

Importance of consideration of radiation doses from cardiac imaging procedures and risks of cancer

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In recent years, there has been more attention and publicity to the radiation exposure experienced by patients undergoing cardiac imaging procedures such as computed tomography coronary angiography (CTA) and SPECT and PET perfusion imaging. The risk of radiation-related cancer risk from CT scans performed in the United States has not been adequately appreciated. Recent publications have voiced concern regarding future cancer risks from the many CT scans performed on an annual basis in the United States.¹⁻³ What is surprising and somewhat alarming is that radiation doses from diagnostic CT examinations are higher and more variable than generally quoted.^{3,4} The issue is not a trivial one since between 1992, the number of CT scans performed in the United States quadrupled. In 2007 alone, 72 million CT scans were performed.⁵ It was estimated that from this number, 29,000 excess cancers would result causing 15,000 deaths in the next 20 to 30 years. Another study published in the *New England Journal of Medicine* surveyed 952,420 adults between the ages of 18 and 64 over a 3-year period.² Of these, 69% (655,613) underwent at least one imaging procedure associated with radiation exposure. CT and nuclear imaging accounted for just 21% of the total number of procedures but 75.4% of the total cumulative effective dose. In this study, a high radiation dose was defined as >20-50 mSv and a very high dose as >50 mSv. High and very high doses were incurred in 18.6 and 1.9 enrollees per 1000 per year, respectively. Cumulative effective doses of radiation increased with advancing age and were higher in women than in men.

These data are particularly pertinent with the understanding that although the United States has a little under 5% of the world's population, it performs 25% of x-ray studies in the world and double and triple that of other developed countries.⁶ Furthermore, half of all nuclear medicine procedures performed in the world are done in the United States. In 2006 alone, almost 380 million diagnostic and interventional radiological

procedures were performed in the United States together with 18 million nuclear medicine tests.⁶ Thus, it is the U.S. population that incurs the greatest risk of radiation exposure and cancer risk. In fact, the per capita dose of radiation from medical imaging increased by a factor of nearly 6 from the 1980s.^{7,8}

The variability in radiation dose for the various CT scans is quite remarkable. This is surely due to lack of standardization. One study found a 13-fold variation between the highest and lowest dose for each type of CT scan studied.⁵ Some patients received only one-tenth the radiation others received. The median effective dose was 22 mSv from a typical CTA procedure and 31 mSv for a multiphase abdomen-pelvis CT scan. At one institution, exposure was 90 mSv for the latter. The authors of this study estimated that the risk of cancer was 1 in 270 for a 40-year-old woman undergoing a CTA (for a man of the same age the figure is 1/600). In this study, it was concluded that some people may be exposed to 4 times as much radiation as estimated by earlier studies. It should be noted that the per capita annual effective radiation dose from natural sources of radiation has remained constant at 3.0 mSv for the past 20 years,⁹ with most of the exposure coming from radon.

The medical imaging community is now highly aware of the risks of radiation exposure from radiological imaging tests. This is why a considerable effort is being undertaken to develop approaches to substantially reduce the effective radiation dose received by patients who get a CTA procedure.¹⁰⁻¹² In the PROTECTION 1 study reducing the tube voltage to 100 kV resulted in a 53% reduction in the median radiation dose for CT coronary angiography (CA) when compared to the conventional 120 kV scan protocol.¹⁰ Although image noise increased, diagnostic image quality was not impaired. One caveat is that this type of dose reduction can only apply to nonobese patients. The median effective dose for CTCA in the Advanced Cardiovascular Imaging Consortium (ACIC) study comprising 40 hospitals using the best practices model for scan acquisition was reduced from 21 to 10 mSv without a significant change in image quality.¹¹ Some approaches included the use of ECG-gated tube current modulation, aggressive beta blocker therapy to reduce heart rate,

reduction in tube voltage, using adjustable acquisitions windows and minimizing the length of the scan range. The use of full thorax scans, including the triple rule out protocol, was inversely associated with achieving the target radiation dose of under 15 mSv. The authors cautioned against the use of triple rule out CT protocol unless there was a very high clinical suspicion of aortic dissection pulmonary embolism. Interestingly, apropos to this warning is the observation that 25 to 40% of CT scans are ordered out of the Emergency Room.⁶

Although most of the recent publicity about medical imaging radiation exposure has been focused on CT scanning, nuclear cardiology procedures such as SPECT myocardial perfusion imaging also expose patients to rather substantial doses of radiation. For Tc-99m sestamibi or tetrofosmin rest/stress imaging, the effective doses are in the range of 9 to 13 mSv. For Tl-201, the dose is substantially higher. This is one reason that dual isotope imaging with Tl-201 imaging performed at rest and one of the Tc-99m-labeled perfusion tracers injected during stress has fallen out of favor. In fact, many laboratories are seeking to perform more stress-only SPECT imaging with sestamibi or tetrofosmin, particularly in low-risk or low-to-intermediate risk patients. If the gated stress study is normal, then the rest of the study is cancelled. The prognosis of patients with a normal stress-only study is similar to the prognosis of patients with a normal rest/stress study with a 61% lower radiopharmaceutical dosage.¹³ Thus, conducting a stress-only perfusion SPECT (or PET) would reduce the radiation exposure to the patient without diminishing scan accuracy. For patients who achieve >10 METs of exercise with no ischemic ST depression, SPECT imaging may not be necessary. Such patients have a very low incidence of reversible defects on SPECT and almost no ischemia comprising 10% or greater if the left ventricle.¹⁴

With hybrid PET-CT imaging, a low dose, prospectively gated CTA procedure yielded good image quality as long as a heart rate of less than 65 beats per minute was reached.¹⁵ The approach to decreasing radiation exposure suggested by Einstein et al (AJC paper) for CTCA is to employ a sequential—if—appropriate scanning protocol rather than the conventional helical scanning protocol if the heart rate can be adequately reduced and the rhythm regular. Sequential scanning means that x-rays are delivered only during diastole. This approach, when it could be used, resulted in a 65.5% decrease in the mean effective dose from 14.9 to 5.2 mSv.

One way clinicians can contribute to reducing the radiation exposure from medical imaging tests is to only order them when deemed appropriate and according to accepted practice guidelines. Emergency room

physicians are quick to order CT scans of all types. These scans are often performed before specialty physicians have the opportunity to interview and examine the patients.¹⁵ Cardiologists should be asked to see emergency room patients for consultations before they are sent for CT scans or nuclear imaging stress tests by Emergency Department personnel.¹⁶ This alone would reduce the number of radiological procedures. We should think twice before ordering a CT angiogram or a nuclear cardiology stress test procedure in a 40-year-old woman with very atypical chest pain and a normal electrocardiogram to rule out coronary artery disease. With more education regarding clinical indications for noninvasive testing including the radiation exposure and future risks of cancer, the number of unnecessary procedures would surely diminish. For the nuclear cardiology community, the findings of the stress-only SPECT protocol recently reported by Mahmorian and colleagues are encouraging for reducing radiation doses. Anecdotal reports of lower radiation exposure with some of the newer digital SPECT cameras are also welcome. We all must strive in whatever way we can achieve the best practices in conducting cardiac imaging tests and adherence to appropriateness criteria for ordering tests. Only in this manner can we do our part in limiting radiation exposure to a minimum while acquiring imaging test results that truly impact on decision making and patient outcomes.

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