

chapter 1

Radiation-Based Diagnostic Technology

CASE STUDY: Francine Yellowquill - a Diagnosis

Francine Yellowquill was an active teenager, enjoying participating in all kinds of sports. Her favourite sport was gymnastics. She regularly practiced somersaults, handstands, and complicated jumps over sawhorses and on balance beams. One day she attempted a new manoeuvre upon dismounting from the balance beam, and ended up accidentally landing on her head. Excruciating pain shot through her back, as if thousands of hot needles were jabbing into her simultaneously. Instantly, her coach was at her side and called for an ambulance. The emergency doctor asked her some key questions and then promptly sent her for x-ray. “You might have a problem with trauma in two or three cervical vertebrae in your neck area,” it was explained following x-ray. The doctor then ordered a CT scan, which confirmed the initial diagnosis of broken vertebrae in Francine’s neck.

As she went for these tests, Francine (who always had an eye for technical explanations of things) began to ask some questions. What kinds of technologies are being used on me? How do these imaging machines actually work? Why did I need to go for more than one type of imaging? Could the doctor obtain the same diagnosis without resorting to a technology that uses ionizing radiation? *Fictitious patient (stock photo)*



X-Rays

In late 1895, Wilhelm Roentgen was working at Wuerzburg University in Germany with a cathode-ray tube in his laboratory. While conducting his experiments, he noticed that phosphorescent crystals glowed in the presence of the working tube. When Roentgen created a vacuum in the tube and applied a high voltage to the electrodes, a fluorescent glow appeared. Roentgen concluded that a new type of ray was being created by this apparatus. Through further experiments, he concluded that this ray could pass through most substances. What he discovered was what we know in a familiar fashion as the “x-ray.” The letter “x” in x-ray derives from the Greek “xenos” which means something “foreign” or “strange” to typical experience.

An x-ray is a photon, or bundle of energy, which is essentially without mass and has no charge. The typical wavelength for an x-ray is between 0.01 to 10 nanometres. Because x-rays are produced by accelerating electrons towards a target (a large potential difference), they are not a natural form of radiation. X-rays are used in both x-ray technology and CT (Computed Tomography) devices.

X-rays are a form of radiation that has shorter wavelengths than UV radiation. For most medical applications, x-rays have a short enough wavelength to demonstrate behaviour more like that of a particle than a wave. So, their particle-like qualities are favoured over their wave-like nature. In x-ray crystallography—where x-rays are used to help determine the structure of crystals—the opposite is the case.

In the decades following Roentgen’s discovery of x-rays, widespread and unrestrained experimentation with this new form of radiation followed. As a result, some excessive experimenters developed serious injury to the body from overexposure to this form of radiation. Typically, these injuries were not attributed to x-rays because the onset of the injuries was progressive over time. At one point, x-rays were used by assistants in shoe shops to determine children’s shoe sizes! Eventually, though, the field of health physics emerged that looked to manage the dangers of radiation technologies while still exploring their potential and real benefits.

Reality Check

Question | Can Sustaining a Physical Injury Cause Cancer?

Origin: In the late 1800s until the early 1920s, some scientists thought injuries (or trauma to the body) could cause cancer, despite the lack of any compelling experimental evidence. Many patients who came in with physical injuries had x-ray imaging performed on them, and in the process tumours were discovered.

Reality Check: A fall, a bruise or any other injury is almost never the cause of cancer. Typically, a physician orders some sort of imaging for injuries incurred, and when images are analyzed a tumour may be found at the same time. This does not mean that the tumour stemmed from the injury, however. The tumour was already there. The diagnostic procedure merely located the tumour while the technologist was requested to take images looking for bone and tissue damage.

Terry Fox, a well-known Canadian who died in 1981, had been an active teenager involved in many sports until a knee injury sidelined him at age 18. During the diagnosis and treatment process, bone cancer was found and he was forced to have his right leg amputated above the knee. Terry is best remembered for his Marathon of Hope, which was a cross-country run to raise funds for cancer research. His legacy lives on through the Terry Fox Foundation.

