Radiation Risk of Medical Imaging for Adults and Children

Consumer Information

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What is radiation – am I exposed to background radiation each day even if I do not have an X-ray examination?

Background radiation

1. Background radiation is the term used to refer to the sources of ionising radiation that we are unavoidably exposed to in our daily lives that provides each of us with a continuous, small ionising radiation dose.
2. X-rays are part of the electromagnetic radiation spectrum that includes radio waves, visible light, X-rays and gamma rays. Visible light and X-radiation (X-rays) both travel in straight lines and cast a shadow when they interact with a solid object.
3. X-rays, gamma rays and some other high energy *particles* can deposit enough energy into a body tissue to change molecules or proteins. These high energy particles or rays are referred to as ionising radiation.
4. The sources of radiation in our environment are cosmic rays from the universe, naturally occurring radioactive substances in the food and water we eat and drink, the air we breathe, in the ground, in building materials, etc. We are all weakly radioactive due to the presence of radioactive elements in our bodies (such as potassium 40 and carbon 14) and this contributes to our background radiation exposure.
5. In Australia, the background radiation is equivalent to approximately 50 single chest X-rays per year. The amount of background radiation varies in different parts of the world due to the radioactivity of the soil, latitude, height above sea level, and lifestyle (predominantly indoors or outdoors). The background radiation varies widely with some parts of the world having background radiation 100 times greater than that generally found in Australia.

X-rays

1. X-rays have more energy than visible light and can therefore penetrate much deeper into and through objects. An X-ray beam is absorbed differently by different structures in the body. These varying densities project a shadow that is used to create a picture or image.
2. A dense structure like bone absorbs a high percentage of the X-ray beam (appears light grey on the image), while low density structures like soft tissues absorb a small percentage (appears dark grey). Metal objects will usually show up as white and air will be black with usual image presentation.
3. Man-made X-rays are electrically generated and are only present when the X-ray machine is switched on, just like a light bulb.
4. Once the X-ray machine is switched off there is no residual radiation coming from the X-ray machine or from a patient who has had an X-ray. Having an X-ray or CT examination does not make you radioactive.

X-ray procedures provide a measurable additional radiation dose to our annual background radiation exposure. The contribution of medical X-rays to the average population background radiation dose has increased over the last few decades as more sophisticated imaging tests have become available; this is especially true of computed tomography (CT or CAT scans).

Which kinds of tests are associated with Ionising radiation and which ones are not?

Radiology is the medical specialty that uses X-rays, ultrasound and magnetic resonance imaging (MRI) to produce images or pictures that help to diagnose disease or injury, or guide therapeutic procedures that treat the disease or condition. Nuclear medicine is a specialty that relies on the administration of a radiopharmaceutical to demonstrate how an organ is working. Certain radiopharmaceuticals can also be used to treat some medical conditions. There are generally 4 types of technology used to perform these different types of medical imaging procedures:

1. X-rays

X-rays are ionising radiation produced by equipment used in the following types of procedures:

- *Computed tomography (CT)*
- Fluoroscopy (where the images produced are displayed like a movie a television screen)
- Plain radiology/X-ray film, digital and computed radiography (see *Plain Radiography / X-rays*)
- Mammography (see *Diagnostic Mammography*)

The radiation exposure from having an X-ray, fluoroscopy, mammography or CT examination only occurs while the machine is on.

2. Magnetic resonance imaging (MRI)

MRI uses strong magnetic fields and radio waves to produce images. It does not use ionising radiation (see *Magnetic Resonance Imaging (MRI)*).

3. Ultrasound

Ultrasound uses high frequency sound waves that the human ear cannot detect to obtain imaging information (see *Ultrasound)*.

4. Nuclear medicine

Nuclear medicine is a medical specialty that involves the administration of a small amount of a radioactive material into the patient. The patient becomes weakly radioactive for a short time and images are made from the radiation given off from the patient (see *Nuclear Medicine*).

Which tests give me the most ionising radiation and which ones the least?

1. Ionising radiation

X-rays and nuclear medicine studies all result in a radiation exposure to the patient. The radiation dose to the patient is smallest in simple X-ray examinations (such as a chest or arm or leg radiograph).

Simple and short fluoroscopy examinations such as a paediatric barium meal, a CT examination of the wrists or ankles, and a nuclear medicine examination for gastro-oesophageal reflux also involve a relatively low dose of radiation to the patient.

CT examinations of the chest, abdomen and pelvis, complex fluoroscopy (such as interventional radiology or interventional cardiology procedures), and some nuclear medicine procedures can result in a radiation dose equivalent to one or more years of background radiation.

2. Non-ionising radiation

Both MRI and ultrasound do not use ionising radiation.

What are the risks associated with radiation from diagnostic X-ray imaging and nuclear medicine procedures?

