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## Stereotactic Radiosurgery

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*This information is reviewed by a physician with expertise in the area presented and is further reviewed by committees from the American College of Radiology (ACR) and the Radiological Society of North America (RSNA), comprising physicians with expertise in several radiologic areas.*

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### What is stereotactic radiosurgery and how is it used?

Stereotactic radiosurgery is a highly precise form of radiation therapy used primarily to treat tumors and other abnormalities of the brain. Despite its name, stereotactic radiosurgery is a non-surgical procedure that delivers a single high-dose of precisely-targeted radiation using highly focused gamma-ray or x-ray beams that converge on the specific area or areas of the brain where the tumor or other abnormality resides, minimizing the amount of radiation to healthy brain tissue. Although stereotactic radiosurgery is often completed in a one-day session, physicians sometimes recommend multiple treatments, especially for tumors larger than one inch in diameter. The procedure is usually referred to as fractionated stereotactic radiosurgery when two to five treatments are given and as stereotactic radiotherapy when more than five treatments are given.

Stereotactic radiosurgery is an important alternative to invasive surgery, especially for tumors and blood vessel abnormalities located deep within or close to vital areas of the brain. Radiosurgery is used to treat many types of brain tumors, either benign or malignant and primary or metastatic and single or multiple. Sometimes radiosurgery is performed after surgery to treat any residual tumor cells. Additionally, radiosurgery is used to treat arteriovenous malformations (AVMs), a tangle of expanded blood vessels that disrupts normal blood flow in the brain and sometimes bleeds. AVMs are the leading cause of stroke in young people. Radiosurgery is also a treatment option for other neurological conditions. A similar technique may be used in other parts of the body and is known as Stereotactic Body Radiosurgery (SBRS).

Stereotactic radiosurgery works in the same way as other forms of radiation treatment. It does not actually remove the tumor; rather, it damages the DNA of tumor cells.

As a result, these cells lose their ability to reproduce. Following the treatment, benign tumors usually shrink over a period of 18 months to two years. Malignant and metastatic tumors may shrink more rapidly, even within a couple of months. When treated with radiosurgery, arteriovenous malformations (AVMs) begin to thicken and close off slowly, typically over several years.

### What equipment is used?

There are three basic kinds of stereotactic radiosurgery equipment, each of which uses different instruments and sources of radiation:

The Gamma Knife®, which uses 192 or 201 beams of highly focused gamma rays all aiming at the target region. The Gamma Knife is ideal for treating small to medium size lesions.

Linear accelerator (LINAC) machines, prevalent throughout the world, deliver high-energy x-rays, also known as photons. The linear accelerator can perform radiosurgery on larger tumors in a single session or during multiple sessions, which is called fractionated stereotactic radiotherapy. Multiple manufacturers make this type of machine, which have brand names such as Novalis Tx™, XKnife™, and CyberKnife®.

Proton beam or heavy-charged-particle radiosurgery is in limited use in North America, though the number of centers offering proton therapy has increased dramatically in the last several years.

## Who will be involved in this procedure and who operates the equipment?

The treatment team is comprised of a number of specialized medical professionals, typically including a radiation oncologist, neurosurgeon, neuro-radiologist, medical radiation physicist, dosimetrist, radiation therapist, radiation therapy nurse, and neurologist or neuro-oncologist.

- The radiation oncologist and/or the neurosurgeon head the treatment team and oversee the treatment; they outline the target(s) to be treated, decide on the appropriate radiation dose, approve the treatment plan, and interpret the results of radiosurgical procedures.
- A neuroradiologist interprets brain imaging that identifies the target(s) to be treated.
- The medical radiation physicist ensures the delivery of the precise dose of radiation.
- The physicist, or a dosimetrist under the supervision of the physicist, uses special computer software to devise a treatment plan; he or she calculates the exposures and beam configuration to conformally treat the target(s) to the prescribed dose.
- A highly trained radiation therapist positions the patient on the treatment table and operates the machine from an adjacent protected area. The radiation therapist can observe the patient through a window or on a closed-circuit television and is able to communicate with the patient throughout the procedure. In the case of the Gamma Knife, the neurosurgeon and/or radiation oncologist may help position the patient for treatment and the radiation oncologist may operate the machine.
- The radiation therapy nurse provides the patient with information about the treatment, monitors the patient during Gamma Knife treatment, and helps answer questions after treatment.
- A neurologist or neuro-oncologist may participate with the radiation oncologist and neurosurgeon in the multidisciplinary team that considers various treatment options for individual cases and helps decide who may benefit from radiosurgery.

## How is the procedure performed?

### Stereotactic Radiosurgery Using the Gamma Knife

Gamma Knife radiosurgery involves four phases: placement of the head frame, imaging of the tumor location, computerized dose planning, and radiation delivery.

In the first phase, a nurse will place a small needle in your hand or arm to give you medications and contrast, if needed, for imaging. A neurosurgeon will use local anesthesia to numb two spots on your forehead and two spots on the back of your head. A box-shaped head frame will be attached to your skull using specially designed pins to keep your head from moving until the treatment session is finished. This lightweight aluminum head frame is also a guiding device that makes sure the Gamma Knife beams are focused exactly where the treatment is needed.

Next, you will be taken to an imaging area where a magnetic resonance imaging (MRI) scan will be performed to show the exact location of the tumor in relation to the head frame. In some cases, a computed tomography (CT) scan may be performed instead of, or in addition to, an MRI scan. If you are having treatment for an arteriovenous malformation, you may also have an angiogram.

