Radiation Therapy Principles

Radiation and radioactivity were discovered more than 100 years ago. Since then advances in technology and a better understanding of its effects on the body have made radiation therapy an important part of cancer treatment. In fact, more than half of all people with cancer will get radiation as at least part of their cancer treatment.

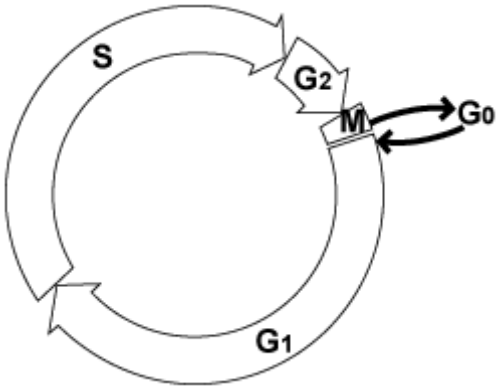
Here we will help you understand what radiation therapy is, how it is used to treat cancer, and what some of the common side effects are. For more detailed information on the possible side effects of radiation and how to deal with them, please see our document called *Understanding Radiation Therapy: A Guide for Patients and Families*.

How does radiation work to treat cancer?

Radiation is energy that is carried by waves or a stream of particles. It damages the genes (DNA) and some of the molecules of a cell. Genes control how cells grow and divide. Radiation damages the genes of a cancer cell so that it cannot grow and divide any more. This means radiation can be used to kill cancer cells and shrink tumors.

To understand how radiation works as a treatment, it is helpful to know about the normal life cycle of a cell. The cell cycle goes through 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*.

The cell life cycle



The cell cycle

G0 = Cell is resting

G1 = RNA and proteins are made

S = DNA is made

G2 = Apparatus for mitosis is built

M = Mitosis (the cell divides into 2 cells)

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

G1 phase: During this phase, the cell starts making more proteins to get ready to divide. Single strands of DNA, called RNA, are also made. This phase lasts about 18 to 30 hours.

S phase: In the S phase, the chromosomes that contain the genetic code (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: The G2 phase is 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.

The cell cycle and radiation

The cell cycle phase is important in cancer treatment because usually radiation first kills the cells that are actively or quickly dividing. It doesn't work so fast on cells that are in the resting stage (G0) or are dividing slowly. 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. Each time radiation therapy is given it means balancing between destroying the cancer cells and minimizing damage to the normal cells.

Radiation does not always kill cancer cells or normal cells right away. It might take days or even weeks of treatment for cells to begin dying, and they may continue to die 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, and bone tissue show later effects. For this reason, radiation treatment can have long-term side effects that might not be seen until long after treatment is over.

In the past, it was thought that once an area was treated with radiation it could not be treated with radiation again because of damage to the normal cells in the treatment area. But research suggests that a second course of radiation therapy can be given to some patients.

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. This can kill cells or change genes so the cells cannot grow.

Other forms of radiation such as radio waves, microwaves, and 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:

- *Photons* (x-rays and gamma rays), which are most widely used
- *Particle radiation* (electrons, protons, neutrons, alpha particles, and beta particles)

Some types of ionizing radiation have more energy than others. The higher the energy, the more deeply the radiation can penetrate (get into) the tissues. The way a certain type of radiation behaves is important in planning radiation treatments. The *radiation oncologist* (a doctor specially trained to treat cancer patients with radiation) selects the type and energy of radiation that is most suitable for each patient's cancer.

Sources of radiation

The more common sources of radiation used for cancer treatment are:

- **High-energy photons** that come from radioactive sources such as cobalt, cesium, or a machine called a *linear accelerator* (or linac, for short). Photon beams of energy

affect the cells along their path as they pass through the body to get to the cancer. This is by far the most common type of radiation treatment in use today.

- **Electron beams** or **particle beams** are also produced by a linear accelerator. These are used for tumors close to a body surface since they do not go deeply into tissues.

