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EDITORIAL COMMENT

New Conversion Factors for Estimating Effective Doses During Cardiac CTA*

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Cardiac computed tomography (CT) examinations are performed in nearly 30% (1) of the CT sites in the United States. As of 2016, nearly 3 million cardiac CT examinations, such as calcium scoring and coronary computed tomography angiography (CTA), were performed in United States alone. Even though this is a small portion of the 82 million CT procedures performed in the United States, the growing evidence of cardiac CT's role in triaging patients with cardiovascular diseases (CVDs) indicates that there will be a steep rise in cardiac CT examinations in the near future. One of the main concerns with medical x-ray imaging studies including cardiac CT is the associated radiation dose.

The radiation dose is commonly expressed in terms of effective dose. Effective dose is a single dose parameter that expresses the risk to the whole body from radiation exposure to any single organ/part of the body. The concept of effective dose was initially developed to estimate risk to radiation workers only, and was not intended to be used for patient-specific dose because of a number of inherent uncertainties (2). However, effective dose has been used to estimate radiation risks for patients as it provides a convenient way to compare radiation risks among different medical x-ray imaging modalities and with other sources of radiation, such as natural background radiation.

There are different ways to estimate effective dose in CT, among them the "gold standard" method is based on organ dose estimations and tissue weighting factors, as specified by the International Commission of Radiation Protection (ICRP) and the most commonly used method is based on multiplying the dose length product (DLP) reported at the end of each CT scan by a conversion factor (k-factor) that is dependent on the anatomical region examined (3,4).

Use of k-factors became popular in CT because of its simplicity to estimate effective dose from scanner-reported radiation dose descriptors such as DLP and computed tomography dose index volume. The issues with the current k-factors are that they were determined using single-slice CT scanners (prior to 1998) and using ICRP tissue weighting factors published in 1991 (ICRP 60) (5) that are now superseded with new tissue weighting factors (ICRP 103 published in 2007) (6); also, the conversion factor for chest CT scans are simply applied to cardiac CT scans. Significant differences between the 2 ICRP reports are the tissue weighting factor for breast tissue, which increased from 0.05 (ICRP 60) to 0.12 (ICRP 103), and inclusion of heart as 1 of the "remainder organs." Different conversion factors have been proposed (7) accounting for the new tissue weighting factors (ICRP 103) (6); however, the study in this issue by Trattner et al. (8) is the first of its kind to perform detailed measurements using anthropomorphic phantom to derive conversion factors that are specific to cardiac CT scans.

In this issue of *iJACC*, Trattner et al. (8) report their findings of new k-factors specifically for cardiac CT protocols that can be used with the scanner-reported DLP to estimate effective dose. Trattner et al. (8) have done detailed measurements by placing metal-oxide-semiconductor field-effect transistor radiation detectors in various organs of whole-body adult anthropomorphic phantom and scanning using cardiac CT protocols. The authors are to be commended

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for performing the radiation dose measurements on a wide range of CT scanners and for all of the routinely used cardiac CT protocols. In total, the authors have performed radiation dose measurements for 120 cardiac CT protocols (for different scan acquisition modes and tube potentials) on 12 different CT scanners ranging from 32- to 320-row detector arrays, encompassing most CT scanners that are currently in clinical use. After determining organ doses for each protocol, authors calculated effective dose based on the new tissue weighting factors (ICRP 103) (6). The new k-factors specific to cardiac CT were then derived from calculated effective doses and CT scanner-reported DLPs for each scanner model and protocol.

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The main finding of this paper (8) is that the authors report an average k-factor of 0.026 $mSv \cdot mGy^{-1} \cdot cm^{-1}$ (range 0.020 to 0.035 $mSv \cdot mGy^{-1} \cdot cm^{-1}$) which is considerably higher (~46%) than the currently used k-factor (0.014 $mSv \cdot mGy^{-1} \cdot cm^{-1}$). The strength of this study is the inclusion of wide range of CT scanners and large numbers of cardiac CT protocols accounting for different scan acquisition modes and tube potentials.

In addition, the authors have also determined cardiac-specific k-factors for the previous tissue-weighting factors (ICRP 60) (Online Table 2 in Trattner et al. [8]). In fact, the average k-factor is 0.021 $mSv \cdot mGy^{-1} \cdot cm^{-1}$, nearly 33% higher than the currently used k-factor (0.014 $mSv \cdot mGy^{-1} \cdot cm^{-1}$), indicating an underestimation in the current effective dose calculations with the use of k-factor originally derived for chest CT scan (0.014 $mSv \cdot mGy^{-1} \cdot cm^{-1}$).

The study by Trattner et al. (8) is notable because it meticulously derived new k-factors for all clinically used cardiac CT examinations. Therefore, the average k-factor (0.026 $mSv \cdot mGy^{-1} \cdot cm^{-1}$) proposed by the authors should be used for estimating effective dose for cardiac CT examinations, as it reflects a wide range of CT scanners, included a large number of cardiac CT examinations, and takes into accounts the new tissue weighting factors (ICRP 103) (6). More specific conversion factors for particular CT scanner models and/or specific cardiac CT protocols can be found in Table 4 of Trattner et al. (8).

This study has the potential to raise concerns about cardiac CT examinations. The aftermath of the new conversion factors proposed in the study (8) must be carefully handled to avoid unnecessary fear and confusion among the patients undergoing cardiac CT scans. As mentioned earlier (2), the effective dose concepts were developed for expressing risks to radiation workers, but unfortunately became used to express radiation risks to patients undergoing x-ray examinations. It is the responsibility of the CT users (cardiologists, radiologists, medical physicists, radiation technologists, and others) to recognize the underlying uncertainties in estimating effective doses. In a very careful analysis, Martin (2) has determined the inherent uncertainties associated in estimating effective dose using organ doses to a single reference phantom to be about ±40%, and discusses why it should be used only as a generic indicator of radiation risk and not for assessing risk to any 1 individual.

Therefore, although the effective dose values estimated using new k-factors can be nearly 46% higher, it is important to recognize that these values are within the underlying uncertainties associated with effective dose estimations, which can be as high as 40%.

Irrespective of the changes in k-factors, the radiation dose per procedure for coronary CTA has been trending lower due to both technological advances and increased user awareness about radiation. Technological advances, such as use of prospectively triggered axial scan modes, tube current modulation (temporal dose modulation), wide-detector arrays, high-pitch scanning, improved CT detection technology and geometric efficiency, use of low tube potentials, iterative image reconstruction methods, and so on, have led to significant radiation dose reduction (9).

With the new k-factors proposed in the study (8), one can imagine the following scenario:

> *"If I use the new conversion factor to estimate effective dose for cardiac CT scans, what can I say to my patients undergoing cardiac CT scans who had similar scans in the past?"*

If effective dose values are provided to patients without any explanations, it can cause concern because the new k-factors can lead to nearly 50% higher effective dose values than in the past. Such concerns can be addressed by examining the DLPs of the new CT scans with the previous CT scans. Also, such scenarios can provide an opportunity for the cardiac CT providers to have an open dialogue with patients and others to explain the variations in effective dose estimations, the uncertainties in effective dose estimations, and the lack of large data to substantiate radiation risks at radiation dose levels that are common in medical imaging (10).

In conclusion, the authors are to be commended for determining cardiac-specific conversion factors critical to the effective dose estimations that reflect the new tissue weighting factors.

It is time to use the new k-factors factors as proposed in the study (8) and also to apply radiation optimization strategies to minimize radiation burden while keeping in mind the underlying uncertainties associated with effective dose estimations.

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