

Introduction to Radiation Therapy

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Overview

Radiation therapy uses controlled high-energy rays to treat tumors and other diseases of the body. Radiation works by damaging the DNA inside cells making them unable to divide and reproduce. Abnormal cancer cells are more sensitive to radiation because they divide more quickly than normal cells. Over time, the abnormal cells die and the tumor shrinks. Normal cells can also be damaged by radiation, but they can repair themselves more effectively, as when your skin heals itself after sunburn (a mild form of radiation exposure).

The goal of radiation therapy is to maximize the dose to abnormal cells while minimizing exposure to normal cells. The effects of radiation are not immediate; the treatment benefit occurs over time. Typically, more aggressive tumors, whose cells divide rapidly, respond more quickly to radiation. Radiation therapy is painless and will not make you radioactive.

Radiation is often given with the intent of destroying the tumor and curing the disease (curative treatment). However, not all disease or cancer can be cured with radiation. Sometimes radiation is used to relieve symptoms, such as pain or seizures (palliative treatment). Sometimes it is used to prevent tumors from developing or spreading (prophylactic treatment). Radiation may be used alone or in combination with other treatments such as surgery, chemotherapy or immunotherapy. If used before surgery, radiation will shrink the tumor to make it easier to remove. If used after surgery, radiation will destroy tumor cells that may have been left behind.

There are two ways to deliver radiation:

- **external beam radiation** is delivered from outside the body by using a machine to aim high-energy rays (x-rays, gamma rays or photons) at the tumor.
- **internal radiation** (brachytherapy) is delivered from inside the body by surgically placing radioactive material, sealed in catheters or seeds, directly into the tumor.

Principles of radiation therapy

All types of radiation therapy follow these general principles:

1. Precisely locate the target
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

1. Precisely locate the target

Any tumor, lesion or malformation to be treated with radiation is called a target. When locating a target, the doctor needs to know several things: its location in the body, its size and shape, and how close it is to important organs and structures. Small targets are harder to locate than large ones. Diagnostic scans such as computerized tomography (CT) and magnetic resonance imaging (MRI) have greatly improved over the years, allowing doctors to locate tumors and diseases earlier, when they are smaller. Also, positron emission tomography (PET) and functional MRI (fMRI) scans provide information about the function of critical areas next to the target.

Determining the exact location and border of a target within normal tissue is not always clear on diagnostic scans. Doctors can use a technique called stereotaxis to precisely locate targets, especially small deep ones. **Stereotactic** means to locate a

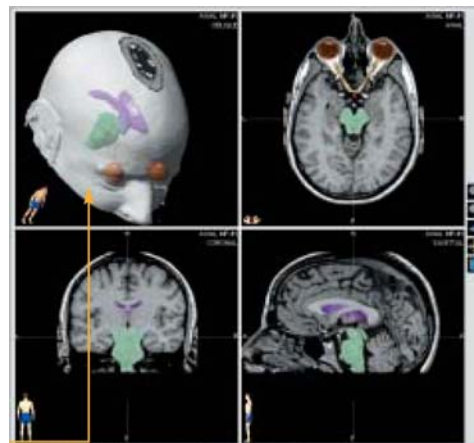


Figure 1. The stereotactic frame serves as a reference on the MRI scan, allowing the computer to plot the exact coordinates (x, y and z axis) and create a 3D reconstruction of the tumor or malformation.

structure by use of three dimensional coordinates (x, y, and z axis). First, a stereotactic head or body frame is attached over the target area. Next, a CT or MRI scan is taken and interpreted by computer software. The stereotactic frame shows up on the scan and helps the doctor pinpoint the exact location of the target (Fig. 1). In some cases, stereotactic localization is performed using internal landmarks, such as bones, and a frame is not necessary.

