Quantitative simultaneous $^{99m}Tc/^{123}I$ cardiac SPECT using MC-JOSEM

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Simultaneous rest ^{99m}Tc-Sestamibi/^{123}I-BMIPP cardiac SPECT imaging has the potential to replace current clinical ^{99m}Tc-Sestamibi rest/stress imaging and therefore has great potential in the case of patients with chest pain presenting to the emergency department. Separation of images of these two radionuclides is difficult, however, because their emission energies are close. The authors previously developed a fast Monte Carlo (MC)-based joint ordered-subset expectation maximization (JOSEM) iterative reconstruction algorithm (MC-JOSEM), which simultaneously compensates for scatter and cross talk as well as detector response within the reconstruction algorithm. In this work, the authors evaluated the performance of MC-JOSEM in a realistic population of ^{99m}Tc/^{123}I studies using cardiac phantom data on a Siemens e.cam system using a standard cardiac protocol. The authors also compared the performance of MC-JOSEM for estimation tasks to that of two other methods: standard OSEM using photopeak energy windows without scatter correction (NSC-OSEM) and standard OSEM using a Compton-scatter energy window for scatter correction (SC-OSEM). For each radionuclide the authors separately acquired high-count projections of radioactivity in the myocardium wall, liver, and soft tissue background compartments of a water-filled torso phantom, and they generated synthetic projections of various dual-radionuclide activity distributions. Images of different combinations of myocardium wall/background activity concentration ratios for each radionuclide were reconstructed by NSC-OSEM, SC-OSEM, and MC-JOSEM. For activity estimation in the myocardium wall, MC-JOSEM always produced the best relative bias and relative standard deviation compared with NSC-OSEM and SC-OSEM for all the activity combinations. On average, the relative biases after 100 iterations were 8.1% for ^{99m}Tc and 3.7% for ^{123}I with MC-JOSEM, 39.4% for ^{99m}Tc and 23.7% for ^{123}I with NSC-OSEM, and 20.9% for ^{99m}Tc with SC-OSEM. The relative standard deviations after 30 iterations were 0.7% for ^{99m}Tc and 1.0% for ^{123}I with MC-JOSEM, as compared to 1.1% for ^{99m}Tc and 1.2% for ^{123}I with NSC-OSEM and 1.3% for ^{99m}Tc with SC-OSEM. Finally, the authors compared the relative standard deviation after 30 iterations with the minimum theoretical variance on activity estimation, the Cramer–Rao lower bound (CRB), and with the biased CRB. The measured precision was larger than the biased bound values by factors of 2–4, suggesting that further improvement could be made to the method. [DOI: 10.1118/1.3063544]

Key words: iterative reconstruction, MC-JOSEM, cardiac SPECT, dual-radionuclide

I. INTRODUCTION

Simultaneous ^{99m}Tc-Sestamibi/^{123}I-BMIPP cardiac SPECT imaging has the potential to replace the current clinically implemented ^{99m}Tc-Sestamibi rest/stress imaging. A simultaneous ^{99m}Tc-Sestamibi/^{123}I-BMIPP protocol has many advantages: First, iodinated fatty acid analogs such as ^{123}I-BMIPP (^{123}I-β-methyl iodophenyl pentadecanoic acid) make possible the assessment of its metabolic state.[1–5] Images of ^{123}I-BMIPP at rest provide an "ischemic memory," which delineates segments of myocardium that have been starved of adequate blood supply (ischemic muscle) at significant time intervals after the event and which correlates with abnormal blood flow patterns typically observed by perfusion tracers during stress testing. Although ^{99m}Tc labeled perfusion agents are very sensitive for the detection of acute cardiac ischemia when injected during active chest pain, their sensitivity is significantly reduced when injected after the chest pain is resolved. In this context, metabolic tracers such as ^{123}I-BMIPP (Refs. 2–4) appear very attractive because of their ability to delineate persistent postischemic changes in myocardial metabolism (ischemic memory). Second, the simultaneous protocol would yield "stress" and rest studies under identical conditions of patient motion, positioning, and attenuation paths. Eliminating the need for stress testing could also improve the sensitivity of identifying coronary artery disease, which is low in patients who are unable to achieve maximum predicted heart rate. The spatial registration of the reconstructed rest and stress images would be perfect, facilitating image interpretation. Third, the simultaneous protocol would obviate the need for patient exercise, a potentially harmful activity in those whose cardiac function is compromised, making it an ideal protocol for the emergency department setting. Fourth, a single acquisition would obviate the need for separate rest/stress protocols, improving the efficiency of nuclear cardiology laboratories.

