NATIONAL CANCER INSTITUTE
FactSheet

Radiation Therapy for Cancer: Questions and Answers

Key Points

- Radiation therapy uses ionizing radiation to kill cancer cells and shrink tumors (see Question 1).
- About half of all people with cancer are treated with radiation therapy, either alone or in combination with other types of cancer treatment (see Question 1).
- Radiation therapy may be external or internal. External radiation, the type most often used, comes from a machine outside the body, and is usually given on an outpatient basis. Internal radiation is implanted into or near the tumor in small capsules or other containers. It may require a hospital stay (see Question 3).
- Different types of radiation are used to treat different types of cancer (see Question 3).
- A team of health care providers helps to plan and deliver radiation treatment to the patient (see Question 11).
- Treatment planning and simulation are critical first steps in the radiation therapy process. The goal of planning and simulation is to make the treatment more precise, more effective, and less damaging to healthy tissues (see Question 12).

1. What is radiation therapy?

Radiation therapy (also called radiotherapy, x-ray therapy, or irradiation) is the use of a certain type of energy (called ionizing radiation) to kill cancer cells and shrink tumors. Radiation therapy injures or destroys cells in the area being treated (the “target tissue”) by damaging their genetic material, making it impossible for these cells to continue to grow and divide. Although radiation damages both cancer cells and normal cells, most normal cells can recover from the effects of radiation and function properly. The goal of radiation therapy is to damage as many cancer cells as possible, while limiting harm to nearby healthy tissue.

There are different types of radiation and different ways to deliver the radiation. For example, certain types of radiation can penetrate more deeply into the body than can others. In addition, some types of radiation can be very finely controlled to treat only a small area (an inch of tissue, for example) without damaging nearby tissues and organs. Other types of radiation are better for treating larger areas.

In some cases, the goal of radiation treatment is the complete destruction of an entire tumor. In other cases, the aim is to shrink a tumor and relieve symptoms. In either case, doctors plan treatment to spare as much healthy tissue as possible.

About half of all cancer patients receive some type of radiation therapy. Radiation therapy may be used alone or in combination with other cancer treatments, such as chemotherapy or surgery. In some cases, a patient may receive more than one type of radiation therapy.

2. When is radiation therapy used?

Radiation therapy may be used to treat almost every type of solid tumor, including cancers of the brain, breast, cervix, larynx, lung, pancreas, prostate, skin, spine, stomach, uterus, or soft tissue sarcomas. Radiation can also be used to treat leukemia and lymphoma (cancers of the blood-forming cells and lymphatic system, respectively). Radiation dose to each site depends on a number of factors, including the type of cancer and whether there are tissues and organs nearby that may be damaged by radiation.

For some types of cancer, radiation may be given to areas that do not have evidence of cancer. This is done to prevent cancer cells from growing in the area receiving the radiation. This technique is called **prophylactic radiation therapy**.

Radiation therapy also can be given to help reduce symptoms such as pain from cancer that has spread to the bones or other parts of the body. This is called **palliative radiation therapy.**

3. What is the difference between external radiation therapy, internal radiation therapy (brachytherapy), and systemic radiation therapy? When are these types used?

Radiation may come from a machine outside the body (external radiation), may be placed inside the body (internal radiation), or may use unsealed radioactive materials that go throughout the body (systemic radiation therapy). The type of radiation to be given depends on the type of cancer, its location, how far into the body the radiation will need to go, the patient's general health and medical history, whether the patient will have other types of cancer treatment, and other factors.

Most people who receive radiation therapy for cancer have external radiation. Some patients have both external and internal or systemic radiation therapy, either one after the other or at the same time.

- **External radiation therapy** usually is given on an outpatient basis; most patients do not need to stay in the hospital. External radiation therapy is used to treat most types of cancer, including cancer of the bladder, brain, breast, cervix, larynx, lung, prostate, and vagina. In addition, external radiation may be used to relieve pain or ease other problems when cancer spreads to other parts of the body from the primary site.

    - **Intraoperative radiation therapy (IORT)** is a form of external radiation that is given during surgery. IORT is used to treat localized cancers that cannot be completely removed or that have a high risk of recurring (coming back) in nearby tissues. After all or most of the cancer is removed, one large, high-energy dose of radiation is aimed directly at the tumor site during surgery (nearby healthy tissue is protected with special shields). The patient stays in the hospital to recover from the surgery. IORT may be used in the treatment of thyroid and colorectal cancers, gynecological cancers, cancer of the small intestine, and cancer of the pancreas. It is also being studied in clinical trials (research studies) to treat some types of brain tumors and pelvic sarcomas in adults.

