Cancer Association of South Africa (CANSA)

Research • Educate • Support

Fact Sheet on Radiation and Radiation Therapy

Introduction

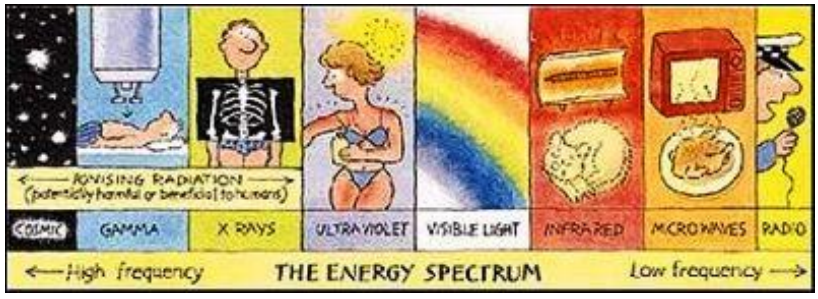
Energy emitted from a source is generally referred to as radiation. Examples include heat or light from the sun, microwaves from a microwave oven, X-rays from an X-ray tube and gamma rays from radioactive elements.

Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionized.

[Picture Credit: Ionizing Radiation]

Forms of electromagnetic radiation. These differ only in frequency and wave length.

- Heat waves
- Radiowaves
- Infrared light
- Visible light
- Ultraviolet light
- X rays
- Gamma rays



[Picture Credit: Energy Spectrum]

Longer wave length, lower frequency waves (heat and radio) have less energy than shorter wave length, higher frequency waves (X and gamma rays). Not all electromagnetic (EM) radiation is ionizing. Only the high frequency portion of the electromagnetic spectrum which includes X rays and gamma rays is ionizing.
(World Health Organization).

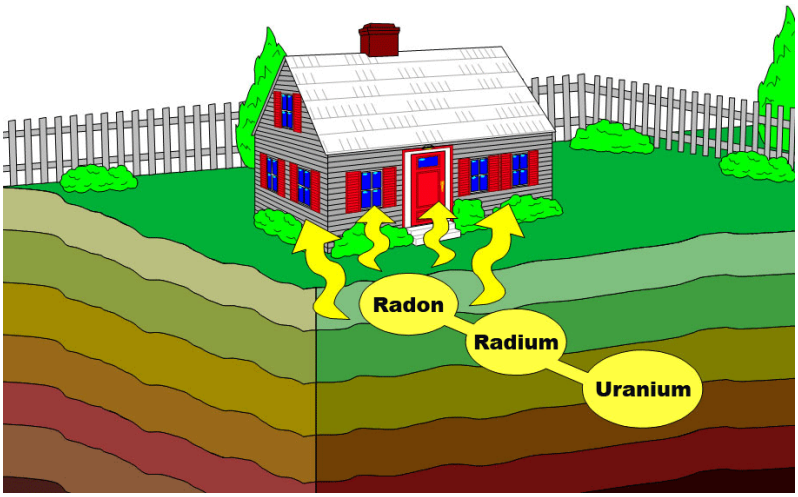
Researched and Authored by Prof Michael C Herbst
[D Litt et Phil (Health Studies); D N Ed; M Art et Scien; B A Cur; Dip Occupational Health; Dip Genetic Counselling; Diagnostic Radiographer; Dip Audiometry and Noise Measurement]
Approved by Ms Elize Joubert, Chief Executive Officer [BA Social Work (cum laude); MA Social Work]

Sources of Radiation

Radiation is, and always has been, around. Natural, 'background' radiation has been with mankind since the birth of the universe. Today modern medical procedures utilise various types of radiation to save lives and heal patients.

Natural Radiation Sources

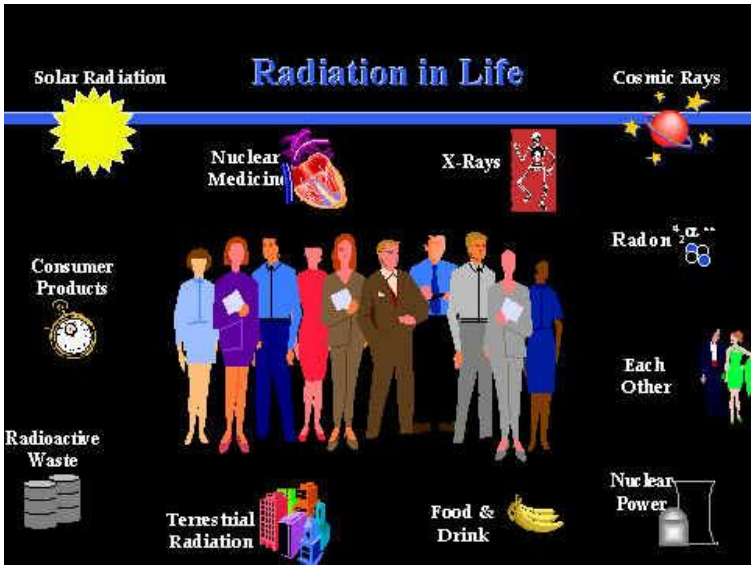
Radon - one cannot see it, smell it, or taste it, but radon is the leading source of natural radiation exposure and the second leading cause of lung cancer. Where does it come from? Usually from soil, but it is found everywhere. The ground that we all walk and build our homes upon contains varying levels of naturally occurring radioactive elements that decay into radon gas, which can seep into homes and become a health concern.



[Picture Credit: Radon]

Cosmic (space) radiation - outer space is full of various types of radiation, such as heavily charged particles and gamma rays. Fortunately, Earth has an atmosphere that helps absorb and filter it out, which protects earth's inhabitants from high doses of cosmic radiation. However, some radiation is able to make it through the atmosphere. The dose of cosmic radiation that one receives varies depending on the altitude of the area in which one lives. Since air is thinner at higher elevations, less cosmic radiation is filtered out than it is at lower altitudes with thicker air.

Other natural radiation sources - other natural sources, such as radiation naturally present in the bodies of humans and radiation from elements in the ground are also present.