Separation of ^{99m}Tc and ^{123}I images is difficult because

Representative Results:

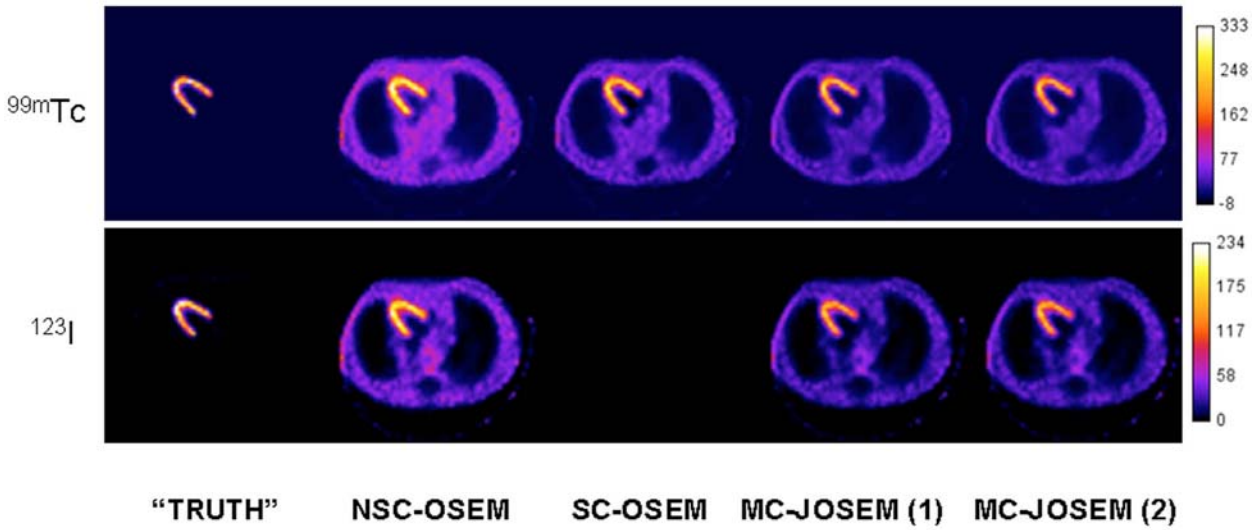

FIG. 2. Comparison of reconstructed images after 40 iterations. The images in the top and bottom rows are for ^{99m}Tc and ^{123}I, respectively. The images from the first column were reconstructed from myocardium–empty-phantom projection data, which were properly scaled to activity combination C1 by MCJOSEM. The images in the second, third, fourth, and fifth columns were reconstructed from noise-free projection data from C1 by NSC-OSEM, SC-OSEM (^{99m}Tc only), MC-JOSEM (1), and MC-JOSEM (2), respectively.

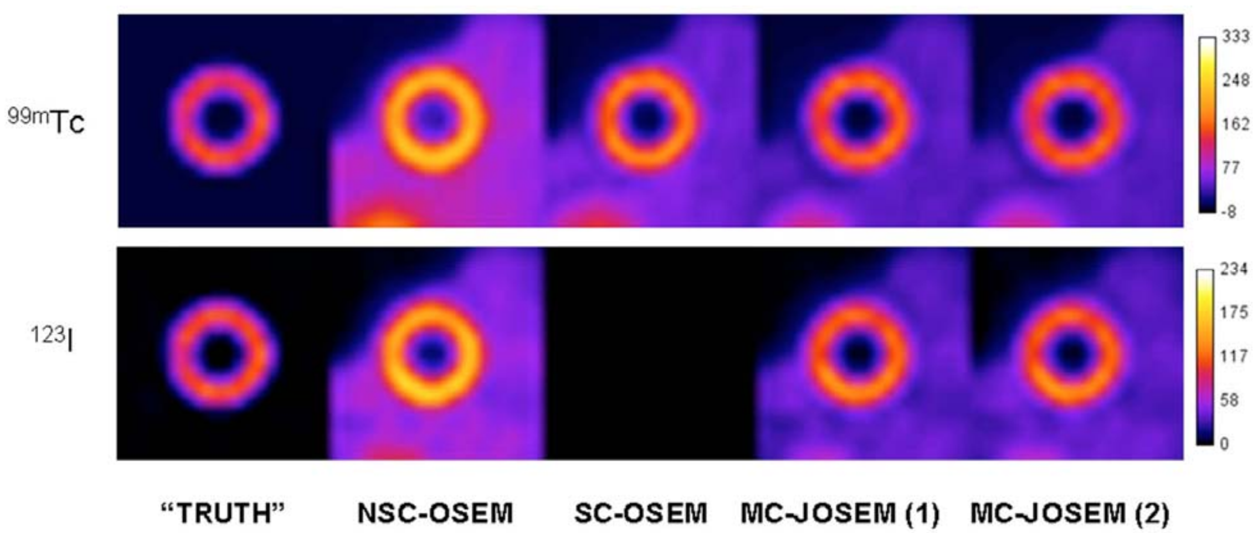

FIG. 3. Comparison of reconstructed short-axis slices after 40 iterations. These slices are from the same image volumes described in Fig. 2.

