Cancer Association of South Africa (CANSA)

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]

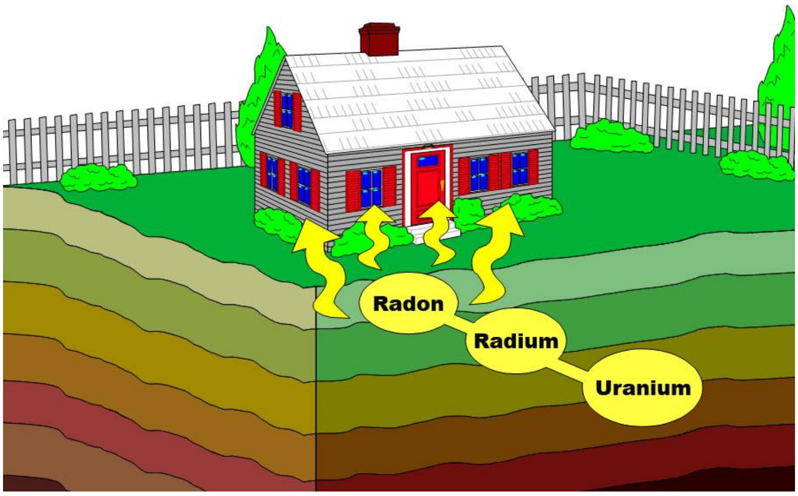
Sources of Radiation

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.

<u>Natural Radiation Sources</u>

<u>Radon</u> - 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.

[Picture Credit: Radon]



Where does it come from? Usually from soil, but it is found everywhere. The ground that we all walk on 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.

Kang, J.K., Seo, S. & Jin, Y.W. 2019.
"Radon is a naturally occurring radioactive material that is formed as the decay product of uranium and thorium, and is estimated to contribute to approximately half of the average annual natural background radiation. When inhaled, it damages the lungs during radioactive decay and affects the human body. Through many epidemiological studies regarding occupational exposure among miners and residential exposure among the general population, radon has been scientifically proven to cause lung cancer, and radon exposure is the second most common cause of lung cancer after cigarette smoking. However, it is unclear whether radon exposure causes diseases other than lung cancer. Media reports have often dealt with radon exposure in relation to health problems, although public attention has been limited to a one-off period. However, recently in Korea, social interest and concern about radon exposure and its health effects have increased greatly due to mass media reports of high concentrations of radon being released from various close-to-life products, such as mattresses and beauty masks. Accordingly, this review article is intended to provide comprehensive scientific information regarding the health effects of radon exposure."

Kim, *et al.,* 2018
PURPOSE:
"Exposure to indoor radon is associated with lung cancer. This study aimed to estimate the number of lung cancer deaths attributable to indoor radon exposure, its burden of disease, and the effects of radon mitigation in Korea in 2010.
MATERIALS AND METHODS:
"Lung cancer deaths due to indoor radon exposure were estimated using exposure-response relations reported in previous studies. Years of life lost (YLLs) were calculated to quantify disease burden in relation to premature deaths. Mitigation effects were examined under scenarios in which all homes with indoor radon concentrations above a specified level were remediated below the level.
RESULTS:
"The estimated number of lung cancer deaths attributable to indoor radon exposure ranged from 1946 to 3863, accounting for 12.5-24.7% of 15623 total lung cancer deaths in 2010. YLLs due to premature deaths were estimated at 43140-101855 years (90-212 years per 100000 population). If all homes with radon levels above 148 Bq/m^3 are effectively remediated, 502-732 lung cancer deaths and 10972-18479 YLLs could be prevented.
CONCLUSION:
"These findings suggest that indoor radon exposure contributes considerably to lung cancer, and that reducing indoor radon concentration would be helpful for decreasing the disease burden from lung cancer deaths."

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.

Blue, R.S., Chancellor, J.C., Suresh, R., Carnell, L.S., Reyes, D.P., Nowadly, C.D. & Antonsen, E.L. 2019.

