The Science Behind Radiation Therapy

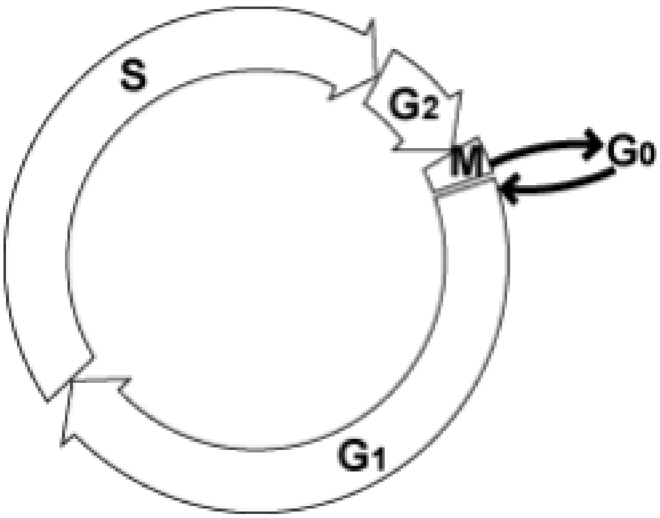
Here you'll find a more in-depth discussion of what radiation therapy is and how it is used to treat cancer.

How does radiation work to treat cancer?

Radiation is energy that's carried by waves or a stream of particles. Radiation works by damaging the genes (DNA) in cells. Genes control how cells grow and divide. When radiation damages the genes of cancer cells, they can't grow and divide any more. Over time, the cells die. This means radiation can be used to kill cancer cells and shrink tumors.

The cell cycle

To understand how radiation works as a cancer treatment, it helps to know the normal life cycle of a cell. The cell cycle has 5 phases, one of which is the actual splitting of the cell. When a cell splits, or divides, into 2 cells, it’s called *mitosis*. This 5-phase process is controlled by proteins known as *cyclin-dependent kinases* (CDKs). Because CDKs are so important to normal cell division, they too have a number of control mechanisms.



The cell cycle

G0 = Cell rests (it’s not dividing) and does its normal work in the body

G1 = RNA and proteins are made for dividing

S = Synthesis (DNA is made for new cells)

G2 = Apparatus for mitosis is built

M = Mitosis (the cell divides into 2 cells)

Steps of the cell cycle

G0 phase (resting stage): The cell has not yet started to divide. Cells spend much of their lives in this phase, carrying out their day-to-day body functions, not dividing or preparing to divide. Depending on the type of cell, this stage can last for a few hours or many years. When the cell gets the signal to divide, it moves into the G1 phase.

G1 phase: The cell gets information that determines if and when it will go into the next phase. It starts making more proteins to get ready to divide. The RNA needed to copy DNA is also made in this phase. This phase lasts about 18 to 30 hours.

S phase: In the S phase, the chromosomes (which contain the genetic code or DNA) are copied so that both of the new cells to be made will have the same DNA. This phase lasts about 18 to 20 hours.

G2 phase: More information about if and when to proceed with cell division is gathered during this phase. The G2 phase happens just before the cell starts splitting into 2 cells. It lasts from 2 to10 hours.

M phase (mitosis): In this phase, which lasts only 30 to 60 minutes, the cell actually splits into 2 new cells that are exactly the same.

Cells and radiation

The cell cycle phase is important because usually radiation first kills the cells that are actively dividing. It doesn't work very quickly on cells that are in the resting stage (G0) or are dividing less often. The amount and type of radiation that reaches the cell and the speed of cell growth affect whether and how quickly the cell will die or be damaged. The term *radiosensitivity* describes how likely the cell is to be damaged by radiation.

Cancer cells tend to divide quickly and grow out of control. Radiation therapy kills cancer cells that are dividing, but it also affects dividing cells of normal tissues. The damage to normal cells causes unwanted side effects. Radiation therapy is always a balance between destroying the cancer cells and minimizing damage to the normal cells.

Radiation doesn't always kill cancer cells or normal cells right away. It might take days or even weeks of treatment for cells to start dying, and they may keep dying off for months after treatment ends. Tissues that grow quickly, such as skin, bone marrow, and the lining of the intestines are often affected right away. In contrast, nerve, breast, brain, and bone tissue show later effects. For this reason, radiation treatment can cause side effects that might not be seen until long after treatment is over.