Source: Gansler, Dr. Ted. "Discovery Health: Top 10 Cancer Myths: Myth 7." *Discovery Health* n.d.. 29 July 2008
<http://health.discovery.com/centers/cancer/top10myths/myth7.html>

The Electromagnetic Spectrum

When you listen to the radio, watch television, cook food in the microwave, use a tanning bed, or go to the doctor to get an x-ray, you are using electromagnetic waves. A wave is simply a vibration that is propagated through a medium such as air. An electromagnetic wave is a vibration produced by the acceleration of an electric charge. Though we cannot actually "hear" sound waves, our ears are designed to respond to these mechanical waves and it is via this response that we hear. Visible light, as part of the electromagnetic spectrum, helps us to "see" colours because photons from light sources fall within the range of wavelengths that the receptors in our eyes can translate into red, blue, green and other variations. Other types of waves are not registered by the human body through sound or sight. Microwaves and x-rays are two examples of such waves.

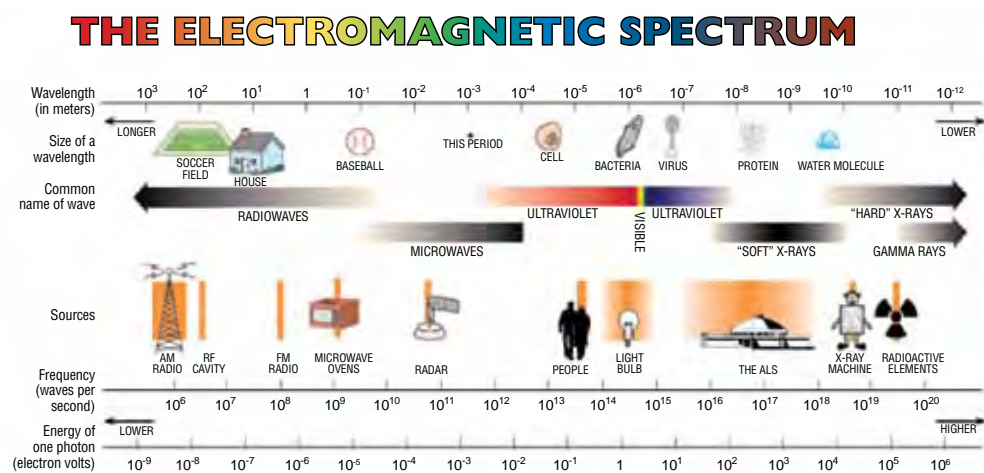


Figure 1-2 shows the different wavelengths, frequencies, and energies that waves in the electromagnetic spectrum have. Note that radio frequency waves are among the largest in wavelength, with x-rays having incredibly small wavelengths. As wavelength decreases, the frequency of the wave (and the amount of energy the wave carries) increases.

Tissue Attenuation



Tissue attenuation is an important concept in our understanding of x-rays and how their penetration into tissues affects image quality.

Shine a flashlight on a piece of tissue paper that someone is holding up in a darkened room. How much light goes through the tissue paper?

Now fold over one corner of the paper so there is a double layer of tissue paper. How much light goes through the double layer compared to the single layer? How do these results help in the understanding of radiographs?

The chart shows the relative sizes, frequencies, and wavelengths of the different types of electromagnetic waves. The visible portion of the electromagnetic spectrum (light) is a small portion of the chart. UV, x-ray, and gamma rays all have shorter wavelengths and higher frequencies than the visible spectrum. By contrast, ultrasound—which is commonly used in medical imaging—is not an electromagnetic wave at all. Rather, it is a very high frequency sound wave beyond what our auditory systems are capable of hearing.

Questions: Electromagnetic Spectrum

- 1 Calculate the wavelength of radiofrequency waves that an FM radio station emits when broadcasting at 88MHz. (Use $v = f\lambda$, and find the speed of sound in air at 20 degrees C from your physics tables)
- 2 What is the difference between “soft” and “hard” x-rays (mentioned in Figure 1-2)?
- 3 What is the wavelength used by cell phones compared to the wavelength of the gamma rays used in PET scans? Which carries more energy?
- 4 What is the difference between UV-A and UV-B ultraviolet light?
- 5 What is the difference between sound waves we hear and ultrasound? Are sound waves considered part of the electromagnetic spectrum?

