Absolute Activity Quantitation from Projections Using an Analytical Approach: Comparison with Iterative Methods in Tc-99m and I-123 Brain SPECT

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Abstract-- **Estimates of SPECT activity within certain deep brain structures could be useful for clinical tasks such as early prediction of Alzheimer's disease with Tc-99m or Parkinson s disease with I-123; however, such estimates are biased by poor spatial resolution and inaccurate scatter and attenuation corrections. We compared an analytical approach (AA) to more accurate quantitation to a slower iterative approach (IA). Monte Carlo simulated projections of 12 normal and 12 pathologic Tc-99m perfusion studies, as well as 12 normal and 12 pathologic I-123 neurotransmission studies, were generated using a digital brain phantom, and corrected for scatter by a multi-spectral fitting procedure. AA included attenuation correction by a modified Metz-Pan algorithm and activity estimation by a technique that incorporated Metz filtering to compensate for variable collimator response (VCR). IA modeled attenuation and VCR in the projector/backprojector of an OSEM algorithm. Bias and standard deviation over the 12 normal and 12 pathologic patients were calculated with respect to the reference values in the corpus callosum, caudate nucleus and putamen. IA and AA yielded similar quantitation results in both Tc-99m and I-123 studies in all brain structures considered in both normal and pathologic patients. The bias with respect to the reference activity distributions was less than 7% for Tc-99m studies, but greater than 30% for I-123 studies, due to partial volume effect in the striata. Our results were validated using I-123 physical acquisitions of an anthropomorphic brain phantom. AA yielded quantitation accuracy comparable to that obtained with IA, while requiring much less processing time. However, in most conditions, IA yielded lower noise for the same bias than did AA.**

Index Terms- **Attenuation correction, I-123 imaging, Monte Carlo simulation, quantitative brain SPECT, scatter correction, Tc-99m imaging, variable collimator response correction.**

I. INTRODUCTION

Brain SPECT perfusion images of patients destined to develop Alzheimer s disease differ from those of normal elderly controls in certain small structures located deep in the brain [1]. Likewise, accurate quantitation of striatal populations of dopamine pre-synaptic transporters and post-synaptic receptors has a potential clinical value for early diagnosis of Parkinson s disease [2]. Therefore, more accurate estimation of activity concentration within small deep brain structures could yield better prediction of the development of Alzheimer and Parkinson s diseases at the pre-clinical stage. SPECT images are characterized by high levels of noise (particularly in the central regions which are of interest in this case), as well as bias due to limited resolution and inaccurate corrections for scatter and attenuation. In this study, we have investigated an analytical approach (AA) to quantitation that incorporates compensation for scatter, attenuation and variable collimator response without tomographic reconstruction and compared it to an iterative approach (IA) consisting of quantitation after scatter correction and reconstruction by OS-EM, with both attenuation and variable collimator response modeled in the projector/backprojector.

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II. METHODS

A. Monte Carlo Simulation Studies

We simulated four sets of brain studies to mimic Tc-99m perfusion SPECT and I-123 neurotransmission studies using a digital brain phantom [3]. The phantom comprised 124 slices of 256x256 pixels each; the voxels were 1.09x1.09x1.4 mm^3. Activity distributions were defined based on measurements from Tc-99m HMPAO images of normal and diseased subjects [4] and I-123 altropane images of normal and diseased primates [5]. For each isotope, the cerebellar activity was assumed to be the same for normal and pathologic studies. Simulated structure-to-cerebellar activity ratios are shown in Table 1.

Four basic activity distributions were considered: two activity distributions mimicked normal and reduced Tc-99m uptakes in the frontal, temporal and parietal lobes (50% reduction) and two activity distributions mimicked normal and reduced I-123 striatal uptake (50% reduction in the caudate nucleus and the putamen). Assumed Tc-99m and I-123 activity distributions in two representative slices are shown in Figure 1 for normal and reduced uptake studies.

The SimSet Monte Carlo code [6] was used to model photon propagation in the phantom, including Compton and coherent scatter. Scattered photons were followed for up to seven scattering events. For each Tc-99m distribution, 2.4 billion 140-keV photon histories were tracked; 1.6 billion 159-keV photon histories were generated for each I-123 study. Variance reduction techniques were used [7].

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Representative Results:

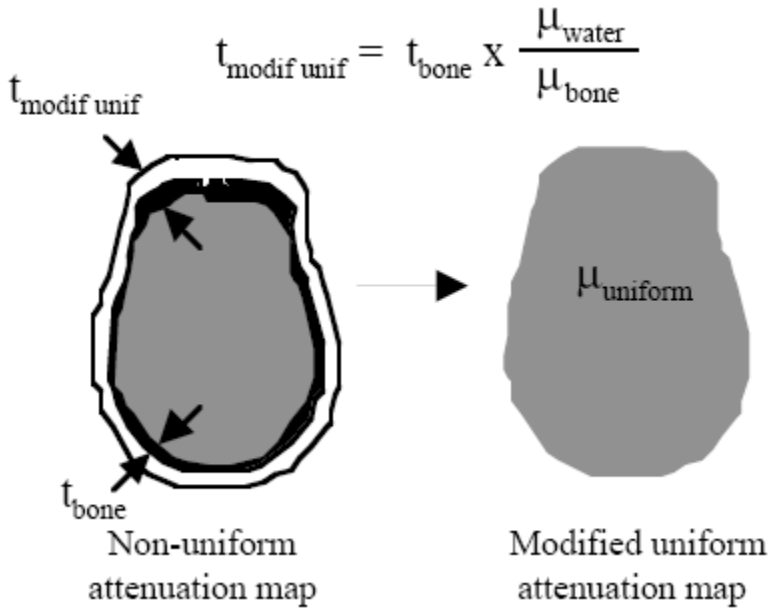

Figure 3: Modified uniform attenuation map used for attenuation correction of brain SPECT studies.