

chapter 4

Radiation and Treatment

CASE STUDY CONTINUED: Francine's Treatment

The doctor explained to Francine that she would have to participate in regular checkups after the surgery to track the healing process and to make sure that the cancer did not return. She had been reassured that there would be no genetic effects (future children she may have would not be affected by the radiation treatments), unless she was currently pregnant. The total amount of radiation she had already been exposed to from her x-rays and CT scan were also considered as minimal in comparison to the treatment options. Francine asked questions and listened carefully to the answers given on the two treatment options the doctor had described: radiation, or surgery along with radiation.



Figure 4-1

History of Radiation Treatment

The discovery of x-rays in 1896 eventually led to their use for cancer treatment by 1899. In that year, the literature reported that skin cancer had been cured on an individual with the use of x-ray treatments.

In the early days of using radiation as treatment, **radium** was the source of choice. Dosage calculations were impossible because there was not enough known about radium and the amount of radiation it emitted. Only superficial cancers could be treated with this limited knowledge and “rough-edged” technology. During this time, there were many reported incidences of tissue damage, recurrence of cancers, and death resulting from radiation treatment. Perhaps much of the fear surrounding radiation treatment today stems from these early days of misunderstood and uncontrolled methods.

By the late 1920s, a unit of measurement for dosage had been established. Physicians changed their techniques, from delivering one massive dose of radiation to delivering daily smaller quantities of radiation to the site that needed treatment. Though treatment did extend patients' lives somewhat, there was still not significant enough a rate of survival to warrant confidence in techniques or technologies. Further research into methods and equipment was needed, with technologies that could deliver higher energy levels of radiation.

Soon after World War II had ended, radioactive **cobalt-60** (synthetically produced from the stable isotope, cobalt-59) replaced radium as the radioactive substance of choice for treatment. Canada played a lead role in this new era of nuclear medicine. Technologies were developed to create mega-voltage outputs of energy and to deliver treatments. With higher energy levels came the ability to target cancers below the skin's surface, decreasing the severe skin reactions of the past. With the advent of the computer age, dosages could be calculated with speed and accuracy, and radiation energy could be delivered to targeted areas with limited to no damage of healthy cells. Physicians and medical physicists soon began clinical trials, to create a database of information to allow for more informed opinions of treatment method choices.

Today, radiation treatments realistically give patients the ability to control and/or cure their cancer.

The Canadian Nuclear Association maintains a large number of online modules for student use that connect you to the world of the nuclear industry. If you have an interest in exploring more of the Canadian history in the field of nuclear medicine, check out:

cna.ca/curriculum and look for the links to “Nuclear Technology at Work”

A Personal Cancer Connection

Have you, or has anyone in your family or circle of friends, been diagnosed with cancer?

What kinds of treatment did that individual go through?

What kinds of side effects did they have?

Did it affect their daily life?

How has their struggle with cancer inspired you?

Did You Know

Chlorinated Drinking Water and Cancer Risk



Figure 4-2

Question: *Is your water source chlorinated?*

For the past few decades, researchers have been studying the link between chlorinated water and cancer. Most studies show that long-term usage of chlorinated water leads to a slightly increased risk of cancer, particularly bladder cancer. Currently, it is believed that the benefits of chlorination outweigh the slight increase in the risk of developing cancer.

Humans have been chlorinating water to make it safer to drink for over 100 years. Using chlorine to disinfect water and kill microbes has prevented many illnesses. In 2000, the improper care and treatment of well water in Walkerton, Ontario resulted in more than 2300 illnesses and 7 deaths. Chlorine not only kills microbes at the treatment station, but its effects last as the water travels from the station to your tap, ensuring the safety of the water you drink.

Problems arise when chlorine reacts with plant matter that has not been properly removed from the water to be treated. Better filtration methods and more accurate determination of the amount of chlorine needed decrease risks associated with chlorination.

Ultraviolet (UV) light treatment is currently being used in Winnipeg, Manitoba in parts of its water treatment system. This type of treatment is effective against most microbes, but is less effective when the water is murky. The effects of UV light treatment do not last from the station to your tap, so this type of treatment is still used in combination with chlorination for better results.