INTRODUCTION: Analysis of historical solar particle events (SPEs) provides context for some understanding of acute radiation exposure risk to astronauts who will travel outside of low-Earth orbit. Predicted levels of radiation exposures to exploration crewmembers could produce some health impacts, including nausea, emesis, and fatigue, though more severe clinical manifestations are unlikely. Using current models of anticipated physiological sequelae, we evaluated the clinical challenges of managing radiation-related clinical concerns during exploration spaceflight.

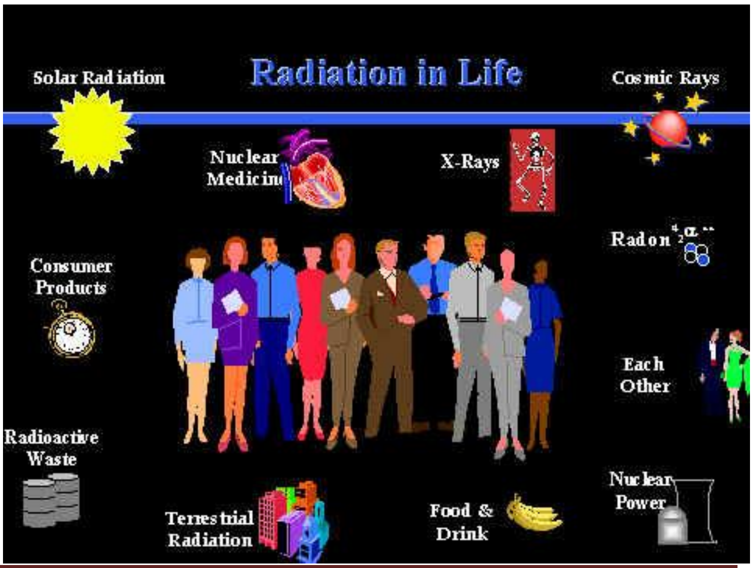
METHODS: A literature review was conducted to identify terrestrial management standards for radiation-induced illnesses, focusing on prodromal symptom treatment. Terrestrial management was compared to current spaceflight medical capabilities to identify gaps and highlight challenges involved in expanding capabilities for future exploration spaceflight.

RESULTS: Current spaceflight medical resources, such as those found on the International Space Station, may be sufficient to manage some aspects of radiation-induced illness, although effective treatment of all potential manifestations would require substantial expansion of capabilities. Terrestrial adjunctive therapies or more experimental treatments are unavailable in current spaceflight medical capabilities but may have a role in future management of acute radiation exposure.

DISCUSSION: Expanded medical capabilities for managing radiation-induced illnesses could be included onboard future exploration vehicles. However, this would require substantial research, time, and funding to reach flight readiness, and vehicle limitations may restrict such capabilities for exploration missions. The benefits of including expanded capabilities should be weighed against the likelihood of significant radiation exposure and extensive mission design constraints.

Desmaris, 2016

"Cosmic radiation in aviation has been a concern since the 1960s, and measurements have been taken for several decades by Air France. Results show that aircraft crew generally receive 3-4 mSv y(-1) for 750 boarding hours. Compliance with the trigger level of 6 mSv y(-1) is achieved by route selection. Work schedules can be developed for pregnant pilots to enable the dose to the fetus to be kept below 1 mSv. Crew members are informed of their exposition and the potential health impact. The upcoming International Commission on Radiological Protection (ICRP) report on cosmic radiation in aviation will provide an updated guidance. A graded approach proportionate with the time of exposure is recommended to implement the optimisation principle. The objective is to keep exposures of the most exposed aircraft members to reasonable levels. ICRP also recommends that information about cosmic radiation be disseminated, and that awareness about cosmic radiation be raised in order to favour informed decision-making by all concerned stakeholders."



[Picture Credit: Radiation]

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.

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 - while 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.

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).

