# MEASURING RADIATION DOSE IN CARDIAC CT

## Part II in our series on Radiation Management in Cardiac CTA

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In Part I of this series we focused on Principle of ALARA and Radiation Safety in Cardiac CT. In the brief discussion to follow, we will examine how to determine radiation dose in Cardiac CT.

The radiation physicist first determines the 'absorbed dose' using a tool called the CTDI (CT Dosimetry Index). For defining absorbed radiation for Cardiac CT, a body phantom with imbedded radiation measuring 'probes' is used as illustrated in Figure 1.

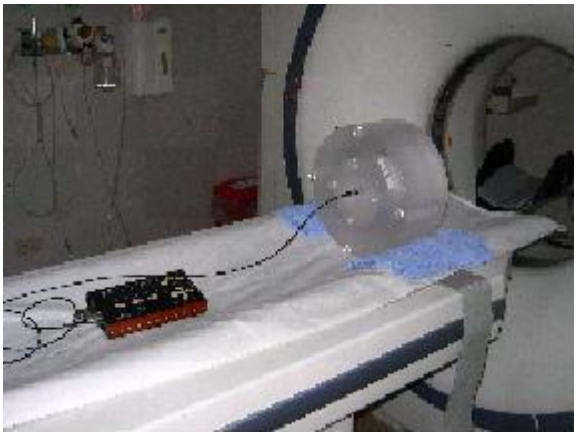

Figure 1.

The phantoms consist of Plexiglas of various sizes – generally a 17 cm in diameter 'head' phantom or a 32 cm in diameter 'body' phantom. The scanner is set up to simulate a patient scan, but the phantom is the target.

The 'absorbed dose' is a measure of the energy deposited in the phantom (or the patient) per unit mass. This is generally expressed in the standardized unit of milli-Grays (mGy). Absorbed Dose is not a good indicator of biological effect because it is only a measurement of the total energy received and does not take into account the biologic effects of different types of radiation. For example, 1 mGy of alpha radiation would have a different biological effect than 1 mGy of microwave radiation. The Absorbed Dose contains no information of the type of radiation or the degree of damage.

The physicist can calculate the CTDI based on the measurements from the phantom. CTDI represents the average absorbed dose from one axial CT scan (or one rotation of the gantry). This theoretically estimates the average dose within the central region of a scan volume. Various calculations are used for CTDI to try to take into account other variables such as radiation scatter, multiple slices and other factors that make an actual multi-detector scan different from a single axial CT slice.

In clinical practice, radiation measuring radiation generally starts with the Dose Length Product (DLP). The DLP reflects the total energy absorbed during the complete scan acquisition. DLP takes into account the total length of the scan, the CTDI for the scanner and variations in CTDI due to factors that will change the radiation of any particular slice, such as ECG Dose Modulation. A scan that is limited to the heart would have a lower DLP than a scan of the full chest because of the greater extent of the z-axis scan volume, even if all other parameters were the same.

DLP will also be affected by factors such as table pitch. The more overlap there between gantry rotations, the more

radiation is delivered in order to scan the same volume of the patient.

DLP is usually reported on the Operators Console at the scanner.

The final determination is the 'effective dose'. The potential biologic effects from radiation are not the same for all tissues. For example, breast tissue is considered to be more sensitive to radiation than the myocardium. Effective Dose was designed to estimate the biological effects of occupationally exposed personnel. These effects may be different in patients exposed to medical imaging where factors such as age, gender, underlying medical condition and duration of exposure are very different from occupational exposure. However, this is a more useful measurement for discussing risk with patients. They are generally not interested in a complex discussion of the dose and type of radiation absorbed and the potential biologic effects on individual organs. Effective Dose attempts to estimate the overall biologic effects of radiation exposure taking into account both the absorbed dose and the site of exposure. Effective Dose is essentially the dose to the patient and is considered to be the yard stick for radiation risk.