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Types of radiation used to treat cancer

Radiation used for cancer treatment is called **ionizing radiation** because it forms ions (electrically charged particles) in the cells of the tissues it passes through. It creates ions by removing electrons from atoms and molecules. This can kill cells or change genes so the cells stop growing.

Other forms of radiation such as radio waves, microwaves, and visible light waves are called **non-ionizing**. They don't have as much energy and are not able to form ions.

Ionizing radiation can be sorted into 2 major types:

- Photon radiation (x-rays and gamma rays)
- Particle radiation (such as electrons, protons, neutrons, carbon ions, alpha particles, and beta particles)

Some types of ionizing radiation have more energy than others. The more energy, the more deeply the radiation can penetrate (get into) the tissues.

The way each type of radiation behaves is important in planning radiation treatments. A radiation oncologist (a doctor specially trained to treat cancer with radiation) selects the type of radiation that's most suitable for each patient's cancer type and location.

Photon radiation

A high-energy **photon beam** is by far the most common form of radiation used for cancer treatment. It is the same type of radiation that is used in x-ray machines, and comes from a radioactive source such as cobalt, cesium, or a machine called a *linear accelerator* (linac, for short). Photon beams of energy affect the cells along their path as they go through the body to get to the cancer, pass through the cancer, and then exit the body.

Particle radiation

Electron beams or **particle beams** are also produced by a linear accelerator. Electrons are negatively charged parts of atoms. They have a low energy level and don't penetrate deeply into the body, so this type of radiation is used most often to treat the skin, as well as tumors and lymph nodes that are close to the surface of the body.

Proton beams are a form of particle beam radiation. Protons are positively charged parts of atoms. They release their energy only after traveling a certain distance and cause little damage to the tissues they pass through. This makes them very good at killing cells at the end of their path. So, proton beams are thought to be able to deliver more radiation to the cancer while doing less damage to nearby normal tissues.

Proton beam radiation therapy is used routinely for certain types of cancer, but still need more study in treating others. It requires highly specialized equipment and is not widely available.

Some of the techniques used in proton treatment can also expose the patient to neutrons (see below).

Neutron beams are used for some cancers of the head, neck, and prostate and for certain inoperable tumors. A neutron is a particle in many atoms that has no charge. Neutron beam radiation can sometimes help when other forms of radiation therapy don't work. Few facilities in the United States offer it, and use has declined partly because it can be difficult to target the beams effectively. Because neutrons can damage DNA more than photons, effects on normal tissue can be more severe.

Carbon ion radiation can be helpful in treating cancers that don't usually respond well to radiation (called *radioresistant* cancers). It's also called *heavy ion radiation* because it uses a particle that's heavier than a proton or neutron. The particle is part of the carbon atom, which itself contains protons, neutrons, and electrons. Because it's so heavy, it can do more damage to the target cell than other types of radiation. As with protons, the beam of carbon ions can be adjusted to do the most damage to the cancer cells at the end of its path. But the effects on nearby normal tissue can be more severe. This type of radiation is only available in a few centers in the world.

Alpha and beta particles are mainly produced by special radioactive substances that may be injected, swallowed, or put into the body. They're most often used in imaging tests, but can be helpful in treating cancer. You can read more about these in Radiopharmaceuticals.

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Goals of radiation therapy

Most types of radiation are considered *local* treatments because the radiation is aimed at a specific area of the body (where there's a tumor). Only cells in that area are affected. Most forms of radiation therapy can't reach all parts of the body, which means they're not helpful in treating cancer that has spread to many distant areas.

Radiation is used to treat cancer in several ways.

To cure or shrink early stage cancer

Some cancers are very sensitive to radiation. Radiation may be used by itself in these cases to make the cancer shrink or disappear completely. Sometimes, a few cycles of chemotherapy are given first. For other cancers, radiation may be used before surgery (as *pre-operative* or *neoadjuvant therapy*) to shrink the tumor, or after surgery to help prevent the cancer from coming back (this is called *adjuvant therapy*).

For certain cancers that can be cured either by radiation or by surgery, radiation may be preferred because it can sometimes preserve the organ's function (such as that of the larynx or the anus).