X-Ray Diagnosis

The use of “x” in the phrase “x-ray” is similar to when mathematicians use the symbol “x” to represent the “unknown.” When x-rays were first discovered, there were many things that were “unknown” about them. Recall the connection to the Greek word “xenos”, meaning ‘foreign’.

X-ray machines use a form of electromagnetic radiation produced when electrons are exposed to a large potential difference, or voltage. The electrons gain so much extra energy that this potential energy becomes kinetic energy and the electrons move quickly, colliding with the metal target plate. The rapid change in velocity causes the release of x-rays. This burst of radiation is aimed by the machine at the patient through positioning an extendable arm over the area of the body to be studied (see Figure 1-3). The x-rays pass through the body and an image of what they pass through is recorded on photographic film or is digitally generated. Because different parts of the body have different densities, the image will show lighter sections (indicating greater density and passage of fewer x-rays through the substance) and darker sections (lesser density and more x-rays traveling through). The picture obtained by this method is called a radiograph. Radiographs show clear images of bones and potential damage to them; however, they are limited in their ability to produce images of soft tissues that have clarity for diagnostic purposes. The reduction in the number of x-rays traveling through dense material is called attenuation, or ‘loss’.

Arthrography is a procedure where a substance such as iodine (mixed with water) is injected into the space between joints so that an x-ray can be taken to study how the joint is functioning and to study its structural anatomy.

Figure 1-3 This x-ray machine has a bed for the patient to lie on and a tray underneath the bed to hold the radiographic film. The source of x-rays comes from the arm extended above the bed. Note that if a patient was lying on the bed, the arm would be rotated to aim the x-rays downward rather than towards the left wall (as is shown on the picture).



Figure 1-3

Mammography is a specialized field of x-ray technology, where low energy x-rays are used to produce images of breast tissue. Radiologists use these images to detect differences in density, mass, or to spot calcifications that may indicate the presence of tumours. Low energy x-rays provide greater definition in the images. Higher energy x-rays travel fast and the result is an indistinct radiograph with lower contrast due to lower attenuation by the tissues involved.

activity

X-Ray analysis

Below are nine different x-rays of various parts of the human body. Imagine you are the x-ray technician asked to analyze each radiograph, or to guide the attending physician. Do you see something that is unusual in any of these images? What do the unusual sections potentially indicate? Why are some areas of the x-rays brighter? For each image, discuss in small groups whether the differences in brightness are more likely due to density, thickness, or the nature of the material (attenuation coefficient).



Figure 1-5 chest



Figure 1-6 molars

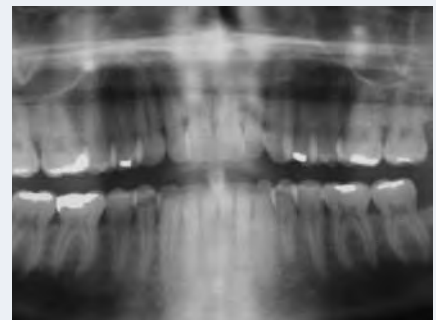


Figure 1-7 panoramic dental



Figure 1-8 forearm



Figure 1-9 knees



Figure 1-10 forearm



Figure 1-11 colon



Figure 1-12 skull

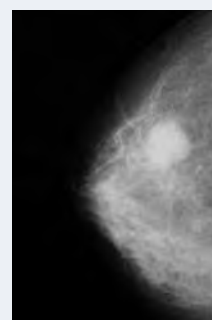


Figure 1-13 breast

Research Questions:

Why use iodine in arthrography and not other elements? What does calcification refer to?

Question:

Note that the wrist joint of Figure 1-4 is brighter than the finger joints. What does this tell you about comparative bone densities or thicknesses of the bone tissues?

Figure 1-4

This is an x-ray image of a person's hand. Note the detailed, high contrast image of the bones, including brighter and darker areas. X-rays can be used to determine whether an individual has osteoporosis by studying the comparative densities of bone areas and noting potential damage.