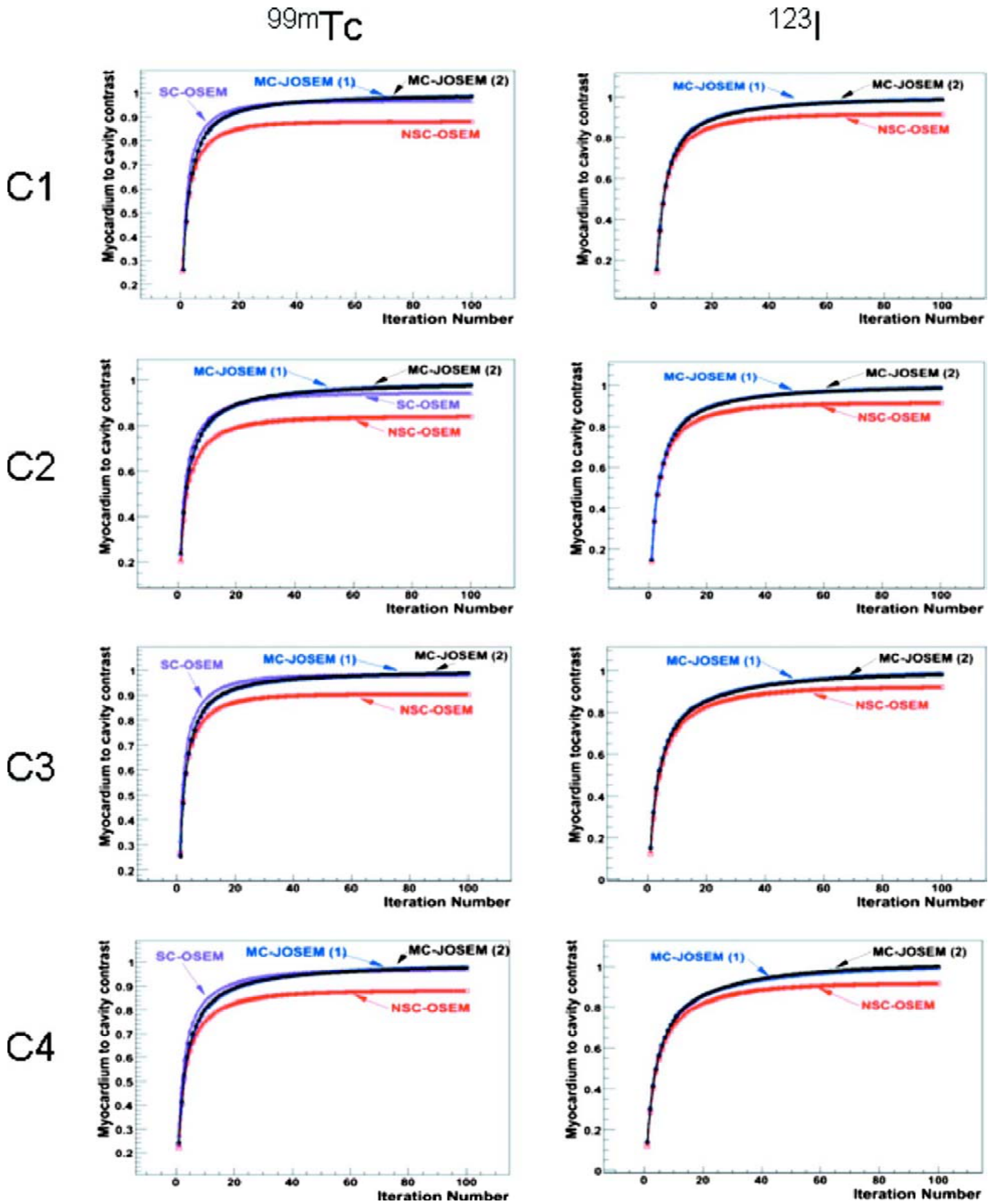

FIG. 6. Myocardium wall to cavity contrast for combinations C1–C4.