In treating some types of cancer, radiation may also be used along with chemotherapy (chemo). This is because certain chemo drugs act as *radiosensitizers;* they make the cancer cells more sensitive to radiation. These drugs make the radiation work better. The drawback of giving chemo and radiation together is that side effects tend to be worse.

When radiation is used along with other forms of therapy, the treatment is planned by the surgeon, medical oncologist, and radiation oncologist, as well as the patient.

To stop cancer from recurring (coming back) somewhere else

If a type of cancer is known to spread to a certain area, doctors often assume that a few cancer cells might already have spread there, even when imaging scans (such as CT or MRI) show no tumors. That area may be treated to keep these cells from growing into tumors. For example, people with some types of lung cancer may get *preventive* (or *prophylactic*) *radiation* to the head because this type of cancer often spreads to the brain. Sometimes, radiation to prevent future cancer can be given at the same time that radiation is given to treat existing cancer, especially if the prevention area is close to the tumor itself.

To treat symptoms caused by advanced cancer

Sometimes cancer spreads too far to be cured. But even some of these tumors can still be treated to make them smaller so that the person can feel better. Radiation might help relieve symptoms such as pain, trouble swallowing or breathing, or bowel blockages that can be caused by advanced cancer. This is often called *palliative radiation*.

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Who gives radiation treatments?

During your radiation therapy, you will be cared for by a team of medical professionals. Some of the people on that team may include:

- A **radiation oncologist** is a doctor specially trained to treat cancer with radiation. This doctor will make many of the decisions about your treatment.
- The **radiation physicist**makes sure that the radiation equipment is working the way it should and that it delivers the dose of radiation your doctor prescribes.
- The **dosimetrist** helps the doctor plan and calculate the needed number of treatments. The dosimetrist is supervised by the radiation physicist.
- The **radiation therapist** or**radiation therapy technologist**operates the radiation equipment and positions you for treatment.
- A **radiation therapy nurse** isa registered nurse with special training in cancer treatment. He or she will be able to give you information about your radiation treatment and advice on how to deal with any side effects you might have.

You also may need the services of a dietitian,a physicaltherapist,a social worker, a dentist, a dental oncologist, or other health care professionals.

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How is radiation given?

Most people think of radiation therapy as coming from a machine outside of the body, but radiation therapy can be given in a number of ways. Sometimes radiation is given more than one way at the same time, or different types of radiation may be given one after the other. Some ways radiation can be given include:

- External beam radiation
- Brachytherapy or internal radiation
- Radiopharmaceuticals

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External beam radiation

External beam radiation is the most widely used type of radiation therapy, and it most often uses photon beams. The radiation comes from a machine outside the body and is focused on the cancer. It's a lot like getting an x-ray, but for longer. This type of radiation is most often given by machines called *linear accelerators* (linacs).

External beam radiation can be used to treat large areas of the body. It also can treat more than one area, such as the main tumor and nearby lymph nodes. External radiation is usually given daily over several weeks. It's given in an outpatient clinic or treatment center, so you don't have to stay in the hospital. The radiation is aimed at the cancer, but in most cases it affects the normal tissue it passes through on its way into and out of the body. (Intensity modulated proton therapy (IMPT), described below, works differently, but is not used very often.)

Special ways to deliver external beam radiation

Three-dimensional conformal radiation therapy (3D-CRT)

This technique uses imaging scan pictures and special computers to map the location of a tumor very precisely in 3 dimensions. The patient is fitted with a plastic mold or cast to keep the body part still during treatment. The radiation beams are matched to the shape of the tumor and delivered to the tumor from several directions. Careful aiming of the radiation beam may help reduce radiation damage to normal tissues and better fight the cancer by increasing the radiation dose to the tumor. Photon beams or particles (like protons) can be used in this way. A drawback of 3D-CRT is that it can be hard to see the full extent of some tumors on imaging tests, and any part not seen will not get treated with this therapy.

Intensity modulated radiation therapy (IMRT)

This is an advanced form of external radiation therapy. As with 3D-CRT, computer programs are used to precisely map the tumor in 3 dimensions. But along with aiming photon beams from several directions, the intensity (strength) of the beams can be adjusted. This gives even more control over the dose, decreasing the radiation reaching sensitive normal tissues while delivering higher doses to the tumor.