Source: Author Unknown. "Chlorinated Water." Canadian Cancer Society 15 May 2008. 29 July 2008 www.cancer.ca/ccs/internet/standard/0,3182,3172_372124_langId-en,00.html



Figure 4-3

Radioisotope Therapy

Radioisotope therapy works by using an isotope as a source of radiation. The radiation source is combined with technology that sends photons, electrons, neutrons, protons, or ion beams to damage the DNA of cells at the atomic level. Cancer cells generally reproduce more and faster than normal healthy cells. Cancer cells also have a lesser ability to repair cellular damage than do normal healthy cells. Thus, when DNA damage occurs through irradiation, this damage is inherited in the next generation of cells. Cancer cells either slow in reproduction or die altogether.

There are three main types of radiotherapy: brachytherapy, systemic radiation, and teletherapy. Each of these types of therapy has advantages and disadvantages, and is more suited for treating particular types of cancer.

Figure 4-3 A "seed" used in brachytherapy is smaller than a grain of wheat (pictured here) and thinner than pencil lead. Palladium-103, iodine-125, and cesium-131 are typical isotopes used in seed implants. These isotopes all emit a very low energy radiation. Nevertheless, patients are cautioned during treatment not to come into contact with pregnant women or children for the first few days, to ensure they are not exposed to radioactive decay.

Internal Methods of Treatment: Brachytherapy

Brachytherapy is sometimes referred to as sealed internal radiation therapy, or implant therapy. Tiny radioactive pellets or seeds are implanted in a patient's body, surrounding the cancerous growth. Brachytherapy is designed to deliver a concentrated dose on or near the tumour in a short amount of time. Anywhere from 40 to 60 implants or seeds may remain in the patient's body or be removed after temporary treatment has occurred. Removal depends upon the type of cancer being treated. Temporary implants remain in the patient's body from several hours to several days. During this time, the patient is isolated in a hospital room.

Typically, anaesthesia is required to perform implantation. Most patients tend to feel little to no discomfort with brachytherapy. When implants are held in place with applicators there is some discomfort, but patients are able to return to their normal routines within a few days of treatment.

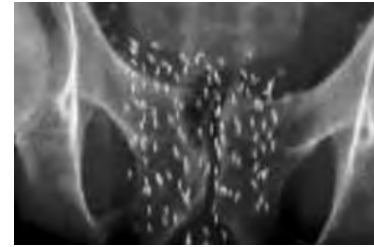


Figure 4-4
Above is actual radiograph showing the arrangement of radioactive pellets around a prostate cancer tumour.

Cancer Connection

Photodynamic Therapy

Within the past 8 years, a relatively new treatment for cancer has been developed—photodynamic therapy. This process involves injecting the patient with a light-sensitive chemical. The chemical travels to the faster-growing cells within the body (cancerous cells). A laser is used to activate the chemical once it is residing in the cancerous growth (*Figure 4-4*), and the chemical then literally destroys cancerous cells.

This technology is far less invasive or damaging than other techniques, is simple to use, but is still quite expensive. Photodynamic therapy works best with cancers of the skin, lungs, esophagus, brain, and bladder.



Figure 4-5

Question:

Would there be complications if this technology were used to treat children?

Internal Methods of Treatment: Systemic Radiation

Systemic radiation therapy is also called unsealed internal radiation therapy. In systemic radiation therapy, the patient is given a radioactive drink, pill, or injection. The radioactive source travels throughout the body and collects at the spots where faster cell growth is occurring (cancerous cells). As time progresses, the radioactive source releases energy and decays, killing cancerous cells and leaving the body. This type of therapy is not painful. Radiation therapists discuss precautions the patient may need to take as the radiation leaves his/her body over the course of a few days. Until the high levels of radiation leave the patient's body, (s)he may need to remain isolated in a hospital room.



Figure 4-6

Figure 4-6 *Radioactive iodine capsules are sometimes given to patients to treat thyroid cancer. An increased incidence of thyroid cancers in Ukraine and the surrounding countries of Belarus and the Russian Federation has been linked by some researchers to the Chernobyl nuclear disaster of 1986. The population most affected by this increase were children at the time of the reactor explosion and fire and were living in close proximity to the Reactor #4 complex. Many scientists accept the position that if a potassium iodide pill had been given to people immediately after exposure to the radioactive fallout, the number of cases of thyroid cancer would have been dramatically reduced. Iodine concentrates itself in the human thyroid gland, and at a more rapid rate among growing children than adults.*



Figure 4-7 A gymnasium near Chernobyl.



Figure 4-8 A chemistry classroom in the “no go zone” near the Chernobyl site.

