Radiation Therapy: Which type is right for me?

- **External radiation therapy**: a beam of radiation is directed into the body. This may also be called x-ray therapy, 3D conformal radiation, intensity modulated radiation therapy (IMRT), cobalt, photon, or proton therapy.

- **Internal radiation therapy**: a source of radioactivity is placed inside the body, near the tumor. This is called brachytherapy or implanttherapy.

Radiation therapy can be classified according to the types of radiation particles or waves that are used to deliver the treatment, such as photons, electrons, or protons. Photons and electrons are the most readily available and most commonly used. Protons are available at some cancer centers in the US and other countries, with new proton therapy centers being built or in the planning stages.

The three major types of radiation therapy (photon, electron, proton) have similar effects on tumor tissue, meaning that they all damage cancer cells. However, each type does have certain advantages and disadvantages. In this article, we will discuss the situations and reasoning of why your treatment team may suggest one treatment over another. Your treatment team will work together to pick the best type of radiation therapy for your type of cancer.

**Photon Treatment**

Photons can be used in a few different types of radiation therapy, such as:

- Conventional radiation therapy.
- 3D conformal radiation therapy.
- Intensity Modulated Radiation Therapy (IMRT).
- Stereotactic radiation therapy, also known as radiosurgery, GammaKnife, CyberKnife, or SBRT.
- Brachytherapy.
- Orthovoltage radiation therapy.
- Volumetric modulated arc therapy (also known as RapidArc).

Photon beams are the same type of beam used in X-ray machines, like those used to take chest X-rays. However, in radiation therapy, much higher energy photon beams are used. Conventional radiation therapy, 3D conformal radiation therapy, and IMRT are often all delivered by machines called linear accelerators, or “linacs” for short.

**Two-Dimensional Photon Therapy ("Conventional" Radiation Therapy)**

When 2D, or conventional radiation therapy is used, X-ray films are used to guide and position the radiation beams. A machine called a “fluoroscopic simulator” is often used to plan the radiation treatments. The bones seen on the X-ray are used as landmarks to find where the tumor is and where to position the radiation beams in order to treat the tumor, while avoiding areas where there is no cancer. Planning does not take a long time and patients can usually start treatment quickly, compared to other kinds of radiation therapy that need more in-depth (and time consuming) planning. This type of treatment is often used for urgent treatments.

**3D Conformal Radiation Therapy**

Many hospitals now have the ability to use a CT scan (Cat Scan) to plan radiation treatments for tumors. This process is called 3D conformal radiotherapy. CT-guided therapy allows the tumor and normal organs to be defined in three dimensions, as opposed to using the “flat” image of an x-ray (in “conventional” radiation therapy).

In this type of therapy, a CT or PET scan, often referred to as a “simulation,” is taken of the person in the position they will be in for their radiation treatment. The tumor is then outlined in three dimensions on the CT scan. Normal organs that are located
near the tumor and need to be avoided are also outlined in 3D (figure I, below). Beams are then arranged to avoid healthy tissue, while giving a dose of radiation to the tumor. Computer software is used to see the amount of radiation the tumor and normal tissues receive to make sure that all parts of the tumor are covered, while healthy organs receive as little radiation as possible.

In addition to arranging the beams, the radiation beam is also shaped. There are two ways of shaping the beam:

- **Cerrobend blocks**: Beams can be individually molded to the shape required.
- **Multileaf collimators (MLC's)**: "Leaves" within the machine can be used to form precise beam shapes. These leaves are skinny metal blocks, which are able to move quickly to form different, complex patterns (figure II, below). These leaves are an important part of IMRT, which we will discuss next.

**Intensity Modulated Radiation Therapy (IMRT)**

IMRT is another way to deliver photons to treat a tumor, but with the benefit of sparing more healthy tissue. Planning IMRT also begins with a simulation. Similar to 3D conformal therapy, the tumor and normal organs are outlined on the CT in 3D (figure III, below). Multiple beams are positioned around the person to deliver the radiation. However, in IMRT, these beams are divided into a grid-like pattern, separating the one big beam into many smaller "beamlets."

Special software is used to find the best pattern of beamlets to use, in order to deliver the correct amount of radiation to the tumor while sparing healthy tissue. To deliver these patterns, the MLC's form many shapes, often 50 or more, during the course of a radiation treatment. The advantage of delivering radiation as beamlets to form these patterns is that there can be precise control of the radiation. IMRT, then, can be used when a tumor is in a hard area to treat. For example, if a tumor is close to or wrapped around a normal organ, IMRT can shape the radiation to avoid as much of the healthy tissue as possible. This is why IMRT is often used in cancers of the head and neck where many critical areas, such as the spinal cord, must be avoided. IMRT has become the most frequently used radiation modality.