Want to learn more about the nuclear model of the atom? **Check out Chapter Five!**



In The Media

Airport x-ray scanning devices are used around the world as a vital component of airport security measures. The devices are used to scan luggage and carry-on items to ensure that accelerants, weapons, and other dangerous goods are not taken onto the plane. In the United States, the National Council on Radiation Protection continues to perform research on the general public to track radiation exposure from every-day devices such as these machines. To date, their studies continue to show that there is only very low radiation exposure from these devices. You can read their most recent findings on their website: www.ncrponline.org



Figure 1-14

Natural Forms of Radiation

The nucleus of an unstable atom can decay, or transform, releasing energy in the form of either particles or waves. There are many types of natural radiation, including exposure to naturally occurring stratospheric radiation when in an airplane and radon exposure from the earth in the form of radon gas. We will focus on the following three forms: alpha, beta, and gamma radiation.

Alpha decay occurs when the nucleus of an unstable atom releases an alpha particle. An alpha particle is positively charged, and is essentially indistinguishable from a helium nucleus. The reason why scientists do not refer to it as a helium nucleus is because at the time alpha particles were discovered, they were not fully understood. It was only much later that it was determined that they were two protons plus two neutrons traveling together. Isotopes of elements that release alpha particles are known as alpha emitters.

Alpha particles carry high amounts of energy, but have low ability to penetrate through substances. In fact, substances as thin as a piece of paper can prevent alpha particles from penetrating through to the other side. Though alpha particles can be stopped by mere paper, if humans inhale or ingest them they can cause enormous amounts of damage.

Uranium-238 is an example of a substance that undergoes alpha decay. Its nucleus is left with two less protons and two less neutrons, so a daughter nucleus is produced. This nucleus forms the centre of the thorium-234 atom. A subatomic change, or transmutation, occurred in the uranium to become a completely different chemical element. You may recall from earlier science courses that it is the number of protons in the nucleus that uniquely defines which element we are referring to.

Beta decay occurs when a beta particle is released from an unstable atom. A beta particle can be either a high speed electron or a proton. If the process of beta decay releases an electron, it is referred to as beta-minus (β^-) decay. Release of a proton is called beta-plus (β^+) decay.

When beta particles enter a substance, they cause a physical/chemical change. Glass, for instance, becomes darker after being exposed to beta radiation. Most beta particles do not have the energy to penetrate the skin, but constant bombardment of one area of skin with these particles can eventually cause damage. One common form of beta decay is when carbon-14 releases a beta particle and becomes nitrogen-14. Because a nuclear change took place, **transmutation** occurred.

Unstable atoms, as mentioned previously, may have an excess of subatomic particles. However, sometimes there is simply an excess of energy rather than an excess of particles. This is when gamma rays are emitted. A **gamma** ray is a high energy photon with a wavelength of less than 0.1 nanometres. Typically, gamma rays are emitted by the nucleus whereas x-rays are emitted from the electron cloud in an atom.

Gamma rays are often produced alongside the release of alpha or beta particles, especially if the substance emitting the particles is in an excited state. Gamma rays are high energy electromagnetic waves, and as such cause serious damage when in contact with living cells.

When a gamma ray is emitted, the nucleus changes from a higher-level energy state to a lower level. Just as electrons in an atom have energy levels, the nucleus has energy levels. When electrons are in a higher energy level (or state), they release usually a few electron-volts (eV) of energy in the form of visible or ultraviolet light. When a nucleus is in a higher energy state and wants to return to a lower and more stable energy level, it releases energy in the range of a few hundred kiloelectron-volts (keV). The chemical makeup of the atom emitting a gamma ray does not change. The chemical makeup of the atom does change if it emits either an alpha or beta particle. (Note: an **electron-volt** is defined as the energy gained by an electron when it travels through a potential of one volt.)



Research Questions: Mammography & Alternatives

Mammograms are not able to confirm the absence or presence of cancer, although mammography combined with pathology confirms or denies the existence of cancer. However mammography is a significant tool in finding abnormal growths that are not at the palpable (sensed by touch examination) stage. What could a doctor, attempting to provide an accurate diagnosis, suggest to a patient who has just received positive test results on her mammogram?

What does a positive test result mean for a mammogram? (Cancer? A calcium deposit? A benign tumour? (What does benign mean?) Something else? All of the above?)