A variation of IMRT is called *volumetric modulated arc therapy*. It uses a machine (called *RapidArc*®) that delivers the radiation quickly as it rotates once around the body. This allows each treatment to be given over just a few minutes. Although this can be more convenient for the patient, it's not yet clear if it's more effective than regular IMRT.

Because of its precision, it's even more important that a person remain in the right position and be perfectly still during treatment. A special cast or mold may be made to keep the body in place during treatment. Again, miscalculations in tumor size and exact location can mean missed areas will not get treated.

Because IMRT uses a higher total dose of radiation, it may slightly increase the risk of second cancers later on. This is something researchers are looking into.

Image-guided radiation therapy (IGRT) is an option on some newer radiation machines that have imaging scanners built into them. This advance lets the doctor take pictures of the tumor and make minor aiming adjustments just before giving the radiation. This may help deliver the radiation even more precisely. It might result in fewer side effects, but more research is needed to prove this.

Intensity modulated proton therapy (IMPT) is IMRT using proton beams instead of photon beams. Protons are parts of atoms that in theory can deliver radiation to the area that they are aimed at (like the cancer), while doing less damage to nearby normal tissues. Still, there have been no studies showing that proton beam radiation is better than the more common photon beam in terms of cancer outcomes or side effects. In fact, a 2012 study of proton beam therapy used to treat localized prostate cancer did not show fewer side effects compared to the more common photon beam radiation. More study on this is needed. Meanwhile, IMPT is often used for tumors near critical body structures such as the eye, the brain, and the spine.

Protons can only be sent out by a special machine called a *cyclotron* or *synchrotron*. This machine costs millions of dollars and requires expert staff to use and maintain it. Because of this, proton beam therapy is expensive, and very few treatment centers in the United States offer it. Many more studies are needed to compare outcomes between proton and photon treatment so that each is used for the cancer type for which it works best.

Stereotactic radiosurgery (SRS) and fractionated stereotactic radiotherapy

These use advanced image-guided techniques to deliver a large, precise dose of radiation to a small, well-defined tumor. The term “surgery” may be confusing because no cutting is involved. This technique is used to treat tumors that start in or spread to the brain or head and neck region. If the radiation is given as a single dose, it’s called *stereotactic radiosurgery*. If the radiation is spread out over several doses, it’s called *fractionated stereotactic radiotherapy*.

When the radiation is aimed at the head, a frame or shell is used to hold the head still and allow for precise aiming of radiation beams.

A related term, **stereotactic body radiation therapy (SBRT)**, is used to describe this technique when it’s used for tumors in other parts of the body, for instance, the spine, liver, pancreas, kidney, lung, and prostate.

Once the exact location of the tumor is mapped (using imaging scans), narrow radiation beams from a machine called a *Gamma Knife*® are focused at the tumor from hundreds of different angles for a short time. The process may be repeated if needed. Another approach that’s much like this uses a movable linear accelerator controlled by a computer. Instead of delivering many beams at once, the linear accelerator moves around to deliver radiation to the tumor from different angles. Several machines, with names like X-Knife®, CyberKnife®, and Clinac® work in this way.

Intraoperative radiation therapy (IORT)

With this technique, radiation is given during surgery. The radiation may be given using a machine for external beam radiation (a linear accelerator). Another option is to put a radioactive substance into the treatment area for a short time (like brachytherapy). IORT is often used along with a course of external radiation given before or after the operation.

IORT is useful for cancers that are deep inside the body, because normal tissues can be moved aside during surgery, exposing the cancer. After as much tumor is removed as possible, one large dose of radiation is directed straight at the cancer without going through normal tissues. Shielding can also be used to further protect the nearby normal tissues. IORT is given in a special operating room lined with radiation-shielding walls.

IORT is most often used for abdominal (belly area) or pelvic cancers that cannot be completely removed (such as those that have grown close to vital body parts) and for cancers that tend to grow back after treatment. This technique is not widely available.

Electromagnetic-guided radiation therapy

This is another way of aiming the radiation beam that can be used with 3D and IMRT. It uses tiny electromagnetic implants (called *transponders*) that are placed into the area being treated. These implants send out radio waves to tell the radiation therapy machines where to aim. This lets the machine compensate for movement (like during breathing) and may help keep some of the radiation from going to normal tissues. It also helps to refocus radiation beams as organs shift or cancer shrinks over time. It's sometimes known as *4-D therapy*, because it includes time in the radiation planning formula. One such system is marketed under the brand name Calypso®. In theory, better focusing radiation could lower side effects. So far, though, studies have not found this type of radiation to be better for patients than other approaches.