- **Proton beams** are a newer form of particle beam radiation. Protons are charged parts of atoms that cause little damage to tissues they pass through but are very good at killing cells at the end of their path. This means that proton beams may be able to deliver more radiation to the cancer while causing fewer side effects to normal tissues. Protons are used routinely for certain types of cancer, but still need more study in treating others. Some of the techniques used in proton treatment can also expose the patient to neutrons (see below). Proton beam radiation therapy requires highly specialized equipment and is currently only offered in certain medical centers. See the section, "What's new in radiation therapy?" for more about protons.

- **Neutron beams** are used for some cancers of the head, neck, and prostate and for inoperable tumors. They can sometimes be helpful when other forms of radiation therapy don't work. Very few facilities in the United States offer this type of treatment. Its use has declined over the years partly because of problems with getting the beams on target. Because neutrons can cause more DNA damage than photons, the effects on normal tissue may be more severe. Beams must be aimed carefully and normal tissue protected. Neutron beams are showing great promise in research with salivary gland cancers that can't be cured with surgery.

Goals of radiation therapy

Radiation is considered a *local* treatment because only cells in and around the cancer are affected. It cannot cure cancer that has already spread to distant parts of the body because most forms of radiation therapy do not reach all parts of the body. Radiation is used to treat cancer in several ways.

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. For other cancers, it may be used before surgery (as *pre-operative therapy*) to shrink the tumor, or after surgery to prevent the cancer from coming back (this is called *adjuvant therapy*). It may also be used along with chemotherapy in some cases. 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.

Stop cancer from recurring (coming back) in another area

If a type of cancer is known to spread to a certain area, doctors often assume that a few cancer cells may have already spread there, even though 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.

Treat symptoms caused by advanced cancer

Some cancers may have spread 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 may help to relieve symptoms such as pain, trouble swallowing or breathing, or bowel problems that can be caused by advanced cancer. This is often called *palliative radiation*.

Who gives radiation treatments?

During your radiation therapy, you will be cared for by a team of medical professionals. Some of the people who may be on that team are listed here.

- A *radiation oncologist* is a doctor specially trained to treat cancer with radiation. This doctor will make many of the decisions regarding 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 prescribed by your doctor.
- 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* is a 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 physical therapist, a social worker, a dentist, a dental oncologist, or other health care professionals.

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.

External beam radiation

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

The radiation is aimed at the tumor, but it also affects the normal tissue it passes through on its way into and out of the body. 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 is given in an outpatient clinic or treatment center, so you do not have to stay in the hospital.

Types of external beam radiation

Three-dimensional conformal radiation therapy (3D-CRT) uses imaging scan pictures and special computers to very precisely map the location of a tumor 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. By aiming the radiation more precisely, it may be possible to reduce radiation damage to normal tissues and better fight the cancer by increasing the radiation dose to the cancer. 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) is an advanced form of external radiation therapy that uses photon beams. 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. Because of its precision, it is even more important that a person remain in the right place 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. IMRT is available mainly in major cancer centers. 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.

A related technique, **intensity modulated proton therapy (IMPT)**, uses proton beams instead of x-rays. Protons are parts of atoms that cause little damage to tissues they pass through but are very good at killing cells at the end of their path. Also, very little of the dose goes beyond the tumor at the end of the beam's path. This means that proton beam radiation may be able to deliver more radiation to the cancer while reducing side effects on nearby normal tissues. It is a good choice for tumors near critical body structures, such as the eye, the brain, and the spine. Protons can only be put out by a special machine called a *cyclotron* or *synchrotron*. This machine costs millions of dollars and requires expert staff. Because of this, proton beam therapy is expensive, and very few treatment centers in the United States offer it. 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 or **stereotactic radiation therapy** delivers a large, precise dose of radiation to a small, well-defined tumor. The term "surgery" may be confusing because no cutting is involved. Some tumors that start in or spread to the brain are treated

with this technique, but it is used for tumors in other places, too, such as the spine, liver, pancreas, kidney, lung, and prostate.

In some cases, a head frame or shell is used to hold the skull still and allow for precise aiming of radiation beams.

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 is 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 such as X-Knife®, CyberKnife®, and Clinac® work in this way.

