

chapter 2

Other Forms of Diagnostic Technology

CASE STUDY CONTINUED: Francine Has Questions About Radiation

Francine knew now that the doctor's initial request for an x-ray was to obtain a quick diagnosis. The doctor ordered the CT scan in order to locate the bone fragments from her injury that first turned up on the initial x-ray image. Next, a neurologist visited Francine and ordered an MRI scan. The results of this procedure confirmed that the second and third vertebrae had two small sections broken off and these sharp bone fragments were dangerously close to the spinal cord. Though she had not been sent for a PET scan or ultrasound, Francine could not help but wonder what the effects from this technology would be on her body in the longer term. Why did she need to get an MRI when she had already had an x-ray and a CT scan? Would she need a PET scan or ultrasound? Did MRI represent another instance of radiation exposure for Francine?

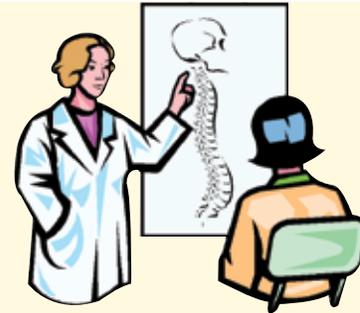


Figure 2-1

Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI), often referred to as magnetic resonance (MR), does not depend on radiation to create images. Instead, MRI devices use powerful **magnetic fields** to align hydrogen atoms in the body. Radiofrequency coils produce high frequency magnetic fields that excite the protons in the nuclei of these atoms. The protons release this gained energy in detectable amounts by creating their own magnetic fields. A computer analyzes these magnetic field signals to produce detailed images of organs, other soft tissues, bone, and almost all other internal body structures with astounding resolution. This type of imaging produces even more contrast detail than that realized by CT scans. Like CT scans, multiple images can be produced and then linked together by a computer to create a three-dimensional image that can then be studied.

The typical contrast agent used in conjunction with an MRI is **gadolinium**. Gadolinium is a ferro-magnetic element, perfect for use in a diagnostic procedure dependent upon magnetic field interactions. Diagnosticians need to be diligent about removing metal objects from the general area where testing occurs, as the objects' magnetic fields could affect the image results.

MRI scans can be used for both diagnosis and monitoring of conditions. Typically, the distinction between abnormal and normal tissues on an MRI is more easily detected than on a CT scan, x-ray, or even ultrasound. This does, however, depend strongly on the type of study done.

Figure 2-2 This image of a cross-section of the human brain was produced using MRI. Whether using colour or black-and-white images, however, technicians will look for a contrast in colour or shading. What they look for depends strongly on the scan parameters and the sequence of scans. Technicians look for “hot spots” (or so-called “false colour” images, hot spots can sometimes be coded as being yellow) that may indicate tumour growth. Cold spots (sometimes shown by selecting cooler colours like shades of blue and violet) may indicate normal tissues and fluids.

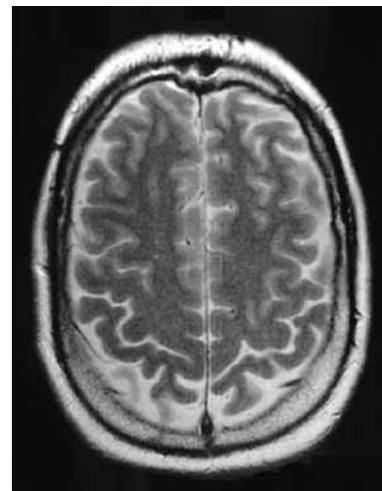


Figure 2-2



Figure 2-3 The MRI machine pictured at left looks similar to a CT scanner in that there is a ring around the patient and bed. In MRI, however, the only moving part is the patient table. Many cross sections or images are taken, and multiple images can be compiled to create a three-dimensional image.

Research & Extension Questions:

1. Why is gadolinium used as a contrast agent for MRI scans? Why wouldn't they use barium? Or cobalt?
2. Discuss with a classmate what the list of general characteristics may be that would qualify an isotope as a "good" choice for use in diagnosis.
3. Could gadolinium be used in PET scans? Why (not)?

