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Rigorous Task-Based Optimization of Instrumentation, Acquisition Parameters and Reconstruction Methods for Myocardial Perfusion SPECT

Dissertation Defense by

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Abstract

Coronary artery disease (CAD) is the most common type of heart disease and a major cause of death in the United States. Myocardial perfusion SPECT (MPS) is a well-established noninvasive diagnostic imaging technique for the detection and functional characterization of CAD. MPS involves intravenous injection of a radiopharmaceutical (e.g. Tc-99m sestamibi) followed by acquiring planar images of the 3-D distribution of the radioactive labeled agent, using one or more gamma cameras that are rotated around the patient, at different projection views. Transaxial reconstructed images are formed from these projections using tomographic image reconstruction methods. The quality of SPECT images is affected by instrumentation, acquisition parameters and reconstruction/compensation methods used. The overall goal of this dissertation was to perform rigorous optimization of MPS using task-based image quality assessment methods and metrics, in which image quality is evaluated based on the performance of an observer on diagnostic tasks relevant to MPS. In this work, we used three different model observers: the Ideal Observer (IO), and the recently developed Ideal Observer with Model Mismatch (IO-MM), and an anthropomorphic observer, the Channelized Hotelling Observer (CHO).

Collimators are a major factor limiting image quality and largely determine the noise and resolution of SPECT images. We sought the optimal collimator with respect to the IO performance on two tasks related to MPS: binary detection and joint detection and localization. The results of this study suggested that higher sensitivity collimators than those currently used clinically appear optimal for both of the diagnostic tasks. In a different study, we evaluated and compared various collimator-detector response (CDR) modeling and compensation methods using the IO (i.e. the observer implicitly used a true CDR model), IO-MM (using an approximate or no model of the CDR) and CHO, operating on images reconstructed using the same compensation methods. An important acquisition parameter is the width of the acquisition energy window, which controls the tradeoff between scatter and noise in SPECT images. We used the IO, IO–MM and CHO to find the optimal acquisition energy window width and evaluate various scatter modeling and compensation methods. Results from the collimator and acquisition energy window optimization studies indicated that the IO-MM had good agreement with the CHO, in terms of the range of optimal Tc-99m acquisition energy window widths, optimal collimators, and the ranking of scatter and CDR compensation methods. The IO was in agreement with the CHO when model mismatch was small.

Dual isotope simultaneous acquisition (DISA) rest Tl-201/stress Tc-99m MPS has the potential to provide reduced acquisition time, increased patient comfort, and perfectly registered images compared to separate acquisition protocols, the current clinical protocols of choice. However, crosstalk contamination, where photons emitted by one radionuclide contribute to the image of the other, degrades image quality. In this work, we optimized, compared and evaluated dual isotope MPS imaging with separate and simultaneous acquisition using the IO in the context of 3-class defect detection task. Optimal acquisition parameters were different for the two protocols. Results suggested that DISA methods, when used with accurate crosstalk compensation methods, could potentially provide image quality as good as that obtained with separate acquisition protocols.

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