Radiation Risks From Diagnostic Exposure

APEX Physics Partners

Risks from Exposures to Ionizing Radiation Exposure from Diagnostic Radiology Procedures

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1. INTRODUCTION

Ionizing radiation is routinely used in medical imaging procedures to visualize anatomy, detect abnormalities, and evaluate the progress of treating disease. There are various types of ionizing radiation. The most common type used in radiology are x-rays which are produced from general radiography, dental, mammography, fluoroscopy, and Computed Tomography (CT) systems. Also, ionizing radiation is used in nuclear medicine. Radiopharmaceuticals (a chemical agent labelled with radioactive atoms) emit gamma rays in a decay process. Gamma rays are basically the same as x-rays. The most common radiopharmaceutical is Technetium - 99m (Tc-99m) which releases a 140 keV gamma ray and decays to one-half of its original activity in 6 hours.

Other modalities such as Magnetic Resonance Imaging (MRI), and ultrasound do not produce ionizing radiation. MRI utilizes a very strong magnetic field, and radiofrequency (RF) waves. Ultrasound uses high frequency sound waves.

Low levels of ionizing radiation are constantly present in our environment from natural sources such as cosmic rays, radon, and other naturally occurring radioactive material (NORM). We are always being exposed to these low levels of ionizing radiation.

Collectively, exposure from these sources is called background radiation.

Ionizing radiation is a known carcinogen. Studies show that high levels of ionizing radiation carry a significant risk of causing various forms of cancer later in life. The cancer risk from low levels of ionizing radiation is uncertain. However, radiobiological models that regulations and radiation safety practice are based on assume a risk proportionate to the amount of radiation exposure - even at very low levels. Based on these models, even a small amount of exposure may have a small amount of risk. In rare cases, the amount of radiation from diagnostic fluoroscopy exams have caused more serious radiation injury to the skin. This has also happened in a series of patients undergoing CT brain perfusion scans at Cedars Sinai Hospital. These patients were scanned with incorrectly modified protocols that resulted in excess radiation dose to the patients. [1]

The primary goal in radiation protection is to ensure that these severe effects (deterministic effects) never happen, while at the same time, reducing the cancer risk as much as practical. This philosophy ensures that radiation exposure to patients and workers is **A**s **L**ow **A**s **R**easonably **A**chievable, or “**ALARA**”.

This tutorial was established as part of an initiative to implement

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[1] Safety Investigation of CT Brain Perfusion Scans: Update 11/9/2010. FDA Medical Device Notice. http://www.ajnr.org/content/31/1/2

recommendations by The Joint Commission regarding radiation risks of diagnostic imaging.[2] More specifically, the purpose of this tutorial is to help you understand and answer the following questions:

1. How much exposure do patients typically receive from diagnostic x-ray exams?
2. What is the cancer risk associated with these exposures?
3. What steps are being taken to minimize risk to patients?

2. RADIATION EXPOSURE FROM DIAGNOSTIC IMAGING

The amount of exposure to ionizing radiation is typically measured in units of millirem, and called "effective dose".

It is easy to measure the effective dose to personnel who work around radiation (radiation workers) by using personal dosimeters. These dosimeters are sensitive enough to detect 1 millirem of radiation exposure. Regulations are in place to maintain exposures to radiation workers and members of the public to within the following annual limits:

Type	Annual Limit
Effective Dose (whole body)	5,000 millirem
Fetal Dose to a Pregnant Radiation Worker	500 millirem
Member of the Public	100 millirem

2 The Joint Commission Sentinel Event Alert, Issue 47, August 24, 2011 "Radiation Risks of Diagnostic Imaging".

It is more difficult to measure the “effective dose” to a patient from a diagnostic x-ray exam for various reasons. The exposure from each x-ray exam can not practically be measured, and will change based on the patients size, technical factors, and type of exam being performed. Also, the effective dose is a measure of risk from exposure to the entire body. X-ray exams only expose certain organs and regions of the body that require visualization for appropriate diagnoses. For these reasons, effective doses for individual exams should only be considered estimates unless a specific calculation is provided by a medical physicist based on well known conditions of a particular exam.

