Scatter and Cross-Talk Corrections in Simultaneous Tc-99m/I-123 Brain SPECT using Constrained Factor Analysis and Artificial Neural Networks[1]

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Abstract

Simultaneous imaging of Tc-99m and I-123 would have a high clinical potential in the assessment of brain perfusion (Tc-99m) and neurotransmission (I-123) but is hindered by cross-talk between the two radionuclides. Monte Carlo simulations of 15 different dual-isotope studies were performed using a digital brain phantom. Several physiologic Tc-99m and I-123 uptake patterns were modeled in the brain structures. Two methods were considered to correct for cross-talk from both scattered and unscattered photons: constrained spectral factor analysis (SFA) and artificial neural networks (ANN). The accuracy and precision of reconstructed pixel values within several brain structures were compared to those obtained with an energy windowing method (WSA). In I-123 images, mean bias was close to 10% in all structures for SFA and ANN and between 14% (in the caudate nucleus) and 25% (in the cerebellum) for WSA. Tc-99m activity was overestimated by 35% in the cortex and 53% in the caudate nucleus with WSA, but by less than 9% in all structures with SFA and ANN. SFA and ANN performed well even in the presence of high-energy I-123 photons. The accuracy was greatly improved by incorporating the contamination into the SFA model or in the learning phase for ANN. SFA and ANN are promising approaches to correct for cross-talk in simultaneous Tc-99m/I-123 SPECT.

I. INTRODUCTION

Simultaneous imaging of Tc-99m and I-123 has, potentially, clinically useful applications since it provides perfectly registered images of brain perfusion with Tc-99m labeled radiotracers (as HMPAO or ECD) and neurotransmission with iodinated tracers (as IBZM or β-CIT). Such studies, however, are compromised by cross-talk, i.e., the detection of photons emitted by one radionuclide in the energy window of the other. Because the emission energies of Tc-99m (140 keV) and I-123 (159 keV) are so close, not only are scattered I-123 photons detected in the Tc-99m window, but, more importantly, primary photons of each radionuclide are detected in the wrong window [1]. Several groups have pointed out major limitations due to cross-talk of Tl-201/Tc-99m [2], and Tc-99m/I-123 imaging [3]. For Tc-99m/I-123 imaging, however, Devous et al. [4] have reported separation of the radionuclide activity distributions using simple energy windowing. Spectral factor analysis has been used to separate Tl-201 and I-131 [5] as well as Tc-99m and I-123 [6]. In [6], only one projection was considered with different relative concentrations of I-123 and Tc-99m in minimally attenuating and scattering uniform cylinders (1.3 cm thick). Furthermore, scatter was assumed to be stationary in the projection, and only relative quantitation was performed. The conclusions of the latter study may not apply to clinical images.

The goal of the present study was to evaluate the accuracy and precision that could be achieved using two different correction methods in anatomically and physiologically realistic cases of normal and pathologic brain activity distributions. The first approach was based on spectral factor analysis (SFA), where scatter was not assumed to be stationary over the brain projections and *a priori* knowledge of the shape of the spectra associated with primary photons was used to correct for cross-talk. The second approach was based on an artificial neural network (ANN) with error back-propagation as learning tool. SFA and ANN were compared to the energy windowing approach proposed by Devous et al. [4]. We investigated these techniques using Monte Carlo simulations of SPECT imaging of a digital human brain phantom. This approach allowed us to mimic a physical acquisition while knowing the true activity and attenuation distributions in the brain as well as the resulting primary photon distribution.

II. METHODS

A. Monte Carlo Simulations

We simulated dual isotope SPECT studies of a digital brain phantom [7]. 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 images of normal and diseased subjects after injections of 740 MBq Tc-99m HMPAO [8] and 111 MBq I-123 IBZM [9] or Altropane [10]. Various simulated activity distributions mimicked normal I-123 and Tc-99m uptakes, reduced I-123 uptake in the striata (25% or 50% reduction), reduced Tc-99m uptake in the frontal and temporal lobes (50% reduction), or temporal and parietal lobes (50% reduction) or a reduction of both I-123 and Tc-99m. Five of the 15 dual isotope distributions considered in this study are described in Table 1. A lookup table of attenuation coefficients, at 1-keV increments over the range 50 to 200 keV, was established for each structure which was assumed to be homogenous within its boundary.

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Representative Results:

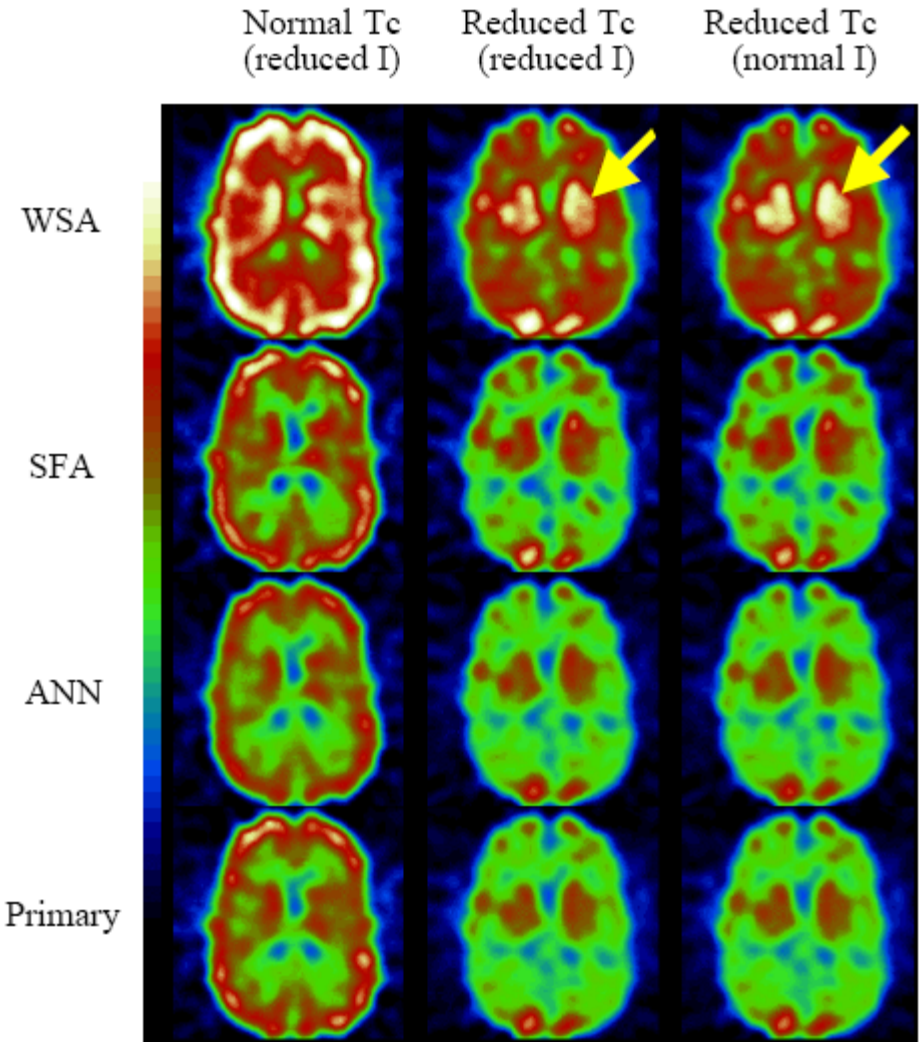

Figure 7: Reconstructed Tc-99m distributions of WSA, SFA, ANN and primary photon distributions in three different studies for the slice shown in Figure 1.