There are two main types of risk to exposure to ionising radiation:

1. Stochastic

This is primarily concerned with a very slight increase in the possibility of cancer being caused as a result of the radiation exposure. This is a complex concept to understand. Risk is expressed as chances per million (or some other number), much the same way as the chance of winning first prize in a lottery or dying in an aeroplane accident. While this risk is expressed as a number, individuals either suffer the consequences or not; one person in a million getting cancer means that one person gets cancer and 999,999 do not. The whole population does not get a tiny bit of cancer!

To a much lesser extent, there is a possibility of genetic damage which may express itself in future generations as mutations (changes in genes or chromosomes resulting in a new trait or characteristic that can be inherited), physical or intellectual disability.

The risk of harmful effects from having X-ray, CT, or nuclear medicine studies only becomes significant in most people after substantial numbers of high dose examinations.

The risk of harmful stochastic effects of ionising radiation is calculated using sophisticated and complex population statistics. The normal lifetime incidence of death from cancer in the Australian population in 2008 was approximately 30% - 40%.

The table below shows the ADDITIONAL percentage risk from radiation exposure from some typical X-ray procedures. For example, if a person had a risk of cancer of 30% before a single chest X-ray it would be 30.00013% after the chest X-ray.

Procedure	Additional % stochastic risk*
Chest X-ray - posterior-anterior (from the back to the front)	0.00013%
Lumbar spine X-ray (single view image of the lower spine for a bad back)	0.0035%
Pelvis X-ray anterior-posterior (from the front to the back)	0.0035%
CT of the chest	0.04%
CT of the abdomen	0.05%
CT of the pelvis	0.05%
Mammogram	0.0065%
Ultrasound	0
Magnetic resonance imaging (MRI)	0

***over and above the normal lifetime incidence of death from cancer in the population**

2. Deterministic

Deterministic damage is predominantly the result of long and complex therapeutic CT or fluoroscopic interventions using diagnostic imaging equipment. It does not normally occur in diagnostic imaging. Examples of deterministic damage include burns to skin which has been exposed to X-rays or hair loss.

Why are these risks different for males and females?

Different body tissues have different sensitivity to radiation. Skin and bone are not very sensitive but breast tissue and the lining of the stomach and intestine are sensitive to the effects of ionising radiation. Women have more breast tissue and the female thyroid gland is also more sensitive to the effects of ionising radiation than the male thyroid gland. However, the male bone marrow is more sensitive to ionising radiation than female bone marrow. On average, females are twice as sensitive to the stochastic effects of ionising radiation than males.

Why are these risks different for children and pregnant women?

The principle risk for children is that they are growing rapidly and more cells are dividing, providing a greater risk for radiation to disrupt cell development. Children also have a longer life expectancy, giving a longer time for the effects of any radiation damage, if present, to have an effect on long term health.

Special care needs to be taken with women of reproductive age as the foetus (unborn baby) is highly sensitive to radiation, particularly early in the pregnancy. If you are or may be pregnant you must advise your doctor referring you for an X-ray examination and the person performing the X-ray examination. They will discuss with you the risks and benefits associated with the particular procedure.

Are there other reasons the risk of harm from ionising radiation is different for different individuals?

As well as the differences in risk associated with age, sex and different body tissues, we know that the time between radiation exposures can influence how the body responds to the effects of ionising radiation. The body has repair mechanisms which can *fix* some damage caused by ionising radiation. Some individuals have a slightly poorer capacity to fix this damage than others but we are still learning about this and are not able to easily identify which people are at a greater risk. An example of this increased genetic tendency to develop radiation – induced cancer is the BRCA1 and BRCA2 gene mutation which predisposes people who carry the gene to develop breast cancer.

There may be other factors that make some people more sensitive to the effects of radiation that are still not known about, and that is why it is important that each X-ray, CT scan or nuclear medicine test can be justified as an important investigation with a benefit to the patient.

How do we know what the risks really are? How accurate are these estimates of risk?

Estimating radiation risk is a complex and problematic task. Most of our knowledge has come from observations of the effects of high doses of ionising radiation on the Hiroshima and Nagasaki atomic bomb survivors. However, other groups of people have also been accidentally exposed to a known ionising radiation dose such as in accidents at nuclear reactors and by accidental use of radioactive material in a building.

As the risk of harm from ionising radiation is so small, it takes very large population samples to be able to provide accurate statistical calculations of risk. At present, the best estimate of risk we have is that we expect a 5% increase in death from solid tumours (masses or lumps of cancerous body tissue) in a population after that population has been exposed to an equivalent dose of 500 years worth of background radiation. This is approximately equivalent to 100 CT abdomen scans or 50,000 chest X-rays.

It is important to realise that these statistical assessments can only be applied to populations and should not be applied to individuals. Each individual's sensitivity to ionising radiation will be different depending on their age, sex and other factors discussed above.

