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Monte Carlo-based compensation for patient and detector scatter and crosstalk contamination in In-111 SPECT imaging

Stephen C. Moore, Jinsong Ouyang, Mi-Ae Park, Georges El Fakhri

Department of Radiology, Brigham and Women's Hospital, Boston, MA 02115

Harvard Medical School, Boston, MA 02115

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Abstract

Objectives: Improvements in the quantitative accuracy and precision of In-111 SPECT should translate into better dose specification for patient-specific radioimmunotherapy treatment planning. We have incorporated Monte Carlo (MC)-based estimates of patient and detector scatter and crosstalk into an iterative reconstruction algorithm, and compared its performance to that of a general spectral (GS) approach described previously. **Methods:** We extended the MC-based reconstruction algorithm proposed by a group from the University of Utrecht by (1) using the "Delta scattering" technique to quickly determine photon interaction points, (2) simulating scatter maps for many energy bins simultaneously to improve accuracy, and (3) decoupling the simulation of the object and detector by using pre-stored point spread functions (PSF) that include all collimator and detector effects. A numerical phantom was derived from a segmented CT scan of the Data Spectrum torso phantom. The relative values of In-111 activity concentration simulated in soft tissue, liver, spine, left lung, right lung, and five spherical tumors (1.3 to 2.0 cm diam.) were 1.0, 1.5, 1.5, 0.3, 0.5, and 10.0, respectively. GS scatter projections were incorporated additively in an OSEM reconstruction (6 subsets x 10 projections x 2 photopeak windows). After three iterations, GS scatter projections were replaced by MC-estimated scatter projections for two additional iterations. MC-based compensation was quantitatively compared to GS-based compensation after five iterations. **Results:** The bias of organ activity estimates ranged from -13% to -6.5% (GS), and from -1.4% to +5.0% (MC); the tumor-activity bias ranged from -20.0% to +10.0% for GS (mean ± st.dev. = -4.3% ± 11.9%), and from -2.2% to +18.8% for MC (+4.1% ± 8.6%). The percentage image noise in all organs was also less with MC than with GS. **Conclusions:** MC-based iterative reconstruction yielded reliable compensation for many effects which currently limit quantitative In-111 SPECT imaging, and is a promising approach for patient-specific radioimmunotherapy.

Keywords: Indium-111; SPECT; Monte Carlo; Scatter Compensation; Quantitation

Representative Results:

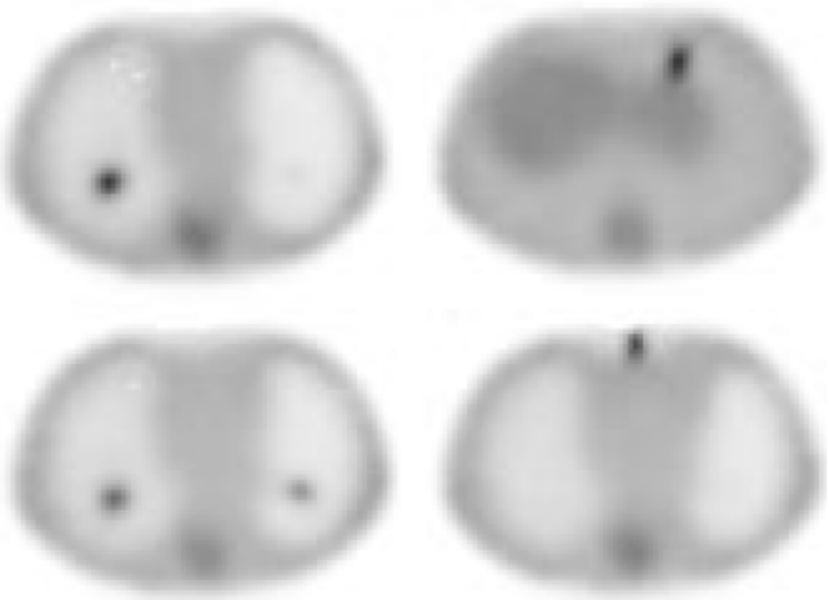

Fig. 3. Low-noise, transverse images of phantom reconstructed with MC-based scatter compensation, showing right-lung tumor (upper left), tumor above liver (upper right), small left-lung tumor with partial-volumed right-lung tumor (lower left), and peristernal lymph node (lower right).