Intraoperative radiation therapy (IORT) delivers radiation to the cancer during surgery. The radiation may be given externally or internally, and it is often used along with a course of external radiation given before or after the operation.

IORT is useful 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. As much tumor is removed as possible, then one large dose of radiation is directed right at the tumor site. Normal tissues can be moved out of the way and protected, so IORT reduces the amount of tissue that is exposed to radiation. This allows a higher dose of radiation to reach the cancer. IORT is delivered in a special operating room lined with radiation-shielding walls.

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 is important for the success of your radiation treatment. The radiation team will design a treatment just for you. The treatment will give the strongest dose of radiation to the cancer but will spare normal tissue as much as possible.

The first part of treatment planning is called *simulation*. It is sometimes referred to as a "marking session." You will 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. Your doctor may use imaging tests to check the size of the tumor, figure out where it is more likely to spread, outline normal tissues in the treatment area, take measurements, and develop the treatment plan. 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 in order to deliver the prescribed dose to the cancer. The doctor and dosimetrist will work together to decide on the amount of radiation you will 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 will 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 several smaller doses (called *fractions*) that are most often given over a number of weeks. This allows the best dose to be given with the least damage to normal tissues. In most cases, treatments are given 5 days a week, for about 5 to 8 weeks.

For some cancers, patients 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 by giving the same dose of radiation more frequently (more 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.

It is important that you are treated in exactly the same way each time so the right amount of radiation will be given to the right area. For external radiation, small, long-lasting or permanent (tattoo) marks may be put on your skin to show where treatment is to be focused. You will 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.

Internal radiation therapy (brachytherapy)

Internal radiation therapy is also known as brachytherapy, which means short-distance therapy. With this method, radioactive containers are placed into the tumor or into a body cavity close to the tumor. The advantage of brachytherapy is the ability to deliver a high dose of radiation to a small area. It is useful for tumors that need a high dose of radiation or a dose that would be more than the normal tissues could stand if it had to come in from the outside.

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 (long-term) or temporary (short-term).

Permanent brachytherapy involves using small containers, 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 briefly places hollow needles, tubes, or fluid-filled balloons into the area to be treated. 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 about 10 to 20 minutes at a time, and then removed. This process may be repeated twice a day over the course of a few days, 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 will need to stay in bed and lie fairly still. For this reason, you will be kept in the hospital during LDR therapy.

Treatment with internal radiation

Severe pain or illness is not likely to happen during implant therapy. You may feel sleepy, weak, or nauseated for a short time because of the anesthesia (drugs that make you sleepy) used while the implant is put in place. Tell the nurse if you have any unusual side effects such as burning or sweating.

Anesthesia usually is not 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 just to be sure you have no problems in the area where the implants were placed.

Once the implant is removed, there is no radioactivity in your body. (See the section, “Safety for the patient and family” for more on this.) 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 will probably feel stronger quickly. The area that has been treated with an implant may be sore or sensitive for some time after treatment.

Radiopharmaceuticals

Radiopharmaceuticals are drugs containing radioactive materials. They may be put into a vein, taken by mouth, or placed in a body cavity. Depending on the drug and how it is

given, these materials travel to various parts of the body to treat cancer or relieve its symptoms.

Treatment of bone pain

Strontium 89 (Metastron®) and samarium 153(Quadramet®) are radiopharmaceuticals often 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 build up in the areas of the bone where there is cancer. The radiation they give off kills cancer cells and eases the pain caused by bone metastases.

For cancer that has already spread to more than one bone, this approach is much 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 an increase in bone pain for the first couple of days after treatment, but this is not 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 known as *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 that may have been left behind. It is also used to treat some types of thyroid cancer that spread to lymph nodes and other parts of the body. For more information, please see our document called *Thyroid Cancer.*

Small doses of radioiodine can be given without the patient having to be in the hospital, but the usual treatment doses for thyroid cancer require 2 to 3 days in the hospital. Several weeks after treatment, the radioiodine is gone from the body. At that point, doctors can check to see how well the treatment worked.