What other types of diagnostic technologies could be used to confirm or nullify the positive test results?

Research and compare rates of breast cancer in males and females of similar ages. Are they the same or different? What have you found?

Figure 1-15

The Canadian Cancer Society has a particular set of positions with respect to breast cancer screening through mammography. It is important that you become familiar with these positions and talk about these with family members who are among the risk groups for developing breast cancer.

Benefits and risks of screening

Almost every test or procedure carries benefits and risks. The important thing is to be aware of them so that you can make an informed decision that is right for you.

No screening test is 100% accurate but a good screening test is one that results in a decrease in death rates in people with cancer.

Researchers also look for other benefits of screening including improved quality of life or less harmful treatments as a result of finding the cancer early.

Benefits of regular screening

- **Earlier detection of cancer:** In most cases, the earlier a cancer is detected, the better your chance of survival. Early detection may also mean less treatment and less time spent recovering.
- **Reducing the anxiety of “not knowing”:** Many people prefer to have ‘check-ups’, just like a physical exam with your family doctor.

Risks of regular screening

- **False positive results:** When test results suggest cancer even though cancer is not present. False positives can result in anxiety, stress and possibly painful and unnecessary tests to rule out cancer (that is, to make sure you don’t have cancer when the screening test has suggested you might).
- **False negative results:** When cancer not detected by the test even though it is present. False negative results can cause you or your physician to ignore other symptoms that indicate the presence of cancer, causing a delay in diagnosis and treatment.
- **Over-diagnosis:** Some cancers would not necessarily lead to death or decreased quality of life. For example, some prostate cancers never become clinically apparent, meaning that they do not cause any symptoms, nor do they affect life expectancy or quality of life. Men with these tumours may not ever develop symptoms or need treatment for cancer.
- **Increased exposure to harmful procedures:** for example very low doses of radiation from x-ray tests.

What makes a good screening test

The World Health Organization (WHO) suggests reviewing several factors before introducing a test as a screening tool for the general population. These include:

- **Sensitivity:** How effectively the test identifies people who actually have cancer?
- **Specificity:** How often a test gives negative (normal) results for people who do not have cancer?
- **Acceptability:** Will the population who will benefit the most from the test (the “target population”) agree to be tested by this method?

Tests that can be used for diagnosis and screening

Some tests that are used for screening can also be used to diagnose or rule out cancer in people who have reported symptoms to their doctors. For example, mammograms can be used for both screening and diagnostic purposes:

- To screen women with no signs of breast cancer, or
- To help diagnose women who do have signs of breast cancer (or rule out cancer in women who have signs of breast cancer)

Your doctor will be able to explain what type of test you are having and why you are having the test.



Canadian Cancer Society
Société canadienne du cancer

MANITOBA DIVISION

You can find much more information from the Canadian Cancer Society’s online information pages found at: www.cancer.ca



Figure 1-16

Did You Know

N-Rays...Debunked!

In the spring of 1903, French researcher Rene Blondlot published a paper explaining the purported discovery of a new type of radiation called N-rays (N for Nancy, his hometown in France). This caused excitement among the scientific community, as the discovery followed closely after x-ray discoveries in 1895. Many scientists published research papers on N-rays in the most prestigious scientific journals in France, and all claimed to have confirmed the existence of the new N-ray experimentally.

Not all physicists were confident in the existence of N-rays, however. One such physicist was Robert Wood (*Figure 1-16*) from Johns Hopkins University in Baltimore, Maryland. In the summer of 1904 he traveled to France to meet Blondlot and observe the experimental apparatus used to confirm the existence of N Rays.

Blondlot chose to show Wood his most well-known demonstration, where he claimed N-rays could be spread out into a spectrum by a prism. The spectrum could be detected by noting small increases in brightness along various points of a phosphorescent strip. Though many experimenters claimed to see these brighter points, others (including Wood) could see no evidence of this. While Blondlot was setting up his equipment to demonstrate the spectrum to Wood, Wood quietly removed the prism and waited for the experiment to be completed. Once again, Blondlot affirmed the existence of the spectrum, which could only be created in the presence of the now-missing prism, and claimed that Wood's eyesight was not good enough to see the results. After repeated demonstrations of this "spectrum," Wood became convinced that experimenters were imagining the results. Without the presence of the prism, a spectrum could not be created, yet experimenters claimed they saw one. Wood concluded N-rays did not exist.