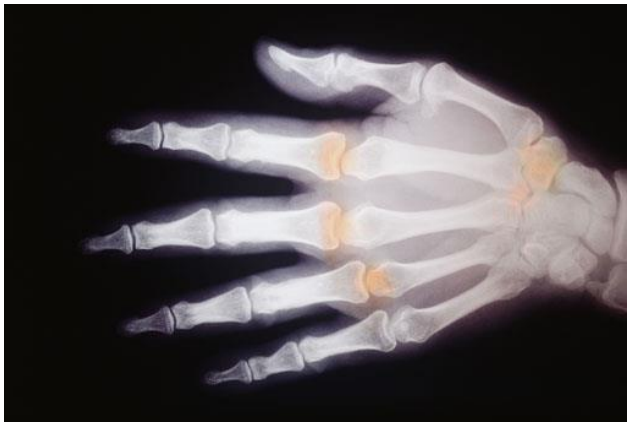
[Picture Credit: Radiation]

The exposure of human beings to ionizing radiation from natural sources is a continuing and inescapable feature of life on earth. For most individuals, this exposure exceeds that from all man-made sources combined. There are two main contributors to natural radiation exposures: high-energy cosmic ray particles incident on the earth's atmosphere and radioactive nuclides

that originated in the earth's crust and are present everywhere in the environment, including the human body itself. Both external and internal exposures to humans arise from these sources.

Man-made Radiation Exposure

Medical radiation exposure - the National Council on Radiation Protection and Measurement (NCRP) published a study in 2009 that found that nearly half of the radiation to which Western populations are exposed comes from medical sources such as CT scans, X-rays, and nuclear medicine. While individual exposure from medical sources varies considerably depending on the number and types of procedures that one undergoes, the NCRP has indicated that medical radiation exposure is much more common now than ever before.



[Picture Credit: X-Rays]

Other Man made Sources of Radiation Exposure - *w*hile the primary source of man-made radiation exposure comes from medical sources, there are various other sources that exposes mankind to small amounts of radiation.
(Environmental Protection Agency).

Man-made Radiation

Although all living things are exposed to natural background radiation, exposure to man-made radiation sources differs for the following groups:

- Members of the public
- Occupationally exposed individuals (workers)

Members of the Public

In general, the following man-made sources expose the public to radiation:

Medical Sources (by far, the most significant man-made source)

- Diagnostic X-rays
- Nuclear medicine procedures (iodine-131, cesium-137, and others)

[Picture Credit: Television]

Consumer Products

- Building and road construction materials
- Combustible fuels including gas and coal
- X-ray security systems
- Television sets

- Fluorescent lamp starters
- Smoke detectors (americium)
- Luminous watches (tritium)
- Lantern mantles (thorium)
- Tobacco (polonium-210)
- Ophthalmic glass used in eyeglasses
- Some ceramics

To a lesser degree, the public is also exposed to radiation from the nuclear fuel cycle, from uranium mining and milling to disposal of used (spent) fuel. In addition, the public receives some minimal exposure from the transportation of radioactive materials and fallout from nuclear weapons testing and reactor accidents (such as Chernobyl).

Occupationally Exposed Individuals

In general, occupationally exposed individuals work in the following areas:

- Fuel cycle facilities
- Industrial radiography
- Radiology departments (medical)
- Nuclear medicine departments
- Radiation oncology departments
- Nuclear power plants
- Government and university research laboratories

Such individuals are exposed to varying amounts of radiation, depending on their specific jobs and the sources with which they work (including cobalt-60, cesium-137, americium-241, and other isotopes).
(US Nuclear Regulatory Commission).

Medical Radiation

Hospitals, doctors, and dentists use a variety of nuclear materials and procedures to diagnose, monitor, and treat a wide assortment of metabolic processes and medical conditions in humans. It is estimated that diagnostic X-rays or radiation therapy have been administered to about 7 out of every 10 individuals. As a result, medical procedures using radiation have saved thousands of lives through the detection and treatment of conditions ranging from hyperthyroidism to bone cancer.

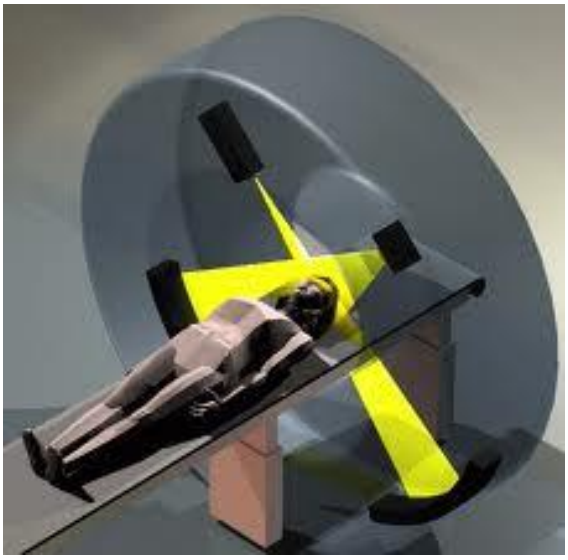
The most common of these medical procedures involve the use of X-rays - a type of radiation that can pass through human skin and deeper tissue. When X-rayed, bones and other structures cast shadows because it is denser than the skin, and those shadows can be detected on photographic film. The effect is similar to placing a pencil behind a piece of paper and holding the pencil and paper in front of a light. The shadow of the pencil is revealed because most light has enough energy to pass through the paper, but the denser pencil stops all the light. The difference is that X-rays are invisible, so one needs photographic film to 'see' it. This allows doctors and dentists to spot broken bones and dental problems.

X-rays and other forms of radiation also have a variety of therapeutic uses. When used in this way, it is most often intended to kill cancerous tissue, reduce the size of a tumour or reduce pain. For example, radioactive iodine (specifically iodine-131) is frequently used to treat thyroid cancer.

X-ray machines have also been connected to computers in machines called computerised axial tomography (CAT) or computed tomography (CT) scanners. These instruments provide doctors with colour images that show the shapes and details of internal organs. This helps physicians locate and identify tumours, size anomalies or other physiological or functional organ problems.

In addition, hospitals and radiology centres administer slightly radioactive substances to patients, which are attracted to certain internal organs such as the pancreas, kidney, thyroid, liver or brain, to diagnose clinical conditions.
(US Nuclear Regulatory Commission).

Radiation therapy, radiation oncology, or radiotherapy (known as in the UK, and Australia), sometimes abbreviated to XRT or DXT, is the medical use of ionizing radiation, generally as part of cancer treatment to control or kill malignant (cancerous) cells.



[Picture Credit: Radiation Therapy]

Radiation therapy may be curative in a number of types of cancer if it is localised to one area of the body. It may also be used as part of adjuvant therapy, to prevent tumour recurrence after surgery to remove a primary malignant tumour (for example, early stages of breast cancer). Radiation therapy is synergistic with chemotherapy, and is often used before, during, and after chemotherapy in susceptible cancers (Wikipedia).