The downsides of IMRT are that it can take longer to both plan the treatment course and deliver the daily treatment than 3D conformal therapy. Also, because so many small beamlets are being used, the dose of radiation going to the tumor may not be as even as might be seen with 3D conformal therapy. The number of beams used to shape the radiation helps keep the dose of radiation to healthy tissue low, but a bigger area of healthy tissue may receive low doses of radiation. The risks of low dose exposure are unknown at this time. Finally, some tumors can move during treatment. For example, the lungs move with breathing, making treatment planning hard.

**Volumetric Modulated Arc Therapy (RapidArc)**

An additional type of IMRT that has developed in the past few years is known as Volumetric Modulated Arc Therapy (VMAT). It is very similar to IMRT except, in VMAT, the Linac rotates 360 degrees around the patient. As it moves around each side of the patient, it delivers the radiation, increasing the number of angles and lowering the dose of radiation to normal tissue. One common type of VMAT is known as RapidArc. RapidArc is used often in head and neck cancers, brain tumors, GI (gastrointestinal) cancers, prostate cancers, and lung cancers.

**Image-Guided Radiotherapy (IGRT)**

During treatment with IGRT, imaging scans are done over and over to guide treatment. The scans are read by computer software to find changes in a tumor’s size and location. This allows for changes in position of the patient and/or the planned radiation dose. The many images can increase the accuracy of the radiation treatment and decrease the amount of radiation to the nearby normal tissue.

**Stereotactic Radiation and Radiosurgery (SBRT, GammaKnife, and Cyberknife)**

Stereotactic radiation therapy delivers a high dose of radiation very precisely to a tumor. Stereotactic radiation therapy uses many different angles to focus the radiation at one small point, like a magnifying glass. There are two types of stereotactic radiation therapy:

- **Stereotactic radiosurgery (SRS).**
- **Stereotactic body radiation therapy (SBRT).**
By using a large number of beam angles to deliver the radiation, stereotactic radiation therapy lowers the effects on the normal tissue, which the radiation passes through, but delivers a large dose of radiation to a single point where all of the beams come together at the tumor site. Since the dose of radiation to that single point is so high, precise targeting of the tumor is needed.

**Stereotactic Radiosurgery**

The most common use of radiosurgery, with one fraction, is with tumors of the brain. The brain does not move and does not have the problems with motion that other tumor sites can have (like the lungs). The skull serves as a stable landmark for the location of the tumor. A head frame or halo may need to be attached to the skull using small screws. This makes sure the head is positioned correctly in the treatment machine and allows the precise delivery of radiation in a single treatment.

With the head frame on, an MRI is done to map the tumor and the frame serves as a landmark for the location of the tumor. The MRI is then used to plan the radiation treatment using computer software. The tumor and healthy areas are outlined on the MRI so that critical brain structures can be avoided while giving the correct dose to the tumor. Because the MRI was taken with the frame on, the tumor location within the frame should be the same on the treatment machine. The frame is then attached to the treatment machine and radiation is delivered with precise accuracy.

A few different machines can be used to deliver radiosurgery, including GammaKnife machines and specialized linacs. Radiosurgery is limited by the need for precise immobilization of the tumor, such as with a head frame (see photo below) and by the size of the tumor that can be treated. Because of its complexity, both neurosurgery and radiation oncology work together during treatment planning and delivery. Due to the very small area of highly intense radiation used in radiosurgery, only tumors less than 5 centimeters can be treated with this technique.

**Stereotactic body radiation therapy (SBRT)**

Stereotactic body radiation therapy (SBRT), involves the precise delivery of radiation in 2-5 fractions. SBRT can be used in many sites of the body, including lung, prostate, liver, brain, and bone. Like radiosurgery, computer software creates and controls many beams with MLC's to create beams with different doses of radiation to allow the tumor to receive a large dose of radiation, while sparing the nearby normal tissue. Because of the big differences in radiation dose, there must be very precise targeting of the tumor. Immobilization (keeping the area receiving radiation still) is critical for accurate targeting and consistency in each treatment. Markers, referred to as “fiducials,” are often placed before the simulation to help locate the same treatment area on a daily basis.

SBRT can be delivered by some linear accelerators as well as the CyberKnife system. CyberKnife is unique in that it is a linear accelerator placed on a robotic arm, giving it a wide range of motion. The robotic arm enables the CyberKnife to treat tumors from a variety of angles, further minimizing radiation exposure to normal tissues. Additionally, the advanced technology of CyberKnife allows it to track tumors in real-time so that it can track respiratory motion (how your lungs move when you breathe) and further reducing normal tissue exposure.