2. Hold the target still

Once the target is located, the doctor must hold the body as still as possible to accurately aim the radiation only at the target and to avoid healthy tissue. This is especially difficult in areas that are normally moving, such as the lungs and abdominal organs. Immobilization also is important for smaller targets, because a slight shift in position can move the target out of the radiation beam's path. Immobilization devices are used to prevent movement and secure the body area to the treatment table. These devices include molds, masks and stereotactic head or body frames (Fig. 2). Molds and masks are custom-made from plastic to fit your body exactly and are used during each treatment.

3. Accurately aim the radiation

Multiple radiation beams are aimed so that they all meet at a central point within the target, where they add up to a very high dose of radiation. In order to accurately aim radiation, both you and the machine must be correctly aligned with each other.

Patient alignment. Depending on the body area to be treated, different techniques may be used to position your body, including: skin markers, laser lights, field lights, infrared cameras and x-ray positioners. Laser lights are used to make sure you are level and straight on the table. Field lights correspond to the skin marks. Infrared cameras use body markers to detect your position and match the markers to the position in the treatment plan. X-ray positioners take stereoscopic x-rays of your anatomy and match them to the position in the treatment plan images (Fig. 3).

Machine alignment. Several types of machines used to create a radiation beam and aim it at the target. Each machine offers a different level of accuracy and ability to deliver various radiation techniques to treat the target.

A Linear Accelerator (LINAC), the most common type of radiation machine, uses electricity to form a stream of fast-moving subatomic particles (Fig. 4). The radiation beam produced by a LINAC can be shaped and aimed at the target from a variety of directions by rotating the machine and moving the treatment table. The advantage of LINAC-based systems is their versatility. They:

- are used for both radiotherapy and radiosurgery treatments



Figure 2. Immobilization devices such as masks (left) or stereotactic head frames (right) attach to the treatment table to hold the head still.



Figure 3. Using skin markers, infrared cameras and x-ray images, the patient's anatomy is matched to the position in the treatment planning software to verify correct positioning.



Figure 4. A linear accelerator aims a single radiation beam by traveling in an arc around the tumor. Multiple arcs are delivered by rotating the patient table and the gantry. Common LINAC systems include LEXAR or X-knife (Radionics), Novalis (BrainLAB), Peacock (NOMOS), Clinac (Varian), Precise (Elekta), and CyberKnife (Accuray).

- treat any area of the body
- treat large and small tumors
- use highly focused radiation sources
- produce high intensity radiation
- can use techniques such as Intensity Modulated Radiotherapy (IMRT)

The Gamma Knife system uses 201 converging beams of gamma radiation (cobalt-60). All 201 beams meet at a central point within the target, where they add up to a very high dose of radiation. In contrast to LINAC, the Gamma Knife does not move around you. Rather, you are placed in a helmet unit that allows the target to be placed exactly in the center of the converging beams. The features of Gamma Knife systems include:

- used for radiosurgery only
- limited to treating head lesions

4. Shape the radiation beam

It is crucial that the radiation dose is delivered only to the target. Shaping the beam to match the target minimizes exposure to normal tissue. The problem is that most tumors are irregularly shaped and most radiation beams are round. Beams can be shaped using treatment planning software and hardware.

Treatment planning software. High-end computers and software are used to plan the treatment so that all beams meet at a central point within the target, where they add up to a very high dose of radiation. The software uses your CT or MRI images to form a 3D view of your anatomy and the target (Fig. 5). The radiation oncologist uses different settings in the software to create a final radiation prescription specifically for you. The prescription includes:

- correct radiation dose of each beam (measured in rads or Gy)
- correct size and shape of the beams
- number and angle of treatment arcs
- number of treatment sessions

Hardware. Radiation beams can be shaped by attaching blocks or collimators to the radiation machine to block a portion of the beam (similar to placing your finger in the path of a flashlight to cast a shadow). The goal is to shape the beam to the exact contour of the tumor and minimize exposure to normal tissue. Block devices shape the beam in a linear fashion and are only able to squarely shape the beam (Fig. 6). Collimator devices are able to shape the beam into circular or elliptical shapes (Fig. 7). Multileaf collimators can focus and shape the beam in infinite ways and are the most precise method at this time (Fig. 8).