Measuring Radiation Exposure
When scientists measure radiation, they use different terms depending on whether they are discussing radiation coming from a radioactive source, the radiation dose absorbed by a person, or the risk that a person will suffer health effects (biological risk) from exposure to radiation. This fact sheet explains some of the terminology used to discuss radiation measurement.

Units of Measure
Most scientists in the international community measure radiation using the *System Internationale* (SI), a uniform system of weights and measures that evolved from the metric system.

Different units of measure are used depending on what aspect of radiation is being measured. The amount of radiation being given off, or emitted, by a radioactive material is measured using the conventional unit **curie** (Ci), named for the famed scientist Marie Curie or the SI unit **becquerel** (Bq). The radiation dose absorbed by a person (that is, the amount of energy deposited in human tissue by radiation) is measured using the conventional unit **rad** or the SI unit **gray** (Gy). The biological risk of exposure to radiation is measured using the conventional unit **rem** or the SI unit **sievert** (Sv).

Measuring Emitted Radiation

When the amount of radiation being emitted or given off is discussed, the unit of measure used is the conventional unit Ci or the SI unit Bq.

A radioactive atom gives off or emits radioactivity because the nucleus has too many particles, too much energy, or too much mass to be stable. The nucleus breaks down, or disintegrates, in an attempt to reach a nonradioactive (stable) state. As the nucleus disintegrates, energy is released in the form of radiation.

The Ci or Bq is used to express the number of disintegrations of radioactive atoms in a radioactive material over a period of time. For example, one Ci is equal to 37 billion (37×10^9) disintegrations per second. The Ci is being replaced by the Bq. Since one Bq is equal to one disintegration per second, one Ci is equal to 37 billion (37×10^9) Bq.

Ci or Bq may be used to refer to the amount of radioactive materials released into the environment. For example, during the Chernobyl power plant accident that took place in the former Soviet Union, an estimated total of 81 million Ci of radioactive cesium (a type of radioactive material) was released.

Measuring Radiation Dose

When a person is exposed to radiation, energy is deposited in the tissues of the body. The amount of energy deposited per unit of weight of human tissue is called the absorbed dose. Absorbed dose is measured using the conventional **rad** or the SI **Gy**.

The rad, which stands for radiation absorbed dose, was the conventional unit of measurement, but it has been replaced by the **Gy**. One Gy is equal to 100 rad.

Measuring Biological Risk

A person's biological risk (that is, the risk that a person will suffer health effects from an exposure to radiation) is measured using the conventional unit **rem** or the SI unit **Sv**.

To determine a person's biological risk, scientists have assigned a number to each type of ionizing radiation (alpha and beta particles, gamma rays, and x-rays) depending on that type's ability to transfer energy to the cells of the body. This number is known as the Quality Factor (Q).

When a person is exposed to radiation, scientists can multiply the dose in rad by the quality factor for the type of radiation present and estimate a person's biological risk in rems. Thus, risk in rem = rad X Q.

The rem has been replaced by the Sv. One Sv is equal to 100 rem.
(Centers for Disease Control and Prevention).

Detecting Radiation

Ionizing radiation is not detectable by one's senses. It cannot be seen, heard, smelled, tasted, or felt. For these reasons, simple visual inspection is insufficient to identify radioactive materials, and radiation sources can be virtually impossible to recognise without special markings. To address these problems, scientists have developed the following major types of instruments to detect and identify radioactive materials and ionizing radiation:

- Personal Radiation Detector (PRD)
- Handheld Survey Meter
- Radiation Isotope Identification Device (RIID)
- Radiation Portal Monitor (RPM)
- Personal Dosimeter

Personal Radiation Detector (PRD) – a PRD is a wearable gamma and/or neutron radiation detector. It is approximately the size of a pager. When it is exposed to elevated radiation levels the device makes an alarm with flashing lights, tones and/or vibrations. Most PRDs display (numerically) the detected radiation intensity on a scale of 0 to 9 and can be used to locate a radiation source. They typically are not as sensitive as handheld survey metres and cannot identify the type of radioactive source.

Handheld Survey Meter – as the name implies, the survey meter is a handheld radiation detector which typically measures the amount of radiation present and provides this information on a numerical display in units of counts per minute, counts per second or microroetngen (µR) or microrem (µrem) per hour. Most of these devices detect beta and gamma radiation only. Some models can detect alpha, beta, gamma and/or neutron radiation emitted from radioactive materials.

[Picture Credit: Handheld Survey Meter]

One particular meter, known as a teledetector, is specifically designed to detect gamma and x-ray radiation. Named for its 'telescoping' ability, this device can be extended to about 4 meters to measure very high dose rates without subjecting the user to unnecessary exposure. In addition, these devices typically have the ability to measure dose rates ranging from 0 to 1,000 rad per hour.

Radiation Isotope Identification Device (RIID) – a RIID is a radiation detector with the ability to analyse the energy spectrum of radiation in order to identify the specific radioactive material (radionuclide) that is emitting the radiation. In addition, these devices can be used as survey instruments to locate radioactive materials.

[Picture Credit: RIID]

[Picture Credit: Radiation Portal Monitor]

Radiation Portal Monitor (RPM) – an RPM is a large pass-through radiation monitor (or 'portal') for personnel, vehicles, container boxes or trains. Typically, these devices consist of two pillars containing radiation detectors, which are remotely monitored from a display panel. These monitors alarm to indicte the presence of radioactive materials including low-radiation materials like uranium.

Personal Dosimeters – the following are the main types of personal dosimeters available. Common types of wearable dosimeters for ionizing radiation include:

- Electronic Personal Dosimeter (EPD)
- Film badge dosimeter
- Quartz fibre dosimeter (QFD)
- Thermoluminescent dosimeter (TLD)

[Picture Credit: Film Badge Dosimeter]

Quartz fibre dosimeters have to be prepared, usually daily, with a high voltage positive charge. As the gas in the dosimeter chamber becomes ionized by nuclear radiation the charge leaks away, causing the fibre indicator to rise up the graduated scale.

Film badge dosimeters are for one-time use only. The level of radiation absorption is indicated by a change to the film emulsion, which is shown when the film is developed.

Both the quartz and film badge types are being superseded by the TLD and Electronic Personal Dosimeter. The latter has a number of sophisticated functions such as alarming at preset levels and live readout of accumulated radiation.
(US Nuclear Regulatory Commission; US Department of Health and Human Services; Wikipedia).