During the next phase, you will be able to relax for an hour or two while your treatment team identifies the tumor(s) for treatment and develops a treatment plan using special computer software to optimally irradiate the tumor and minimize dose to surrounding normal tissues.

Next, you will lie down on the Gamma Knife bed and your head frame will be fixed to the machine before beginning treatment. You will be made comfortable with a pillow or wedge-shaped sponge under your knees and a blanket over you. The treatment team will then go to the control area outside the treatment room to begin your treatment. You will be able to talk to your physician through a microphone in the helmet and a camera will allow the team to see you at all times. The bed you are lying on will move backward into the Gamma Knife machine. You will not feel the treatment and the machine is very quiet. Depending on the Gamma Knife model and the treatment plan, the whole treatment may be performed without interruption or it may be broken up into multiple smaller parts. The total treatment may last less than one hour or up to four hours. A chime will sound when the treatment is complete and the bed will return to its original position.

As soon as the treatment is finished, you will sit up and the head frame will be removed. In most cases, you should be able to go home soon afterward.

## **Radiosurgery Using the Linear Accelerator**

Linear accelerator (LINAC) radiosurgery is similar to the Gamma Knife procedure and its four phases: head frame placement, imaging, computerized dose planning and radiation delivery. Unlike the Gamma Knife, which remains motionless during the procedure, part of the LINAC machine called a gantry rotates around the patient, delivering radiation beams from different angles. Compared to the Gamma Knife, the LINAC is able to use a larger x-ray beam, which enables it to treat larger tumors more uniformly and it can be used for fractionated radiosurgery or stereotactic radiotherapy using a relocatable frame, which is an advantage for large tumors or particularly critical locations.

## **Radiosurgery Using the CyberKnife**

A head frame is not necessary for CyberKnife treatment. Instead, a plastic mesh mask will be made to help hold your head in position and a detailed CT scan will be performed with your mask on. You may also have an MRI scan to align with this CT scan in the treatment planning computer. The imaging, treatment planning, and first treatment may be spread out over multiple days. You may have up to five treatments over the span of one or one and a half weeks. For the treatment, you will lie down and the mask will be placed over your head. X-ray images will be taken to ensure that you are in proper position, and then the treatment will begin. Your radiation therapist will monitor you at all times from outside the treatment room. The robotic arm will move around you to aim at the target from a hundred or several hundred directions. Your head won't have to remain perfectly still during treatment; x-ray images taken every minute or so will detect any small movements of your head and the robot will correct for these small movements to ensure accuracy throughout the treatment. The treatment may last about one or two hours.

## **Is any special preparation needed for the procedure?**

Stereotactic radiosurgery is usually performed on an outpatient basis. However, be prepared to spend between 12 and 16 hours in the hospital. You will need to have someone accompany you and drive you home afterward.

You may be asked not to eat or drink anything after midnight on the night before your treatment.

You should ask your physician about taking any medications on the day of your treatment and bring those medications with you to the procedure. You should also tell your physician if any of the following apply to you:

- You are taking medications by mouth or insulin to control diabetes.
- You are allergic to intravenous contrast material, shellfish, or iodine.
- You have a pacemaker, artificial heart valve, defibrillator, brain aneurysm clips, implanted pumps or chemotherapy ports, neurostimulators, eye or ear implants, stents, coils or filters.
- You suffer from claustrophobia.

## **What will I feel during and after the procedure?**

Radiosurgery treatments are similar to having an x-ray. You will not be able to see, feel or hear the x-rays. There is no pain or discomfort from the actual treatment. If you experience pain for other reasons, such as back pain or discomfort from the head frame, you should let your doctor or nurse know.

When the head frame is removed, there may be some minor bleeding from the pin sites that will be bandaged. You may experience a headache and can ask for medication to help make you feel more comfortable. In most cases, patients can resume all of their normal activities within one or two days.

Side effects of radiation treatment include problems that occur as a result of the treatment itself as well as from radiation damage to healthy cells in the treatment area.

The number and severity of side effects you experience will depend on the type of radiation and dosage you receive and the part of your body being treated. You should talk to your doctor and nurse about any side effects you experience so they can help you manage them.

Radiation therapy can cause early and late side effects. Early side effects occur during or immediately after treatment and are typically gone within a few weeks. Common early side effects of radiation therapy include tiredness or fatigue and skin problems. Skin in the treatment area may become more sensitive, red, irritated, or swollen. Other skin changes include dryness, itching, peeling and blistering.

Depending on the area being treated, other early side effects may include:

- hair loss in the treatment area
- mouth problems and difficulty swallowing
- eating and digestion problems
- diarrhea

- nausea and vomiting
- headaches
- soreness and swelling in the treatment area
- urinary and bladder changes

Late side effects, which are rare, occur months or years following treatment and are often permanent. They include:

- brain changes
- spinal cord changes
- lung changes
- kidney changes
- colon and rectal changes
- infertility
- joint changes
- lymphedema
- mouth changes
- secondary cancer

There is a slight risk of developing cancer from radiation therapy. Following radiation treatment for cancer, you should be checked on a regular basis by your radiation oncologist for recurring and new cancers.

Using techniques such as stereotactic radiosurgery, imaging specialists are maximizing the cancer-destroying capabilities of radiation treatment while minimizing its effect on healthy tissues and organs and the side effects of the treatment itself.

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