the LINAC machine is calibrated and prepared for your specific treatment plan, you will lie on the treatment table. The stereotactic face mask or head frame is secured to the table. Alignment lasers and localizing x-rays help the radiation therapist position you correctly. Stereoscopic x-rays are taken and compared to the treatment plan. Any misalignments are detected and corrected before treatment.

Step 5: deliver the radiation
Once exact positioning is confirmed, the therapist leaves the room and operates the LINAC machine from the control room. The treatment team watches you through video monitors and speaks to you over an intercom. The LINAC and treatment table periodically move to deliver radiation beams from one or more directions (Fig. 6).

The LINAC 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. Treatment may take 30 to 60 minutes or longer, depending on the number of targets.

What happens after treatment?

After treatment the radiation therapist releases the stereotactic face mask or head frame from the table. If multiple treatments are planned, the face mask is stored at the center for your next treatment 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.

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, separation, or sign of infection at the pin sites.

Recovery and prevention

Side effects of radiation vary, depending on the tumor type, total radiation dose, size of the fractions, length of therapy, 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 you may experience. General side effects may include:

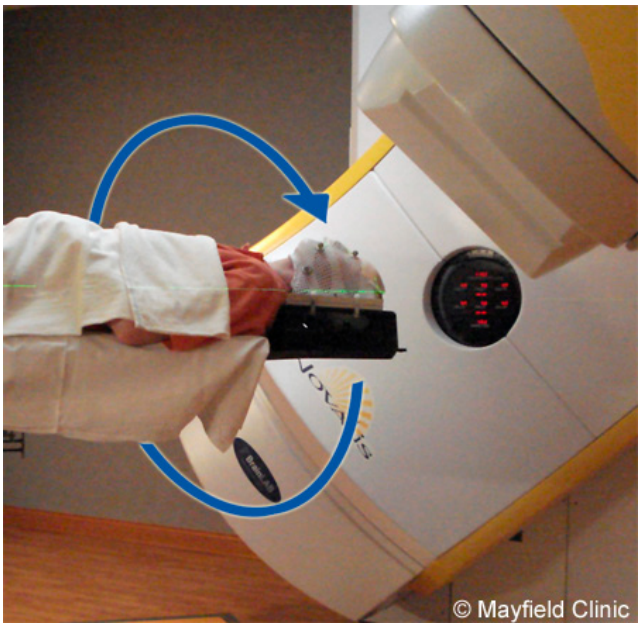

Figure 5. The stereotactic face mask is secured to the treatment table and holds the patient's head perfectly still and positioned in the treatment field. The LINAC rotates around the patient, aiming radiation beams at the tumor.

Fatigue
Fatigue is the most common side effect of radiotherapy. You may feel more tired than usual for a few weeks following treatment. In addition to fighting the tumor cells, your body is repairing the normal cells that may have been damaged by the radiation. Fatigue can continue for weeks or months after treatment stops. Save your energy for your most important obligations and allow others to assist you with chores or errands. Make sure you get plenty of sleep, take a nap after treatment, and eat a balanced diet. Some patients may need to increase their caloric and protein intake because their bodies are working hard to repair itself. Some may notice a lack of appetite and a loss of taste.

Exercise and/or stretching can also help you to combat fatigue. A short, brisk walk can be rejuvenating and can give you a mental and physical boost.

Skin irritation
The skin in the area where the radiation beams pass through may occasionally become slightly reddened and dry. This will resolve after treatment stops. To prevent irritation, use mild soap when bathing. Apply lotion daily, immediately after a shower, to those areas exposed to radiation. It is important to monitor your skin throughout the entire course of radiotherapy. Left untreated, skin irritation can lead to a small infection.

Hair loss
You may experience hair loss in the treated area about 2 weeks after treatment begins. Hair will often grow back after treatment stops, though in some cases the regrowth may be incomplete. To prevent further hair loss, use a mild shampoo (not harsh or fragranced) when bathing. Soft hairbrushes and low heat while blow-drying will also help prevent further damage to your hair. Wearing a wig, hat, or scarf may improve your image and self-confidence. Be sure to apply sunscreen to skin that has been exposed to radiation. These areas tend to sunburn more easily.

Swelling (edema)
Radiation causes 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, discuss this with your radiation oncologist. Steroid medication (dexamethasone or methylprednisolone) 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 – whitish patches on the tongue. Do not abruptly stop taking steroids. A tapering schedule is required to avoid withdrawal.

What are the risks?