Ionizing Radiation and Health

Radioactive materials that decay spontaneously produce ionizing radiation, which has sufficient energy to strip away electrons from atoms (creating two charged ions) or to break some chemical bonds. Any living tissue in the human body can be damaged by ionizing radiation in a unique manner. The body attempts to repair the damage, but sometimes the damage is of a nature that cannot be repaired or it is too severe or widespread to be repaired. Also mistakes made in the natural repair process can lead to cancerous cells. The most common forms of ionizing radiation are alpha and beta particles, or gamma and X-rays.

In general, the amount and duration of radiation exposure affects the severity or type of health effect. There are two broad categories of health effects: stochastic and non-stochastic.

Stochastic Health Effects - stochastic effects are associated with long-term, low-level (chronic) exposure to radiation. ('Stochastic' refers to the likelihood that something will

happen.) Increased levels of exposure make these health effects more likely to occur, but do not influence the type or severity of the effect.

Cancer is considered by most people the primary health effect from radiation exposure. Simply put, cancer is the uncontrolled growth of cells. Ordinarily, natural processes control the rate at which cells grow and replace themselves. They also control the body's processes for repairing or replacing damaged tissue. Damage occurring at the cellular or molecular level, can disrupt the control processes, permitting the uncontrolled growth of cells cancer This is why ionizing radiation's ability to break chemical bonds in atoms and molecules makes it such a potent carcinogen.

Other stochastic effects also occur. Radiation can cause changes in DNA, the ‘blueprints’ that ensure cell repair and replacement produces a perfect copy of the original cell. Changes in DNA are called mutations.

Sometimes the body fails to repair these mutations or even creates mutations during repair. The mutations can be teratogenic or genetic. Teratogenic mutations are caused by exposure of the foetus in the uterus and affect only the individual who was exposed. Genetic mutations are passed on to offspring.

Non-Stochastic Health Effects - non-stochastic effects appear in cases of exposure to high levels of radiation, and become more severe as the exposure increases. Short-term, high-level exposure is referred to as 'acute' exposure.

Many non-cancerous health effects of radiation are non-stochastic. Unlike cancer, health effects from 'acute' exposure to radiation usually appear quickly. Acute health effects include burns and radiation sickness. Radiation sickness is also called 'radiation poisoning.' It can cause premature aging or even death. If the dose is fatal, death usually occurs within two months. The symptoms of radiation sickness include: nausea, weakness, hair loss, skin burns or diminished organ function.

Medical patients receiving radiation treatments often experience acute effects, because they are receiving relatively high ‘bursts’ of radiation during treatment.

There is no firm basis for setting a ‘safe’ level of exposure above background for stochastic effects. Many sources emit radiation that is well below natural background levels. This makes it extremely difficult to isolate its stochastic effects. In setting limits, one can make the conservative (cautious) assumption that any increase in radiation exposure is accompanied by an increased risk of stochastic effects.

Some scientists assert that low levels of radiation are beneficial to health (this idea is known as hormesis).

There do appear to be threshold exposures for the various non-stochastic effects.

(Please note that the acute affects in the following table are cumulative. For example, a dose that produces damage to bone marrow will have produced changes in blood chemistry and be accompanied by nausea.)

Exposure (rem)	Health Effect	Time to Onset (without treatment)
5-10	changes in blood chemistry	
50	nausea	hours
55	fatigue	
70	vomiting	
75	hair loss	2-3 weeks
90	diarrhoea	
100	haemorrhage	
400	possible death	within 2 months
1,000	destruction of intestinal lining	
	internal bleeding	
	death	1-2 weeks
2,000	damage to central nervous system	
	loss of consciousness;	minutes
	and death	hours to days

(EPA Radiation Protection).

World Health Organization - Key Facts of Ionizing Radiation

- Ionizing radiation is a type of energy released by atoms in the form of electromagnetic waves or particles.
- People are exposed to natural sources of ionizing radiation, such as in soil, water, vegetation, and in human-made sources, such as x-rays and medical devices.
- Ionizing radiation has many beneficial applications, including uses in medicine, industry, agriculture and research.

- As the use of ionizing radiation increases, so does the potential for health hazards if not properly used or contained.
- Acute health effects such as skin burns or acute radiation syndrome can occur when doses of radiation exceed certain levels.
- Low doses of ionizing radiation can increase the risk of longer term effects such as cancer.

(World Health Organization).

Radiation Therapy

Radiation therapy treats cancer by using high energy to kill tumour cells. The goal is to kill or damage cancer cells without hurting healthy cells.

Different people have different side effects with radiation. One may have little or only mild side effects from treatment; someone else may have many or very severe side effects. Unfortunately, it is impossible to predict who will have what side effects. In addition, the specific side effects one may have depends on the type of radiation being used, the dose of radiation, the area of the body that is being targeted and the state of the patient's health. (WebMD).

Radiotherapy destroys cancer cells in the area of the body it is aimed at, but the treatment also affects some of the normal cells nearby. Radiotherapy affects people in different ways, so it is difficult to predict exactly how a particular patient will react. Some people have only mild side effects but for others the side effects may be more severe.

The main side effects of radiotherapy treatment include tiredness and weakness, sore skin, and loss of hair in the treatment area.

Tiredness and weakness - most people feel tired while they are having radiotherapy, particularly if they are having treatment over several weeks. This is because the body is repairing the damage to healthy cells. Tiredness can also be due to low levels of red blood cells (anaemia). One may also feel weak and as though one does not have the energy to do one's normal daily activities. This may last for a few weeks after the treatment ends.

Rest is important and one should try to exercise a little when possible. This may help to reduce the tiredness.

Sore skin - some people get sore skin in the area being treated. The skin may look reddened or darker than usual. It may also get dry and itchy. The staff in the radiotherapy department can advise on the best way of coping with this.

Loss of hair - radiotherapy makes the hair fall out in the treatment area. Hair in other parts of the body is not affected. The hair should begin to grow back again a few weeks after the treatment ends.

Possible long term side effects - for many people the side effects of radiotherapy wear off within a few weeks of the treatment ending and they can go back to a normal life. But for some people radiotherapy can cause long term side effects. The possibility of long term side effects can depend on the type of cancer and its size and position. It may also depend on how close the cancer is to nerves or other important organs or tissues.

