Patient-specific CT dose determination from CT images using Monte Carlo simulations

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Radiation dose from computed tomography (CT) has become a public concern with the increasing application of CT as a diagnostic modality, which has generated a demand for patient-specific CT dose determinations. This thesis work aims to provide a clinically applicable Monte-Carlo-based CT dose calculation tool based on patient CT images.

The source spectrum was simulated based on half-value layer measurements. Analytical calculations along with the measured flux distribution were used to estimate the bowtie-filter geometry. Relative source output at different points in a cylindrical phantom was measured and compared with Monte Carlo simulations to verify the determined spectrum and bowtie-filter geometry. Sensitivity tests were designed with four spectra with the same kVp and different half-value layers, and showed that the relative output at different locations in a phantom is sensitive to different beam qualities.

An mAs-to-dose conversion factor was determined with in-air measurements using an Exradin A1SL ionization chamber. Longitudinal dose profiles were measured with thermoluminescent dosimeters (TLDs) and compared with the Monte-Carlo-simulated dose profiles to verify the mAs-to-dose conversion factor.

Using only the CT images to perform Monte Carlo simulations would cause dose underestimation due to the lack of a scatter region. This scenario was demonstrated with a cylindrical phantom study. Four different image extrapolation methods from the existing CT images and the Scout images were proposed. The results show that performing image extrapolation beyond the scan region improves the dose calculation accuracy under both step-shoot scan mode and helical scan mode.

Two clinical studies were designed and comparisons were performed between the current CT dose metrics and the Monte-Carlo-based organ dose determination techniques proposed in this work. The results showed that the current CT dosimetry failed to show dose differences between patients with the same scan parameters.

The methodology proposed in this work required simple measurements on the CT scanner for scanner-specific Monte Carlo model establishment, and uses patient CT images to provide patient-specific organ dose calculations. This is an improvement on current CT dosimetry and benefits the patient dose tracking and individual risk estimates.