Radiation necrosis
Uncommonly, the radiation dose can cause the tumor tissue to become necrotic. Dead or necrotic tissue can become toxic to surrounding normal tissue, and swelling may occur. Radiation necrosis can happen anytime, but it most commonly occurs 6 to 12 months after radiotherapy. On an MRI scan, radiation necrosis can look similar to a recurrent tumor. A positron emission tomography (PET) scan may be done to differentiate between active tumor and radiation necrosis. However, sometimes these tests are not definitive. Treatment for radiation necrosis may include:

- A combination of medicines that promotes blood vessel formation called pentoxifylline (Trental) and Vitamin E.
- Hyperbaric oxygen therapy. Just as wounds need air to heal, damaged tissue within the brain may need a high stream of oxygen to regenerate itself.
- A drug called bevacizumab (Avastin) may be given if swelling persists.
- In some cases, radiation necrosis can progress and cause compressive symptoms similar to those of a tumor. Surgery may be needed to remove the necrotic tissue.

Cognitive problems
Some patients experience cognitive symptoms such as memory loss and difficulty concentrating after radiotherapy. Typically this occurs when large areas of the brain must be treated with radiation. The simple explanation for this decline is that radiotherapy has the potential to injure good brain cells as well as bad tumor cells. Clinical trials are being conducted to investigate why this happens and what can be done to prevent or treat it. Some patients may benefit from seeing a neuropsychologist, who can evaluate cognitive status and give professional recommendations about what areas need improvement.

What are the results?

Following radiosurgery or fractionated radiotherapy treatment, you will undergo diagnostic imaging (MRI, CT) periodically so that your treatment team can look for signs of response. Several months may pass before the effects of treatment are visible.

For AVMs, the goal is to thicken the vessel walls and create clots that will close off the blood supply to the AVM. It may take up to 3 years for an AVM to close off completely. Results are related to the size and flow rate of the AVM. Small AVMs (<3 cm) have an 80% success rate. Larger AVMs (>5cm) may require multiple radiosurgery treatments spaced several years apart.

For acoustic neuromas, meningiomas or pituitary adenomas, the goal is to stop or control the tumor's growth. About 40% of patients with an acoustic neuroma or meningioma show tumor shrinkage after radiosurgery, while about 40% of tumors remain the same. Fewer than 20% of these tumors continue to grow. Facial nerve and/or trigeminal nerve problems develop in about 3% of patients with an acoustic neuroma.

For metastatic tumors, the goal of shrinking or stopping the tumor's growth is achieved in the majority of patients.

For trigeminal neuralgia, the goal is to control pain. Pain relief occurs in the majority of patients. Pain relief may not occur immediately but rather gradually over several months to a year. Patients remain on medication following treatment to control the pain while the radiation takes effect. Initially, 70% of patients are relieved of pain for 2 years. However in the long-term, 45% of patients may experience pain recurrence. Facial numbness may develop in 10% of patients.

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

Sources & links

If you have more questions or would like to schedule an appointment with one of our neurosurgeons, please call (515) 241-5760. Our offices are located on the Iowa Methodist Campus.

Sources

1. Breneman JC, Steinmetz R, Smith A, Lamba M, Warnick RE. Frameless image-guided intracranial stereotactic radiosurgery: clinical outcomes for brain metastases. Int J Radiat Oncol Biol Phys 74(3):702-6, 2009

Links

National Cancer Institute www.cancer.gov

International Radiosurgery Association www.irsa.org

American Brain Tumor Association www.abta.org

www.radiologyinfo.org

www.oncologychannel.com

Glossary

acoustic neuroma: a benign, slow-growing tumor that forms on the sheath of the eighth cranial nerve. This tumor can cause hearing loss, balance problems, and facial palsy.

arteriovenous malformation (AVM): an abnormal tangle of blood vessels in which arteries connect directly to veins without an intervening capillary bed.

benign: not cancerous.

brachytherapy: a type of radiation therapy in which capsules containing radioactive substances are surgically implanted into the tumor to deliver radiation; also called internal radiotherapy.

cavernoma: an abnormal cluster of enlarged capillaries with no significant feeding arteries or veins.

chemotherapy: treatment with toxic chemicals (e.g., anticancer drugs).

fractionated: delivering the radiation dose over multiple sessions.

lesion: a general term that refers to any change in tissue, such as a tumor, blood clot, malformation, infection, or scar tissue.

linear accelerator: a machine that creates a high-energy radiation beam, using electricity to form a stream of fast-moving subatomic particles; also called a LINAC.

malignant: cancerous.

meningioma: a tumor that grows from the meninges, the membrane that surrounds the brain and spinal cord.

metastatic: a cancerous tumor that has spread from its original source.

radiation necrosis: death of healthy tissue caused by the delivery of radiation to kill tumor cells.

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 other abnormality of the body.

trigeminal neuralgia: a painful disorder of the fifth cranial nerve (trigeminal nerve). Irritation of this nerve can cause intense pain that usually affects one side of the face.

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