In The Media

The Chernobyl Incident... Two Decades Later

In 1986, the world's worst nuclear disaster of a civilian nature occurred in Chernobyl, Ukraine. On April 25, workers were preparing to shut down Reactor #4 for regular maintenance. They decided to perform a safety test of the electrical grid to determine if enough energy was there to keep the reactor core's cooling system running. They turned off the emergency cooling system, and what occurred after that was a series of operational errors and results of design flaws that led to a power surge, a hydrogen and steam explosion, and the world's largest nuclear disaster.

Over the next few days, fallout dropped on Belarus, Ukraine, The Russian Federation, Poland, and Sweden. Sweden's scientists were the first to alert the world of the disaster, as the Soviet Union at the time was remaining officially silent.

Two people died in the explosion and twenty-nine firemen died in the following week. The deaths of the firemen could have been prevented, as they were sent to the site without proper radiation protection.

Today, long-term effects of the radioactive isotope release are still being studied. Children, both those who were near the site when the explosion took place and the following generation of children, have had a statistically significant increase in thyroid cancers. Nearly two thousand cases have been reported thus far. The ongoing list of diseases occurring among the more than 200,000 individuals sent to clean up the site is staggering—more than 4,000 have died from radiation exposure, and more than 170,000 suffer from various chronic illnesses. These recovery operation workers received doses between 0.01 and 0.5 Gy (grays). This cohort is at potential risk of late consequences such as cancer and other diseases and their health will likely be followed closely for decades to come.

The last working nuclear reactor at Chernobyl was shut down in 2000. Though the damaged reactor and the ensuing rubble were quickly enclosed in a concrete and steel tomb, that structure is now crumbling. Ukraine hoped to complete the re-sealing of this tomb by the end of 2008.

Note: The photographs are by David McMillan of Manitoba, who first visited the Chernobyl Exclusion Zone in 1994, eight years after the accident.

Source: Mulvey, Stephen. "The Chernobyl Nightmare Revisited." *BBC News* 18 Apr. 2006. 29 June 2008
news.bbc.co.uk/1/hi/world/europe/4918742.stm



Photographing in the Chernobyl Exclusion Zone

David McMillan

In 1986, because of poor design and human error, one of four reactors near the Ukrainian city of Chernobyl* exploded. The radioactive contamination was widespread, but it was considered so severe in an area extending 30 kilometres around the damaged reactor that 135,000 people had to be evacuated. I became interested in visiting what became known as the Chernobyl Exclusion Zone after reading a 1994 magazine article about the area's post-accident condition. After many telephone calls and faxes, I was able to gain entry and was allowed to photograph freely. I soon recognized that the subject was diverse and complex, offering the opportunity of making photographs that couldn't be made anywhere else. I never expected to return more than once or twice, but after each subsequent visit, I discovered new possibilities which encouraged me to return. Within the millions of acres of the exclusion zone, there are fields left to lie fallow and cities and villages where the vestiges of the defunct Soviet Empire and the everyday remnants of the lives of the former citizenry remain. Superimposed on this is the proliferation of nature and the deterioration of the built environment – all blanketed with unseen radiation. Every time I've returned to photograph I've realized the subject is larger than my original conception. Within this area, virtually untouched by civilization since the 1986 accident, there was a kind of change that was the result of the passage of time and the inexorability of nature. For the past several years, I've photographed almost exclusively in the city of Pripyat. Once home to 45,000 people, it was the largest population centre within the exclusion zone. It was built to house the workers from the nearby nuclear power plant, and several apartments were still under construction at the time of the accident. Pripyat has many schools, kindergartens, playgrounds, hospitals, and cultural facilities. The city was considered one of the finest places to live in the former Soviet Union, but it will never be lived in again. Although the geographical location for my work has become circumscribed, the photographic possibilities still seem rich and varied.

David McMillan is a photographer who teaches at the University of Manitoba's School of Art. As of 2008, he has photographed in the Exclusion Zone 14 times.

* The English translation of the Russian word is "Chernobyl." Since Ukraine established its independence from the Soviet Union in 1991, the Ukrainian spelling is translated as "Chornobyl."

activity

Flashlight “Beamlets”



Choose two classmates to help you. Each person should have a flashlight of differing dimensions and power, and should stand in different spots around the classroom. Attempt to illuminate Figure 4-7 on page 34 and nothing else.

What problems occur?

What variables do you need to control or change to obtain a better result?

How do these results help in understanding IMRT?



Figure 4-9 An image of the Clinac Linear Accelerator Treatment Machine. Note how the source of high energy beams rotates around the patient.