Short-term side effects of radioiodine treatment are rare, but may include neck tenderness, nausea and stomach irritation, tenderness of the salivary glands, and dry mouth. Large doses may cause low blood cell counts. Men may become infertile (unable to father children) after large doses.

There may be some longer-term risks, too. Large studies have found that there may be a very slight increase in the risk of developing other types of cancer, including leukemia, in the future.

It is recommended that women of childbearing age avoid becoming pregnant during treatment and for at least a year after treatment. If a woman gets pregnant after that, there is no evidence of a higher risk of birth defects or miscarriage. Women treated with radioactive iodine during their childbearing years may have slightly earlier menopause.

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 is 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 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. They might cause allergic reactions when first infused. They might also lower blood cell counts, which can raise the risk of infections, bruising, or bleeding.

Safety for the patient and family

People who get any type of radiation therapy often worry about whether the radiation poses a risk to themselves or to others around them.

If you get **external beam radiation therapy**, you are **NOT** radioactive and do not need to take special precautions to protect others from radiation. Treatments are given in special rooms that contain the radiation. The radiation therapist is not in the room during the treatment but can see you and talk with you over an intercom the whole time.

If you are given a **radiopharmaceutical** such as radioactive iodine, it will leave your body within a few weeks, mainly through your urine, but also through saliva, sweat, and stool. To reduce the exposure of others, you will be asked to follow some basic instructions for the first few days after treatment. Your health care team will tell you about specific precautions, which could include:

- Flushing the toilet twice after each use
- Good hand washing after using the toilet

- Using separate eating utensils and towels (laundry may need to be washed separately)
- Drinking plenty of fluids to help flush the radioactive substance from your body
- No kissing or sexual contact for at least a week
- Keeping a distance of one arm's length between yourself and any others who spend more than 2 hours next to you in any 24-hour period
- Avoiding prolonged contact with infants, children, pregnant women, and pets

For a **temporary internal radiation implant**, you will need to take special precautions only while the implant is in place to avoid exposing others to radiation. With this type of radiation, body fluids such as urine, sweat, blood or stool are usually not radioactive and probably will need no special handling. Your health care team will give you more specific instructions.

If you need to stay in the hospital while you are getting temporary internal radiation therapy, you will most likely be in a private room. Although the nurses and other people caring for you will not be able to spend a long time in your room, they will give you all of the care you need. There will also be limits on visitors while your implant is in place. As a precaution, most hospitals do not let pregnant women or children younger than 18 visit patients who have a radiation implant. Visitors should sit at least 6 feet from your bed and stay for only a short time (less than 30 minutes each day).

Permanent implants use weaker radiation, and patients can usually go home after the implant procedure. If you have permanent implants, such as seed implants, you may need to avoid close contact with other people for the first few days while the radiation is most active. The implant will lose energy each day. For a few weeks or months after the implant, you may be told not to have daily close contact with pregnant women or children for more than just a few minutes. Use of a condom during sex is often recommended for a short time. Talk to your health care team about any special precautions you need to use at home.

Possible side effects of radiation therapy

Normal body tissues vary in their response to radiation. As with tumors, normal tissues in which cells are quickly dividing may be affected. This causes some of the side effects of radiation treatment. Since radiation is a local treatment, side effects depend on the area of the body being treated. The early effects of radiation may be seen a few days or weeks after treatments have started and may go on for several weeks after treatments have ended. Other effects may not show up until months, or even years, later. The most common side effects are discussed below. Please see our document, *Understanding Radiation Therapy: A Guide for Patients and Families* for more ideas on dealing with side effects.

Fatigue

Fatigue is extreme tiredness that does not get better with rest. It is a common effect of radiation, but the exact cause is unknown. Sometimes tumors cause the immune system to make substances that lead to fatigue. Fatigue may also be caused by anemia (a low red blood cell count), poor nutrition, pain, certain drugs such as steroids or chemotherapy, depression, and stress.

There is no single treatment for fatigue, but if a cause can be found it should be treated. For example, if the fatigue is caused by anemia, some patients may benefit from blood transfusions or from medicines that cause the body to make more red blood cells.