Wilson-Stewart, K., Hartel, G. & Fontanarosa, D. 2019.
Aims: This study aimed to compare the head dose of a cardiologist to scrub and scout nurses during cardiac angiography.
Design: A correlational longitudinal quantitative design was used to examine the relationship between the variable of occupational dose to the medical operator when compared with the dose to the scrub and scout nurses.
Methods: A quantitative analysis was performed on data collected during coronary angiograms (N = 612) for one cardiologist and 22 nurses performing either the scrub or scout role between May 2015 and February 2017. Analysis was based on log-transformed dose levels and reported as geometric means and associated 95% confidence intervals.
Results: It was found that scrub nurses received on average 41% more head dose than the cardiologist during diagnostic procedures and 52% higher doses during interventional cases.

Conclusion: Nurses working in fluoroscopic cardiovascular procedures should be provided with appropriate training and protective equipment, notably lead skull caps, to minimize their occupational radiation exposure.
Impact: There is a notable lack of research evaluating the occupational head and eye exposure to nurses involved in fluoroscopic procedures. This study found that during diagnostic coronary angiograms, the scrub nurses received 41% more occupational head dose than the cardiologist and 52% higher head doses during interventional cases. Radial access resulted in higher doses to scrub nurses than femoral artery access. It is advisable that staff wear protective lead glasses and skull caps and use appropriately positioned ceiling mounted lead shields to minimize the risk of adverse effects of occupational exposure to ionizing radiation.

Varani, A.S., Saboori, S., Shahsavari, S. Yari, S. & Zaroushani, V. 2019.
Objective: Microwave radiation is one of the most growing environmental workplace factors that exposes too many workers in the various workplaces. Regard to concerns about cancer incidence in these workers and lack of systematic or meta-analytic studies about this object, so, we conducted a meta-analysis to acquire an understanding of the association between cancer risk and occupational exposure to radar radiation.
Methods: A systematic search was carried out on case-control, cohort and clinical control trial studies that published in the Cochrane Library, PubMed, ISI Web of Science, Scopus and Google scholar databases that accomplished from March 2017 to March 2018 and updated on 30 September, 2018 in English and Persian articles without time limit in publication date. Keywords were selected based on PICO principle and collected from MeSH database. After removal of duplicated studied, taking into inclusion and exclusion criteria, the process of screening was carried out and data were extracted after preparation of the full text of included articles. Article collection was completed by manually searching for a reference list of eligible studies. For quality assessment of included studies, Newcastle-Ottawa scale was used.
Results: a total of 533 studies was found in the first step of literature search, only 6 were included with 53,008 sample size according to inclusion and exclusion criteria. Estimated pooled random effects size analysis showed no significant increasing effect of occupational exposure to radar radiation on mortality rate (MR=0.81, 95%CI: 0.78, 0.83) and relative risk (RR=0.87, 95%CI: 0.75, 0.99, P <0.0001) of cancer with a significant heterogeneity between the selected studies.
Conclusions: In conclusion, the results of this meta-analysis study have shown no significant increase in overall mortality ratio and cancer risk ratio from occupational exposure to the radar frequency of workers. But, these results are not conclusive. As regards to some limitation such as fewer numbers of included studies, lack of data about exposure characterizations and demographic characterizations in this meta-analysis, this result is not certain and conclusive. It is recommended to conduct future studies.