It is important to ask one's doctor, specialist nurse or radiographer about the possibility of long term side effects. Depending on the position of the cancer the possible long term effects may include:

- A change in skin colour in the treatment area
- A dry mouth
- Breathing problems
- Loss of ability to become pregnant or father a child (infertility)
- Low sex drive
- Erection problems (impotence)
- Long term soreness and pain
- Bowel changes
- Bladder inflammation

(Cancer Research UK).

Goals of Radiation Therapy

There are several different possible goals of radiation treatment:

Curative - for curative purposes, treatment is usually prolonged. Reactions to the radiation range from mild to severe.

Relief from Symptoms - this treatment seeks to relieve symptoms of the cancer and to prolong survival, making life more comfortable. This type of treatment is not necessarily done with the intent of curing the patient. Frequently this type of treatment is done to prevent or eliminate pain caused by cancer that has metastasized to bones.

Radiation instead of surgery - radiation in place of surgery is effective against a limited number of cancers. The treatment is most effective if the cancers are caught early while still small and non-metastatic. Radiation may be used instead of surgery if the location of the cancer makes surgery difficult or impossible to perform without severe risks to the patient. Surgery is the preferred treatment for lesions that are located in an area where radiation treatment might cause more damage than the surgery. The time that it takes for the two treatments is also very different. Surgery can be performed quickly after a diagnosis; radiation treatment may take weeks to be fully effective.

There are pros and cons for both procedures. Radiation therapy can be used to preserve organs and/or to avoid surgery and its risks. Radiation destroys rapidly dividing cells within the tumour, while surgical procedures may miss some of the outer cells. However, large tumour masses often contain oxygen-poor cells in the centre that do not divide as rapidly as the cells near the surface of the tumour. Because these cells are not rapidly dividing, they are not as sensitive to radiation therapy. For this reason, larger tumours cannot be destroyed with radiation alone. Radiation and surgery are often combined during treatment.
(Cancer Quest).

The Benefits of Radiation Therapy

The benefits of radiation therapy includes:

- It destroys quickly dividing cells at the margins of tumours. Surgery may miss these cells leading to recurrence of disease.
- It can successfully eradicate growth without permanently damaging the adjacent normal tissue. If these tumours can be treated early before metastasis, there is a very high rate of curability.
- In conjunction with other treatments, it may cure tumours that are not responsive to any single agent.
- Radioactive seed implants can deliver high doses of radiation directly to the tumour sparing nearby healthy cells. Has less severe side effects than external radiation therapy.
- Preoperative radiation therapy can kill tumour cells at margins of the tumour site. It can keep the cancer under control and prevent metastases, and also convert technically inoperable tumours into operable ones.
- Postoperative radiation therapy can destroy cancer cells still present around the margins after a tumour has been surgically removed.

(Cancer Quest).

Possible Side Effects of Radiation Therapy

Why radiotherapy causes side effects - radiotherapy destroys cancer cells in the area of the body it is aimed at but it also affects some of the normal cells nearby. Radiotherapy affects people in different ways, so it is difficult to predict exactly how each patient will react. Some people have only mild side effects but for others the side effects are more severe.

Side effects during treatment - most people feel tired while they are having radiotherapy, particularly if they are having treatment over several weeks. This is because the body is repairing the damage to healthy cells. Tiredness can also be due to low levels of red blood cells (anaemia). The patient should try and rest if necessary to and try to exercise a little when possible, as this may help to reduce the tiredness.

Some patients may have other general symptoms, such as feeling weak or as if coming down with flu, for a few days after having received radiotherapy.

Some people get sore skin in the area being treated.

Radiotherapy makes the hair fall out in the treatment area. Hair in other parts of the body is not affected. The hair should begin to grow back again a few weeks after the treatment ends.

Other side effects will depend on the area of the body being treated. Tell the treating doctor, oncology nurse or radiographer about any side effects.
(Cancer Research UK).

Brain Radiotherapy Side Effects

Side effects can be mild or more troublesome depending on the amount of radiotherapy given and the length of the treatment. Radiotherapy can cause side effects such as tiredness (fatigue), headaches, hair loss and feeling sick (nausea).

Tiredness - as radiotherapy often makes one feel tired, one should try and get as much rest as possible, especially if one has to travel a long way for treatment each day.

Headaches - some people develop headaches during the course of their radiotherapy. These can be controlled with painkillers and sometimes steroids, which will be prescribed by the doctor.

Hair loss – the patient will lose hair in the area being treated. Most hair loss is temporary but, unfortunately, it may be permanent for some people. It will depend on the dose of treatment given. Sometimes hair grows back with a slightly different colour and texture and perhaps not as thickly as before. It usually starts to grow back within 2–3 months of finishing treatment.

Skin changes - some people develop a skin reaction, similar to sunburn, while having radiotherapy. This normally happens 3-4 weeks after the start of treatment. People with pale skin may find that the skin in the treatment area becomes itchy, or red and sore.

People with darker skin may find that their skin becomes darker and can have a blue or black tinge. The amount of the reaction depends on the area being treated and the individual person's skin. Some people have no skin problems at all.

The radiographers will be checking the patient's skin but they should be informed if it feels sore. Staff at the radiotherapy department will be able to give advice on skin care. As the skin is sensitive it is best not to over-expose it to the sun or cold winds. Try wearing a soft cotton or silk scarf or hat to cover the area when going outside.

Somnolence (feeling drowsy) - after finishing radiotherapy the patient may find that they generally slow down, have very little energy and feel much less active. This can happen about 4-8 weeks after treatment. The patient may also feel drowsy and spend more time sleeping. This gradually gets better over a few weeks.

Feeling sick - some people may feel sick but this can usually be treated effectively with anti-sickness drugs (anti-emetics), which the doctor can prescribe. The patient may also find that food tastes different and may have a metallic taste in the mouth.

If not feeling like eating, the patient can try replacing meals with nutritious, high-calorie drinks. These are available from most pharmacies and can also be prescribed by the doctor. (MacMillan Cancer Support).

Head and Neck Radiotherapy Side Effects

Side effects of radiation therapy to the head and neck may include:

- dry mouth
- difficulty swallowing
- mouth and gum sores
- stiffness in the jaw
- nausea

- a type of swelling called lymphedema
- tooth decay may occur

Before beginning radiation therapy for any head and neck cancer, visit a dentist (if possible a dentist experienced in treating people with head and neck cancer). This dentist may prescribe a special fluoride treatment to help prevent tooth decay and may recommend removing already decayed teeth before beginning treatment to help prevent osteoradionecrosis (a type of jaw disease). (Cancer.Net).