    - **Prophylactic cranial irradiation (PCI)** is external radiation given to the brain when the primary cancer (for example, small cell lung cancer) has a high risk of spreading to the brain.

- **Internal radiation therapy (also called brachytherapy)** uses radiation that is placed very close to or inside the tumor. The radiation source is usually sealed in a small holder called an implant. Implants may be in the form of thin wires, plastic tubes called catheters, ribbons, capsules, or seeds. The implant is put directly into the body. Internal radiation therapy may require a hospital stay.

    Internal radiation is usually delivered in one of two ways, each of which is described below. Both methods use sealed implants.

    - **Interstitial radiation therapy** is inserted into tissue at or near the tumor site. It is used to treat tumors of the head and neck, prostate, cervix, ovary, breast, and perianal and pelvic regions. Some women treated with external radiation for breast cancer receive a “booster dose” of radiation that may use interstitial radiation or external radiation.

    - **Intracavitary or intraluminal radiation therapy** is inserted into the body with an applicator. It is commonly used in the treatment of uterine cancer. Researchers are also studying these types of internal radiation therapy for other cancers, including breast, bronchial, cervical, gallbladder, oral, rectal, tracheal, uterine, and vaginal.

- **Systemic radiation therapy** uses radioactive materials such as iodine 131 and strontium 89.

The materials may be taken by mouth or injected into the body. Systemic radiation therapy is sometimes used to treat cancer of the thyroid and adult non-Hodgkin lymphoma. Researchers are investigating agents to treat other types of cancer.

4. Will radiation therapy make the patient radioactive?

Cancer patients receiving radiation therapy are often concerned that the treatment will make them radioactive. The answer to this question depends on the type of radiation therapy being given.

External radiation therapy will not make the patient radioactive. Patients do not need to avoid being around other people because of the treatment.

Internal radiation therapy (interstitial, intracavitary, or intraluminal) that involves sealed implants emits radioactivity, so a stay in the hospital may be needed. Certain precautions are taken to protect hospital staff and visitors. The sealed sources deliver most of their radiation mainly around the area of the implant, so while the area around the implant is radioactive, the patient's whole body is not radioactive.

Systemic radiation therapy uses unsealed radioactive materials that travel throughout the body. Some of this radioactive material will leave the body through saliva, sweat, and urine before the radioactivity decays, making these fluids radioactive. Therefore, certain precautions are sometimes used for people who come in close contact with the patient. The patient's doctor or nurse will provide information if these special precautions are needed.

5. How does the doctor measure the dose of radiation?

The amount of radiation absorbed by the tissues is called the radiation dose (or dosage). Before 1985, dose was measured in a unit called a "rad" (radiation absorbed dose). Now the unit is called a gray (abbreviated as Gy). One Gy is equal to 100 rads; one centigray (abbreviated as cGy) is the same as 1 rad.

Different tissues can tolerate various amounts of radiation (measured in centigrays). For example, the liver can receive a total dose of 3,000 cGy, while the kidneys can tolerate only 1,800 cGy. The total dose of radiation is usually divided into smaller doses (called fractions) that are given daily over a specific time period. This maximizes the destruction of cancer cells while minimizing the damage to healthy tissue.

The doctor works with a figure called the therapeutic ratio. This ratio compares the damage to the cancer cells with the damage to healthy cells. Techniques are available to increase the damage to cancer cells without doing greater harm to healthy tissues. These techniques are discussed in Questions 8, 9, and 15.

6. What are the sources of energy for external radiation therapy?

The energy (source of radiation) used in external radiation therapy may come from the following:

- **X-rays or gamma rays**, which are both forms of electromagnetic radiation. Although they are produced in different ways, both use photons (packets of energy).

  - **X-rays** are created by machines called linear accelerators. Depending on the amount of energy the x-rays have, they can be used to destroy cancer cells on the surface of the body (lower energy) or deeper into tissues and organs (higher energy). Compared with other types of radiation, x-rays can deliver radiation to a relatively large area.

  - **Gamma rays** are produced when isotopes of certain elements (such as iridium and cobalt 60) release radiation energy as they break down. Each element breaks down at a specific rate and each gives off a different amount of energy, which affects how deeply it can penetrate into the body. (Gamma rays produced by the breakdown of cobalt 60 are used in the treatment called the "gamma knife," which is discussed in Question 8).