In the end, many researchers reluctantly, and quietly, retracted their published results in what became a rather spectacular blunder in the history of modern physics. Was it a classic case of "believing is seeing"? In science, we often say that "extraordinary claims require the most extraordinary evidence to back them up." Maybe, in the N-ray affair, we learned that valuable lesson yet again. What you may want to do now is to turn up what you can on a very recent example of nuclear science controversy – the so-called "cold fusion" phenomenon. Access information online at: <http://freeenergynews.com/Directory/ColdFusion/> or a rather advanced level discussion at:

www.infinite-energy.com/iemagazine/issue1/colfusthe.html

For more information on Wood, Blondlot, and N-Rays, see the website of the American Physics Society at www.aps.org



Figure 1-17 Similar to an x-ray machine, a CT scanner has a flat bed for the patient to lie on. The bed slides into the “donut hole,” where one section of the ring contains a source of x-rays that radiate outwards in a fan shape. The other section of the ring contains a banana-shaped detector. This ring can rotate around the patient. One full rotation produces one cross-sectional slice or “profile.”

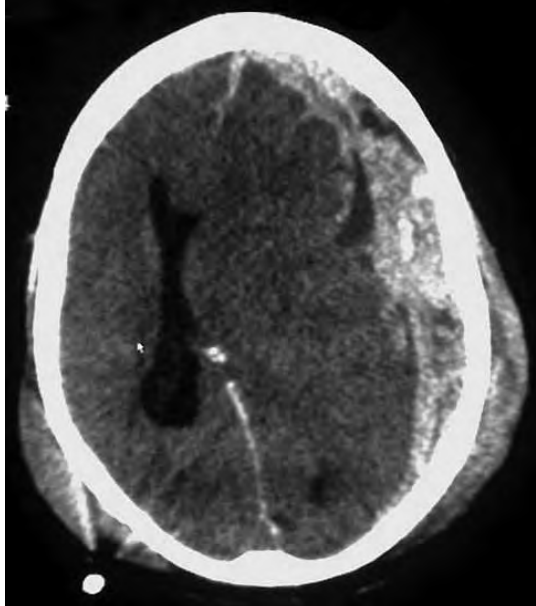


Figure 1-18 Here is an example of a cross-section of a person’s brain produced by a CT scanner. Note that the image is not in colour. Images can be checked by technicians for bone abnormalities, fluid retention, tumours, haemorrhages, trauma or skull fractures among other things. In this image, the darker areas in the upper right indicate the presence of subdural (beneath the skull) trauma or blood clotting.

Computed Tomography (CT)

Computed Tomography (CT) uses x-radiation to create higher resolution images than a simple x-ray machine can produce alone.

Tomography is the process of obtaining a two-dimensional “slice” or cross section of a three-dimensional object, such as a patient undergoing imaging to detect an abnormality.

In CT scans, multiple tomographs, or cross sections (from the Greek words “tomos” meaning “section” and “graphos” meaning a “picture”) of a patient can be produced and linked together by a computer to create a three-dimensional image of the area being studied, something not possible with simple x-ray machines. This type of technology is invaluable in determining the presence of cancer, as the images produce measurable pictures of tumour growths. They also clearly show soft tissues (and potential damage), as well as even the tiniest bones or fragments broken off due to injury. CT scans can be used to determine bone mineral density too.

Sometimes, patients are asked not to eat or drink anything for 12 hours before going for a CT scan. This is so that technicians can administer a contrast agent internally, allowing for better diagnosis of certain conditions or diseases. For instance, barium sulfate is sometimes used to make parts of the gastrointestinal tract opaque (dense to x-rays) during a CT scan.

Francine’s Case Study Continued:

Francine’s doctor ordered a CT scan to confirm the initial diagnosis of a broken neck. The x-ray obtained showed fractures in two vertebrae. The CT scan confirmed those fractures, but was also able to show if there were any bone fragments and where they were located. The doctor then determined if the fragments should be removed, or if they would be able to remain safely.

