Sequential and simultaneous dual-isotope brain SPECT: Comparison with PET for estimation and discrimination tasks in early Parkinson disease

Cathryn M. Trott[a] and Georges El Fakhri
Department of Radiology, Brigham and Women's Hospital and Massachusetts General Hospital, Harvard Medical School, 55 Fruit Street, Boston, Massachusetts 02114

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Parkinson disease (PD) is the second most frequently occurring cerebral degenerative disease, after Alzheimer disease. Treatments are available, but their efficacy is diminished unless they are administered in the early stages. Therefore, early identification of PD is crucial. In addition to providing perfectly registered studies, simultaneous ^{99m}Tc/^{123}I imaging makes possible the assessment of pre- and postsynaptic neurotransmission functions under identical physiological conditions, while doubling the number of counts for the same total imaging time. These advantages are limited, however, by cross talk between the two radionuclides due to the close emission energies of ^{99m}Tc (140 keV) and ^{123}I (159 keV). PET, on the other hand, provides good temporal and spatial resolution and sensitivity but usually requires the use of a single radionuclide. In the present work, the authors compared brain PET with sequential and simultaneous dual-isotope SPECT for the task of estimating striatal activity concentration and striatal size for a normal brain and two stages of early PD. Realistic Monte Carlo simulations of a time-of-flight PET scanner and gamma cameras were performed while modeling all interactions in the brain, collimator (gamma camera) and crystal (detector block in PET), as well as population biological variability of pre- and postsynaptic uptake. For SPECT imaging, we considered two values of system energy resolution and scanners with two and three camera heads. The authors used the Cramer–Rao bound, as a surrogate for the best theoretical performance, to optimize the SPECT acquisition energy windows and objectively compare PET and SPECT. The authors determined the discrimination performance between 500 simulated subjects in every disease stage as measured by the area under the ROC curve (AUC). The discrimination accuracy between a normal subject and a subject in the prodromal disease stage was AUC=0.924 with PET, compared to 0.863 and 0.831 with simultaneous and sequential SPECT, respectively. The significant improvement in performance obtained with simultaneous dual-isotope SPECT compared to sequential imaging (p=0.019) was due primarily to the increased number of counts detected and resulted in comparable performance when performing simultaneous SPECT on a two-head camera with 9.2% energy resolution to that obtained with sequential SPECT on a three-head camera with 6.2% energy resolution. [DOI: 10.1118/1.2940605]

Key words: Parkinson disease, Cramer–Rao bound, simultaneous dual-isotope SPECT, activity and size estimation

I. INTRODUCTION

Parkinson disease (PD) is the second most frequently occurring cerebral degenerative disease, after Alzheimer disease. Management of PD is complicated by the fact that clinical symptoms appear only after advanced loss of dopamine sites. Treatments are available, but their efficacy is diminished unless they are administered in the early stages. Therefore, early identification of PD is crucial. Dopamine transporter density is diminished in PD in proportion to disease severity, and the value of PET and SPECT imaging of dopamine transporter function in this and other neurological diseases has been previously established.[1–3] Furthermore, it has been suggested that the activity of dopamine receptors is increased in the earliest stages.[3] Therefore, simultaneous assessment of pre- and postsynaptic functional status may be an especially promising approach to early identification of PD. Discrimination between normal and early PD brains can be achieved based on striatal size and pre- and postsynaptic dopamine activity concentrations, which are altered during disease progression. However, discrimination is affected by properties of the scanner, such as spatial resolution and sensitivity.

We investigated the performance of dual-isotope SPECT using two- and three-head gamma cameras with an energy resolution at 140 keV of 9.2%, which is that available today with NaI(Tl) crystals from most manufacturers, as well as an energy resolution of 6.2% associated with newer detector materials such as CdZnTe. We compared PET and dual-isotope SPECT (simultaneous and sequential) imaging on the basis of performance when estimating striatal activity concentration and size for dual-isotope SPECT with four different scanner designs. The system performance metric we used

Representative Results:

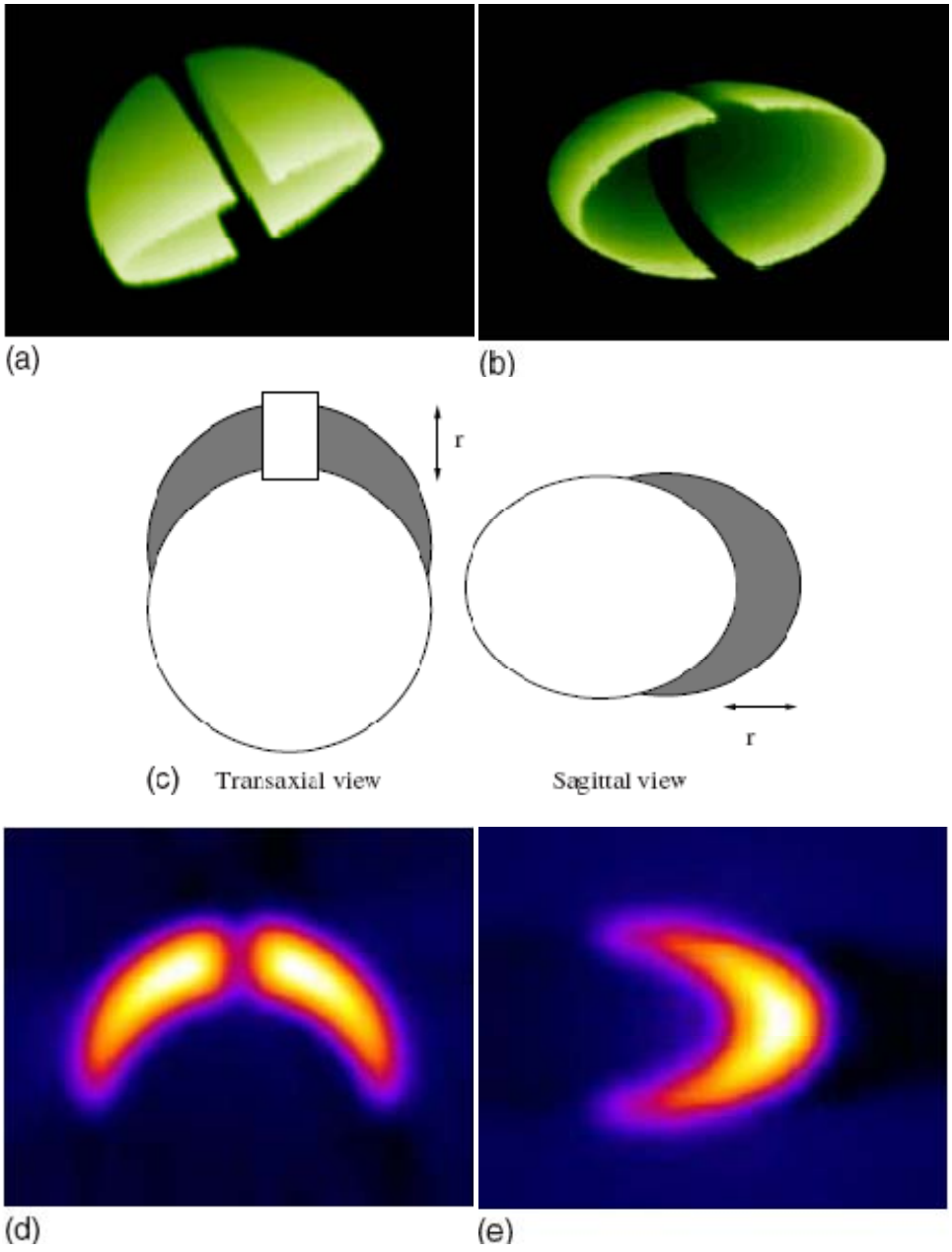

FIG. 1. Construction of the striata, parametrized by *r*. (a,b) Volume-rendered perspectives of the striatal model, displaying the separation of hemispheres. (c) The striatal volume gray shadingis the difference between two offset prolate ellipsoids with a central region removed to mimic the separation of hemispheres. (d,e) Example striatal slices, convolved with system PSFs.

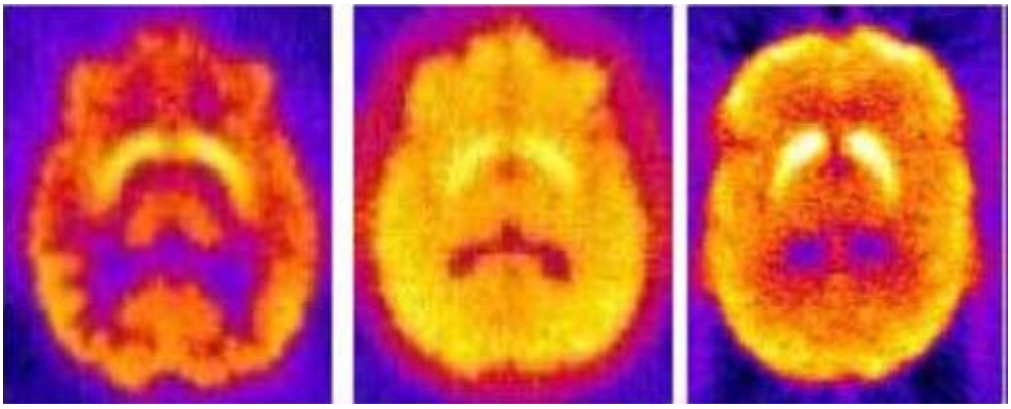

FIG. 2. Example slices of reconstructed projections for a normal brain containing the striata FBP, no corrections applied. ^{99m}Tc-TRODAT, ^{123}I-IBZM, ^{11}C-altropane (left to right).