Francine's Case Study Continued:

Francine found out that the MRI scan did not involve any exposure to radiation. Though her x-ray and CT scan involved radiation exposure, her doctor assured her that total exposure was so minor it would not affect her overall health. In fact, her total exposure was much less than that received by a business traveller who flies periodically at high altitudes in jet aircraft. Just to provide some background on this issue, according to the Health Physics Society we receive about 3,600 microsieverts of radiation exposure every year from the environment as background radiation. A chest x-ray provides about 170 microsieverts, and a dental x-ray about 7 microsieverts. If you were a very frequent air traveller (say, >120,000 kilometres per year), then you actually receive the recommended yearly dose of radiation just by doing that. For more answers, check out the FAQs at: <http://hps.org/publicinformation/ate/faqs/>



Figure 2-4

Reality Check

Question | Do Magnetic Fields Created By Power Lines Cause Cancer?

Origin: Various researchers have studied the relationship between the rates of certain types of childhood cancer and the proximity of the children to high-voltage power transmission lines. Over the years, various e-mails have circulated saying that there is a direct link between how close you live to power lines and your risk of getting cancer.

Reality Check: According to Health Canada, research has shown that electromagnetic fields (EMFs) from electrical devices and power lines are not associated with any known health risks.

Many studies have been done on the effects of exposure to EMFs at extremely low frequencies. Though some studies have suggested a possible link between exposure to electromagnetic fields and certain types of childhood cancer, scientists at Health Canada claim that the evidence appears to be very weak.

The International Agency for Research on Cancer has classified electromagnetic fields as "possibly carcinogenic" to humans based on studies of childhood cancer. According to Health Canada, however, the evidence is not strong enough to conclude that EMFs definitely cause cancer in children. They believe that more studies are needed to draw firm conclusions.

Source: Minister of Health. "It's Your Health – Electric and Magnetic Fields at Extremely Low Frequencies." Health Canada April 2004. 29 July 2008
www.hc-sc.gc.ca/hl-us/iyh-usv/environ/magnet-eng.php



Figure 2-5 Although ultrasound may be better known for its use in prenatal care, it is also an effective diagnostic tool for blood and fluid-related problems. In a very specialized technique using dedicated equipment, ultrasound may also be used to detect osteoporosis. Ultrasound does not have the potential harmful side effects of radiation exposure possible from x-ray, CT, and PET scanners.



Figure 2-6 An ultrasound image is best analyzed in real time as the image changes on the monitor. A technician uses the real time images to determine whether heartbeats are normal, to analyze the regularity of blood flow, and to determine whether fluids and tissues are abnormal. Still images from ultrasound, in certain particular instances, are studied to analyze abnormalities in bone density or fluid flow.

Ultrasound

Ultrasound imaging uses ultrasonic sound waves to diagnose various conditions. A transducer converts an electrical pulse into a mechanical vibration – a high frequency sound wave. This sound wave bounces off various surfaces in the body. The transducer registers returning reflected sound waves, and converts them back into electrical pulses. A computer transforms these pulses into an image on a monitor.

Some kinds of tissue or fluid cannot be detected in x-ray images but are locatable with ultrasound technology. A large advantage of ultrasound technology is the ability to produce real-time images in motion format.

The **Doppler Effect** and ultrasound technology can be used to determine blood flow. The Doppler Effect registers the change in frequency with which a wave from a given source reaches an observer if the source is in motion relative to the observer. This ability to determine motion can help diagnose narrowing of blood vessels, clogged arteries, and fetal heartbeats. It is also useful in determining if a structure in the body is fluid-filled (like a cyst) or a more dense mass such as a tumour.



Figure 2-7

Cancer Connection

Sorenson's Tumour-Suppressing Gene

Tumour-suppressing genes are regular genes whose job it is to slow down cell division, repair mistakes in DNA, and tell cells when to die. If these genes do not do their jobs, cells can grow out of control. When cells grow out of control, cancer may form. Approximately 30 different genes like this have already been discovered.