X-RAYS and CT SCANS –the LINKS

One of the main differences between x-ray machines and CT scanners is that CT scanners are highly sensitive in detecting abnormalities in soft body tissues. CT scanners have the ability to provide images of internal organs, which x-ray machines cannot.

LIST—list in point form what you know or remember about x-rays and CT scans. If you remember a term but not the definition, make a note of that too.

INQUIRE—share your list with three of your classmates. Have them share their lists with you. Ask each other what connections between x-rays and CT scans were made in your notes and why.

NOTE—put away your lists and give yourself a brief quiz to see what you remember about your discussions and connections made.

KNOW—compare your quiz results to your notes. What do you still need to know or learn?

Cancer Connection

Do x-rays, CT and PET scans increase your risk of getting cancer?

Exposure to x-rays and gamma rays over time, even at low-dose levels, increases the risk of cancer. That is the conclusion of a comprehensive five-year study by a National Research Council (NRC) committee. Keep in mind that this is a statistical risk based on who gets cancer and who does not seem to.

“There appears to be no threshold below which exposure can be viewed as harmless,” said Stanford University’s Herbert L. Abrams, Professor Emeritus of radiology at both Stanford and Harvard Universities and a member in residence at the Centre for International Security and Cooperation (CISAC) in the Freeman Spogli Institute for International Studies.

However, if you were to ask Dr. David Boreham of McMaster University in Canada the same question, his experimental results suggest otherwise.

“There are lots of people out there making the argument that if you get a single CT scan a year over five years, your risk of getting cancer goes up four or five percent. This is all based on extrapolation from radiation exposure studies of WWII atomic bomb survivors, and that was one single, large dose.” Based on his research that studies patients who have x-ray exposures and other diagnostic radiation procedures, Boreham believes that low dose radiation may not be cumulative in its effects at all. In fact, he believes that cells can even adapt to low levels of radiation exposure. This is an exciting scientific debate, and you are encouraged to explore it.

Sources: Stanford University. “Even Low Exposure To X-rays, Gamma Rays Increases Cancer Risk, Study Finds.” ScienceDaily 27 October 2005. 29 July 2008 www.sciencedaily.com/releases/2005/10/051027090539.htm

McMaster University. “The Strange Arithmetic of Radiation.” Ontario Innovation Trust n.d.. 29 July 2008 www.oit.on.ca/Pages/SStories41-60/StoryMcMasterRadiation.html



Figure 1-19

CASE STUDY CONTINUED: Francine’s Next Steps

Francine now understood with greater clarity what the differences were between x-ray and CT scans. She knew that CT scans provided her doctor with more information than the x-ray had due to its greater resolution of soft tissues. She understood the importance of having more than one type of diagnostic procedure, because each technology could provide her doctor with different information.

Could her doctor obtain a diagnosis without resorting to technology that uses radiation? Not likely with this kind of injury that can have hidden difficulties. She was beginning to realize that radiation-based technology was sometimes the only choice available. As is always the case with radiation exposure, the benefits of undergoing the procedure are weighed against the known risk factors. In this case, Francine and her doctor looked at both the nature of her injury and the consequences of low-level exposure to ionizing radiation sources.

So now that they knew two vertebrae were damaged, what would be the next steps for Francine? Her doctor told her that at least one other diagnostic procedure needed to be performed in order to confirm whether any soft tissue damage had occurred around the spinal cord. But he had other news for her too....

Positron Emission Tomography (PET) Scanning

Positron Emission Tomography (PET) usually involves injected radioactive tracer material (radiotracers) to diagnose differences in biological activity in the body. Thus, the source of radiation is internal rather than external (as with x-ray and CAT scanners). The radiotracer collects in the area of body to be examined. The tracer continually radioactively decays, producing **gamma rays** that are detected by the PET scanner. A computer takes the detected ray data and converts it into pictures that show details of organs and tissues. These pictures do not produce clear images of organ and tissue structure (as CT scans would). Rather, the pictures show levels of biological activity in the body. Violet areas (areas of greater chemical activity) are called hot spots and indicate where large amounts of the radiotracer have accumulated. Lighter (blue) areas, or cold spots, show smaller concentrations of the radiotracer and therefore less chemical activity.