5. Deliver an optimal dose

Radiation works best when given in high rather than low doses; however, normal cells that border the target cannot repair themselves very well after a high-dose exposure. Determining the best radiation dose is a balance between the maximum dose tolerated by normal cells versus the minimum dose

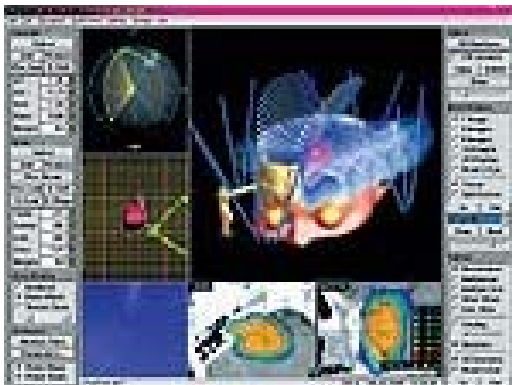


Figure 5. Treatment planning software uses CT images to create a 3D view of the body area.

Evolution of Beam Shaping

In the past, we were limited in how accurately we could focus radiation on the target because tumors are often an irregular shape and radiation beams are round. Technology has advanced our ability to deliver multiple beams at various angles and shape the radiation to the exact contour of the tumor.



Figure 6. Conventional radiotherapy delivers a radiation beam along a single treatment arc. It uses blocks to shape the radiation beam in a square-edged fashion.

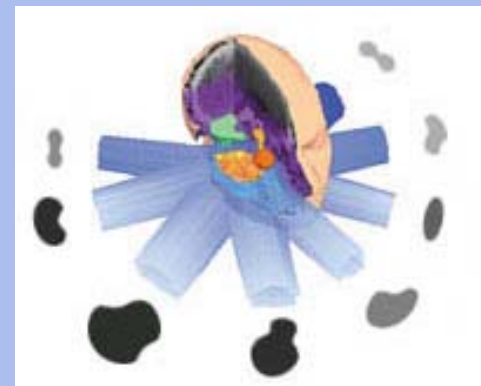


Figure 7. 3D conformal radiotherapy delivers radiation beams in multiple arcs at various angles. It uses collimators to shape each radiation beam in an elliptical-shaped fashion to conform the dose to the tumor (orange).

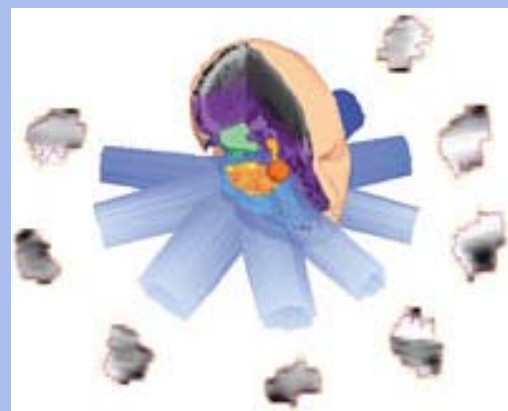


Figure 8. Intensity modulated radiotherapy (IMRT) delivers radiation beams in multiple arcs, similar to 3D conformal. It uses sophisticated inverse planning software and multileaf collimators to both shape the radiation beam and change the intensity within each beam to deliver the optimum dose.

necessary to cause tumor cell death. Doctors can take advantage of the body's own healing process by delivering a fraction of the complete dose over multiple sessions. In this method, called fractionated radiotherapy, normal cells are allowed time to repair between each radiation session and are protected from permanent injury or death. The fewer the treatment fractions, the more the radiation affects tumor and normal tissue equally. The greater the number of treatment fractions, the less the risk of injury to normal cells and the fewer the side effects. During fractionated radiotherapy, patients receive treatment daily for 3 to 6 weeks.

Forms of Radiation Therapy

There are many forms of radiation therapy, all of which use the general principles discussed previously. Each patient's treatment is individualized. Radiation may be used alone or in combination with other therapies such as surgery, chemotherapy and immunotherapy. Two patients - even if they have the same kind of cancer - may not receive the same kind of radiation therapy.