Fatigue can last for a long time after treatment is over and some people never have as much energy as they did before treatment. Light or moderate exercise with frequent rest breaks may help to reduce fatigue. Talk with your doctor about this and other treatments that may work for you.

You can learn more about fatigue and how to deal with it in our documents called *Fatigue in People With Cancer* and *Anemia in People With Cancer*.

Skin changes

Radiation therapy today causes less skin damage than it did in the past because most of the radiation dose is delivered below the surface of the skin, but your skin might still show a response to treatments. During the first 2 weeks of treatment, you may notice a faint redness. Your skin may become tender or sensitive. Dryness and peeling may occur in 3 to 4 weeks. After that, the skin over the treatment area may become darker. This is because of the effect radiation has on the cells in the skin that produce pigment (color). You also may lose hair in the skin over the area that is being treated.

The skin in the treatment area may also become dry and itchy. Moisturizing the skin with aloe vera, lanolin, or vitamin E may help. But before using any skin products during treatment, ask the radiation doctor or nurse if it is OK. Some lotions that are safe to use *after* treatment ends can actually make things worse *during* treatment.

Do not use perfumes, deodorants, and skin lotions that contain alcohol or perfume. Also avoid powders unless your doctor or nurse says they’re OK to use. Stay out of the sun as much as you can. If you must be outdoors, wear a hat and clothes that will protect your skin. After about a month of treatment, some people getting radiation may notice skin peeling and moist (weeping) areas. Let your medical care team know if this happens to you.

Later effects of radiation may include thinning of the skin. The skin may feel hard, especially if surgery has also been done in the same area. Some people may have trouble with wound healing in the area that was treated. The skin in the treatment area may always be more sensitive to the sun, and you should be extra careful to protect it when you are outdoors.

Mouth and throat problems

Mucositis (inflammation inside the mouth) is a short-term side effect that can happen when radiation is given to the head and neck area. It usually gets better within a few weeks after treatments are completed. Dry mouth and a loss of taste can be caused by radiation damage to the salivary glands and taste buds. Thick, sticky, rope-like saliva and swallowing problems may develop, too. These side effects often go away after treatments end, but in some cases may be permanent.

Keeping your mouth clean is important to lower your risk of infection. If your mouth becomes sore, you may be given medicine to numb the mouth or help the pain. You may need to take it before meals so that it is easier to eat. Be sure to tell your doctor about any pain and if the medicines to help it are working.

Good nutrition is important for people with cancer. If mouth pain and irritation make it hard to eat or swallow, you may need to have a feeding tube put into your stomach for a while so you can take in enough nourishment. Your health care team will help you develop a plan to manage your symptoms. For more suggestions, see our documents, *Understanding Radiation Therapy: A Guide for Patients and Families*, *Caring for the Patient With Cancer at Home: A Guide for Patients and Families*, and *Nutrition for the Person With Cancer During Treatment: A Guide for Patients and Families*.

Radiation to the head and neck area can affect your teeth, too, and increase your chances of getting cavities. Mouth care to prevent problems will be an important part of your treatment. Before starting radiation, talk to your dentist and have a complete check-up. Also ask your dentist to talk to your radiation oncologist before your radiation treatments begin. Any dental work you need may have to be done before radiation begins and daily fluoride treatments may be prescribed to help protect your teeth.

Side effects of radiation to specific areas

Brain

Radiation therapy to large areas of the brain can sometimes cause changes in brain function that can lead to memory loss, lower sexual desire, or poor tolerance for cold weather. Nausea, unsteady walking, and changes in vision may also be noticed. Usually these symptoms are minor compared to those caused by a brain tumor, but they can be a bother.

Sometimes a large area of dead cells, called *radiation necrosis*, forms at the site of the radiation in the brain. This can happen months to years after radiation is given. Patients with radiation necrosis usually do better than patients whose brain tumors come back. But still, a small number of patients with radiation necrosis do poorly or even die.