Wang, *et al*., 2015
"Medical diagnostic X-ray workers are one occupational group that expose to the long-term low-dose external radiation over their working lifetime, and they may under risk of different cancers. This study aims to determine the relationship between the occupational X-ray radiationexposure and cancer risk among these workers in Jiangsu, China. We conducted Nested case-control study to investigate the occupational X-ray radiation exposure and cancer risk. Data were collected through self-administered questionnaire, which includes but not limits to demographic data, personal behaviors and family history of cancer. Retrospective dose reconstruction was conducted to estimate the cumulative doses of the x-ray workers. Inferential statistics, t-test and 2 tests were

used to compare the differences between each group. We used the logistic regression model to calculate the odds ratio (OR) and 95% confidence interval (CI) of cancer by adjusting the age, gender. All 34 breast cancer cases and 45 esophageal cancer cases that detected in a cohort conducted among health workers between 1950~2011 were included in this presented study, and 158 cancer-free controls were selected by frequency-matched (1:2). Our study found that the occupational radiation exposure was associated with a significantly increased cancer risk compared with the control, especially in breast cancer and esophageal cancer (adjusted OR=2.90, 95% CI: 1.19-7.04 for breast cancer; OR=4.19, 95% CI: 1.87-9.38 for esophageal cancer, and OR=3.43, 95% CI: 1.92-6.12 for total cancer, respectively). The occupational X-ray radiation exposure was associated with increasing cancer risk, which indicates that proper intervention and prevention strategies may be needed in order to bring down the occupational cancerrisk."

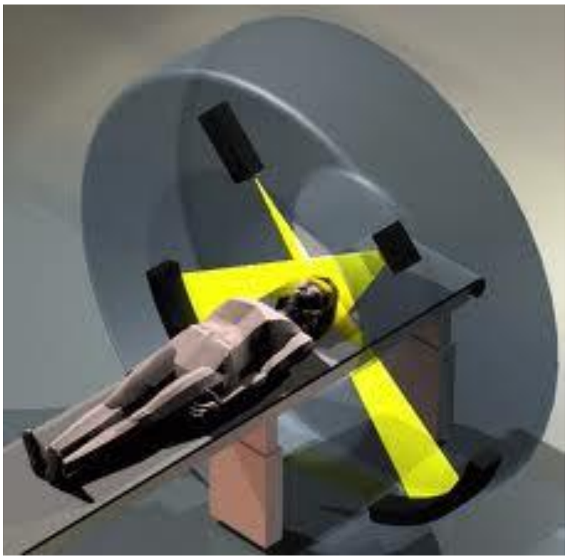
Medical Radiation

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

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.



Radiation therapy, radiation oncology, or radiotherapy, 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.

Radiation therapy is synergistic with chemotherapy, and is often used before, during, and after chemotherapy in susceptible cancers.

Sun, *et al.,* 2016
The objective of this study was to estimate solid cancer risk attributable to long-term, fractionated occupational exposure to low doses of ionizing radiation. Based on cancer incidence for the period 1950-1995 in a cohort of 27,011 Chinese medical diagnostic X-ray workers and a comparison cohort of 25,782 Chinese physicians who did not use X-ray equipment in their work, we used Poisson regression to fit excess relative risk (ERR) and excess absolute risk (EAR) dose-response models for incidence of all solid cancers combined. Radiation dose reconstruction was based on a previously published method that relied on simulating measurements for multiple X-ray machines, workplaces and working conditions, information about protective measures, including use of lead aprons, and work histories. The resulting model was used to estimate calendar year-specific badge dose calibrated as personal dose equivalent (Sv). To obtain calendar year-specific colon doses (Gy), we applied a standard organ conversion factor. A total of 1,643 cases of solid cancer were identified in 1.45 million person-years of follow-up. In both ERR and EAR models, a statistically significant radiation dose-response relationship was observed for solid cancers as a group. Averaged over both sexes, and using colon dose as the dose metric, the estimated ERR/Gy was 0.87 (95% CI: 0.48, 1.45), and the EAR was 22 per 10(4)PY-Gy (95% CI: 14, 32) at age 50. We obtained estimates of the ERR and EAR of solid cancers per unit dose that are compatible with those derived from other populations chronically exposed to low dose-rate occupational or environmental radiation.

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).

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

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.

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.

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.

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

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.

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.

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.

<u>Heart problems</u> - 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)

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.

Medical Disclaimer

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Handheld Survey Meter
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Ionizing Radiation
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