Position Sensitivity of Calculated Dose-Length-Product-to-Effective-Dose Conversion Factors in Computed Tomography Examination

Innovation/Impact: Published k-factors for converting CT Dose Length Product (DLP) to Effective Dose (E) assume a fixed exam protocol. This work quantifies the sensitivity of these k-factors to scan lengths or scan boundaries that differ from the definition of the protocol standard.

Introduction: Conversion factors, known as k-factors, have been developed to convert the DLP for a particular protocol (i.e., a chest scan), which the CT scanner typically records and reports, to an estimate of E for that scan, which is a more appropriate measure of patient dose. However, published k-factors are mostly based on simulations of stylized phantoms with fixed scan lengths and scan positions. In real-world examinations, patient scans do not necessarily match these pre-determined boundaries. K-factors remain useful because they can generate effective dose estimates from information easily extracted from archived DICOM reports.

Method and Materials: Monte Carlo simulations are performed using the MCNPX radiation transport code, a validated model of the CT source, and realistic computational phantoms (RPI-AM and RPI-AF). Scan slices of 1-cm were simulated one at a time over the entire length of the torso, and the effective dose from that slice ($E_i$) was calculated. The DLP for the slice is the $\text{CTDI}_{\text{VOL}}$ for the scan multiplied by the slice thickness ($T$), the quotient is a “local” k-factor ($k_i$). Over a full scan length, the effective doses from the individual slices and the DLPs are summed, so that the k-factor is given by:

$$k = \frac{E}{DLP} = \frac{\sum E_i}{N \times \text{CTDI}_{\text{VOL}} \times T} = \frac{\sum k_i}{N} = \bar{k}$$

Results: The local k-factors produced are shown in Figure 1. Using the chest scan as an example, an expansion of the scan region around the “standard” protocol definition results in a steady decrease in the calculated k-factor. The calculated k-factor decreases by approximately 2% for each additional cm at the upper scan boundary, and 1% for each additional cm at the lower scan boundary. Therefore, as seen in Figure 2, a chest scan that is only 10 cm longer would have a k-factor 18% lower when compared to the standard protocol.

Conclusion: By improving the understanding of the sensitivity of k-factors to scan length and position, more accurate estimates of effective dose from CT examination can be provided without sacrificing the efficiency and simplicity that the use of k-factors provides, perhaps ultimately suggesting ways of improving dose tracking and optimization in medical exams.

| Figure 1. Local k-factors ($k_i$) generated from slice-by-slice Monte Carlo simulations | Figure 2. Change in k-factor for chest scan due to increased scan length |