External beam radiation

- **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 or body frame. Although it is called surgery, no incision is made. Patients spend most of the day at the center while the tumor is precisely located, a treatment plan is developed, and a radiation dose is delivered. For details, see:
 - [Stereotactic Radiosurgery & Radiotherapy for the Head](#)
 - [Stereotactic Radiosurgery & Radiotherapy for the Body](#)

- **Fractionated Stereotactic Radiotherapy (FSR)** delivers radiation over many visits and uses stereotaxis to precisely locate the target and accurately reposition the patient for each treatment session. Until recently, fractionation was not possible using stereotaxis because there was no way to keep the rigid frame in place after the first treatment session. Repositionable masks and molds along with x-ray and infrared positioners ensure treatment accuracy, making multiple radiosurgery sessions possible. FSR offers the precision of stereotaxy for those with lesions near critical structures that cannot tolerate high doses. Patients return daily over several weeks to receive the complete radiation dose.
- **Conventional Radiotherapy** delivers fractionated radiation doses over many visits. The target area usually includes a margin of normal tissue. Patients have an initial consultation and simulation in which a treatment plan is developed, and will return daily over several weeks to receive the complete radiation dose. In whole brain radiotherapy (WBRT), the radiation dose is delivered to the entire brain and is often used to treat multiple brain tumors.

Internal beam radiation

- **Brachytherapy** delivers a high dose of radiation from within the tumor through the surgical implantation of radioactive material into the tumor. The radioactive material is sealed in catheters, seeds or capsules. For some procedures, the patient stays in the hospital for several days while the radioactive seeds deliver their dose to the tumor. The seeds are then removed and the patient can go home. In other instances, the radioactive implant stays in permanently, and the patient may go home soon after the procedure is completed.

	Stereotactic Radiosurgery (SRS)	Fractionated Stereotactic Radiotherapy (FSR)	Conventional Radiotherapy
Locate target	Uses stereotactic localization	Uses stereotactic localization	Uses standard diagnostic scans
Immobilization device	Uses a rigid stereotactic head or body frame	Uses a repositionable stereotactic mask or body mold	May use a mask or body mold
Accurately aim radiation beam	Most precise Uses laser, infrared and x-ray body tracking	Very precise, Uses laser, infrared and x-ray body tracking	Larger target area that includes normal brain margin
Beam shaping	IMRT or 3D conformal	IMRT or 3D conformal	IMRT or 3D conformal
Optimal dose	Very high dose delivered during one treatment session	Moderate "fractions" of the complete high dose delivered over multiple treatment sessions	Moderate "fractions" of the complete dose delivered over multiple treatment sessions

Adjunctive therapies

Immunotherapy activates your own immune system (T-cells and antibodies) to destroy cancer cells. Researchers are also exploring ways to prevent or treat cancer through vaccines. This research is still in an experimental stage.

Gene therapy uses viruses or other vectors to introduce new genetic material into tumor cells. This can cause them to die, or make them more susceptible to other cancer therapies. Gene therapy is currently experimental.

Hyperbaric oxygen uses oxygen at higher than normal levels to promote wound healing and help fight infection. It may also improve the tumor's responsiveness to radiation, which is being studied experimentally. Currently it is being used to help the body naturally remove dead tumor cells and treat radiation necrosis.

Radiosensitizers are drugs used before or during radiation therapy to make tumor cells more sensitive to radiation therapy. Once taken into the body, the drug concentrates in the abnormal tumor cells. 5-fluorouracil, topotecan and tirapazamine are some radiosensitizers.

Radioprotectors are drugs used to protect normal cells from the effects of radiation therapy in select cases.

Am I a candidate?

Discovering that you have a tumor, cancer or other disease raises many concerns and questions. Learning as much as possible about your condition and available treatment options is critical in selecting the best course of treatment, as well as providing peace of mind for you and your family. How well a particular tumor will respond to radiation treatment depends on its cell type, grade and stage.

