Performance of a novel collimator for high-sensitivity brain SPECT

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(Received 15 August 2005; revised 13 October 2005; accepted for publication 4 November 2005; published 28 December 2005)

We assessed improvements in performance in detection and estimation tasks due to a novel brain single photon computed tomography collimator. Data were acquired on the CeraSPECT™ scanner using both new and standard collimators. The new variable focusing collimator SensOgrade™ samples the projections unequally, with central regions more heavily represented, to compensate for attenuation of counts from central brain structures. Furthermore, it utilizes more of the cylindrical crystal surface. Two phantom studies were performed. The first phantom was a 21-cm-diameter cylindrical background containing nine spheres ranging from 0.5 to 5 cm^3 in volume. ^{99m}Tc sphere to background activity ratio was 10:1. Twenty-nine 10-min datasets were acquired with each collimator. The second phantom was the Radiology Support Devices (Long Beach, CA) striatal phantom with striatal-background ratios of 10:1 on the left and 5:1 on the right. Twenty-nine 4-min datasets were acquired with each collimator. Perfusion imaging using ^{99m}Tc-HMPAO was also performed in three healthy volunteers using both collimators under identical simulations. Projections were reconstructed by filtered backprojection with an unwindowed ramp filter. The nonprewhitening matched filter signal-to-noise ratio (NPW-SNR) was computed as a surrogate for human performance in detecting spherical lesions. Sphere activity concentration, radius, and location coordinates were simultaneously estimated by fitting images to an assumed model using an iterative nonlinear algorithm. Resolution recovery was implicit in the estimation procedure, as the point spread function was incorporated into the model. NPW-SNR for sphere detection was 1.5 to 2 times greater with the new collimator; for the striatal phantom the improvement in SNR was 54%. The SNR for estimating sphere activity concentration improved by 46 to 89 % for spheres located more than 5 cm from the phantom center. Images acquired with the standard collimator were too noisy in the central regions to allow estimation of sphere activity. In ^{99m}Tc-HMPAO human studies, SNR was improved by 21 to 41 % in the cortex, 66% in the basal ganglia, and 74% in the thalamus. The new collimator leads to substantially improved detection and estimation performance throughout the brain. The higher sensitivity will be particularly important for dynamic imaging. [DOI: 10.1118/1.2143140]

Key words: high-sensitivity brain SPECT, variable focusing collimator, estimation, and detection SNR

I. INTRODUCTION

Brain single photon computed tomography (SPECT) in general, and dynamic brain SPECT in particular, are affected by Poisson noise. This is especially true in the vicinity of the center of the field of view (FOV), where the basal ganglia are located, due to the loss of photons by attenuation. Furthermore, post-acquisition attenuation correction can compensate for the bias associated with the attenuation of centrally emitted photons but does not reduce the noise. This is of particular concern when performing dopamine transporter/receptor imaging where the target is usually the centrally located caudate nucleus and putamen. We have shown previously that a collimator that samples the projections more heavily at the center than at the periphery could lead to significant reductions in noise over most of the reconstruction volume, with the greatest improvements near the center.[1] It is important to note that the gains in sensitivity do not affect spatial resolution. A collimator with a centrally peaked sensitivity profile has been manufactured for the Ceraspect brain scanner.[2] The aim of this work is to evaluate the improvements in performance in lesion detection and activity estimation tasks due to the "SensOgrade" collimator.

Representative Results:

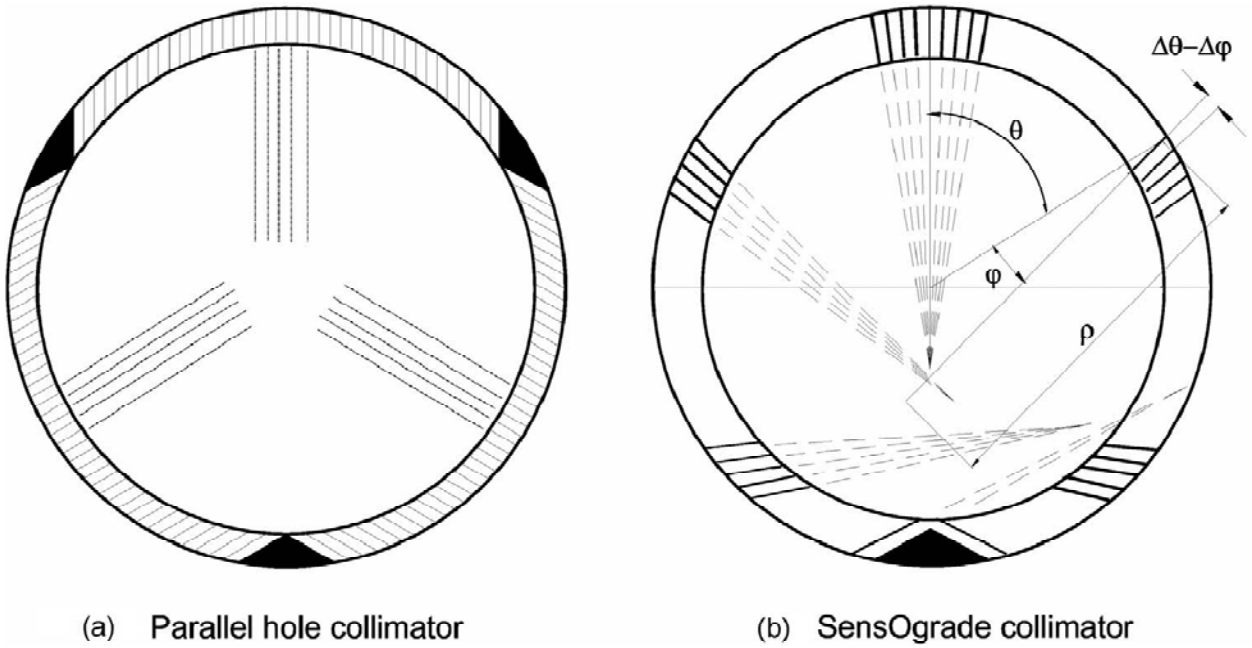

FIG. 1. (a) Standard, parallel-hole CeraSPECT collimator (b) Angle θ − ϕ of the SensOgrade collimator holes varies from zero to the maximum value needed to tangentially encompass the field of view. The functional variation of the angles over the circumference of the collimator has been set to sample the interior of the FOV more heavily than its perimeter.

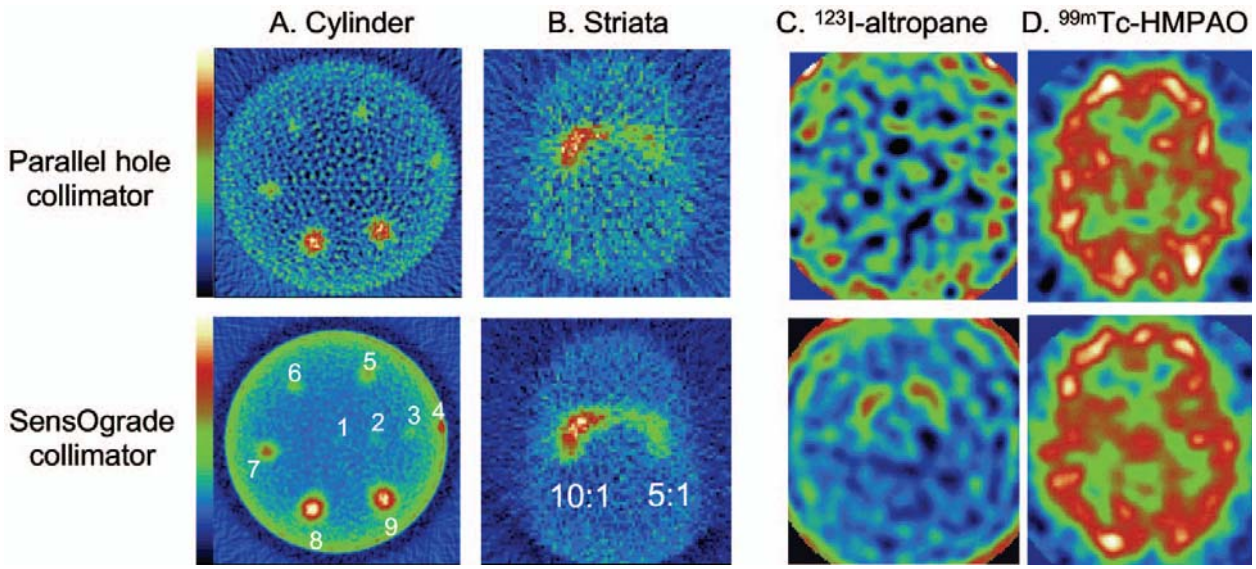

FIG. 2. (a) Transverse reconstructed slices of the cylindrical phantom with nine spheres of activity ten times background acquired with the standard, parallel-hole CeraSPECT collimator (1) and the SensOgrade collimator (2). (b) Transverse reconstructed slices of the striatal phantom with ^{99m}Tc striatal-background ratio 10:1 on the left and 5:1 on the right. (c) and (d) ^{123}I-altropane dopamine transporter (c) and ^{99m}Tc-HMPAO perfusion study (d).