Chest Radiotherapy Side Effects

Some people develop side effects from radiation therapy. The type and how severe they are depend on many factors. These include the dose of radiation, the number of treatments, and overall health. Side effects may be worse if one is also getting chemotherapy. Below are the most common side effects of radiation therapy to the breast or chest wall. A patient may experience all, some, or none of these.

Skin and hair reactions - during the course of radiation therapy, the skin and hair in the area being treated will change. This is normal and expected. After 2 to 3 weeks, the skin will become pink or tanned. As treatment goes on, it may become bright red or very dark. It may also feel dry and itchy, and it may look flaky. The skin reaction from radiation therapy generally peaks 1 or 2 weeks after radiation therapy ends, and begins to heal after that point.

The patient may also notice a rash, especially in any area where they have had previous sun exposure. Although this may be a side effect of treatment, a rash could also be a sign of infection. If a rash develops at any time during treatment, the doctor or professional nurse should be informed.

Sometimes, the skin in sensitive areas, such as under the breast or arm and near the collarbone, may blister, open, and peel. If this happens, tell the doctor or nurse. The nurse will apply special dressings or creams and teach the patient how to care for his/her skin. The doctor may also stop the treatment until the skin heals. This skin reaction sometimes becomes more severe during the week after treatment is done. If this happens, call the doctor or nurse. The skin will gradually heal after the treatment is completed, but this often takes 3 to 4 weeks.

Patients may lose some or all of the hair under the arm. The hair will usually grow back 2 to 4 months after the treatment is completed.
(Memorial Sloan Kettering Cancer Center).

Abdomen and Pelvic Area Radiotherapy Side Effects

After radiotherapy to the lower part of the abdomen (pelvis), the patient might get pain some time afterwards. Pain can occur for various reasons. It is important to see a doctor quickly if having pain. The type of pain that happens with each cause, along with other symptoms, is described below.

Infection - bladder infections can cause pain and are more common after pelvic radiotherapy. The pain is usually worse when the bladder is full. It may be at its worst when passing urine or just afterwards. The urine may be cloudy or smelly or have small amounts of blood. The patient may also feel ill, have a high temperature or feel sick (nauseated). The urine will need to be tested to find out which type of infection is present. The doctor can then prescribe the correct antibiotic.

Bowel changes - cramps (spasm) of the muscles lining the bowel can cause pain. This type of pain is made worse when the bowels open. The pain is cramp-like and may come in waves. Constipation or a narrowing of the back passage (an anal stricture) can cause pain. Sometimes the pain may be due to a split in the skin of the anus known as a fissure. A fissure causes a very sharp and intense pain when passing stools. The patient may be asked to have an examination of the bowel to find out whether there are any changes. This examination is done with a flexible sigmoidoscopy. A gastroenterologist usually does this test.

Fine cracks in the pelvic bones - pelvic radiotherapy can sometimes cause tiny cracks in the pelvic bones some time later. It is more likely to happen in people who have general weakening of their bones as they get older (osteoporosis). It is also more likely in people who are taking hormone therapies or steroids
.
The tiny cracks are called pelvic insufficiency fractures. The pain in this case can be quite bad. It usually gets worse if one moves around or does exercise and gets better when one sits still or rests. This type of pain normally goes away overnight. It does not stop one from sleeping well. The patient may be asked to have X-rays, a CT scan or an MRI scan (or a combination of these) to see if there are any fractures in the pelvic bones.
(Cancer Research UK).

Radiotherapy Side Effects on the Blood
Low blood cell counts occur because of the effect of radiotherapy on blood cells made in the bone marrow.

Blood cell counts are more likely to be affected if:

- a person receives chemotherapy at the same time as radiation therapy
- the pelvic bones (where many of an adult's blood cells are made) are in the treatment area
- total body irradiation (TBI) is given before a stem cell transplant

Drops in blood cell levels are rarely severe enough to cause problems. When there is a break from treatment for a few days, blood cell counts usually recover.

Bone marrow suppression is a condition in which one or more of the main types of blood cells are decreased.

- a low white blood cell count (neutropenia or leukopenia) increases the risk of infection.
- a low platelet count (thrombocytopenia) increases the risk of bruising and bleeding.
- a low red blood cell count (anaemia) causes fatigue, paleness and malaise.

Radiation therapy does not usually affect red blood cells very much, except when there is bleeding and blood loss.
(Canadian Cancer Society).

Radiotherapy Fatigue

Cancer-related fatigue (CRF - sometimes simply called 'cancer fatigue') is one of the most common side effects of cancer and its treatments. It is often described as 'paralysing'. Usually, it comes on suddenly, does not result from activity or exertion, and is not relieved by rest or sleep. It may not end - even when treatment is complete.

What causes CRF? - the exact reason for cancer fatigue is unknown. CRF may be related to both the disease process and treatments, including surgery, chemotherapy, and radiation therapy.

Cancer treatments commonly associated with CRF are:

- Chemotherapy. Any chemotherapy drug may result in fatigue. This may vary from person to person. Some people say it lasts only a couple of days. Others feel the CRF persists through and beyond completion of treatment. Drugs such as vincristine, vinblastine, and cisplatin often cause CRF.
- Radiation therapy. Radiation therapy can cause cumulative fatigue (fatigue that increases over time). This can occur regardless of treatment site. CRF usually lasts from 3-4 weeks after treatment stops, but can continue for up to 2-3 months.
- Bone marrow transplant. This aggressive form of treatment can cause CRF that lasts up to one year.
- Biologic therapy. Cytokines are natural cell proteins, such as interferons and interleukins, that are normally released by white blood cells in response to infection. These cytokines carry messages that regulate other elements of the immune and endocrine systems. In high amounts, these cytokines can be toxic and lead to persistent fatigue.

Other factors that may contribute to cancer-related fatigue include:

- Anaemia. Anaemia can result from blood counts that are reduced by treatments reducing the oxygen-carrying ability (haemoglobin) of the blood. About 7 in 10 patients experience anaemia during chemotherapy.
- Combination therapy. Patients experiencing more than one treatment at the same time or one after the other may experience more CRF.
- Tumour-induced 'hyper-metabolic' state. Tumour cells compete for nutrients, often at the expense of the normal cell's growth and metabolism. Weight loss, decreased appetite, and fatigue are common results.
- Decreased nutrition from the side effects of treatments (i.e., nausea, vomiting, mouth sores, taste changes, heartburn, and diarrhoea).
- Hypothyroidism. If the thyroid gland is underactive, metabolism may slow down so that the body does not burn food fast enough to provide adequate energy. This is a common condition in general but may happen after radiation therapy to the lymph nodes in the neck.
- Medications used to treat side effects such as nausea, pain, depression, anxiety, and seizures can contribute to CRF.
- Pain. Research shows that chronic, severe pain increases fatigue.