Treatment planning for external beam radiation

The process of planning external beam radiation therapy has many steps and may take several days to complete. But it's a key part of successful radiation treatment. The radiation team will design a treatment just for you. The treatment will give the strongest dose of radiation to the cancer while sparing normal tissue as much as possible.

The first part of treatment planning is called *simulation*. It's sometimes referred to as a "marking session." You'll be asked to lie still on a table while the health care team works out the best treatment position for you and how to keep you in that position (tape, headrests, casts, body molds, or foam pillows may be used). They will then mark the *radiation field* (also called the *treatment port*), which is the exact place on your body where the radiation will be aimed. The marks may be done with permanent markers or with tattoos that look like tiny freckles. If you don't want to be tattooed, ask beforehand how your radiation marking will be done and what your options are.

Your doctor may use imaging tests to check the size of the tumor, figure out where it's most likely to have spread, outline normal tissues in the treatment area, take measurements, and plan your treatment. Photos may also be taken and are used to make the daily treatment set-up easier.

Through a complex process called *dosimetry*, computer programs are used to find out how much radiation the nearby normal structures would be exposed to if the prescribed dose were delivered to the cancer. The doctor and dosimetrist will work together to decide on the amount of radiation you need to get and the best ways to aim it at the cancer. They base this on the size of the tumor, how sensitive the tumor is to radiation, and how well the normal tissue in the area can withstand the radiation.

Dosing and treatment with external beam radiation

The total amount of radiation you'll get is measured in units called *Gray* (Gy). Often the dose is expressed in *centigray* (cGy), which is one-hundredth of a Gray.

For external radiation, the total dose is often divided into smaller doses (called *fractions*) that are typically given over a number of weeks. This allows the best dose to be given with the least damage to normal tissues. Treatments are usually given 5 days a week, for about 5 to 8 weeks.

Some cancers may be treated more often than once a day.

- **Hyperfractionated radiation** divides the daily dose into 2 treatment sessions without changing the length of the treatment. In this case, you would be treated twice a day for several weeks.
- **Accelerated radiation** gives the total dose of radiation over a shorter period of time. In other words, giving more frequent doses (more than once a day) to get the same total dose of radiation; it may shorten the course of treatment by a week or two.
- **Hypofractionated radiation** breaks radiation into fewer doses, so that each dose is larger. Sometimes, this could mean it's given less often than once a day.

These types of schedules can make the radiation work better for some tumors. The down side is that radiation side effects are seen earlier and may be worse, even though it doesn't increase the radiation's late effects.

It’s important that you are in the correct position each time so the right amount of radiation will be given to the right area. The marks on your skin will show where treatment is to be focused. You’ll need to stay very still and in the same position during each treatment, which can last up to 30 minutes. Sometimes a special mold or cast of the body part to be treated will be used to hold you in a certain position. This helps make sure you’re in the right place and helps you stay still. Your health care team may also need to make special blocks or shields to protect certain parts of your body from radiation during treatment.

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Internal radiation therapy (brachytherapy)

Internal radiation therapy is also known as *brachytherapy*, which means short-distance therapy. With this method, sources of radiation are put into or near the area that needs treatment. The radiation only travels a short distance, so there’s less risk of damaging nearby normal tissues. Brachytherapy can be used to deliver a high dose of radiation to a small area in a fairly short period of time. It’s useful for tumors that need a high dose of radiation or are near normal tissues that are easily hurt by radiation.

The main types of internal radiation are:

- **Interstitial radiation:** the radiation source is placed directly into or next to the tumor using small pellets, seeds, wires, tubes, or containers.
- **Intracavitary radiation:** a container of radioactive material is placed in a cavity of the body such as the chest, rectum, uterus, or vagina.

Ultrasound, x-rays, or CT scans are used to help the doctor put the radioactive source in the right place. The placement can be permanent or temporary.

Permanent brachytherapy uses small containers, often called *pellets* or *seeds*, which are about the size of a grain of rice. They are put right into the tumors using thin, hollow needles. Once in place, the pellets give off radiation for several weeks or months. Because they are very small and cause little discomfort, they are simply left in place after their radioactive material is used up.

