# PRINCIPLES OF ALARA AND RADIATION SAFETY IN CARDIAC CT

**Part I in our series on Radiation Management in Cardiac CTA**
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In the 1970's researchers noted an increased frequency of solid tumors in survivors of the atomic bombs dropped on Japan in 1945. It had been known for some time that the acute and high doses of radiation from the bombs AND the increased background radiation around Hiroshima and Nagasaki were associated with the development leukemia. The bone marrow is especially sensitive to whole body radiation and it had been known for nearly a century that high and prolonged radiation exposure could increase risk for lymphoma as well. It is been suggested that Marie Curie (the discoverer of radium) and perhaps her daughter both died of radiation induced leukemia. However, the discovery of 'solid' tumors (e.g. lung, breast, reproductive system) after radiation exposure was a surprise.

Data demonstrated that the incidence of solid tumors in survivors of atomic bomb attacks was as much as 50% greater than that of the non-exposed population. It has been estimated that those with cancers had > 100 mSv acute exposure; however, nobody has been able to absolutely demonstrate whether similar results would occur with smaller doses.

Committees, including the ICRP (International Commission on Radiological Protection), were formed and soon suggested that *"As any* [ionizing radiation] *exposure may involve some degree of risk recommends that all unnecessary exposures be kept as low as is reasonable achievable…"*

ALARA (As Low As Reasonably Achievable) is based on the generally accepted notion that higher doses of radiation are linked to both short-term and long-term effects on the human body. One can extend this concern, using the LNT (Linear, Non-Threshold) hypothesis stating: 'any radiation, no matter how low, carries with it a certain level of risk proportional to exposure'. In contrast, studies done in airline pilots and health care workers exposed to frequent doses of radiation have not shown clear evidence for increased cancer rates. But, because of the relatively long time lines between acute exposure and development of solid cancers (as noted, at least 12 years in survivors of Hiroshima), concerns have been raised, especially in younger individuals who would have longer life spans after radiation exposure. As part of this concern another term came into being – LAR – which is 'Lifetime Attributable Risk'.

There is no clear agreement that the risks of radiation exposure using diagnostic medical imaging significantly increases an individual's LAR, but there are data extrapolated from nuclear explosions and 'accidents' that have been scaled down to the amounts of exposure that might come from a Cardiac CTA. Although there is much discussion on the potential 'accumulative' risk of repeated diagnostic medical examinations, there are no scientific data to deny or refute the inferred increased risk. The acute exposure to 100 mSv of gamma radiation from a nuclear explosion and the acute exposure to 10 mSv of beta radiation from a Cardiac CT may be different, but may have similar dose-related consequences, thus the LNT hypothesis.

A recent scientific analysis was published regarding the LAR for solid tumor cancers of men and women exposed to a single Cardiac CT examination (JAMA 2007;298;317-323). As with other investigations, the data were extrapolated using the LNT hypothesis. The effective radiation dose for a retrospective, ECG-gated Cardiac CT in women (14 mSv) is higher than men (10 mSv) due largely to the amount of breast tissue present and the known higher radio-sensitivity of the breast. The report indicated the LAR was highest in younger individuals who would have more time to develop the consequences of ionizing radiation (as noted previously, solid tumors were found in atomic bomb survivors at 12 or more years after acute exposure) and declined rapidly as initial exposure age was increased.  The results indicated small but not negligible risks.  For example the LAR for a 20 year old woman receiving her first Cardiac CTA was 0.7% (this translates into one additional cancer in 143 Cardiac CT scans) while for a 20 year old man the LAR is 0.19% (1 in 526).  At age 40 the LAR in women would be 0.35% (1 in 285) and in men 0.099% (1 in 1,010).  The analysis also indicated that using ECG-dose modulation, the effective radiation dose in women and in men would be cut nearly in half (7.4 mSv in women and 5.4 mSv in men) and would also effectively cut the LAR for cancer by a similar proportion.  The conclusions of this paper are really the basic principals of CTA radiation safety:

1. Justification of dose (is the incremental diagnostic value of performing Cardiac CTA versus the risk of the study sufficient AND are there alternative non-ionizing radiation methods that may provide the same or similar results), and

2. Make radiation dose as low as reasonably achievable (ALARA)

One might ask – why the fuss here?  The use of Cardiac CTA is largely to diagnose coronary artery disease, which is much more common in a 50 year old than a 30 year old – suggesting that such a test would be uncommonly performed in a younger person (with higher LAR) than in an older person (with lower LAR).  But the issue goes beyond just Cardiac CT and extends to the rapid adoption of CT in general for diagnostic imaging in all age groups, including pediatrics.  Thus, the real issue is not just Cardiac CTA, but CT in general and the potential increased LAR as the utilization of these moderately high radiation dose examinations increases.  This is a fundamental question that is being addressed by major regulatory agencies.  In 1980, the number of CT examinations was estimated at 3 million per year; but in 2008, it is estimated that this will be 68 million/year.  To give you a better feeling for the rapid increase in the use of CT scanning, consider Figure 1.

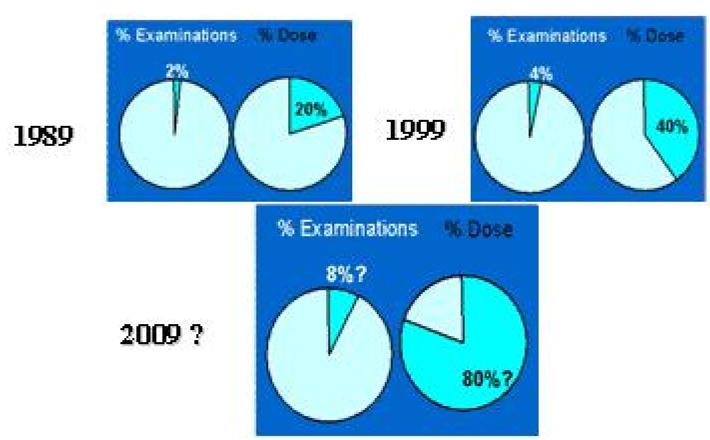


Figure 1.

In 1989, CT represented only 2% of all radiological procedures, but accounted for 20% of the total burden of medical radiation to the populace.  In 1999, CT represented 4% of the diagnostic radiology procedures and accounted for 40% of the total medical radiation.  It is estimated that in 2009 these numbers will increase to 8% of the total exams and account for up to 80% of the diagnostic imaging radiation dose to patients.

In Part II of our series we will discuss how to determine the radiation dose of a CTA.