Absolute Activity Quantitation in Simultaneous $^{123}I/^{99m}Tc$ Brain SPECT

Georges El Fakhri, Stephen C. Moore, Philippe Maksud, André Aurengo, and Marie Foley Kijewski

Department of Radiology, Harvard Medical School and Brigham and Women's Hospital, Boston, Massachusetts; and U494 INSERM, CHU Pitié-Salpêtrière, Paris, France

Dual-isotope imaging can allow simultaneous assessment of brain perfusion using a ^{99m}Tc-labeled tracer and neurotransmission using an ^{123}I-labeled tracer. However, the images are affected by scatter, cross talk, attenuation, distance-dependent collimator response (DCR), and partial-volume effect. We determined the accuracy and precision of activity quantitation in simulated normal and pathologic studies of simultaneous $^{123}I/^{99m}Tc$ brain SPECT when compensating for all degrading phenomena. **Methods:** Monte Carlo simulations were performed using the Zubal brain phantom. Contamination caused by high-energy ^{123}I decay photons was incorporated. Twenty-four ^{99m}Tc and ^{123}I activity distributions were simulated on the basis of normal and pathologic patient activity distributions. Cross talk and scatter were corrected using a new method based on a multilayer perceptron artificial neural network (ANN), as well as by the asymmetric window (AW) approach; for comparison, unscattered (U) photons of ^{99m}Tc and ^{123}I were recorded. Nonuniform attenuation and DCR were modeled in an iterative ordered-subset expectation maximization (OSEM) algorithm. Mean percentage biases and SDs over the 12 normal and 12 pathologic simulated studies were computed for each structure with respect to the known activity distributions. **Results:** For ^{123}I, AW + OSEM yielded a bias of 7% in the cerebellum, 21% in the frontal cortex, and 36% in the corpus callosum in the simulated normal population. The bias was increased significantly in the striata of simulated pathologic studies ($P < 0.05$). The bias associated with ANN was significantly lower (<9% in these brain structures, $P < 0.05$). For ^{99m}Tc with AW + OSEM, the bias was 60% in the corpus callosum, 36% in the striata, and 18%–22% in the cortical lobes in the simulated normal population. This bias was <11% in all brain structures with ANN. In the simulated pathologic population, the bias associated with AW increased significantly in the cortical lobes to 55% ($P < 0.05$), although it did not change significantly with ANN. **Conclusion:** The accuracy and variability over simulated normal and pathologic studies of both ^{99m}Tc and ^{123}I activity estimates were very close with ANN to those obtained with U + OSEM. ANN + OSEM is a promising approach for absolute activity quantitation in simultaneous $^{99m}Tc/^{123}I$ SPECT.

Key Words: dual-isotope brain SPECT; absolute quantitation; Monte Carlo simulation; artificial neural network; cross-talk compensation

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Dual-isotope imaging ($^{123}I/^{99m}Tc$) has potential clinical applications in the simultaneous assessment of neurotransmission and brain perfusion. ^{123}I tracers allow imaging of both presynaptic (e.g., 2β-carbomethoxy-3β-(4-iodophenyl)tropane (*1*)) and postsynaptic (e.g., iodobenzamide [IBZM] (*2*)) phases of dopaminergic transmission and have potential clinical use in various movement disorders including Parkinson's disease, Huntington's disease, progressive supranuclear palsy, multiple-system atrophy, and Wilson's disease (*3*), whereas ^{99m}Tc tracers (e.g., hexamethylpropyleneamine oxime [HMPAO] or ethylcysteinate dimer) allow the assessment of brain perfusion. Furthermore, simultaneous acquisition of ^{123}I and ^{99m}Tc studies reduces the acquisition time while allowing perfect registration of perfusion and neurotransmission studies. Despite these advantages, this technique has not been routinely implemented in the clinic. Because the emission energies of ^{99m}Tc (140 keV) and ^{123}I (159 keV) are close, not only are scattered ^{123}I photons detected in the ^{99m}Tc window, but, equally important, primary photons of each radionuclide are detected in the wrong window (cross talk) (*4*). Furthermore, like all SPECT images, dual-isotope images are affected by attenuation and both distance-dependent and intrinsic components of collimator and detector response. Previous physical phantom studies of dual-isotope $^{99m}Tc/^{123}I$ imaging, with cross-talk correction by simple energy windowing techniques, yielded conflicting results: Ivanovic et al. (*5*) reported major limitations, whereas Devous et al. (*6,7*) obtained accurate quantitation.

