Radiation and medical procedures

How do we do no harm?

Cathy Vakil MD CCFP FCFP

Ms Jones is an 80-year-old woman with abdominal pain. An ultrasound showed a possible mass in her pancreas, likely a cyst, and the radiologist has recommended a computed tomography (CT) scan. You have ordered the CT scan but worry about radiation exposure.

Beth is a 28-year-old basketball player who twisted her foot in a game 4 weeks ago. Findings of the initial x-ray scan were normal, but she still has a lot of pain and wants to get back on the court as soon as possible. You consider a repeat x-ray scan but worry about the radiation exposure.

Jay is a 17-year-old who has had typical migraines for 4 to 5 years; the frequency and severity have been gradually increasing for the past 2 years, which concerns his parents. Although there are no worrisome symptoms or signs, you consider a head CT scan to make sure you do not miss anything ominous but worry about the radiation exposure.

You know that radiation is harmful and have questions: What is radiation and how exactly is it harmful? How much harm is caused by x-ray scans, CT scans, medical isotopes, ultrasound scans, and magnetic resonance imaging (MRI)? What can help you make a decision about ordering a test? Many of your colleagues struggle with these same decisions. Let's start with your first question.

What is radiation and how exactly is it harmful? Radiation is the process by which radioactive elements emit subatomic particles and γ rays as they undergo nuclear decay. If living cells are within the trajectory of these particles or rays, they can damage the cells' DNA, which can cause cancer as well as other diseases such as birth defects, inheritable disease, immune dysfunction, diabetes, and heart disease.

X-rays are similar to the γ rays emitted by radioactive elements. Computed tomography scans consist of multiple x-ray scans that produce a 3-dimensional image. In fluoroscopy, many x-ray scans are done over seconds or minutes to observe the movement of body parts or fluids. Fluoroscopy is used for coronary angioplasty, hysterosalpingograms, cystourethrograms, endoscopic retrograde cholangiopancreatography, and barium studies. Because CT scans and fluoroscopy use many x-ray scans per procedure, they cause much more radiation exposure than single x-ray scans do.

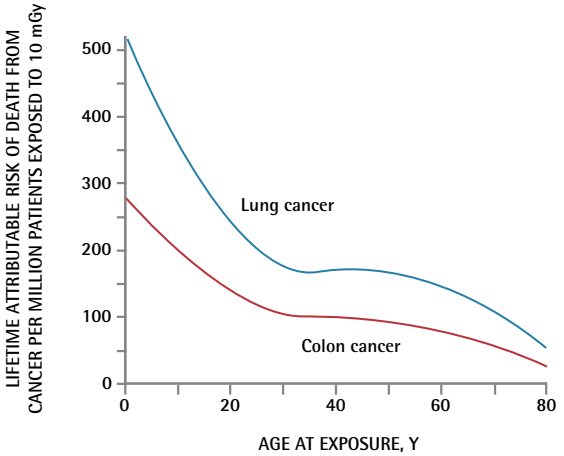
Medical isotopes emit subatomic particles or γ rays that are tracked to observe the pooling and movement of the isotope as it undergoes nuclear decay. This is used for bone, thyroid, and multigated acquisition scans. The isotopes typically have short half-lives of a few days, but until they are excreted from the body they can damage cells.

Children are much more susceptible to the damaging effects of radiation because they have a larger proportion of dividing cells. Also, effects of radiation can take decades to manifest, and children have more years ahead of them to experience these deleterious effects. Risk is cumulative over a lifetime. Ultrasound and MRI tests do not use radiation.

How much radiation do these procedures expose your patients to? It is estimated that about half of the population's radiation exposure beyond background radiation is from medical procedures, mostly CT scans, the number of which has increased severalfold in recent years. Currently in Canada our regulations recommend a maximum of 1.0 mSv per year from all causes beyond background radiation and medical procedures.[1] There is controversy as to whether lifetime doses under 100 mSv can cause cancer, but it is accepted by most radiologic organizations that all radiation is harmful, with risk increasing linearly with dose.

Figure 1 outlines radiation exposure and risk of death from cancer[2]; keep in mind that an average CT scan exposes a patient to approximately 1 to 10 mGy (1 to 10 mSv). Note that the younger a patient is, the higher the risk of cancer is. The Committee on the Biological Effects of Ionizing Radiation estimates that for every 1000 people

Figure 1. Radiation exposure and risk of death from cancer



From Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med* 2007;357(22):2277-84.[2] Copyright © 2017, Massachusetts Medical Society. Reprinted with permission from the Massachusetts Medical Society.

receiving a 10 mSv dose of radiation, 1 person will develop cancer because of that exposure.[3]

Table 1 lists the extent of radiation exposure from various tests.[4,5] Keep in mind that the recommended maximum annual exposure is 1.0 mSv beyond background radiation and medical testing.