Researchers at the University of British Columbia, headed by Dr. Poul Sorenson (*Figure 2-7*), have discovered a new tumour-suppressing gene for the most common type of kidney tumour seen in childhood. Their studies have shown that lower levels of this gene, called HACE 1, may contribute to tumour development. As well, restoring levels of this gene within cancer patients has inhibited tumour formation.

This ongoing study will help scientists understand how loss of this gene leads to tumour formation in children, which may then lead to new preventive treatments for patients.

Source: University of British Columbia. "Award Recipients – Trainee Profiles – Fan Zhang."
 Michael Smith Foundation for Health Research June 14 2005. 29 July 2008
www.msfbcr.org/sub-funding-recipients-profile.asp?award_recipient_id=549

Barium Enemas and Colonoscopy

The diagnosis of cancer and other diseases of the colon are usually aided by using an isotope of **barium**. A barium **enema** procedure involves injecting a barium sulphate fluid into the patient's lower digestive tract. While the patient clenches the anal muscles, the **colon** is slowly filled with this liquid. Once that is done, air is injected into the colon to inflate it. The procedure allows for a greater contrast in soft tissues around the gastrointestinal tract when an x-ray radiograph is taken. If a patient is required to undergo a barium enema, fasting and laxatives are prescribed up to two days in advance of the procedure to ensure that the colon is empty and the x-ray image is not blocked by partially digested food particles.

Another diagnostic procedure that can be used instead of barium enemas and x-rays is to obtain a colonoscopy. In this procedure, a small camera at the end of a long flexible tube, called an endoscope, is inserted into the patient's lower digestive tract (via the anus) and is slowly pushed further into the colon right up to the junction of the large and small intestines (at the caecum). Real-time imagery is observed on a television screen or monitor, allowing doctors to pause and examine questionable areas. The flexible tube contains fibre optic light and miniature diagnostic tools for obtaining tissue samples as well. As with the barium enema, patients who participate in this procedure undergo a fasting and laxative regimen two days in advance to ensure an empty colon for observation.

Check out the online colonoscopy activity at www.insidestory.iop.org/insidestory_flash1.html



Figure 2-8

Did You Know

Canadian Isotope Production

Producing isotopes for use in medicine was a field pioneered in Canada. Two hospitals in Saskatchewan and Ontario became the first to apply radioactive cobalt to the treatment of cancer in the early 1950s, a technique now widely used around the world. Today the National Research Universal reactor (NRU) in Chalk River (Ontario) is the world's main source for both cobalt-60, a high-activity radioisotope used for cancer treatment, and technetium-99, used for diagnostic imaging, as well as many other isotopes.

The range of isotopes produced at NRU are distributed across Canada and internationally by MDS Nordion, the world's largest medical isotope supplier. Periodically, due to unplanned reactor shutdowns, the world supply of needed medical isotopes from the Chalk River facility has been strained or stopped altogether. On occasion, the very short half-life of certain radioactive isotopes (e.g. fluorine-18) raises particular problems, as these have only hours or days of effective use in such applications as PET scans. How might such a concentration of production constitute a risk to ongoing treatment programs for patients around the world? Might you be able to offer a solution to this dilemma?

internet activity

The Visible Human Project ®: www.nlm.nih.gov/research/visible/visible_human.html

Explore what's available at "A Guided Tour of the Visible Human" website. This is the effort of over a decade of cross-sectional CT and MRI scans of both male and female cadavers compiled for access online to both students and teachers. The Visible Human Project® is part of the U.S. National Library of Medicine's long-range plan to create "complete, anatomically detailed, three-dimensional representations of the normal male and female human bodies." Note that this website does not show abnormalities or diseases on the CT and MRI scans, but it does provide detailed 3D images of healthy humans.

www.dhpc.adelaide.edu.au/projects/vishuman2/VisibleHuman.html

(Java Applet—you decide what cross-section of the Visible Human you want to see!)

www.uchsc.edu/sm/chs/browse/browse_m.html (Male-clickable)

www.uchsc.edu/sm/chs/browse/browse_f.html (Female-clickable)

Medical Isotopes

An **isotope** of an atom is another atom with the same **atomic number** but a different **mass number**. In other words, the two different atoms have the same number of protons and electrons, but the number of neutrons in each nucleus varies. The differing number of neutrons in the nucleus can make the atom unstable, and then the isotope has the ability to release energy in the form of photons or particles. It is these unstable, particle-releasing isotopes that are useful in medical procedures.