- Many patients try to maintain their normal daily routine and activities during treatments. Modification may be necessary in order to conserve energy.
- Stress can worsen feelings of fatigue. This can include any type of stress: from dealing with the disease and the unknowns to worrying about daily accomplishments to worrying about not meeting the expectations of others.
- Depression and fatigue often go hand in hand. It may not be clear as to which started first. Families may be confused as well. One way to sort this out is to try to understand how much of a problem is caused by the depressed feelings. Are you depressed all the time? Were you depressed before your cancer diagnosis? Are you preoccupied with feeling worthless and useless? If the answers to these questions are yes, you may need treatment for depression.
- Insomnia. Inability to sleep 8 hours a night will cause both mental and physical fatigue.

(Cleveland Clinic).

Long-term Effects of Radiation Therapy

A late effect is a side effect that occurs months or years after cancer treatment. Many people who have received treatment for cancer have a risk of developing long-term side effects. In fact, evaluating and treating late effects is an important part of survivorship care.

Nearly any treatment can cause late effects, and these are specific to the treatment one received. Below is a list of some of the more common late effects. Talk with a Oncology health professional about any concerns about a specific late effect.

Heart problems - both chemotherapy and radiation therapy to the chest can cause heart problems. Survivors who may have a higher risk include:

- Anyone who received treatment for Hodgkin lymphoma as a child
- Anyone 65 and older
- Those who received higher doses of chemotherapy
- Those who received trastuzumab (Herceptin) and doxorubicin (Adriamycin, Doxil)

Below is a list of common heart conditions. Talk with your doctor right away if you experience any of these symptoms:

- Congestive heart failure (CHF) - weakening of the heart muscle. People with CHF may experience shortness of breath, dizziness, and swollen hands or feet.
- Coronary artery disease - heart disease. This condition is more common in those who had high doses of radiation therapy to the chest. People who have heart disease may experience chest pain or shortness of breath.
- Arrhythmia - irregular heartbeat. People who have an arrhythmia may experience lightheadedness, chest pain, and shortness of breath.

These drugs tend to cause more heart problems:

- Trastuzumab
- Doxorubicin
- Daunorubicin (Cerubidine)
- Epirubicin (Ellence)

- Cyclophosphamide (Neosar)

For people taking trastuzumab, doctors usually recommend checking heart function and watching for heart damage during and after treatment. This may be done with a test called echocardiography, also called an echo. An echo measures LVEF, or left ventricular ejection fraction.

Other heart tests may include a physical examination, an electrocardiogram (ECG), and a multigated acquisition scan (MUGA) scan.

Hypertension - high blood pressure. This may occur along with CHF (see above) or be a separate symptom. Talk with a doctor if you have high blood pressure. One may need to have one's blood pressure watched more closely during cancer treatment. A more serious condition, called accelerated hypertension, is when a person's blood pressure suddenly and rapidly rises. Because this condition often causes organ damage, it is important to get medical help right away.

Drugs that target the vascular endothelial growth factor (VEGF) are a common cause of high blood pressure. Examples of these drugs include:

- Bevacizumab (Avastin)
- Sorafenib (Nexavar)
- Sunitinib (Sutent)

The risk of high blood pressure decreases once a person stops taking these drugs. But, the long-term effects are not known. Survivors at higher risk for high blood pressure should work with their doctors to lower this risk. This may include steps such as testing blood pressure, losing weight, eating less salt, taking medicine, and being active.

Lung problems - chemotherapy and radiation therapy to the chest may damage the lungs. Cancer survivors who received both chemotherapy and radiation therapy may have a higher risk of lung damage. Some of the drugs that are more likely to cause lung damage include:

- Bleomycin (Blenoxane)
- Carmustine (BiCNU)
- Prednisone (multiple brand names)
- Dexamethasone (multiple brand names)
- Methotrexate (multiple brand names)

The late effects may include the following:

- A change in how well the lungs work
- Thickening of the lining of the lungs
- Inflammation of the lungs
- Difficulty breathing

People with a history of lung disease and older adults may have additional lung problems.

Endocrine (hormone) system problems - some types of cancer treatments may affect the endocrine system. The endocrine system includes the glands and other organs that make hormones and produce eggs or sperm. Cancer survivors who have a risk of hormone changes from treatment should have regular blood tests to measure hormone levels.

- Menopause. Many cancer treatments may cause a woman to have menopausal symptoms. These include surgery to remove a woman's ovaries (oophorectomy), chemotherapy, hormone therapy, and radiation therapy to the pelvic area.

  The symptoms of menopause caused by cancer treatment may be worse than the symptoms of natural menopause. This is because the decrease in hormones happens more quickly.

  Women taking hormone therapy who have not been through menopause may have lighter and fewer regular menstrual periods. Or, these women may have their menstrual periods stop completely.

  For some younger women, menstrual periods may return after treatment. But women older than 40 are less likely to have their menstrual periods return. Even if cancer treatment does not cause menopause right away, it may still cause menopause to start sooner than normal.

- Hormone problems for men. Men may experience symptoms similar to menopause from some treatments. These include hormone therapy for prostate cancer or surgery to remove the testicles.

- Infertility. Treatments that affect reproductive organs or the endocrine system increase risk of infertility. Infertility from cancer treatment may last a short time or it may be permanent.

- Hormone problems from head and neck radiation therapy. Radiation therapy to the head and neck area can lower hormone levels or cause changes to the thyroid.

Bone, joint, and soft tissue problems. Chemotherapy, steroid medications, or hormonal therapy may cause osteoporosis, which is thinning of the bones, or joint pain. Some people may have a higher risk of these conditions if they are not physically active.

Cancer survivors can lower their risk of osteoporosis in these ways:

- Avoiding tobacco products
- Eating foods rich in calcium and vitamin D
- Becoming and remaining
- Avoiding alcohol consumption. Alcohol is a Group 1 cancer causing agent according to the International Agency for Research on Cancer (IARC).

