Medical Imaging: The Radiation Issue

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Recent years have witnessed important advances in medical imaging coupled with extraordinary growth in its utilization. Since most of these procedures involve the exposure of patients to ionizing radiation, it is not surprising that "the radiation issue" has engendered considerable controversy.

First, the scope of the problem. A subcommittee of the National Council on Radiological Protection and Measurements has recently published preliminary data on changes in radiation dose to the United States population. Ionizing radiation from is commonly quantified in terms of the effective dose, a measure reflecting the concentration of energy deposited in each organ, the type of radiation, and the relative sensitivities of different tissues to undesirable effects of radiation, and measured in units of milliSieverts (mSv).[1] *Per capita* annual effective dose from natural sources has remained basically constant over the past 25 years at roughly 3 mSv. The largest portion of this is the radiation due to radon, accounting for slightly over 2 mSv, and thought to account for about 20,000 lung cancer deaths per year in the U.S.[2] What has changed is the dose due to medical exposures, which has increased sixfold from 0.5 mSv to 3.0 mSv per person each year, reflecting the dose from the 384 million non-dental imaging procedures involving the use of ionizing radiation. Of this, 1.5 mSv is from the 67 million CT scans performed annually, 0.6 mSv is from the 9 million nuclear stress tests, and 0.4 mSv is from the 17 million interventional fluoroscopy procedures.[3]

While such detailed dose estimates are not available in most developed nations, this trend of increased utilization and dose appears to be similar. For example, data from the United Kingdom Department of Health indicates a near-tripling in the number of CT scans performed in England in the past decade to 3 million.[4] Many of these procedures with the greatest increase in frequency are also among the medical imaging procedures with the highest effective dose per study. For example, some nuclear cardiology and cardiac CT protocols can be associated with doses exceeding 20 mSv.[5]

A source of some controversy is the relationship between the radiation doses received by patients and attributable risks of events such as cancer. Radiation is a weak carcinogen, and thus the chance of a patient developing cancer from a single imaging test is small, even in a worst-case scenario. Thus, a relationship between ionizing radiation exposure and cancer risk is difficult to establish epidemiologically without very large sample sizes. For example, assuming excess cancer risk is proportional to radiation dose, for a cohort study with lifetime follow-up to have 80% power to detect a significant increase in cancer mortality from a 20 mSv medical imaging test, half a million adults would need to be studied.[6, 7] Such cohorts are not available in adults undergoing medical imaging, and thus we are forced to make extrapolations about cancer risk from other populations.

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Most experts agree that the existing epidemiological data appear to support increased cancer risk at doses similar to those received by some patients undergoing a medical imaging study. For example, a cohort of Japanese atomic bomb survivors with a mean dose equivalent to 29 mSv had a statistically significant increase in cancer incidence, with 1.8% of cancers in the cohort attributable to the bomb's radiation.[7, 8] Similarly, the literature from *in utero* x-ray exposure supports an increase in cancer at a fetal dose of 10 mGy,[9] and a study of over 400,000 radiation workers with a mean dose of 19 mSv concluded a significant increase in cancer risk.[10] Nevertheless, these data are subject to interpretation and a vocal minority disagrees with the consensus of most experts, instead arguing that there is insufficient evidence to conclude an increased cancer risk from doses less than 100 mSv.[11] Closely related is the question of which model best describes the relationship between dose and cancer risk. Most experts support the linear-no-threshold (LNT) model, in which cancer risk increases linearly with dose and there is no dose threshold below which there is no risk of cancer, as best fitting the available data for purposes of radiological protection, but others argue that this over- or under-estimates risk.[12]

Given this controversy, how should clinicians approach the issue of radiation risk from medical imaging? Ionizing radiation should be employed in accordance with the ALARA principle, keeping patients' radiation exposure as low as reasonably achievable. This encompasses both *justification*, i.e. applying a medical imaging test involving ionizing radiation only when it is the best test for a particular patient at a particular time, and *optimization*, i.e. when a test is optimal keeping radiation exposure to a minimum. Appropriateness criteria provide good general guidelines for test justification,[13, 14] but of necessity cannot incorporate all patient-specific information. Moreover, in their initial formulation, cardiac appropriateness criteria have been organized around specific imaging modalities rather than around specific patient populations. Thus, more than one medical imaging test may be "appropriate" in a diagnostic scenario according to these criteria, again leaving the clinician without a clear directive in terms of what is the best test for a specific patient. Hence, while useful, appropriateness criteria are not a substitute for a careful analysis of the benefits and risks of each testing option under consideration, including the option to perform no testing.

Such benefit-risk analyses can be informed by patient-specific radiation risk estimates when available, as in e.g. CT coronary angiography[12] and CT colonography.[15] These estimates derive from methods that assume the LNT model, and the point estimates reported are associated with considerable statistical uncertainty. Nevertheless, I believe that for purposes of risk-benefit analyses, such best estimates are reasonable to use and in many cases can be quite informative. For example, despite the high effective dose from helical CT coronary angiography, in an elderly man the risk of attributable cancer is estimated as less than 1 in 3000, and thus the potential for iatrogenic cancer should not be considered as a significant element of a benefit-risk analysis. Nevertheless, should CT coronary angiography be chosen in this patient, the low estimated cancer risk does not excuse the imager from applying the principle of optimization.

Thus, "the radiation issue" is not so much an isolated issue to be debated, but rather one of the many factors to be considered in thoughtful patient management. While in some cases radiation risk will be a significant concern with an impact on the selection of medical imaging tests, in most cases it will not, although it should always be a significant concern in test performance. As in many other aspects of clinical medicine, the data on the health effects of radiation upon which our practice is based are limited, but imperfect information does not free us from weighing the best available evidence to tailor the care of each patient.

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