Artificial neural networks (ANNs) were used previously to correct for scatter in ^{99m}Tc SPECT studies (*8,9*). In previous work, we proposed two original approaches to correct for cross talk and scatter based on constrained factor analysis and ANNs (*10*); we found the latter more promising. The aim of this study was to assess the quantitation accuracy and precision that could be achieved in normal and pathologic dual brain studies when correcting for scatter and cross talk using ANN, for attenuation and variable collimator response using an iterative ordered-subset expectation maximization (OSEM) algorithm, and for the residual partial-volume effect (PVE) using three-dimensional recovery coefficients. Results were compared with those of a spectral

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For correspondence or reprints contact: Georges El Fakhri, PhD, Department of Radiology, Brigham and Women's Hospital, Boston, MA 02115.

Representative Results:

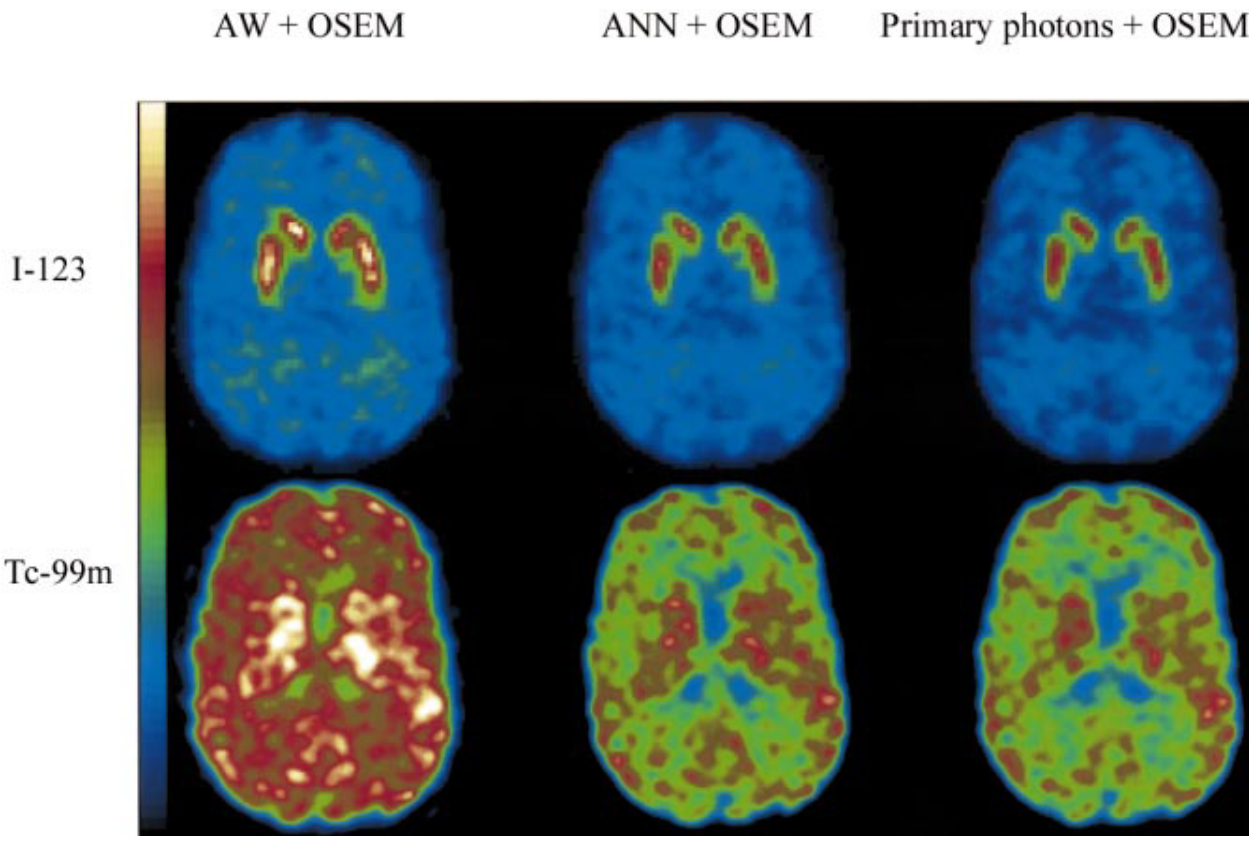

FIGURE 5. OSEM reconstructed ^{123}I and ^{99m}Tc distributions of AW, ANN, and primary photon distributions in normal patient with low ^{99m}Tc uptake for slice shown in Figure 1. Artifactually increased activity is seen in different brain structures in AW 1 OSEM ^{99m}Tc image.