Temporary brachytherapy can be *high-dose rate* (HDR) or *low-dose rate* (LDR). Either type places cylinders, hollow needles, tubes (catheters), or fluid-filled balloons into the area to be treated, and then they're removed after treatment. Radioactive material can be put in these containers for a short time and then removed. This may be done by hospital staff or the radioactive material can be put into the device remotely by machine.

- **For HDR brachytherapy**, the radiation source is put into place for a few minutes at a time, and then removed. This process may be repeated twice a day for up to a week, or once a week for a few weeks.
- **For LDR brachytherapy**, the radiation source stays in place for up to 7 days. To keep the implant from moving, you'll need to stay in bed and lie fairly still. For this reason, you will stay in the hospital during LDR therapy.

Treatment with internal radiation

Severe pain or illness isn't likely while putting in radioactive implants or the catheters, devices, or tubes for temporary placement of radioactive materials. You may feel sleepy, weak, or nauseated for a short time if you get anesthesia (drugs that make you sleepy) while the implant or device is put in place. Tell the nurse if you have any unusual side effects such as burning or sweating.

Anesthesia usually isn't needed to take out temporary brachytherapy implants. Most can be taken out right in your hospital room. (The room is specially shielded to contain the radioactivity and the staff use mobile shields to protect themselves while handling radioactive materials.) If you had to stay in bed during implant therapy, you might have to stay in the hospital an extra day or so after the implant is removed. This is just to be sure you have no problems in the area where the implants were placed.

Once implants are removed, there's no radioactivity in your body. The doctor will tell you if you should limit your physical activity for a time. Most patients are encouraged to do as much as they can. Some people need extra sleep or rest breaks during their first days at home, but you'll probably feel stronger quickly. The area that has been treated with an implant may be sore or sensitive for some time after treatment.

Radioembolization

This is a special type of internal radiation that's now used only for cancer in the liver that can't be surgically removed. Small radioactive beads (called *microspheres*) are injected into the artery that feeds the liver tumor. Brand names for these beads include TheraSphere® and SIR-Spheres®. Once infused, the beads lodge in blood vessels near the tumor, where they give off small amounts of radiation to the tumor site for several days. The radiation travels a very short distance, so its effects are limited mainly to the tumor. In some cases, it can cause other problems, like ulcers in the intestine, low white blood cell counts, lung damage, or serious damage to the normal liver cells.

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Radiopharmaceuticals

Radiopharmaceuticals are drugs that contain radioactive materials called *radioisotopes*. They may be put into a vein, taken by mouth, or placed in a body cavity. Depending on the drug and how it's given, these materials travel to various parts of the body to treat cancer or relieve its symptoms. They put out radiation, mostly in the form of alpha and beta particles that target the affected areas. They're most often used in small amounts for imaging tests, but larger doses can be used to deliver radiation.

Treatment of bone pain

Strontium-89 (Metastron®), samarium-153 (Quadramet®), and radium-223 (Xofigo®) are radiopharmaceuticals that can be used for tumors that have spread to the bones (bone metastases). Other drugs are also being studied. These medicines are given in veins (intravenously or IV), so that they go into the blood circulation. They travel through the body and build up in the areas of the bone where there is cancer. The radiation they give off then kills cancer cells and eases the pain caused by bone metastases.

For cancer that has already spread to several bones, this approach can be better than trying to aim external beam radiation at each affected bone. These drugs may be used along with external beam radiation which is aimed at the most painful bone metastases. This combined approach has helped many men with prostate cancer, but it has not been studied as much for use in other cancers.

Some people notice more bone pain for the first couple of days after treatment, but this isn't common. These drugs can also lower blood cell counts, especially white blood cells (which can increase the risk of infection) and platelets (which can raise the risk of bruising or bleeding).

Treatment of thyroid cancer

The thyroid gland absorbs nearly all of the iodine in the blood. Because of this, *radioactive iodine* (also called *radioiodine* or *iodine-131*) can be used to destroy the thyroid gland and thyroid cancer with little effect on the rest of the body. This treatment is often used after thyroid cancer surgery to destroy any thyroid cells left behind. It's also used to treat some types of thyroid cancer that spread to lymph nodes and other parts of the body.

Phosphorus-32

This form of phosphorus (also known as *P-32* or *chromic phosphate P 32*) is put inside brain tumors that are cystic (hollow) to kill the tumor without hurting the healthy parts of the brain.