To calculate Effective Dose, one more parameter must be defined and this is the 'organ weighting coefficient". Although a particular organ may be more radio-sensitive (for instance the bone marrow), the actual amount of the organ exposed is also important to define 'risk'. For instance in the chest, the amount of bone marrow in the sternum and other surrounding bones is only a portion of the bone marrow found in the entire body while the breasts are almost surely completely contained within the imaging field. The organ weighting coefficient is dependent on the radiation sensitivity of the organs in the region scanned and can be found in several widely available tables. The coefficient varies by body region.

| *Region of Body* | *k (mSv mGy$^{-1}$ cm$^{-1}$)* | | | | |
|---|---|---|---|---|---|
| | *0 year old* | *1 year old* | *5 year old* | *10 year old* | *Adult* |
| Head and neck | 0.013 | 0.085 | 0.0057 | 0.0042 | 0.0031 |
| Head | 0.011 | 0.067 | 0.0040 | 0.0032 | 0.0021 |
| Neck | 0.017 | 0.012 | 0.011 | 0.0079 | 0.0059 |
| Chest | 0.039 | 0.026 | 0.018 | 0.013 | 0.014 |
| Abdomen =& pelvis | 0.049 | 0.030 | 0.020 | 0.015 | 0.015 |
| Trunk | 0.044 | 0.028 | 0.019 | 0.014 | 0.015 |

The Effective Dose is determined by multiplying the DLP times the coefficient for the region scanned. When multiple regions are scanned, such as a chest and abdomen, and DLP is not reportedly separately for each region, the dose can be estimated as the DLP times the average of the two regions.

As noted the absorbed radiation dose and the organ radiation dose are given in units of mGy; this is a measure of the physical aspects of radiation. However, the ICRP has designated the measure of the 'Effective Dose' using the mSv (milli-Sievert). This unit is named after the Swedish medical physicist, Rolf Sievert, who did pioneering work on radiation dosage and the biological effects of radiation. Thus the physical measures of mGy and mSv are identical, but the designation of mSv represents the unit used as the yard stick for defining patient risk.

Of course, medical diagnostic imaging using x-rays of any kind will result in ionizing radiation exposure to the individual. Ionizing radiation refers to the highly-energetic particles or waves that can detach (ionize) at least one electron from an atom or molecule. Other more ubiquitous sources of radiation, and thus contributing to 'risk' in a given individual for their lifetime, come from cosmic radiation (your personal exposure varies throughout the world and is based largely on geomagnetic field strength, altitude, and solar cycles). You get additional cosmic radiation every time you fly on an airplane. Some data suggest that airline pilots receive more average radiation exposure

than any other worker, including those working in nuclear power plants.

Of course, direct solar radiation (from the sun) is variable also depending on where you live and is a well known major concern in the development of skin cancer. There are also terrestrial sources of ionizing radiation from radioactive atoms such as potassium, uranium, and thorium. Radon gas is produced from the decay of radium and seeps into the soil and may be the largest single source of radiation dose to any living person and has been suggested to be the second largest cause of lung cancer in America, after smoking. Human-made resources of ionizing radiation (in addition to medical imaging) include tobacco, ophthalmic glass, television and computer monitors, luminous watches, airport security systems, smoke detectors, road construction materials, electron tubes, fluorescent lamp starters, and gas lantern mantles.

A very interesting web site can give you an idea of your own personal radiation exposure; look up: http://www.ans.org/pi/resources/dosechart/.

Below is a table of common sources and effective amounts of ionizing radiation (mSv) from diagnostic imaging and daily living.

| Source | mSv | Source | mSv |
|---|---|---|---|
| Cardiac CTA (maximum) | 10-14 | Mammogram (women) | 0.7 |
| Heartscan (calcium scan) | 1-2 | Airplane Trip to Asia | 2 |
| Thallium Stress Test | 14-25 | 'Background'/year (USA) | 2.5-3.5 |
| Diagnostic Cardiac Catheterization | 5-7 | Barium Enema X-ray | 10 |
| MIBI Stress Test | 8-12 | Ru82 PET Scan | 15 |