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VIEWPOINT

Ionizing radiation risks of cardiac imaging: estimates of the immeasurable

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For many decades, the search for a non-invasive visualization of the coronary arteries seemed to remain an unfulfilled promise to clinical cardiologists. Owing to the rapid refinements successfully implemented in computed tomography (CT) technology over the past few years, non-invasive imaging of coronary arteries is now not only feasible but also has become a reality in daily routine. This may—at least in part—have contributed to the fact that the number of CT scans performed in the USA has quadrupled since 1993.[1] Although in a recent US survey CT and nuclear imaging accounted for just 21% of the total number of procedures, they resulted in >75% of the total cumulative effective radiation dose. We have witnessed an impressive six-fold increase in the radiation dose from medical imaging delivered per patient over the last 3 decades.[1–2] Interestingly, half of all nuclear medicine procedures worldwide and 25% of all X-ray studies are performed in the USA (constituting 5% of the world's population), doubling and tripling that of other developed countries.[3]

In this context, it appears appropriate that the radiation exposure experienced by patients undergoing any medical imaging procedure has recently obtained a growing attention and publicity.[4] Although some surveys have investigated on the overall amount of radiation exposure (*Table 1*) from any medical imaging procedure,[5] others have focused specifically on the radiation dose to patients from cardiac imaging.[6–7] Among these, CT coronary angiography has faced the greatest attention, probably because this modern development has been introduced as a last cardiac imaging technique and also because CT is generally perceived as being associated with a high radiation dose to the patient. In fact, in its infancies, radiation doses >20 mSv were reported for a CT coronary angiography.[8] Although comparable doses have also been reported from some surveys for purely diagnostic coronary catheterization,[6] which is invasive and achieves only low diagnostic yield in the actual daily clinical routine,[9] this has fuelled a vivid discussion on the potential harms arising from non-invasive CT coronary angiography, questioning the justification of its use in large populations and calling for more efficient radiation protection measures of patients undergoing CT angiography.[8]

Remarkably, whereas the potential benefits of medical imaging procedures are generally left unmentioned in the radiation safety discussion although they can be scientifically quantified, the risk of cancer from low radiation doses used in medical imaging can only be roughly estimated by statistical calculations based on assumptions of the linear no-threshold theory.[4] This means that data from Hiroshima are extrapolated down to the lowest doses, although no studies have ever verified the assumptions about cancer associated with the doses used in medical imaging. Instead, even the authors of the largest recent survey on low-dose ionizing radiation from medical imaging procedures[5] have agreed that the data associating low-dose radiation to cancer risk are not definitive.[10] Similarly, the Health Physics Society has concluded in a position statement that although there is substantial and convincing scientific evidence for health risks following high-dose exposures, risks of health effects for doses <50–100 mSv are 'either too small to be observed or are nonexistent'.[11]

Nevertheless, following the principle of keeping radiation exposure as low as reasonably achievable, several strategies to reduce radiation dose in CT coronary angiography have been explored, such as automated exposure control, electrocardiographically controlled tube modulation, and reduced tube voltage (from 120 to 100 kV) in non-obese patients.[12] A prospective controlled multicentre trial has confirmed that introduction of a collaborative radiation dose-reduction programme was associated with a 53% reduction in radiation dose from 21 to 10 mSv in patients undergoing CT coronary angiography.[13] A recent milestone in

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Table 1 Effective dose estimates for selected studies and sources

Examination	Representative effective dose value (mSv)
Chest X-ray postero-anterior	0.02
Round-trip flight (Europe—North America)	
Average	0.05
Peaks during solar cosmic events[20]	>2
Smoking cigarettes (natural Po-210 in tobacco)[21]	2.8/year
Radon in home	
Average	3.2/year
Peak exposures[22]	>200/year
Coronary calcium scoring (prospective triggering)	1
CT coronary angiogram (64-slice)	
Without tube current modulation	20
With tube current modulation	12
Prospective triggering	2
Prospective triggering with high-pitch spiral	1
CT chest	7
CT abdominal	8
Diagnostic invasive coronary angiogram	7
Myocardial perfusion study	
Thallium stress/rest	25
Sestamibi (1-day) stress/rest	10
N-13 ammonia stress/rest	3

dose reduction has been achieved by introducing prospective ECG triggering, limiting scanning to a narrow pre-defined end-diastolic phase, which resulted in a massive 90% reduction in radiation dose down to an average of about 2 mSv without loss of image quality[14] or accuracy.[15] Very recent introduction of prospective high-pitch spiral scanning has enabled to lower radiation dose <1 mSv.[16] Similarly, substantial dose reduction in nuclear myocardial perfusion imaging to <2 mSv has been achieved by new reconstruction algorithms,[17] by introducing low-dose stress-only protocols suitable for hybrid imaging with low-dose CT coronary angiography,[18] and by implementing semiconductor detectors into latest generation gamma cameras allowing massive scan shortening or dose reduction.[19]

As CT coronary angiographies can now be achieved with a radiation dose <1 mSv,[16] the estimated risk of inducing a fatal malignancy (*Table 2*) is now in the range of the lifetime odds of dying from a lightning strike.[7] Thus, although we agree that the time is right to initiate long-term observational studies involving patients who have undergone imaging, we should at the same time stop making assumptions—invoked by health care professionals and the media—that are not adequately supported by data but may harm our patients by deferring them from a needed diagnostic procedure.

Table 2 Estimated risks of fatal malignancy from radiation exposure and lifetime odds of dying due to selected underlying causes

Exposure	Lifetime odds of dying (per 1000 individuals)
Effective radiation dose	
1 mSv	0.05
10 mSv	0.5
20 mSv (yearly radiation worker allowance)	1
100 mSv (definition of low exposure)	5
Natural fatal cancer[7]	212
Motor vehicle accident[7]	11.9
Lightning strike[7]	0.013

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