Also, radiation doses are often misunderstood, or not considered in appropriate context because most people have very limited knowledge of radiation dose, units, and risk. For this reason, estimated radiation doses are often compared to an equivalent number of chest x-rays or amount of time it takes to get that same exposure from background radiation, or occupational exposure. This may help provide perspective to a concerned patient. For example, most diagnostic procedures result in less exposure than a radiation worker, who is performing the procedure, is allowed to receive in a single year.

Similarly, many procedures that utilize ionizing radiation result in less exposure than a few days, or a few weeks of background equivalent exposure.

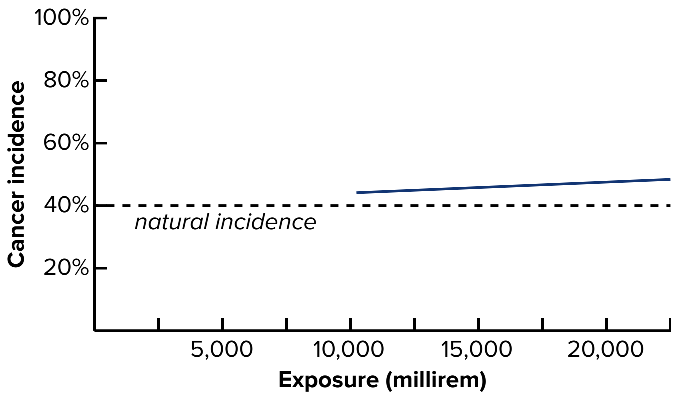
Here are some estimates for routinely performed diagnostic imaging exams:

Comparison of Whole-Body Effective Dose for Diagnostic Procedures			
Procedure	**Effective Dose (mrem)**	**Equivalent Number of Chest (PA) x-rays**	**Background Equivalent Time (BERT**
Chest			
Chest X-Ray (PA)	4	1	4.7 days
Chest X-Ray (Later)	8	2	9.5 days
Chest CT	780	195	2.5 years
Abdomen			
Abdomen X-Ray	120	30	4.6 months
Abdomen CT	760	190	2.5 years
Abdomen & Pelvis CT	1500	375	4.8 years
Heart			
Myocardial Perfusion Study (9 9mTc Stress/ Rest)	1140	285	3.7 years
Myocardial Perfusion Study (9 9mTc Stress/ 2 01Tl Rest)	2920	730	9.4 years
Head			
Skull X-Ray	10	3	12 days
Head CT	180	45	7 months
PET Brain Scan	700	175	2.3 years
Nuc Med Brain (20 mCi9 9m Tc-HMPAO)	690	173	2.2 years
Panoramic Dental X-Ray	1	¼	1.2 days
Breast			
Mammogram (per view)	10	3	12 days
Bone			
DEXA (Bone Density) scan	3	1	3.5 days
Nuc Med Bone Scan (20 mCi 9 9mTc-HDP)	440	110	1.4 years
Other			
Average annual background dose (from natural sources)	310	78	1 year

3. CANCER RISK FROM DIAGNOSTIC IMAGING PROCEDURES

There is substantial data available regarding health effects from ionizing radiation. This data includes cancer incidence in survivors of atomic bombs in Hiroshima and Nagasaki, studies of persons exposed to radiation for medical reasons, and studies of nuclear workers exposed to low and high levels of radiation. The following graph illustrates what we know about cancer incidence as the result of radiation exposure:

Increased Incidence of Cancer from Ionizing Radiation



There is substantial data that shows high levels of radiation exposure result in increased occurrence of cancer in a population. Current estimates predict that a population exposed to 10,000 millirem would experience a 1% increase in cancer (solid cancer or leukemia) over their lifetime.[3] So if 100 people received this dose of ionizing radiation, we would expect 1 excess case of cancer from the radiation exposure. This is in addition to the

3 Beir VII: Health Effects from Exposure to Low Levels of Ionizing Radiation. Expert Consensus Report. The National Academy of Sciences. National Academies Press, 500 Fifth St. NW, Washington DC.