- **Particle beams** use fast-moving subatomic particles instead of photons. This type of radiation may be called particle beam radiation therapy or particulate radiation. Particle beams are created by linear accelerators, synchrotrons, and cyclotrons, which produce and accelerate the particles required for this type of radiation therapy. Particle beam therapy uses electrons, which are produced by an x-ray tube (this may be called electron-beam radiation); neutrons, which are produced by radioactive elements and special equipment; heavy ions (such as protons and helium); and pi-mesons (also called pions), which are small, negatively charged particles produced by an accelerator and a system of magnets. Unlike x-rays and gamma rays, some particle beams can penetrate only a short distance into tissue. Therefore, they are often used to treat cancers located on the surface of or just below the skin.

  - **Proton beam therapy** is a type of particle beam radiation therapy. Protons deposit their energy over a very small area, which is called the Bragg peak. The Bragg peak can be used to target high doses of proton beam therapy to a tumor while doing less damage to normal tissues in front of and behind the tumor. Proton beam therapy is available at only a few facilities in the United States. Its use is generally reserved for cancers that are difficult or dangerous to treat with surgery (such as a chondrosarcoma at the base of the skull), or it is combined with other types of radiation. Proton beam therapy is also being used in clinical trials for intraocular melanoma (melanoma that begins in the eye), retinoblastoma (an eye cancer that most often occurs in children under age 5), rhabdomyosarcoma (a tumor of the muscle tissue), some cancers of the head and neck, and cancers of the prostate, brain, and lung.

7. **What are the sources of energy for internal radiation?**

The energy (source of radiation) used in internal radiation comes from the radioactive isotope in radioactive iodine (iodine 125 or iodine 131), and from strontium 89, phosphorous, palladium, cesium, iridium, phosphate, or cobalt. Other sources are being investigated.

8. **What are stereotactic radiosurgery and stereotactic radiotherapy?**

Stereotactic (or stereotaxic) radiosurgery uses a large dose of radiation to destroy tumor tissue in the brain. The procedure does not involve actual surgery. The patient's head is placed in a special frame, which is attached to the patient' skull. The frame is used to aim high-dose radiation beams directly at the tumor inside the patient's head. The dose and area receiving the radiation are coordinated very precisely. Most nearby tissues are not damaged by this procedure.

Stereotactic radiosurgery can be done in one of three ways. The most common technique uses a linear accelerator to administer **high-energy photon radiation** to the tumor (called "linac-based stereotactic radiosurgery"). The **gamma knife**, the second most common technique, uses cobalt 60 to deliver radiation. The third technique uses **heavy charged particle beams** (such as protons and helium ions) to deliver stereotactic radiation to the tumor.

Stereotactic radiosurgery is mostly used in the treatment of small benign and malignant brain tumors (including meningiomas, acoustic neuromas, and pituitary cancer). It can also be used to treat other conditions (for example, Parkinson's disease and epilepsy). In addition, stereotactic radiosurgery can be used to treat metastatic brain tumors (cancer that has spread to the brain from another part of the body) either alone or along with whole-brain radiation therapy. (Whole-brain radiation therapy is a form of external radiation therapy that treats the entire brain with radiation.)

Stereotactic radiotherapy uses essentially the same approach as stereotactic radiosurgery to deliver radiation to the target tissue. However, stereotactic radiotherapy uses multiple small fractions of radiation as opposed to one large dose. Giving multiple smaller doses may improve outcomes and minimize side effects. Stereotactic radiotherapy is used to treat tumors in the brain as well as other parts of the body.

Clinical trials are under way to study the effectiveness of stereotactic radiosurgery and stereotactic radiotherapy alone and in combination with other types of radiation therapy.

9. **What other methods are in use or being studied to improve external radiation therapy?**

A number of refinements and techniques are in use or under study to improve the effectiveness of external radiation therapy. These are described below:

- **Three-dimensional (3–D) conformal radiation therapy**. Traditionally, the planning of radiation treatments has been done in two dimensions (width and height). Three-dimensional (3–D) conformal radiation therapy uses computer technology to allow doctors to more precisely target a tumor with radiation beams (using width, height, and depth). Many radiation oncologists use this technique. A 3–D image of a tumor can be obtained using computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), or single photon emission computed tomography (SPECT). Using information from the image, special computer programs design radiation beams that “conform” to the shape of the tumor. Because the healthy tissue surrounding the tumor is largely spared by this technique, higher doses of radiation can be used to treat the cancer. Improved outcomes with 3–D conformal radiation therapy have been reported for nasopharyngeal, prostate, lung, liver, and brain cancers.