External Methods of Treatment: Teletherapy

Teletherapy, also known as external beam radiation therapy, uses a machine outside of the body to direct radiation at the cancer and surrounding tissue. This type of therapy is widely used to treat most types of cancer. A linear accelerator, or “linac,” produces a beam of high energy x-rays or electrons. A technician, in conjunction with an oncologist and a medical physicist, plans the size and shape of the beam as well as the amount of time the patient is exposed to the beam.

Because this form of treatment uses an external source of radiation, surgery is not necessary. However, teletherapy may be combined with other forms of treatment such as brachytherapy (depending on the type of cancer).

Proton beam therapy is a similar treatment method, using protons instead of x-rays or electrons. The advantage of proton beam therapy is that it is easier to control the size and shape of the beam, reducing damage to normal healthy tissue surrounding the cancerous tissue. Not all hospitals have access to the equipment needed for this type of treatment, as it is more expensive than the classic teletherapy procedure.

Intensity Modulated Radiation Therapy (IMRT) is a particular kind of external beam therapy, which allows radiation to be shaped specifically to a tumour’s size and shape. Instead of one intense beam, the beam is broken up into smaller “beamlets,” with each smaller beam’s intensity individually adjustable. This increases the chance for a cure while decreasing damage to healthy tissues.

Francine’s Case Study Continued:

Francine and her doctor decided that it was impossible to perform surgery to remove the tumour. The tumour was not uniform, and chances were good that surgery would be unsuccessful to remove the tumour in its entirety. But what was the best option? Systemic radiation? Teletherapy? Some combination of both? Francine needed more information to make a more informed decision.

Reality Check

Question | Is a barium enema dangerous?

Origin: A high level of discomfort is associated with a barium enema procedure. Placing radioactive liquid into an orifice in your body has led people to believe that this is dangerous to your health.

Reality: Barium is not radioactive. According to Health Canada, a barium enema, though uncomfortable, does not pose any significant health danger to the patient unless there is a small tear in the gastrointestinal tract. On rare occasions, the act of blowing air into the gastrointestinal tract during the barium procedure may cause a tear in the lining. If there is a tear in the lining, there is a chance of the barium sulphate liquid leaking into the intestinal area. If this occurs, surgery must be performed and antibiotics given to prevent infection.

Rarely, a patient may experience constipation as a side effect after the procedure. Drinking lots of water will eventually take care of this problem. After having a barium enema, most patients will have light-coloured stool for two to three days afterward, and will feel fatigued. Drinking water to expunge the last remaining amounts of barium sulphate from the gastrointestinal tract is recommended. Fatigue is dealt with by obtaining more rest.

An alternative to the barium enema is to have a colonoscopy, though currently more details are seen through the barium enema contrast radiographs than through colonoscopy procedures. This may change as technology and training improve.

Source: MediResource Clinical Team. "Barium Enema: Lower GI (gastrointestinal) Series - Lower GI Exam." MyFox Dallas n.d.. 29 July 2008

health.myfoxdfw.com/TestFactsheet.aspx?id=10&pg=1#S4



Figure 4-10
X-ray of a colon with a barium contrast agent injected

The Gamma Knife

Neurosurgeons, radiation oncologists, and medical physicists team up to carry out a procedure known as gamma knife surgery (GKS). In this procedure, a patient is fitted with an almost helmet-like contraption called a collimator. The collimator helps guide the technology to pinpoint a brain tumour's location. Up to 201 different sources of the cobalt-60 isotope are used to irradiate the tumour, inundating it with a single high dose of ionizing radiation in a small amount of time. Typically, patients remain in the hospital for a day if complications do not arise. They resume their normal activities within a couple of days of having the procedure. No actual knife is used during the procedure.

The individual beams entering each hole do not have enough energy to damage the normal tissue. When these beams meet at a focal point (the tumour), they have a combined effect powerful enough to deliver a deadly dose of radiation to the cancerous cells.

Gamma knife surgery has benefits over the use of linear accelerators (linacs) to deliver radiation treatment. Rather than having multiple visits with lower doses of radiation delivered in fractions (fractionated treatment), GKS delivers one dose in one visit with outpatient processing happening within 24 to 48 hours.

The first gamma knife, invented in Sweden, was installed in a private hospital in Stockholm in 1968. The United States installed its first gamma knife in Pittsburgh in 1987. Winnipeg became home to Canada's first gamma knife equipment and GKS program in 2003, with Quebec City obtaining one in 2004 and Toronto in 2005. This technology is used only for intracranial conditions.



