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Analytical Method for Cardiac SPECT Simulation

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Introduction: Simulation studies of medical imaging techniques such as single photon emission computed tomography (SPECT) are essential for determining accuracy and reproducibility of image analysis methods. This paper presents a novel, analytical approach for simulating cardiac SPECT imaging.

Methods: In the proposed method, the geometry of the Left Ventricle (LV) is constructed by two different compartments: cylindrical and spherical portions. The human body cross-section is modeled by an elliptic contour and two spheres are added to the body surface to model the breasts. A standard map of activity (2D-bull's-eye) is generated from a patient cardiac SPECT study which is processed by the sedar-sinaei method and mapped onto the LV surface. Liver superposition effects are excluded from the bull's e-ye map using a hierarchical Fuzzy Clustering algorithm. The effects of primary and secondary photon scattering and the detector response are modeled by an experimental Point Spread Function (FPS) reported by the ADAC laboratory. An analytical re-projector is designed and used to generate the ray-sums. Semi-empirical attenuation coefficient is used to calculate the photon attenuation for each individual ray-sum. A Low-Energy High-Resolution (LEHR) collimator is modeled and its 2-D spatial efficiency curve is used to correct the ray-sums. At the end, Poisson noise is added to each simulated projection to model the random nature of the photonic emissions.

Results: To evaluate the proposed approach, real and simulated LVs were processed by a conventional processing method to generate their short, vertical, and horizontal views along with their 2D bull's-eye. Real LVs were obtained from 40 patients (17 female and 23 male) diagnosed with mild to severe ischemia. In the imaging simulation, acquisition parameters matched those of a commercial SPECT imaging system. To evaluate the accuracy of the simulation and the order of its generalization error, bull's-eye maps of the real and simulated LV's were used to generate the fixed defect, reversibility, and wash-out maps. The correlation coefficient between the simulated and real maps was 0.87 with $p<0.00001$.

Conclusions: The proposed method is accurate for simulating cardiac SPECT images of patients. There is only a very small chance for generating or eliminating an additional pattern of the fixed defects or severe ischemia in the simulation results.