How do I decide whether to order a test that exposes my patient to radiation? To make this decision you need to assess the risks and benefits of every test.

Benefits of a procedure:

- I will not miss any important diagnoses.
- I will comply with the radiologist's recommendations.
- I am less likely to get sued if I do a test than if I do not.
- I will be criticized for missing a diagnosis because I elected to not do a procedure, but I am unlikely to be criticized for doing a procedure that might cause cancer in a patient 30 years from now.

Risks and drawbacks of a procedure:

- There is a cost associated with the procedure.
- Patients can experience contrast allergy or claustrophobia.
- The patient will be exposed to radiation—this is especially important if the patient has had multiple exposures from previous tests.

What could help you make your decisions?

- Could you obtain similar information by doing an ultrasound scan or MRI instead of a CT scan?
- Can you start to track your patients' radiation doses in your electronic medial record? Does your local radiology department already track doses?
- Is your local CT scanner a newer one that reduces radiation exposure?

The risk of cancer for Ms Jones from a CT scan is fairly low because of her age, so probably a CT scan is warranted, especially if she has never had one.

The risk of cancer due to an extremity x-ray scan is negligible, so repeating it for Beth increases her cancer risk minimally, even though she is fairly young.

With no apparent red flags for brain tumour for Jay, further investigation is probably unnecessary. However, if you feel you should do something, consider MRI.

Conclusion

We all want to do the best for our patients and we certainly do not want to inadvertently cause harm. Hopefully this article will help you to make decisions regarding radiologic procedures so that you can be confident in ordering appropriate tests while "doing no harm."

Dr Vakil is a family doctor in a teaching practice at the Queen's Family Health Team in Kingston, Ont, and Assistant Professor in the Department of Family Medicine at Queen's University.

Acknowledgment
I thank **Drs Katie Webb** and **Nicola Gambarotta** for their help preparing this manuscript.

Competing interests
None declared

Correspondence
Dr Cathy Vakil; e-mail **cathy.vakil@dfm.queensu.ca**

Table 1. Radiation exposures of various tests

TEST	EXPOSURE, mSv
X-ray scans causing very little exposure	
• Bone density test	0.001
• Hand or foot	0.001
• Knee	0.005
• Dental	0.005
• Shoulder	0.01
X-ray scans causing more exposure	
• Posterioranterior and lateral chest	0.1
• Skull	0.1
• Mammogram	0.4
• Pelvic	0.6
• Abdominal	0.7
• Hip	0.7
• Lumbosacral spine	1.5
Fluoroscopy procedures	
• Barium swallow	1.5
• Barium enema	7
• Hysterosalpingogram	1.2
• Myelogram	2.5
• Cystourethrogram	1.2
• Coronary angioplasty or stent placement	15
Medical isotopes	
• Thyroid scan (iodine I 123)	1.9
• HIDA scan (technetium Tc 99)	4
• Bone scan (technetium Tc 99)	6.3
• Coronary angiogram (technetium Tc 99)	7
• Multigated acquisition scan	9.4 to 12.8
CT scans	
• Head	1 to 5
• Neck	1 to 5
• Spine	1 to 5
• Chest	5 to 10
• Abdomen	1 to 10
• Colonography	1 to 5
• Arthrogram of the shoulder	1 to 5
• Pelvis	5 to 10
• Angiogram of the head	1 to 5

CT—computed tomography, HIDA—hepatobiliary iminodiacetic acid.
Data from Lee and Elmore[4] and the Canadian Association of Radiologists.[5]

References
1. Canadian Nuclear Safety Commission [website]. *Radiation doses.* Ottawa, ON: Government of Canada; 2017.
2. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med* 2007;357(22):2277-84.
3. Committee to Assess the Health Risks from Exposure to Low Levels of Ionizing Radiation. *BEIR VII: health risks from exposure to low levels of ionizing radiation. Report in Brief.* Washington, DC: National Academies Press.
4. Lee CI, Elmore JD. *Radiation-related risks of imaging studies.* Waltham, MA: UpToDate; 2015.
5. Canadian Association of Radiologists. *2012 CAR diagnostic imaging referral guidelines.* Ottawa, ON: Canadian Association of Radiologists; 2012.