Procedure	**Risk of Fatal Cancer**	**Equivalent to number of cigarettes smoked**	**Equivalent to number of highway km driven***
Chest radiograph	1.3 per million	9	37 - 62
Skull X-ray series	6 per million	44	166 - 277
Barium enema	20 per million	148	571 - 952
CT scan of the chest	400 per million	2960	11,420 – 19,040
Radiation exposure from 18 hour plane flight at 1300m	1.3 per million	9	37 - 62

*Based on Australian road trauma statistics

Adapted from information in *Radiobiology for the Radiologist*, Fourth Edition; Eric Hall 1994, J.B. Lippincott Company.

Radiation doses from various sources:

Source of Exposure	Radiation dose in millisievert (mSv)	Range* (mSv)
Average dose to Australians from background radiation per year	2.0	
Arm or leg X-ray	0.005 – 0.05	
Chest X-ray 2 views	0.08	0.05 – 0.2
CT scan	3	1 – 15
Ultrasound	0	0
Magnetic resonance imaging	0	0

*There is some variability in the dose associated with certain procedures because of variation in patient size and, in the case of CT scanning, the part of the body being scanned and the technique that is used.

Radiation dose to passengers from air travel:

Route Estimates	Dose/Flight (mSv)	Flights for 1 (mSv)
Darwin – Perth	0.016	62
Perth – Broome – Darwin	0.008	131
Darwin - Singapore	0.009	107
Frankfurt-Singapore	0.039	25
Melbourne - Johannesburg	0.071	14
Melbourne-Singapore-London	0.065	15
London-Singapore-Melbourne	0.042	23
Adapted from data provided by Capt Ian Getley and adapted for presentation		

Source : http://www.arpansa.gov.au/radiationprotection/Factsheets/is_cosmic.cfm

The radiation risk from X-ray procedures is not zero but it is, in most cases, extremely small and should be far outweighed by the benefits of the procedure. Every X-ray examination should be looked at in terms of its expected benefits.

What are the benefits of diagnostic radiology using ionising radiation?

The purpose of diagnostic radiology is to provide the radiologist or nuclear medicine specialist and your doctor with images of sufficiently high quality to assist them to understand and explain your medical problem or symptom and confirm either the presence or absence of disease or injury.

X-ray imaging procedures, in the main, offer the advantage of being:

- Low risk
- Non-invasive
- Fast
- Accurate, and
- Well established as an investigative technique.

Your doctor, in consultation with you, will make an assessment that the benefits of the X-ray procedure outweigh any possible risks. The radiologist or nuclear medicine specialist supervising the procedure will also assess if it is the most appropriate test, taking into account the information your doctor has written on the request form together with your medical history.

How do I decide whether the risks are outweighed by the benefits of exposure to ionising radiation when I have a radiology test or procedure?

Your decision should be made in close consultation with your referring doctor. Ask your doctor about the procedure and how it will help to provide information about your symptom or the presence of disease or injury. Ask your doctor about the risks of the procedure and what the risks would be of not having the procedure, i.e. if your doctor needs the information in order to identify and plan the most appropriate treatment.

While there is a small risk of harm from ionising radiation, there could be a greater risk of not having the information, e.g. failure to detect potentially serious disease that may be easily treated at an early stage but harder to treat or incurable if detected later.

Discuss any concerns with your doctor. Access reputable websites to find out information and you may also be able to obtain information from the hospital or private practice where your doctor has referred you for the procedure.

It may also be as beneficial to you to confirm the absence of disease or injury as it is to confirm its diagnosis.

Are there alternatives to procedures that involve ionising radiation that would answer my doctor's question?

X-rays, CT scans, nuclear medicine studies, MRI and ultrasound each have a greater or lesser ability to scan and provide an image of specific parts of the body and/or to identify the presence or absence of certain conditions or disease. MRI and ultrasound studies are usually used in preference to other imaging tests when it is practical to do so. Your referring doctor will consider which imaging procedure is most appropriate depending on the type of information required and your medical history. Your doctor can also discuss the most appropriate choice of test with the radiologist or nuclear medicine physician.

Useful websites about radiation:

- Australian Radiation Protection & Nuclear Safety Agency
  www.arpansa.gov.au
- Image Gently
  http://www.pedrad.org/associations/5364/ig/
- International Atomic Energy Agency -
  http://rpop.iaea.org/RPoP/RPoP/Content/index.htm
- National Council on Radiation Protection & Measurements
  http://www.ncrponline.org/
- Health Physics Society
  http://www.hps.org/

Please note:

This information is of a general nature only and is not intended as a substitute for medical advice. It is designed to support, not replace, the relationship that exists between a patient and his/her doctor. It is recommended that any specific questions regarding your procedure be discussed with your family doctor or medical specialist

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