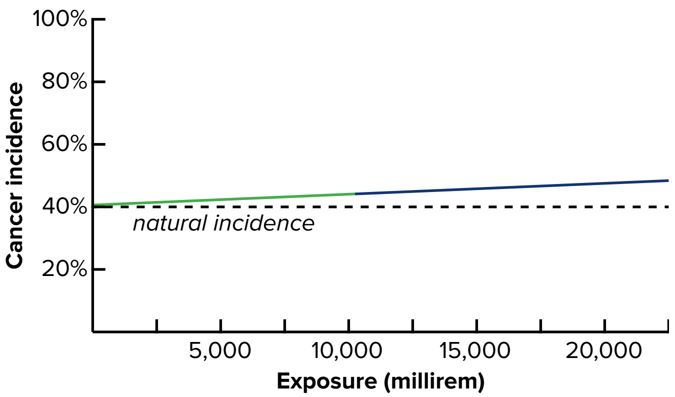
cancers that ordinarily occur. We would expect 42 cases of cancer in that population from other causes. This is considered the natural incidence of cancer.

Cancer risks from lower levels of radiation exposure is speculative. There is no proven correlation between low levels of radiation exposure (10,000 millirem or less) and increased incidence of cancer in human populations. There are two possible reasons for this:

1. There is no increase in cancer risk at these levels, or
2. The increase is too small to be detected in comparison to the natural incidence of cancer in the population.

Since the natural incidence of cancer is quite high, and the potential increase in cancer risk from low level exposure is very low, it has not been possible to prove or disprove a correlation between the two. Because we want to be as safe as possible, we assume that option 2 is the correct answer. Current risk models assume a proportionate risk at lower doses. The following graph shows this presumed model of risk:

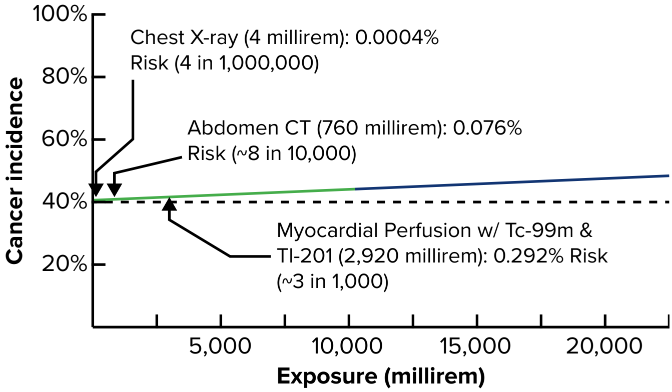
Linear No-Threshold Relationship



The green line indicates the risk in the low dose range. This line happens to intersect the y-axis at the baseline level (natural incidence of cancer). This means, that based on this model, there is no threshold of exposure at which there is absolutely no risk. This relationship between exposure and cancer risk is called the Linear No-threshold Model.

Based on this model, even small amounts of exposure to ionizing radiation result in small amounts of cancer risk. However, it is important to keep discussions of radiation risk in context. The following graph places several diagnostic procedures on this graph in terms of exposure and risk:

Speculative Cancer Risk in Low Dose Range



As you can see, the theoretical risk from diagnostic procedures has a wide range, but is still well within the low dose region of the graph. However, there is also concern due to the increasing number of x-ray exams being performed. Over the last two decades, exposure to ionizing radiation has nearly doubled in the United States.[4] In 2018, approximately 75 million CT exams were performed.[5] This number is expected to reach 84 million per

[4] National Council on Radiation Protection and Measurements: Ionizing radiation exposure of the population of the United States (2009). NCRP Report No. 160, Bethesda Md., 142-146.

