## Abstract

We have developed and implemented an analytic simulation system to evaluate and correct quantitative imaging distortions in positron emission tomography (PET) scans. It is based on measured tomograph characteristics and realistic 3-D brain models generated from regionally segmented brain image data. Each structure is assigned with a regional radiotracer concentration and attenuation coefficient to create 3-D dynamic brain models and tissue attenuation maps. Projection data are then generated by incorporating key physical factors of detector geometry and resolution, attenuation, scatter, randoms, efficiency, deadtime and counting statistics. This has been done for a multi-slice PET scanner and includes temporal sampling and radiotracer decay. Simulated emission and transmission data are reconstructed by a filtered-backprojection algorithm.

The simulation methods are validated by scan data from both geometrical and anatomically realistic brain phantoms. Simulated projection components of a uniform phantom and a 3-D Hoffman brain phantom agree accurately with the measured data from our PET scanner. We then summarize current applications of this simulation tool to improve regional radioactivity quantification and optimize imaging protocols. In particular we have implemented a novel methodology to estimate and correct 3-D partial volume effects in dynamic PET studies using correlated magnetic resonance images. Simulations and phantom data in both single and double isotope experiments reveal substantial errors in striatal and cortical structures. Both show spatially variant and nonlinear distortions in time-activity curves which become more significant

with degrading image resolution. These errors are removed completely by the partial volume correction algorithm with a reasonable increase in variance.

This software package is flexible and extensible. We have added many automatic steps to increase computational efficiency and simplify its usage in a clinical environment. This simulation tool offers a unified framework to evaluate and optimize PET imaging methodology from data acquisition, processing, and reconstruction to image analysis and parameter estimation.