Lung

When radiation treatments include the chest area, it can also affect the lungs. One early change is a decrease in the levels of a substance, called *surfactant*, which helps keep the air passages open. Low surfactant levels keep the lungs from fully expanding. This may cause shortness of breath or a cough. These symptoms are sometimes treated with steroids. Depending on the location of the area getting radiation, some people also have trouble swallowing.

Radiation pneumonitis occurs in about 5 to 20% of people have radiation therapy for lung cancer, but can also result from radiation to the chest for breast cancer, lymphomas, or other cancers. This inflammation may occur from about 6 weeks to 6 months after completing external radiation therapy. Common symptoms include shortness of breath, chest pain, cough, and fever. Radiation pneumonitis is treated by trying to decrease the inflammation. Steroids, like prednisone, are usually used.

Another possible effect radiation can have on the lungs is *fibrosis* (stiffening or scarring). This reduces the ability of the lungs to expand and take in air. Fibrosis can cause shortness of breath and less tolerance for physical exercise. This problem may show up months or even years after treatment.

Digestive tract

Radiation to the chest and abdomen (belly) may cause swelling and inflammation in the esophagus (swallowing tube), stomach, or intestine (bowels). This can cause pain, nausea, vomiting, or diarrhea. Antacids, sometimes combined with a numbing medicine such as lidocaine, may help relieve pain from an inflamed esophagus. Nausea and vomiting can also be treated with medicines. If it is severe, some patients may need intravenous (IV) fluids to avoid or treat dehydration. Diarrhea also can be treated with medicines and may be helped by avoiding spicy, fried, or high fiber foods.

Reproductive/sex organs

Fertility: Radiation to the testicles can cause permanent loss of sperm production. Unless the cancer is in the testicles, they can usually be protected from radiation by using a shield called a *clam shell*.

It is harder to protect the ovaries when women are getting radiation to the abdomen (belly). If both ovaries are exposed to radiation, early menopause and permanent infertility can result. Sparing one ovary can prevent these side effects. If the uterus (womb) is exposed, radiation can cause scarring and fibrosis. See our document called *Fertility and Cancer: What Are my Options?* to learn more about preserving fertility in men and women.

Sexual impact of radiation therapy on women: Radiation to the pelvic area can cause the vagina to be tender and inflamed during and for a few weeks after treatment. The area may scar as it heals. This scarring can interfere with the ability of the vagina to stretch. The lining of the vagina also gets thinner, and might bleed slightly after sex. A few

women get ulcers, or sore spots, in their vaginas. It may take many months for these areas to heal after radiation therapy ends.

The scarring that normally occurs after pelvic radiation can also shorten or narrow the vagina so much that a woman might not be able to have sex or get a Pap smear without pain. This can often be prevented by stretching the walls of the vagina a few times a week. One way to do this is to have sexual intercourse at least 3 to 4 times a week. Another option is to use a *vaginal dilator*. A dilator is a plastic or rubber rod or tube used to stretch out the vagina. It feels much like putting in a large tampon for a few minutes. Even if a woman is not interested in staying sexually active, keeping her vagina normal in size allows her doctor to do pelvic exams. This is an important part of follow-up care after treatment. Doctors, nurses, and other health care team members can tell you more.

As long as a woman is not bleeding heavily from a tumor in her bladder, rectum, uterus, cervix, or vagina, she may be able to have sex during pelvic radiation therapy. The outer genitals and vagina are just as sensitive as usual. But if the vagina is being radiated, sex may be uncomfortable because of sore spots or inflamed tissues. Women should follow their doctors' instructions about sex during radiation therapy. Talk with your doctor or nurse about any sexual problems you may have. You can read more about this in our booklet, *Sexuality for the Woman With Cancer*.

Sexual impact of radiation therapy on men: Radiation therapy to the pelvis can damage the arteries and nerves that supply the penis and as a result, cause problems with erections. The higher the dose of radiation and the wider the area of the pelvis treated, the greater the chance that a man will develop erection problems.

About 1 in 3 men who get radiation in the pelvic area will notice a change in his ability to have erections. This change most often develops slowly over the first year or so after radiation treatment. Some men continue to have full erections but lose them before reaching climax. Others no longer get firm erections at all. Men who are older, who didn't have full erections before they were treated, who have high blood pressure, or who have been heavy smokers seem to have a higher risk of having erection problems after radiation.