- **Intensity-modulated radiation therapy (IMRT)**. IMRT is a new type of 3–D conformal radiation therapy that uses radiation beams (usually x-rays) of varying intensities to deliver different doses of radiation to small areas of tissue at the same time. The technology allows for the delivery of higher doses of radiation within the tumor and lower doses to nearby healthy tissue. Some techniques deliver a higher dose of radiation to the patient each day, potentially shortening the overall treatment time and improving the success of the treatment. IMRT may also lead to fewer side effects during treatment.

  The radiation is delivered by a linear accelerator that is equipped with a multileaf collimator (a collimator helps to shape or sculpt the beams of radiation). The equipment can be rotated around the patient so that radiation beams can be sent from the best angles. The beams conform as closely as possible to the shape of the tumor. Because IMRT equipment is highly specialized, not every radiation oncology center uses IMRT.

  This new technology has been used to treat tumors in the brain, head and neck, nasopharynx, breast, liver, lung, prostate, and uterus. However, IMRT is not appropriate or necessary for every patient or tumor type. Long-term results following treatment with IMRT are becoming available.

10. What are low-LET and high-LET radiation?

Linear energy transfer (LET) describes the rate at which a type of radiation deposits energy as it passes through tissue. Higher levels of deposited energy cause more cells to be killed by a given dose of radiation therapy. Different types of radiation have different levels of LET. For example, x-rays, gamma rays, and electrons are known as low-LET radiation. Neutrons, heavy ions, and pions are classified as high-LET radiation.

Most high-LET radiation is investigational treatment. The cost of the equipment and the amount of specialized training needed to perform high-LET radiation therapy restrict its use to only a few facilities in the United States.

11. Who plans and delivers the radiation treatment to the patient?

Many health care providers help to plan and deliver radiation treatment to the patient. The radiation therapy team includes the radiation oncologist, a doctor who specializes in using radiation to treat cancer; the dosimetrist, who determines the proper radiation dose; the radiation physicist, who makes sure that the machine delivers the right amount of radiation to the correct site in the body; and the radiation therapist, who gives the radiation treatment. Often, radiation treatment is only one part of the patient's total therapy. Combined modality therapy, the use of radiation with drug therapy, is commonly used.

The radiation oncologist also works with the medical or pediatric oncologist, surgeon, radiologist (a doctor who specializes in creating and interpreting pictures of areas inside the body), pathologist (a doctor who identifies diseases by studying cells and tissues under a microscope), and others to plan the patient's total course of therapy. A close working relationship between the radiation oncologist, medical or pediatric oncologist, surgeon, radiologist, and pathologist is important in planning the total therapy.

12. What is treatment planning, and why is it important?

Because there are so many types of radiation and many ways to deliver it, treatment planning is a very important first step for every patient who will have radiation therapy. Before radiation therapy is given, the patient's radiation therapy team determines the amount and type of radiation the patient will receive.

If the patient will have external radiation, the radiation oncologist uses a process called **simulation** to define where to aim the radiation. During simulation, the patient lies very still on an examining table while the radiation therapist uses a special x-ray machine to define the treatment port or field—the exact place on the body where the radiation will be aimed. Most patients have more than one treatment port. Simulation may also involve CT scans or other imaging studies to help the radiation therapist plan how to direct the radiation. The simulation may result in some changes to the treatment plan so that the greatest possible amount of healthy tissue can be spared from receiving radiation.

The areas to receive radiation are marked with either a temporary or permanent marker, tiny dots or a "tattoo" showing where the radiation should be aimed. These marks are also used to determine the exact site of the initial treatments if the patient should need radiation treatment later.

Depending on the type of radiation treatment, the radiation therapist may make body molds or other devices that keep the patient from moving during treatment. These are usually made from foam, plastic, or plaster. In some cases, the therapist will also make shields that cannot be penetrated by radiation to protect organs and tissues near the treatment field.

When the simulation is complete, the radiation therapy team meets to decide how much radiation is needed (the dose of radiation), how it should be delivered, and how many treatments the patient should have.

13. What are radiosensitizers and radioprotectors?

Radiosensitizers and radioprotectors are chemicals that modify a cell's response to radiation. Radiosensitizers are drugs that make cancer cells more sensitive to the effects of radiation therapy. Several compounds are under study as radiosensitizers. In addition, some anticancer drugs, such as 5-fluorouracil and cisplatin, make cancer cells more sensitive to radiation therapy.

