Ionizing Radiation Exposure from Radiologic Imaging: The Issue and What We Can Do

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Background

The increased use of diagnostic imaging requiring the use of "ionizing radiation," the rapidly expanding use of computed tomography in the emergency setting, the introduction of multi-detector CT units and newly reported concerns related to the human consequences of low-level radiation exposure have revitalized a long-standing concern over the quantification and management of an individual's cumulative "medical" radiation exposure.[1,2,3] Studies have shown that many physicians, including radiologists, have developed a misconception that the shorter imaging acquisition times have resulted in lower doses of radiation, when in fact many times the opposite is true. The multi-detector CT units today, even with shorter scan times, expose patients to higher doses of radiation per scan than earlier units.

In the mid-'90s the Food and Drug Administration suggested a method for the lifelong recording of X-ray absorbed dose, and as recently as July 2005 the National Academy of Science published their most recent report underscoring the fact that *any* level of ionizing radiation may have carcinogenic effects.[4,5] With the exception of fluoroscopy and screening mammography, attention to the subject has waxed and waned over the years, no doubt due to the historically low dose of earlier procedures compared to the markedly higher dosages in today's mix of examinations. Most recently, the ACR published an American College of Radiology White Paper on Radiation Dose in Medicine in which they outlined numerous steps and interventions designed to help address this issue.[6]

The end user must be aware that there is an age and sex variable regarding adverse organ tissue effects from ionizing radiation. Typically children and women (breast and ovaries) are more radiosensitive, and the literature estimates that it may take upwards of 15 to 20 years before the increased risk of cancer becomes manifest. The current and common unit of measurement of "absorbed" ionizing radiation is a milliSievert (mSv). Chest, abdomen or pelvis CTs will typically expose one to between 8–10 mSv.

Specifically, a CT coronary angiogram may carry an overall effective radiation dose in a 20 mSv range; the organ equivalent dose is quite different.[7] Anthromorphic mathematical phantoms have shown that such studies will expose 20-year-old female breast tissue to an organ equivalent dose of 75–80 mSv, and lung tissue as high as 90 mSv. The cancer incidence for a 20-year-old in this example is believed to be in the one in 143 range…quite significant! With improvements in technology and CCTA imaging protocols, effective dose has been reduced significantly, to less than 10 mSv in many cases.

Population studies on atom bomb survivors from Hiroshima and Nagasaki have allowed one to estimate the increased risk of developing cancer expressed in the mSv unit of measurement. It has been well documented that this risk is significant when one is exposed to 100 mSv. The BEIR VII report estimates that a population of individuals exposed to 100 mSv has a one percent increased risk of developing cancer during a lifetime. The risk becomes enough of a concern when one is exposed to 50 mSv. Accordingly, this is beginning to be used as a threshold in identifying those who merit special levels of intervention.

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The following tables outline general effects of ionizing radiation and the radiation dose of some commonly used medical imaging procedures.

Radiation Dose and General Effects

10,000 mSv	Radiation sickness with death in several weeks
1,000 mSv	Immediate radiation sickness. Unlikely to cause death
100–1,000 mSv	Dose related risk of developing cancer
50 mSv	Associated statistically with increased cancer risk. Highest dose allowed annually with occupational exposure
20 mSv	Maximum allowable dose in radiation workers over a 5 year period
1.5–2 mSv	Background annual radiation exposure

Radiation Dose of Common Medical Procedures

Abdomen or Pelvis CT: 10 mSv	Chest CT: 8 mSv
Abdominal CTA (w/o contrast): 10 mSv	IVP: 4–5 mSv
Abdominal CTA (w/ and w/o contrast): 20 mSv	Mammogram: 1.3 mSv
Barium Enema (double contrast): 8 mSv	MPI SPECT (Multiple): 15 mSv
Bone Scan: 4 mSv	MUGA: 7 mSv
Brain PET: 7 mSv	Tumor Imaging PET: 7 mSv
Cardiac PET: 15 mSv	PET/CT: 20 mSv
Coronary Artery CTA (CCTA): +/- 10 mSv	Plain films: 0.04–0.10 mSv

Summary of the Issue

- The use of diagnostic imaging where patients are exposed to ionizing radiation is increasing.
- Radiation exposure will increase the risk of carcinogenesis.
- Women and younger patients have a greater degree of risk.
- Some body tissues are more radiosensitive and accordingly carry a higher degree of risk of carcinogenesis when exposed to a given level of mSv compared to other body tissues (thyroid, breast, gonads).
- Body parts located in the central part of the body (chest/abdomen and pelvis) generally require higher levels of radiation exposure in order to obtain adequate imaging.
- While controversial, many feel that any level of exposure to ionizing radiation carries an increased risk of carcinogenesis; atom bomb survivor studies have documented an increased incidence in cancer to as little as 50 mSv.
- While it is possible that with a spiral CT patients can receive a lower dose of ionized radiation compared to a “slice-by-slice” CT, often this is not the case. The technique of the spiral image often exposes the patient to higher doses due to scan volume, mAs, pitch and slice width.[8]
- While special CT exposure factors can be used to image children, this often does not occur in practice, thus unnecessarily resulting in higher doses of ionizing radiation.
- Time and radiation dose are not proportional with CT imaging.

What Can Be Done?

Excellent references that suggest what can be done include the ACR White Paper of Radiation Dose in Medicine[6] and Publication 87 from the International Commission on Radiological Protection.[8]

Operators:

- Reduce/limit the scan volume with CTs. Avoid unnecessary overlapping of images. With spiral CTs, modify the pitch factor.
- Use z-filtering with multi slice CT units.
- Reduce the mAs values.
- Use automatic exposure control by adapting scanning parameters to the patient cross section.
- Shield superficial organs such as eyes, thyroid and breast (bismuth shields).
- Separate factors for children.
- Use partial rotation techniques for head CTs.
- Become familiar with and use the radiation dose reduction techniques developed by the CT manufacturer of the unit being used.

Ordering Physicians and Radiologists:

- Assess the risk-benefit of the study being performed. Use your careful clinical acumen regarding your history and physical, and then make appropriate use of investigative studies in a logical stepwise manner. Make sure that the information used will allow you to arrive at a necessary diagnosis at the right time, and will then result in directing you to a specific way of managing your patient. (Answer the question: How will the results of this study help me in managing this patient? If the results of the study won't modify how you will manage your patient, step back and question whether you need it.)
- Is the ionizing radiation study the best one to perform? Are there other blood or lab tests that will direct you down a different path that won't require such testing? Will an ultrasound be a better initial investigative study? Will an endoscopic GI exam be appropriate for the evaluation of abdominal/pelvis complaints?
- Make sure that imaging studies are only performed by properly qualified medical personnel.
- CT exams should not be repeated without specific clinical indications and where other approaches cannot be utilized.
- The ordering clinician has an obligation to attempt to obtain the prior history of previous ionizing radiation imaging studies. Such information should be communicated to the radiologist.
- CT imaging of the chest and abdomen/pelvis in young girls and young women should undergo careful risk-benefit considerations, given the radiation dose to breasts and ovaries.
- Radiologists should have a primary responsibility to ensure that studies are done with a good technique.
- Special approaches should be undertaken by hospital facilities where the cumulative dose of ionizing radiation is calculated for each patient and made available to practitioners when specific thresholds are reached. Medical staffs should develop clinical care pathways for the use of CTs in the emergency department setting, paying particular attention to such imaging for patients being evaluated for uncomplicated headaches, chest pain and nephrolithiasis.

For more information or to learn more about NIA, contact your NIA representative or call 1-877-NIA-9762.

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