Testosterone is a male hormone that plays an important role in erections. Some men have less testosterone after pelvic radiation. The testicles, which make testosterone, may be affected either by a mild dose of scattered radiation or by the general stress of cancer treatment. Testosterone levels usually return to normal within 6 months of radiation therapy. But if a man notices erection problems or low sexual desire after cancer treatment, the doctor may decide to do a blood test to find out if testosterone is low. Some men can take testosterone to raise low levels to normal. Men with prostate cancer should know that replacement testosterone can speed up the growth of prostate cancer cells. You can read more about sexual problems during cancer in our booklet called *Sexuality for the Man With Cancer*.

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 previous 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 cancer of the breast or lung. 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, please see our document called *Second Cancers Caused by Cancer Treatment*.

Other general health concerns

Many patients want to know how they can improve their general health to help their body's natural defenses fight the cancer. They may also want to do things to speed up their recovery from radiation's side effects.

Smoking

For patients who still smoke, it's never too late to quit. Studies show that people with some types of cancer who keep smoking during and after treatment have a greater risk of the cancer coming back and of new cancers forming. Smoking can increase many side effects, too. It can also reduce appetite at a time when extra nutrition is needed. For help quitting smoking, please see our *Guide to Quitting Smoking* or call us at 1-800-227-2345.

Diet

You may need to avoid certain foods because of your treatment, but a eating a balanced diet is important. It's also important to eat foods high in calories to provide enough energy for healing. If you're having trouble getting enough nutrition or are worried about what types of food you should be eating, ask your doctor about a referral to a dietitian. You may also want to see our document called *Nutrition for the Person With Cancer During Treatment: A Guide for Patients and Families*.

Patients should check with their doctors before taking any vitamins on their own during radiation treatment. Certain vitamins, such as A, E, and C act as *antioxidants*. They

prevent the formation of ions (electrically charged particles) that damage DNA in cells. This damage is thought to have an important role in causing cancer. There is some evidence that getting enough of these vitamins might help reduce the risk of getting some types of cancer. But during treatment, radiation therapy works to fight cancer by producing ions that severely damage the DNA of cancer cells. Some scientists believe that taking high doses of antioxidant vitamins during treatment may make radiation therapy less effective by reducing this damage to cancer cells. So far, studies have not fully tested this theory. While this is being researched, many radiation oncologists recommend the following:

- If your doctor has not prescribed vitamins for a specific reason, it is best not to take any on your own.
- A single multivitamin tablet each day is probably OK for patients who want to take a vitamin supplement, but check with your doctor first.
- It is safest to avoid taking high doses of antioxidant vitamins or other antioxidant supplements during treatment. Ask your doctors when it might be safe to start such vitamins or supplements after treatment is finished.

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 our document called *Hyperthermia*.

Radiosensitizers are drugs that make cancer cells more sensitive to radiation. Some chemotherapy drugs already in use (such as 5-fluorouracil or 5-FU) are known to be radiosensitizers. Researchers are trying to find 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 is 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.

To learn more

More information from your American Cancer Society

The following information may also be helpful to you. These materials may be read online or ordered from our toll-free number, 1-800-227-2345.

After Diagnosis: A Guide for Patients and Families (also available in Spanish)

Understanding Radiation Therapy: A Guide for Patients and Families (also available in Spanish)

Health Professionals Associated With Cancer Care

Choosing a Doctor and a Hospital (also available in Spanish)

Caring for the Patient With Cancer at Home: A Guide for Patients and Families (also available in Spanish)

Nutrition for the Person With Cancer During Treatment: A Guide for Patients and Families (also available in Spanish)

A Message of Hope: Coping With Cancer in Everyday Life (also available in Spanish)

Imaging (Radiology) Tests

Fatigue in People With Cancer

Sexuality for the Man With Cancer (also available in Spanish)

Sexuality for the Woman With Cancer (also available in Spanish)

Fertility and Cancer: What Are my Options?