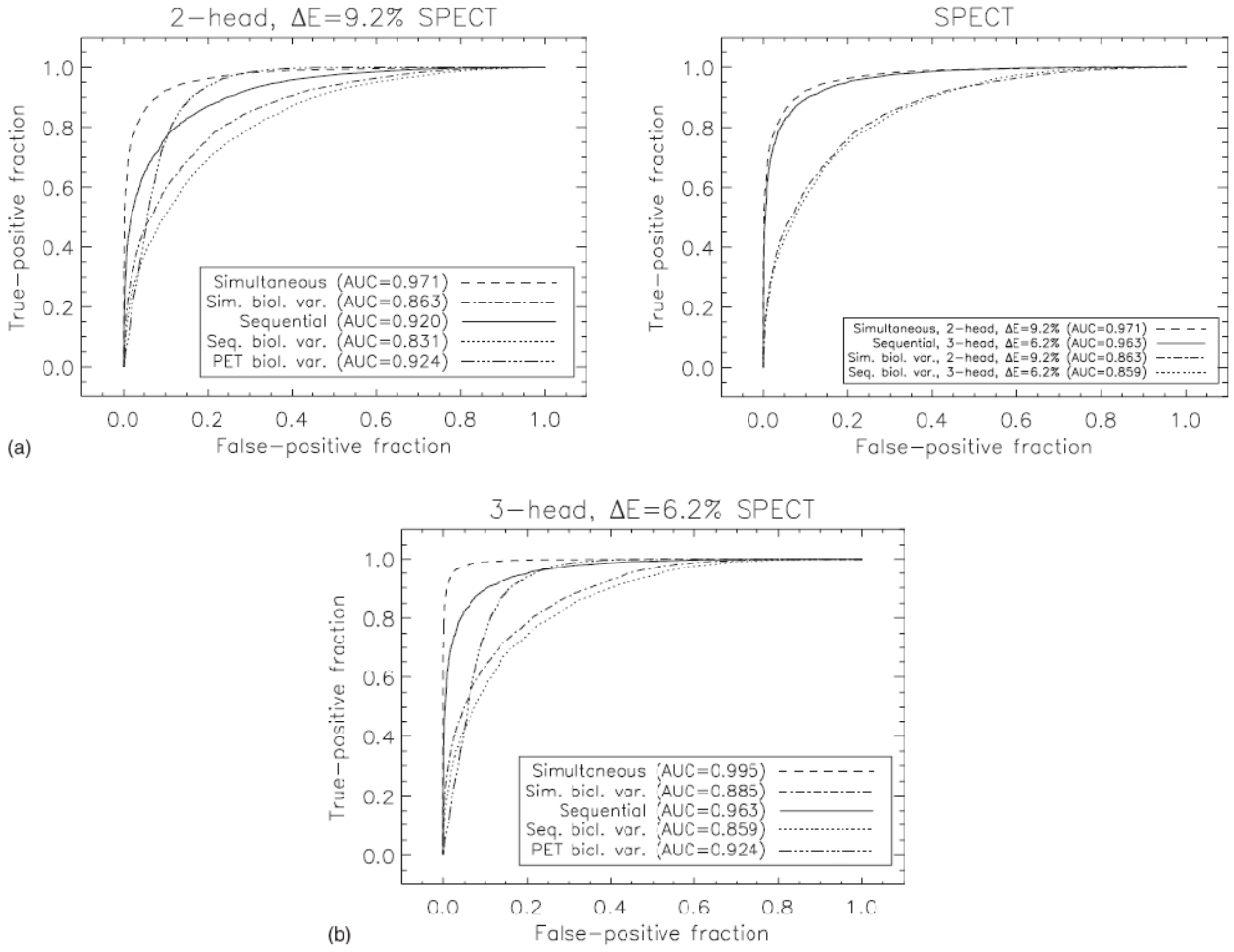

FIG. 7. Comparison of simultaneous and sequential SPECT imaging with different SPECT system designs for classification of subjects into normal or prodromal disease stages. Simultaneous imaging with a two-head, ΔE=9.2% scanner delivers slightly

improved performance over sequential imaging with a three-head, ΔE=6.2% scanner ($p<0.001$). Both ideal system performance, and performance including biological variability are displayed.