- **Cell type.** Different types of cells respond differently to radiation. The cell type also refers to whether the tumor is benign (non-cancerous) or malignant (cancerous).
- **Grade.** Grade refers to the aggressive-ness of the tumor cell type (how fast it will grow on a scale of 1 to 4).
- **Stage.** Stage refers to the extent of tumor spread. Tumors can remain in one area (localized) or can spread to nearby organs (metastasized).

While tumors are the most common indication, many other conditions respond to radiation treatment. Ask your doctor if radiation therapy can help provide a better quality of life and longer survival for you.

Who performs radiation therapy?

Radiation oncologists are doctors with 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 daily treatments.

The treatment decision

Your treatment team—a pathologist, surgeon, internist, chemotherapist and radiation oncologist—consults and determines the best treatment for you.

Sometimes you may want to speak to another doctor to get a second opinion. This is common practice and is sometimes required by your insurance. However, you should ask whether it is safe to delay treatment while you get a second opinion.

What are the side effects?

Side effects 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 are permanent. Ask your doctor about specific side effects you may experience. General side effects may include:

Fatigue

Fatigue, or tiredness, is the most common side effect. Make sure you get plenty of sleep, take a nap after treatment, and eat a balanced diet during treatment. Fatigue can continue for weeks or months after treatment stops. Some may notice a lack of appetite and a loss of taste. Nausea and diarrhea may occur; medications can provide relief.

Skin irritation

The skin in the area where the radiation beams pass through may occasionally become reddened and dry. This will resolve after treatment stops.

Hair Loss

You may experience hair loss in the treated area about 2 weeks after treatment begins. This is often temporary; your hair will grow back after treatment stops.

Swelling

Radiation causes cells to lose their ability to regulate fluids, and swelling may occur. This does not always happen. If swelling occurs, it can cause headaches, seizures and confusion. Steroid medication may be

given to reduce the fluid within the tumor cavity.

Necrosis

On rare occasions, the radiation dose can cause the tumor tissue to become necrotic several weeks to months after treatment. Dead or necrotic tissue can become toxic to surrounding normal tissue, and swelling may occur. Treatment for radiation necrosis may include steroid medication, hyperbaric oxygen treatments or surgical removal.

Clinical trials

Clinical trials are research studies in which new treatments - drugs, diagnostics, procedures, vaccines and other therapies - are tested in people to see if they are safe and effective. Research is always being conducted to improve the standard of medical care and explore new drug and surgical treatments. You can find information about current clinical investigations, including their eligibility requirements, protocol and participating locations, on the web. The National Institutes of Health (NIH), at clinicaltrials.gov, sponsors many trials. Private industry and pharmaceutical companies also sponsor trials; see www.centerwatch.com

Sources & links

If you have more questions, please contact Precision Radiotherapy at 513-475-7777. Additional information is available on the web at www.PrecisionRadiotherapy.com.

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

arteriovenous malformation (AVM): a congenital disorder in which there is an abnormal connection between arteries and veins without an intervening capillary bed.

benign: not cancerous.

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

cancer: generic term for more than 100 different diseases caused by uncontrolled, abnormal growth of cells. Cancer cells can invade and destroy normal tissue, and can travel through the bloodstream and lymphatic system to reach other parts of the body.

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

fractionated: delivering the radiation dose over multiple sessions.

immunotherapy: treatment designed to improve or restore the immune system's ability to fight infection and disease.

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

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

malignant: cancerous.

metastatic: cancerous tumor that has spread from its original source through the blood or lymph systems.

radiation: high-energy rays or particle streams used to treat disease.

stereotactic: a precise method for locating deep brain structures by the use of 3-dimensional coordinates.

target: area where the radiation beams are aimed; usually a tumor, malformation, or other abnormality of the body.

tumor: an abnormal growth of tissue resulting from uncontrolled multiplication of cells and serving no physiological function. A tumor can be benign or malignant.

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