Figure 4-11
The picture above is of a collimator. The collimator serves two purposes: it holds the patient's head still, and it guides the gamma rays through small openings found throughout the surface of the half-sphere.

Questions For Further Research:

1. Which type of radiation therapy discussed in this chapter is the least invasive? Which one has the least impact on quality of life immediately after treatment?
2. Why do you think it took more than 30 years to obtain gamma knife technology in Canada from the time of its invention? Justify your answer.
3. What types of treatment is your water plant using to make sure drinking water is safe? How have methods changed with time? Acknowledge your sources of information.
4. Research the Three Mile Island disaster that took place in Pennsylvania in 1979. Discuss the similarities and differences between this disaster and the Chernobyl disaster, both in terms of damage to the environment and in how the government handled the public health after that. Acknowledge your sources of information.



Career Moves

Radiation Oncologist

A radiation oncologist works together with physicists and technicians to develop a radiation treatment plan for cancer patients. In consultation with the patient, decisions are made as to whether and which type of radiation treatment is needed, which particular part of the body will be irradiated, and how long treatment will last. The oncologist has expertise in cancer management, and is with the patient throughout the treatment process and afterwards, assessing treatment success and side effects.

Career Connection Website – Canadian Association of Radiation Oncologists
www.caro-acro.ca/site3.aspx

Figure 4-12



CASE STUDY CONTINUED: The Final Decision

The treatment plan that Francine and her doctor agreed upon to eradicate the thyroid tumour was a combination of systemic radiation and teletherapy. Francine's systemic radiation therapy was the ingestion of radioactive iodine capsules, the same effective treatment given to many people who suffered from the Chernobyl disaster in the Ukraine in 1986. The iodine capsules were added to her treatment plan to ensure that any cancerous cells left behind by teletherapy treatments would be obliterated. Her hospital stay was brief—only two weeks—and her side effects were manageable. She felt nauseous and weak after each of her two teletherapy treatments. The iodine pills left her with a strange taste in her mouth and no appetite for food. When she did eat, she occasionally had difficulty keeping the food down. She noticed, too, that she tired more easily. Her doctor had alerted her to all of these side effects before her treatments, so she was fully prepared for them. She also knew that with time they would reduce and disappear—in about a month.

Figure 4-13

Chapter 4 Review: Concepts and Terms

Concepts: A summary of the history of radiation treatment from the early 1900s began this chapter. Radioisotope therapy was then described as an external treatment method using an isotope as a source of radiation for treatment of cancer cells. Cancer cells either slow in reproduction or die altogether with this treatment.

Brachytherapy is an internal treatment method, which is designed to deliver a concentrated dose of radiation on or near a tumour in a short amount of time. Typically, anaesthesia is needed to perform the implantation of a brachytherapy seed.

Systemic radiation therapy involves the patient ingesting a source of radiation that collects at cancer cells, killing them. Until the high levels of radiation leave the patient's body, the individual may need to remain in a hospital room.

Teletherapy uses a machine outside of the body to direct radiation at cancer and surrounding tissue. Though surgery is not necessary, teletherapy may be combined with other forms of treatment such as brachytherapy.

Gamma knife surgery uses extremely precisely aimed ionizing radiation, usually from cobalt-60, to inundate a tumour with a single high dose of radiation in a small amount of time. This type of treatment delivers one dose in one visit, whereas teletherapy may involve multiple visits and doses.

Terms of Interest:	
anaesthesia	intensity modulated radiation therapy (IMRT)
barium enema	intracranial
biopsy	linear accelerator (linac)
brachytherapy	neurosurgeon
cobalt	photodynamic therapy
collimator	radiation oncologist
colonoscopy	radioisotope
esophagus	radium
fractionated treatment	systemic radiation
gamma knife	teletherapy



The image here is of a “creation mural” inside one of the schools in Pripyat, Ukraine. The photograph was taken in 2003 by Winnipeg arts professor Dr. David McMillan, who has an interest in documenting the “return to nature” of the human-constructed world in and around the Chernobyl nuclear power facility. The so-called 30-kilometere Exclusion Zone surrounding the science city of Pripyat is still so radioactive, humans cannot live there for the foreseeable future. This is a good opportunity to assess the benefits and risks of operating a nuclear facility without the necessary safeguards against the release of radioactive isotopes. Many more images and commentary can be found online at: <http://home.cc.umanitoba.ca/~dmcmill/index.html>