**Immobilization devices**

**Brachytherapy**

Brachytherapy is the use of a radioactive source, often one that releases photons. The source is either implanted into the tumor (interstitial brachytherapy) or placed near the cancer, often in a body cavity (intracavity brachytherapy). Prostate seeds are an example of interstitial brachytherapy, where radioactive seeds are placed directly into the prostate using needles. Uterine cancer treated with a removable implant (called tandem & ovoids or rings) placed in the uterine cavity through the vagina is an example of intracavity brachytherapy. The advantage of brachytherapy is that since the source of the radiation can be placed in, or very close to the tumor, the amount of normal tissue affected by the radiation is less. This is because the dose of radiation
released from the source is very high near the tumor itself, but the dose falls off rapidly within a few centimeters. This limits brachytherapy to cancers in locations where a radioactive source can be inserted safely, but still treat the tumor effectively. Brachytherapy is not effective for treating large areas or deep tumors unless the source can be implanted correctly.

Implanting prostate brachytherapy "seeds"

Radiation "seeds" used for prostate brachytherapy

Applicator for cervical HDR

X-Ray of tandem and ovoids apparatus (white & gray piece) inserted for endometrial cancer brachytherapy.

Orthovoltage Radiation

Orthovoltage was often used before linear accelerators became available for the treatment of many different tumors. Orthovoltage radiation uses lower energy photons to treat tumors, which are located on the skin or very close to the skin. The lower energy of orthovoltage beams doesn’t work well for deep tumors compared to the higher energy beams available today with most linacs. However, orthovoltage treatment can be very effective for some skin tumors and other superficial lesions. Orthovoltage units are becoming rare, as many of the treatments that were done previously by orthovoltage units are now treated with electrons.

Electron Radiation

Electrons are a different form of radiation than photons and have different physical properties, but work like photons. Linear accelerators, in addition to producing photons, can also produce electrons. Electrons are available at most treatment centers. Electrons tend to release their energy close to the skin's surface and are often used to treat superficial tumors (tumors close to the surface of the skin), such as skin cancers and some lymph nodes. Electrons are able to release most of their energy near the skin. The radiation does not go too much past the skin to deeper normal tissues. However, this also limits the use of electrons for deeper areas. This treatment has generally replaced orthovoltage because it can be combined in the same machine as a linear accelerator.

Proton Therapy

Proton therapy is a type of radiation that uses a particle, the proton, to deliver radiation while keeping the dose low to nearby healthy tissue. The use of proton therapy has increased in the past few years as technology has improved. However, this treatment is still not widely available because the machines that produce and deliver protons are extremely large (about 3 stories in height), need dedicated space, and are very expensive. Smaller machines are in development, which is expected to
make this treatment available in more locations.

The advantage of protons is that where and how deep they release their energy can be precisely controlled. As the proton enters the body, it releases small amounts of energy, and slows down. At the end of its path, it releases a large amount of energy, and very little energy is released past that point. Using computer software, the protons can release their energy within the tumor, without any of the energy exiting out of the back of the tumor. If the back edge of the tumor is against the spinal cord, it may be possible to spare any radiation dose to the spinal cord using protons. The cons of proton therapy are mostly related to their limited availability, which may delay or prevent treatment for patients who need treatment quickly. Due to the high cost of proton therapy, some insurance companies may not approve payment of this treatment.

Summary

This article has outlined several different types of radiation therapy, as well as some of the pros and cons of each. No one type of radiation is perfect for every situation. Your radiation care team must take many factors into account, including the individual patient, type and location of tumor, as well as the available clinical evidence when choosing the treatment option that is best. Talk with your radiation care team about your plan and about any questions you might have.

Figures

Figure I. Shown on the right is a single cross-sectional image from a CT scan. The red arrows indicate where the radiation oncologist has circled the kidneys, which have a low tolerance for radiation. The figure on the left shows that by combining these outlines, the kidneys can be seen in a reconstructed image of the person in a standing position, hence the position of the kidneys can be seen in all three dimensions. The radiation beams passing through the center have been positioned to avoid the kidneys while optimally covering the tumor.

Figure II. Shown in green are the leaves or multileaf collimator (MLC’s) used to shape radiation. As you can see, each leaf can
be moved independently to form shapes. The kidneys are being shielded (pink and green structures) while maximum dose is
going to the tumor (red).

Figure III. Shown is a single cross-sectional image from a CT of the head that is being used to plan Intensity Modulated Radiation Therapy (IMRT). The blue line encompasses areas that are at risk for tumor involvement. The red and green lines indicate where the radiation oncologist wants a higher dose of radiation directed because these areas had definite tumor involvement. The light blue line outlines the spinal cord, which indicates to the software that we want to protect the spinal cord.

Figure IV: Demonstrates how the dose of radiation can be shaped to avoid normal organs using IMRT. The highest doses are in red with lower doses in blue and green. Notice that the spinal cord has been protected and is green (red arrow), indicating it is getting a low dose of radiation compared with the red areas where the tumor was known to be, which is covered with a high
dose of radiation.

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