In the past, P-32 was given into a vein (as an IV) as a common treatment for a blood disease called *polycythemia vera*. P-32 was also placed inside the abdomen (belly) as a treatment for ovarian cancer. It's rarely used in these ways today, because there are better drugs with fewer side effects.

Radio-labeled antibodies

Monoclonal antibodies are man-made versions of immune system proteins that attack only a specific molecular target on certain cancer cells. Scientists have learned how to pair these antibodies with radioactive atoms. When put into the bloodstream, the antibodies act as homing devices. They attach only to their target, bringing tiny packets of radiation directly to the cancer.

Radio-labeled antibodies are used to treat some non-Hodgkin lymphomas, especially those that don't respond to other treatments.

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Does radiation therapy cause second cancers?

The link between radiation and cancer was confirmed many years ago through studies of the survivors of the atomic bombs in Japan, the exposures of workers in certain jobs, and patients treated with radiation therapy for cancer and other diseases.

Some cases of leukemia are related to past radiation exposure. Most develop within a few years of exposure, with the risk peaking at 5 to 9 years, and then slowly declining. Other types of cancer that develop after radiation exposure have been found to take much longer to show up. These are solid tumor cancers, like breast or lung cancer. Most are not seen for at least 10 years after radiation exposure, and some are diagnosed even more than 15 years later.

Radiation therapy techniques have steadily improved over the last few decades. Treatments now target the cancers more precisely, and more is known about setting radiation doses. These advances are expected to reduce the number of secondary cancers that result from radiation therapy. Overall, the risk of second cancers is low and must be weighed against the benefits gained with radiation treatments.

To learn more about this, see Second Cancers in Adults.

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What’s new in radiation therapy?

New ways of delivering radiation therapy are making it safer and more effective. Some of these methods are already being used, while others need more study before they can be approved for widespread use. And scientists around the world continue to look for better and different ways to use radiation to treat cancer. Here are just a few areas of current research interest:

Hyperthermia is the use of heat to treat cancer. Heat has been found to kill cancer cells, but when used alone it does not destroy enough cells to cure the cancer. Heat created by microwaves and ultrasound is being studied in combination with radiation and appears to improve the effect of the radiation. For more information, see Hyperthermia to Treat Cancer*.*

Hyperbaric oxygen therapy consists of breathing pure oxygen while in a sealed chamber that's been pressurized at 1½ to 3 times normal atmospheric pressure. It helps to increase the sensitivity of certain cancer types to radiation. It's also being tested to see if it can reverse some of the damage to normal body tissues caused by radiation.

Radiosensitizers are a growing field in cancer treatment. Researchers are continuing to look for new substances that will make tumors more sensitive to radiation without affecting normal tissues.

Radioprotectors are substances that protect normal cells from radiation. These types of drugs are useful in areas where it's hard not to expose vital normal tissues to radiation when treating a tumor, such as the head and neck area. Some radioprotectors, such as amifostine (Ethyol®), are already in use, while others are being studied in clinical trials.

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To learn more

Other national organizations and websites*

Along with the American Cancer Society, other sources of information and support include:

American Society for Radiation Oncology (ASTRO) Toll-free number: 1-800-962-7876 Website: www.astro.org Website for patients: www.rtanswers.org

- Patient website has a locator of member radiation oncologists; has free brochures, including specific brochures on radiation for bladder, breast, colorectal, gynecologic, head and neck, Hodgkin's, lung, non-Hodgkin's, skin, and prostate cancers

National Cancer Institute Toll-free number: 1-800-422-6237 (1-800-4-CANCER) TTY: 1-800-332-8615 Website: www.cancer.gov Website in Spanish: www.cancer.gov/espanol

- Offers accurate, up-to-date information about cancer and cancer treatments to patients, their families, and the general public.

American College of Radiology (ACR) Website: www.acr.org/Quality-Safety/Radiology-Safety/Patient-Resources

- Has information on radiation and radiation safety, including short videos and apps; also offers an online tool to find ACR-accredited facilities

**Inclusion on this list does not imply endorsement by the American Cancer Society.*

No matter who you are, we can help. Contact us anytime, day or night, for cancer-related information and support. Call us at **1-800-227-2345** or explore our content on www.cancer.org.

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