The most common radiopharmaceutical (or radiotracer) used in conjunction with PET scans is fluorine-18 (^{18}F). Other radiotracers used are oxygen-15 (^{15}O), nitrogen-13 (^{13}N), and carbon-11 (^{11}C), however these isotopes are typically confined to use in research activities. All of these isotopes emit positrons. A positron has the same mass as an electron, but has opposite charge.

PET scanners are commonly used to detect cancers. Images from PET scanners are created by having the device measure the varying amounts of radiotracer within the patient's body.



Figure 1-20 PET scans measure body functions such as blood flow, oxygen use, and metabolic rates. This helps doctors evaluate how well organ and tissue systems are working. Oftentimes, medical technicians are able to superimpose CT scans with PET scans from the same diagnostic machine, which correlate information and images from more than one source and leads to greater accuracy in information obtained and diagnosis of conditions. Most modern PET scanners incorporate a CT scanner within them.

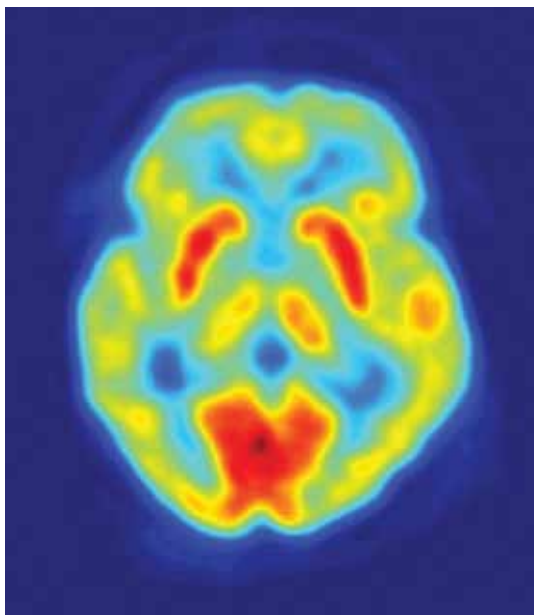


Figure 1-21 PET scans can be in black and white or in colour. Darker images (on black and white scans) or “hot spots” (red and orange parts of colour scans) indicate the collection of more of the tracer given to the patient. Tracers tend to be added to something like sugar water that is injected, so the tissues and organs that use glucose for energy show radioactive decay. Cancerous tissue uses more glucose than normal tissue, thus the darker images or hot spots can be cause for analysis by the technician.

Career Moves

Nuclear Medicine Technologist

All it takes is two years post-secondary to become a nuclear medicine technologist. In this growing career area, trained individuals use radiopharmaceuticals and specialized instruments to help with diagnosis and treatment of injuries and diseases. As of 2009, there are practicum programs located in Calgary, Edmonton, Red Deer, Regina, Saskatoon, and Winnipeg. After graduation, work can be found in a hospital, private laboratory, community clinic, and in research or teaching institutions.

Career Connection Website – Canadian Association of Medical Radiation Technologists:
www.camrt.ca/english/career/nmt.asp



Figure 1-22

Chapter 1 Review: Concepts and Terms

Concepts: X-ray machines and CT (computed tomography) scanners both use radiation in order to create an image for diagnostic analysis. Contrast agents (which are not radioactive) can be used in concert with these procedures to develop greater contrast in the images for better analysis. Arthrography and mammography are specialized forms of x-ray diagnosis.

PET (positron emission tomography) scanners use radiopharmaceuticals (radioactive tracers) to create a tomographic image (cross-sections in the body) for diagnostic analysis. Modern PET scanners have CT technology built into them.

There are many forms of natural radiation – this chapter focused on alpha, beta, and gamma radiation.

Terms of Interest:

alpha particle	health physics
arthrography	isotope
attenuation	mammography
beta particle	PET (Positron Emission Tomography)
CT (Computed Tomography)	positron
electromagnetic radiation	radiograph
electromagnetic spectrum	radiopharmaceutical
electromagnetic wave	tomography
electron-volt (eV)	x-ray
frequency	UV radiation
gamma ray	