Second Cancers Caused by Cancer Treatment

Guide to Quitting Smoking (also available in Spanish)

Hyperthermia

National organizations and Web sites*

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

American College of Radiology
Toll-free number: 1-800-227-5463
Web site: www.acr.org

> Provides patient information regarding radiology procedures, radiation safety, FAQs, and a radiology glossary, as well as a list of accredited facilities

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

> Patient Web site has a locator of member radiation oncologists. 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 are available.

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

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

**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 visit www.cancer.org.

References

American Society for Therapeutic Radiology and Oncology. Answers to Your Radiation Therapy Questions. Accessed at www.rtanswers.org on June 28,2011.

Brown AP, Chen J, Hitchcock YJ, et al. The risk of second primary malignancies up to three decades after the treatment of differentiated thyroid cancer. *J Clin Endocrinol Metab*. 2008;93(2):504−515.

Constine LS, Milano MT, Friedman D, et al. Late Effects of Cancer treatment on Normal Tissues. In: Halperin EC, Perez CA, Brady LW, (Eds.) *Perez and Brady's Principles and Practice of Radiation Oncology*, 5th ed. Philadelphia, Pa: Lippincott Williams & Wilkins; 2008: 320−355.

Douglas JG, Goodkin R, Laramore GE. Gamma knife stereotactic radiosurgery for salivary gland neoplasms with base of skull invasion following neutron radiotherapy. *Head Neck*. 2008;30(4):492−496.

Gosselin-Acomb TK. Principles of Radiation Therapy. In: Henke Yarbro C, Hansen Frogge M, Goodman M, eds. *Cancer Nursing Principles and Practice*. 6th ed. Boston: Jones and Bartlett Publishers, Inc. 2005:229−249.

Halperin EC. Particle therapy and treatment of cancer. *Lancet Oncol*. 2006;7:676−685.

Halperin EC, Perez CA, Brady LW (eds). *Principles and Practice of Radiation Oncology, Fifth Ed*. Philadelphia, Pa: Lippincott Williams & Wilkins 2008.

Hede K. Research groups promoting proton therapy “lite.” *JNCI*. 2006;98:1682−1684.

Khan FM. *The Physics of Radiation Therapy*. *4th ed*. Philadelphia, Pa: Lippincott Williams & Wilkins 2010.

Kry SF, Salehpour M, Followill DS, et al. The calculated risk of fatal secondary malignancies from intensity-modulated radiation therapy. *Int J Radiat Oncol Biol Phys*. 2005;62(4):1195−1203.

Lawrence TS, Haken RKT, Giaccia A. Principles of Radiation Oncology. In: DeVita VT Jr, Lawrence TS, Rosenberg SA, (Eds.) *DeVita, Hellman, and Rosenberg’s Cancer: Principles and Practice of Oncology*, 8th ed. Philadelphia, Pa: Lippincott Williams & Wilkins; 2008: 307−336.

Mundt AJ, Roeske JC, Chung TD, Weichselbaum RR. Principles of radiation oncology. In: Kufe DW, Bast RC, Hait WN, Hong WK, Pollock RE, Weichselbaum RR, Holland JE, Frei E, eds. *Cancer Medicine*. 7th ed. Hamilton, Ontario: BC Decker Inc; 2006:517−536.

National Cancer Institute. Radiation Therapy and You: Support for People with Cancer. Accessed at www.cancer.gov/cancertopics/radiation-therapy-and-you on June 10, 2011.

National Cancer Institute. Radiation Therapy for Cancer FactSheet. Accessed at www.cancer.gov/cancertopics/factsheet/Therapy/radiation on June 10, 2011.

Paes FM, Serafini AN. Systemic Metabolic Radiopharmaceutical Therapy in the Treatment of Metastatic Bone Pain. *Semin Nucl Med*. 2010;40:89-104.

Sawka AM, Lakra DC, Lea J, et al. A systematic review examining the effects of therapeutic radioactive iodine on ovarian function and future pregnancy in female thyroid cancer survivors. *Clin Endocrinol (Oxf)*. 2008;69(3):479−490.

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