Brain, spinal cord, and nerve problems. Chemotherapy and radiation therapy can cause long-term side effects to the brain, spinal cord, and nerves. These late effects include:

- Hearing loss from high doses of chemotherapy, especially drugs like cisplatin (Platinol)

- Increased risk of stroke from high-dose radiation therapy to the head, usually to treat a brain tumour
- Nervous system side effects, including damage to the nerves outside the brain and spinal cord (called peripheral neuropathy)

To check for these effects, cancer survivors should have regular physical examinations, hearing tests, and x-rays after treatment.

Learning, memory, and attention difficulties. Chemotherapy and high-dose radiation therapy to the head may cause these problems for both adults and children. Cancer survivors who experience any of these problems should talk with their doctor.

Dental and oral health and vision problems. Cancer survivors may have the following dental and oral health and vision problems, depending on the treatments they received:

- Chemotherapy may affect tooth enamel and increase the risk of long-term dental problems.
- High-dose radiation therapy to the head and neck area may change tooth development. It can also cause gum disease and lower saliva production, causing a dry mouth.
- Steroid medications may increase the risk of eye problems such as a clouding of the eye that affects vision (cataracts).

To watch for future problems, survivors should schedule regular appointments with a dentist and an ophthalmologist. An ophthalmologist is a doctor who specializes in treating eye conditions.

Digestion problems. Chemotherapy, radiation therapy, and surgery may affect how well a person digests food. Surgery or radiation therapy to the abdominal area can cause tissue scarring, long-term pain, and intestinal problems affecting digestion. Moreover, some survivors may have chronic diarrhoea that reduces the body's ability to absorb nutrients. A registered dietitian (RD) can help make sure people with digestion problems are getting enough nutrients.

Emotional difficulties. Cancer survivors often experience various positive and negative emotions, including:

- Relief
- A sense of gratitude to be alive
- Fear of recurrence of cancer
- Anger
- Guilt
- Depression
- Anxiety
- Feeling alone

Cancer survivors, caregivers, family, and friends may also experience post-traumatic stress disorder. This is an anxiety disorder. It may develop after living through an extremely frightening or life-threatening event, such as cancer diagnosis and treatment.

Each person's post-treatment experience is different. For example, some survivors struggle with negative emotional effects of the cancer. Others say that they have a renewed, positive outlook on life because of the cancer.

Secondary Cancers. A secondary cancer includes a new primary cancer. Or, it may be a cancer that has spread to other parts of the body from where it started. It may develop as a late effect of previous cancer treatments, such as chemotherapy and radiation therapy.

Chemotherapy and radiation therapy can also damage bone marrow stem cells. This increases the risk of either acute leukaemia or myelodysplasia. Myelodysplasia is a blood cancer where the normal parts of the blood are either not made or are abnormal. Talk with your doctor about common signs and symptoms of a new cancer.

Fatigue. Fatigue is a persistent feeling of physical, emotional, or mental tiredness or exhaustion. It is the most common side effect of cancer treatment. Some cancer survivors experience fatigue for months or even years after finishing treatment.
(Cancer.Net).

Radiotherapy and Sex Life
Although it can be embarrassing to talk to health professionals about intimate concerns, it must be remembered that they are used to dealing with these issues and can suggest things that will help.

Both men and women may temporarily lose interest in sex. This is common and may happen because of worries about the future, or even because the treatment is making them too tired to think about sex. Men may become temporarily unable to get an erection (erectile dysfunction – ED).

Losing interest in sex can be distressing, but it will usually come back as the effects of treatment wear off.

Having external or internal radiotherapy to the pelvic area can also cause specific side effects that may affect one's sex life.

Effects on women - radiotherapy to the pelvis usually affects the ovaries. Radiotherapy to the ovaries will bring on the menopause, which can cause dryness in the vagina. Treatment to the vaginal area can make the vagina narrower and also cause dryness.

There are a number of practical ways to manage menopausal symptoms and vaginal problems. It is important to let the healthcare team know about any concerns so they can help.

Effects on men – radiotherapy to the pelvis to treat bladder, rectal and prostate cancer may cause erectile dysfunction. This may develop months or even years after the radiotherapy has finished.

If someone is likely to develop any of these problems, the oncologist or specialist nurse will discuss them with the patient before he consents to the treatment. There are a number of practical ways to help overcome this problem. It is important to let the healthcare team know about any concerns so they can help.

Contraception - even if the treatment is likely to make one infertile, it is still to be advised to use a reliable form of birth control. If pregnancy occurs during or shortly after radiotherapy, there is a possibility that the unborn baby could be harmed.

Feelings about sexuality and infertility – it is not easy to come to terms with the prospect of infertility, or with the other side effects of treatment. It will take a while for anyone to come to terms with these feelings and be able to talk about them. When ready, it may help to talk openly to a partner, a relative or friend. This will make it easier for them to provide help and support.
Some people prefer to talk to someone they do not know. Support groups offer the chance to talk to other people who have been through a similar experience. Another possibility is to talk things over with a counsellor.
(MacMillan Cancer Support).

Emotional and Psychological Effects of Radiotherapy
Many patients feel tired during radiation therapy, and this can affect emotions. Some also might feel depressed, afraid, angry, frustrated, alone, or helpless. Getting involved with a support group and meeting other people with cancer may help a lot. Contact the nearest CANSA office to find out about support groups.

The Future of Radiation Therapy
Radiation therapy is an active area of research. One of the key objectives is the design of treatments that are more selective in their effects, damaging cancer cells and sparing normal cells. We will look at one current treatment being studied; Radiogenic therapy and Equivalent Uniform Dose (EUD) in conjunction with Intensity Modulated Radiation Therapy(IMRT).

Radiogenic therapy has been proposed as a method of using radiation technology to induce the formation of cytotoxic (cell killing) agents within cancer cells. Using lower doses of radiation with a biological agent may yield the same results as higher dose radiation alone, but with reduced toxicity.

There are three groups of radiogenic therapy:

- Stimulation by radiation to directly or indirectly produce cytotoxic agents. The objective of this technique is to control genes with a radiation-inducible promoter so that they can produce cytotoxic proteins or enzymes that can then activate a drug. The activated form of the drug will kill the cancer cells.

- Auger-emitting radio-labelled molecules. These therapies can control cancer by delivering targeted radiation to specific receptor bearing cells. Auger electrons are emitted by radioactive isotopes (Iodine-125 or Indium-111). The electrons have very short ranges and therefore have the potential to be delivered to specific sets of target cells, sparing healthy cells.
- Radiation-induced genes that produce a protein that can be targeted by a cytotoxic agent.

(Cancer Quest).

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