[5] Berrington de Gonzales A, et al: Projected Cancer Risks from Computed Tomographic Scans Performed in the United States in 2007. Archives of Internal Medicine, 2009; 169: 2071-2077.

year by 2022. Also, risk is expected to accumulate over multiple exams to the same individual. Children and young adults may be more sensitive to radiation exposure as well.

These concerns, as well as isolated incidents of extreme over-exposure have resulted in increasing regulation, safety controls, and attention to radiation dose. Risks from these levels of exposure should be understood and weighed against the medical necessity and appropriateness of each exam. When used correctly, ionizing radiation is an effective tool that can save lives. If medical appropriateness is established, the risk to the patient from ionizing radiation is probably insignificant in comparison to the medical benefit.

4. REDUCING RISK

On August 24, 2011, the Joint Commission published a Sentinel Event Alert entitled “Radiation Risks of Diagnostic Imaging”. The purpose of the Alert was to increase awareness of the potential risks of ionizing radiation produced in diagnostic imaging, and to propose specific actions to minimize patient doses, and ensure appropriateness of imaging exams. Some of these steps are summarized here.

Many processes and controls are in place to ensure that radiation doses to patients are ALARA. This includes routine quality control and preventive maintenance of imaging systems that produce ionizing radiation. Also, annual radiation safety and performance evaluations are completed by professionally licensed medical physicists. Operators of equipment are licensed Medical Radiologic Technologists with specialized training in the modality in which they practice. Many imaging systems now incorporate dose saving features that customize dose delivery based on the patient size and anatomy.

Also, protocols for imaging procedures that could potentially result in higher patient doses are reviewed by appropriate personnel. An important part of protocol development is the use of reference doses that are used to optimize the resulting image quality and patient dose. Progress in protocol review is reported to the Radiation Safety Committee.

A consolidated effort has been initiated to ensure that these exams are only performed when medically appropriate. The Joint Commission has recommended that effective processes be in place to ensure that each patient receives the right test at the right dose.

All diagnostic imaging exams must be ordered by a licensed practitioner, but many things can still lead to unnecessary radiation exposure. These include miscommunication, lack of knowledge, failure to use alternative exams that may not involve ionizing radiation, and practice of defensive medicine. The use of effective criteria can help minimize or eliminate these factors. Radiology departments have begun implementing and using the *American College of Radiology's (ACR) Appropriateness Criteria.*[6] These are evidence-based guidelines meant to help ensure the most appropriate imaging or treatment decision for a specific clinical condition.

These guidelines are available on-line and can be used by all personnel from the referring physicians to the technologists performing the study. CT Technologists should verify patient identity according to hospital policy, and compare each patient's history and indications with the Appropriateness Criteria prior to performing each exam.

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[6] ACR Appropriateness Criteria, http://www.acr.org.

5. CONCLUSION

Numerous controls are in place to minimize the patient's risk from ionizing radiation during diagnostic imaging. These processes are carried out in a team environment by technologists, medical physicists, radiologists, and referring physicians. Proper communication among these personnel is essential. Also, education and general awareness are an integral part of effectively minimizing risk to the patient. The Joint Commission has recommended that hospitals take steps to ensure that there is adequate awareness among staff, administration, and referring physicians of the "potential dangers from diagnostic radiation" and "levels of radiation typically used and related risks".[2] Questions regarding appropriateness and patient dose should be addressed with technologists, radiologists and medical physicists through contacting the Radiology Department or modality team leaders. Any questions or concerns regarding Radiation Safety should also be addressed to the facility Radiation Safety Officer (RSO).

Apex prides itself on providing RSOs who are experts on these issues and help actively manage compliance. For additional information related to radiation risk, facility staff education, or our RSO services, please contact Apex Physics Partners at 410.339.5447, or email apexinfo@apexphysicspartners.com.

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