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Permalink

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Journal

Journal of Cardiovascular Computed Tomography, 14(3)

ISSN

1934-5925

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Publication Date

2020-07-01

DOI

10.1016/j.jcct.2020.06.136

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CardiAcquire Beam-Shaping Filter Enables Significant Radiation Dose Reduction: Patient- and Organ-Specific Results

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Introduction: Despite its tremendous diagnostic value for cardiovascular medicine, the benefits of CT imaging must be weighed against the risks associated with ionizing radiation. Recent increases in frequency of use have raised concern about accumulation of radiation dose in the population. We developed a beam-shaping filtration approach called CardiAcquire which reduces radiation exposure to peripheral tissues outside of the cardiac ROI while preserving image quality in the heart. This study aims to quantify patient- and organ-specific reductions in dose afforded by CardiAcquire.

Methods: Patient-specific voxelized anatomies were generated by segmenting axial slices from six (N = 3 female) clinical imaging studies at different BMI levels (normal, over-weight, obese) obtained as part of a retrospective IRB-approved study, see Figure 1a. Simulations of image acquisition and dose deposition were performed using an in-house code based on the central slice of a typical cone-beam CT scanner. Mass density-weighted average dose was then calculated for five clinically-relevant anatomical regions (spine, left and right lungs, anterior and posterior soft tissues). Dose for both CardiAcquire and conventional bowtie filters was normalized by the interior tomography limit (zero fluence outside the cardiac ROI) for each patient and compared. Significance of dose reduction was assessed using a right-tailed Wilcoxon rank sum test.

Results: Significant ($p < 0.01$) dose reductions are observed for all anatomical regions (Figure 1b,c). Anterior tissues and those on the right side experience greater dose reduction than posterior and left side due to proximity to the cardiac ROI.

Conclusions: CardiAcquire enables significant dose reductions to tissues outside of the cardiac ROI while preserving image quality in the heart, sparing radiosensitive organs such as the breasts and lungs. These results are demonstrated in a small cohort of patient-specific analyses. In addition to enabling single acquisitions at lower dose, CardiAcquire also enables lower-dose dynamic and longitudinal studies.

Figure 1: (a) Clinical images (N=6) were segmented into tissue types and simulations of dose deposition were performed. Two beam-shaping filters were simulated, the conventional bowtie and CardiAcquire. (b) Doses were normalized by the interior tomography limit for each patient, and mass density-averaged regional doses were computed for six anatomical regions: the spine, right and left lungs, peripheral, anterior, and posterior soft tissues. For each region, median and interquartile range are annotated. Dose is reduced nearly to the interior tomography limit for all anatomical regions. (c) Dose reductions afforded by CardiAcquire are significant ($p < 0.01$) in all cases, and higher for anterior tissues and those on the right side.