Respective roles of scatter, attenuation, depth-dependent collimator response and finite spatial resolution in cardiac single-photon emission tomography quantitation: a Monte Carlo study

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Abstract. The purpose of this study was to investigate the relative influence of scatter, attenuation, depth-dependent collimator response and finite spatial resolution upon the image characteristics in cardiac single-photon emission tomography (SPET). An acquisition of an anthropomorphic cardiac phantom was performed together with corresponding SPET Monte Carlo simulations. The cardiac phantom and the Monte Carlo simulations were designed so that the effect of scatter, attenuation, depth-dependent collimator response and finite spatial resolution could be studied individually and in combination. The impact of each physical effect and of combinations of effects was studied in terms of absolute and relative quantitative accuracy, spatial resolution and signal-to-noise ratio (SNR) in the resulting images. No corrections for these effects were assessed. Results obtained from Monte Carlo simulations and real acquisitions were in excellent agreement. Attenuation introduced about 90% activity underestimation in a 10-mm-thick left ventricle wall while finite spatial resolution alone introduced about 30% activity underestimation. Scatter had a negligible impact on quantitative accuracy in the recontructed slices when attenuation was present. Neither bull's eye map homogeneity nor contrast between a hot and a cold region were affected by depth-dependent collimator response or finite spatial resolution. Bull's eye map homogeneity was severely affected by attenuation but not by scatter. Attenuation and scatter reduced contrast by about 20% each. Both attenuation and scatter increased the full-width at half-maximum (FWHM) characterizing the spatial resolution of the imaging system by ≈1 mm each but the main effect responsible for the observed 11-mm FWHM spatial resolution was the depth-dependent collimator response. SNR was reduced by a factor of ≈2.5 because of attenuation, while scattered counts increased SNR by ≈10%. In conclusion, the quantification of the relative influence of the different physical effects showed that attenuation is definitely the major phenomenon affecting cardiac SPET imaging accuracy, but that finite spatial resolution, scatter and depth-dependent collimator response also contribute significantly to the errors in absolute and relative quantitation and to the poor spatial resolution.

Key words: Quantitation – Cardiac single-photon emission tomography – Monte Carlo simulation

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Introduction

The accuracy of quantitation in single-photon emission tomography (SPET) is affected by many effects among which attenuation, scatter, depth-dependent collimator response and finite spatial resolution (FSR) play a major role. Studying the impact of each of these effects on the image characteristics (e.g. image resolution, relative and absolute quantitation, and signal-to-noise ratio) is necessary to determine what improvement could be expected if we were to perform an ideal correction for a given effect. However, these phenomena are not independent and each one should be considered only as a component responsible for part of the SPET system inaccuracies. Therefore, it is not sufficient to determine how each phenomenon taken independently affects the images. The impact of each phenomenon should also be characterized when it is combined with other phenomena affecting the imaging process, to determine the respective role of each phenomenon and the improvements that could be expected when correcting for some effects but ignoring the others.

Although many studies have been devoted to the investigation of the qualitative and quantitative conse-

Representative Results:

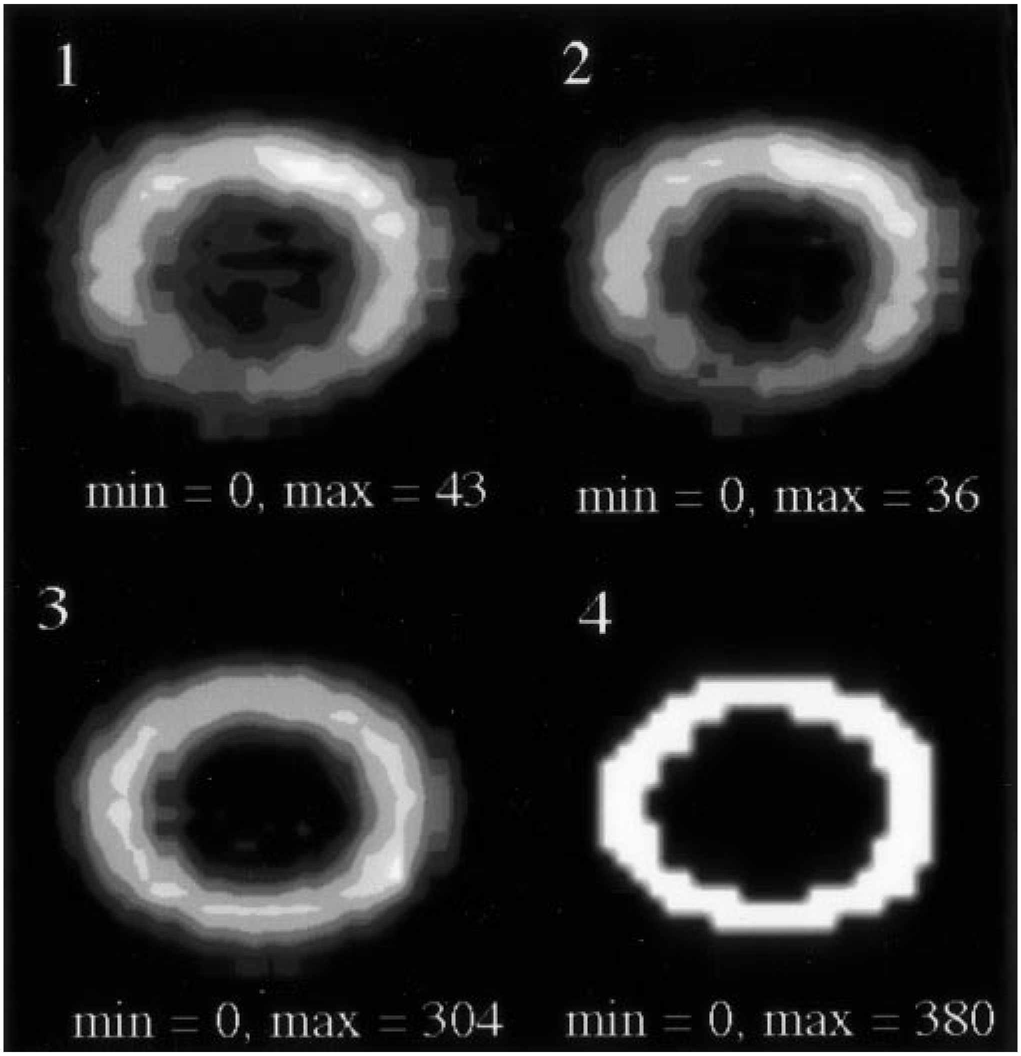

Figure 3. Short-axis images corresponding to I20 + FBP (*1*), primary + FBP (*2*), air + FBP (*3*) and reference activity distribution (*4*)