We have seen in the previous chapter that contrast agents (which are not radioactive) can be used with some forms of diagnostic technologies. These contrast agents can improve scan results and show more details than without their use. CT scanners can be used in conjunction with a barium contrast agent. This chapter has described the use of the contrast agent gadolinium alongside MRI technology to produce better images.

Some forms of diagnostic technologies can be coupled with the use of a medical isotope, sometimes referred to as a **radiotracer** or **radiopharmaceutical**. Using radiotracers alongside technology can also improve scan results and allow the technician to focus on details of certain organs, tissues, or even bone structure. We have seen in Chapter 1 how there are four isotopes used in conjunction with PET scanners (oxygen-15, nitrogen-13, carbon-11 and fluorine-18).

Each radioactive isotope used in a medical procedure is chosen for its half-life, its ability to be injected or ingested, and its risk potential for side effects (having little to no side effects is the goal). The use of these isotopes can allow for detection of diseases or tumours weeks or months in advance of using the diagnostic technologies alone.

The following is a chart of the different types of radioisotopes used in diagnosis, or treatment, of illness.

Isotope	Half-life	Uses
Arsenic-74	17.9 days	Locate brain tumours
Barium-131	12.0 days	Detect bone tumours
Carbon-14	5730 days	Treat brain tumours
Chromium-51	27.8 days	Determine blood volume
Cobalt-60	5.26 years	Treat brain tumours
Fluorine-18	109 minutes	Ideal for PET scans
Gold-198	64.8 hours	Test kidney activity
Iodine-131	8.05 days	Treat thyroid problems; find blood clots
Iron-59	45.6 days	Test rate of blood cell production
Mercury-197	65.0 hours	Find brain tumours; test spleen function
Technetium-99	6.0 hours	Detect brain tumours; detect blood clots



In The Media

Cobalt-60 and the Canadian Connection

Before 1947, radium was considered the best available option for treatment of cancerous tumours. Doctors and treatment specialists realized, though, that radium had limitations when it came to deep-seated tumours in the body. But it was because of a uniquely Canadian research group that cobalt-60 quickly became the isotope of choice for treating cancer patients. Radium was effective only when in direct contact with cancerous tissue—cobalt-60 allowed treatment specialists to create “cobalt bombs” which would attack cancerous growths almost anywhere in the body. By 1951, treatments were being tested in Saskatoon. Eldorado Mining and Refining, a Crown Corporation that owned and operated many of Canada’s uranium mines then, quickly retooled MDS Nordion, its radium sales department, to handle the high demand for cobalt-60 worldwide, positioning Canada as a world leader in isotope production and delivery.

Figure 2-10
Canadian researchers and the equipment needed to create quantities of the cobalt-60 isotope.

Comparing Diagnostic Technologies and Techniques

activity

Concept Map

Sometimes a picture that shows the connections amongst all the vocabulary works better than forming categories to sort the words. **Create a concept map for RADIATION** (like a spider-web that shows how the concepts are interconnected) to link the diagnostic technologies and techniques vocabulary together.