Radioprotectors (also called radioprotectants) are drugs that protect normal (noncancerous) cells from the damage caused by radiation therapy. These agents promote the repair of normal cells that are exposed to radiation. Amifostine (trade name Ethyol®) is the only drug approved by the U.S. Food and Drug Administration (FDA) as a radioprotector. It helps to reduce the dry mouth that can occur if the parotid glands (which help to produce saliva and are located near the ear) receive a large dose of radiation. Additional studies are under way to determine whether amifostine is effective when used with radiation therapy to treat other types of cancer. Other compounds are also under study as radioprotectors.

14. What are radiopharmaceuticals? How are they used?

Radiopharmaceuticals, also known as radionucleotides, are radioactive drugs used to treat cancer, including thyroid cancer, cancer that recurs in the chest wall, and pain caused by the spread of cancer to the bone (bone metastases). The most commonly used radiopharmaceuticals are samarium 153 (Quadramet®) and strontium 89 (Metastron™). These drugs are approved by the FDA to relieve pain caused by bone metastases. Both agents are given intravenously (by injection into a vein), usually on an outpatient basis; sometimes they are given in addition to external beam radiation. Other types of radiopharmaceuticals, such as phosphorous 32, rhodium 186, and gallium nitrate, are not used as frequently. Still other radiopharmaceuticals are under investigation.

15. What are some new approaches to radiation therapy?

Hyperthermia, the use of heat, is being studied in conjunction with radiation therapy. Researchers have found that the combination of heat and radiation can increase the response rate of some tumors.

Researchers are also studying the use of radiolabeled antibodies to deliver doses of radiation directly to the cancer site (radioimmunotherapy). Antibodies are highly specific proteins that are made by the body in response to the presence of antigens (substances recognized as foreign by the immune system). Some tumor cells contain specific antigens that trigger the production of tumor-specific antibodies. Large quantities of these antibodies can be made in the laboratory and attached to radioactive substances (a process known as radiolabeling). Once injected into the body, the antibodies seek out cancer cells, which are destroyed by the radiation. This approach can minimize the risk of radiation damage to healthy cells.

The success of this technique depends on identifying appropriate radioactive substances and determining the safe and effective dose of radiation that can be delivered in this way. Two radioimmunotherapy treatments, ibritumomab tiuxetan (Zevalin®) and tositumomab and iodine 131 tositumomab (Bexxar®), have been approved for advanced adult non-Hodgkin lymphoma (NHL). Clinical trials of radioimmunotherapy are under way with a number of cancers, including leukemia, NHL, colorectal cancer, and cancers of the liver, lung, brain, prostate, thyroid, breast, ovary, and pancreas.

Scientific advances have led to the discovery of new targets that are being investigated to attract radioactive materials directly to cancer cells. Laboratory and clinical research is in progress using the new molecular therapeutic agents, such as gefitinib (Iressa®) and imatinib mesylate (Gleevec®), with radiation therapy.

16. Where can people find more information about radiation therapy?

The National Cancer Institute (NCI) booklet *Radiation Therapy and You: Support for People With Cancer* has more information about this topic. This publication is available from the NCI Publications Locator Web site at http://www.cancer.gov/publications on the Internet, and from the NCI's Cancer Information Service (see below).

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Related NCI materials and Web pages:

- National Cancer Institute Fact Sheet 2.11, *Clinical Trials: Questions and Answers* (http://www.cancer.gov/cancertopics/factsheet/Information/clinical-trials)
- National Cancer Institute Fact Sheet 7.3, *Hyperthermia in Cancer Treatment: Questions and Answers* (http://www.cancer.gov/cancertopics/factsheet/Therapy/hyperthermia)
- National Cancer Institute Fact Sheet 7.7, *Photodynamic Therapy for Cancer: Questions and Answers* (http://www.cancer.gov/cancertopics/factsheet/Therapy/photodynamic)
- National Cancer Institute Fact Sheet 7.47, *How To Find a Doctor or Treatment Facility If You Have Cancer* (http://www.cancer.gov/cancertopics/factsheet/Therapy/doctor-facility)
- National Cancer Institute Fact Sheet 7.49, *Targeted Cancer Therapies: Questions and Answers* (http://www.cancer.gov/cancertopics/factsheet/Therapy/targeted)
- *Radiation Therapy and You: Support for People With Cancer* (http://www.cancer.gov/cancertopics/radiation-therapy-and-you)

For more help, contact:

NCI's Cancer Information Service
Telephone (toll-free): 1–800–4–CANCER (1–800–422–6237)
TTY (toll-free): 1–800–332–8615
LiveHelp® online chat: https://cissecure.nci.nih.gov/livehelp/welcome.asp

This fact sheet was reviewed on 8/25/04