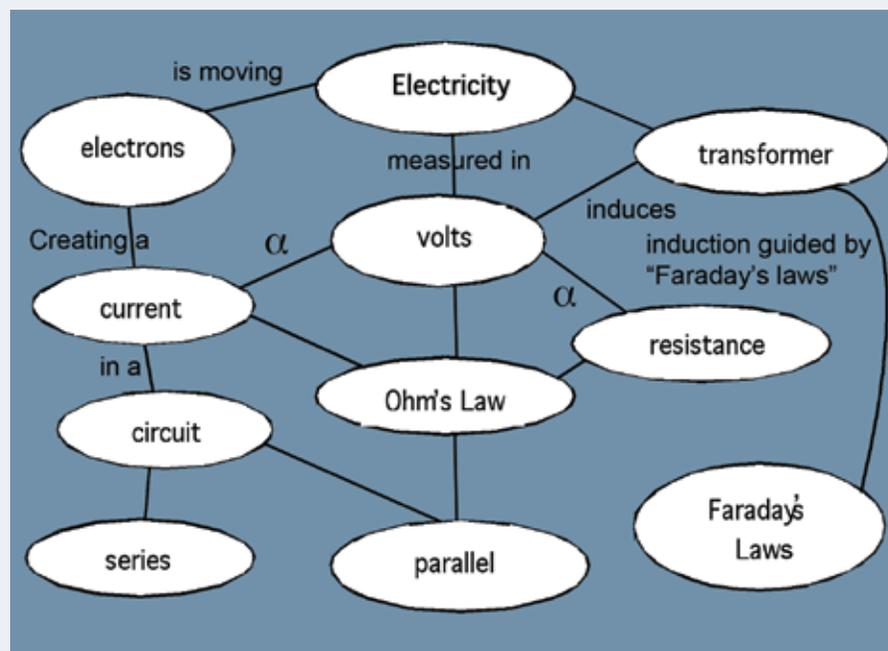


Figure 2-11

This simple example of a concept map shows how the individual thought of the words and concepts within the larger topic of Electricity. Inter-connections between concept “bubbles” are labeled with a word or a phrase to show how the two concepts are related.

CASE STUDY CONTINUED: Francine's Diagnosis

After the technician and the doctor discussed the results of the CT and MRI imaging, Francine's doctor shared the information with her. The MRI showed that the spinal cord had slight abrasions on it due to the bone fragments grinding against it. Thankfully, the spinal cord had not been severely damaged. The CT scan clearly showed where the bone fragments were, and the doctor was confident that with careful surgery, they could be removed.

The MRI showed one more unexpected result—a tumour on the thyroid gland at the base of Francine's neck. Francine was informed that there were various treatment options available to her, including surgical removal of the tumour. She would be provided with details on the various options, and her doctor assured her that with treatment, this isolated growth could be removed completely and most likely without recurrence.



Figure 2-12

Career Moves

Health Physicist

As a health physicist, you participate in both protecting humans from the harmful effects of technologies using ionizing radiation while encouraging its beneficial uses. Career opportunities exist in any field or industry using such technology—nuclear reactor energy plants, research laboratories, hospitals, and defence plants. Typically, health physicists also perform work as environmental consultants for both government and industry when issues such as decontamination and decommissioning of reactors are required.

Career Connection Website – Manitoba Career Profiles:

mb.jobfutures.org/profiles/profile.cfm?noc=2111&lang=en&site=graphic



Figure 2-13

Chapter 2 Review: Concepts and Terms

Concepts: MRI (magnetic resonance imaging) uses high frequency magnetic fields to produce detailed images of organs, soft tissues, and bones—more detailed than x-ray or CT scans. This diagnostic technology is not dependent on radiation to create images.

Ultrasound imaging uses ultrasonic sound waves to diagnose various conditions involving biological functions. Sound waves converted into electrical pulses are transformed by a computer into an image on a monitor.

Two different diagnostic procedures used to analyze the colon were discussed in this chapter: barium enemas and colonoscopy. An enema involves injecting a barium sulphate contrast agent into a patient's anus to create a more detailed x-ray of the region. A colonoscopy involves inserting into the anus, and up into the colon, a long flexible tube with a small camera at the end of it.

An isotope of an atom is another atom with the same atomic number but a different mass number. Medical isotopes, sometimes called radiotracers or radiopharmaceuticals, can be used alongside technology to improve scan results and allow the technician to focus on details of certain organs, tissues, or even bone structure.

Terms of Interest:

atomic number	gadolinium
barium	HACE 1 gene
cobalt-60	isotope
colon	MRI (Magnetic Resonance Imaging)
colonoscopy	magnetic field
Doppler Effect	mass number
electromagnetic field (EMF)	radiofrequency coil
endoscope	radium
enema	transducer
fibre optic light	ultrasound