Relative Impact of Scatter, Collimator Response, Attenuation, and Finite Spatial Resolution Corrections in Cardiac SPECT

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We determined the relative effect of corrections for scatter, depth-dependent collimator response, attenuation, and finite spatial resolution on various image characteristics in cardiac SPECT. **Methods:** Monte Carlo simulations and real acquisition of a ^{99m}Tc cardiac phantom were performed under comparable conditions. Simulated and acquired data were reconstructed using several correction schemes that combined different methods for scatter correction (3 methods), depth-dependent collimator response correction (frequency–distance principle), attenuation correction (nonuniform Chang correction or within an iterative reconstruction algorithm), and finite spatial resolution correction (use of recovery coefficients). Five criteria were considered to assess the effect of the processing schemes: bull's-eye map (BEM) uniformity, contrast between the left ventricle (LV) wall and the LV cavity, spatial resolution, signal-to-noise ratio (SNR), and percent errors with respect to the known LV wall and liver activities. **Results:** Similar results were obtained for the simulated and acquired data. Scatter correction significantly improved contrast and absolute quantitation but did not have noticeable effects on BEM uniformity or on spatial resolution and reduced the SNR. Correction for the depth-dependent collimator response improved spatial resolution from 13.3 to 9.5 mm in the LV region, improved absolute quantitation and contrast, but reduced the SNR. Correcting for attenuation was essential for restoring BEM uniformity (78% and 89% without and with attenuation correction, respectively [ideal value being 100%]) and accurate absolute activity quantitation (errors in estimated LV wall and liver activity decreased from 90% without attenuation correction to ~20% with attenuation correction only). Although accurate absolute activity quantitation was achieved in the liver using scatter and attenuation corrections only, correction for finite spatial resolution was needed to estimate LV wall activity within 10%. **Conclusion:** The respective effects of corrections for scatter, depth-dependent collimator response, attenuation, and finite spatial resolution on different image features in cardiac SPECT were quantified for a specific acquisition configuration. These results give indications regarding the improvements to be expected when using a specific processing scheme involving some or all corrections.

Key Words: cardiac SPECT; quantitation; Monte Carlo simulation; scatter; depth-dependent collimator response; attenuation; finite spatial resolution

J Nucl Med 2000; 41:1400–1408

Scatter, depth-dependent collimator response, attenuation, and finite spatial resolution are major factors affecting cardiac SPECT and have received substantial attention in the past years. Many correction methods have been proposed to compensate for scatter (*1*), depth-dependent collimator response (*2,3*), and attenuation (*4*), whereas few studies have been devoted to the issue of finite spatial resolution (FSR) in SPECT (*5,6*). Although the evaluation of a single correction or of a combination of corrections in cardiac SPECT has been reported—e.g., scatter (*7,8*), attenuation (*9,10*), attenuation and variable collimator response (*11*), attenuation and scatter (*12*), attenuation, scatter, and variable collimator response (*13*)—there is a lack of data regarding the respective contribution of the different corrections to the final image characteristics.

Using Monte Carlo simulations and real acquisitions of a cardiac phantom, we previously determined how scatter, depth-dependent collimator response, attenuation, and FSR impacted the image features in cardiac SPECT (*14*). This allowed us to predict which corrections should be essential for the recovery of uniformity, contrast, spatial resolution, signal-to-noise ratio (SNR), and accurate quantitation. In this study, we have considered available correction methods for scatter, depth-dependent collimator, attenuation, and FSR and incorporated them into various processing schemes on the same simulated and acquired cardiac data to determine how current corrections compare with ideal corrections and to assess their respective impact on the image characteristics.

MATERIALS AND METHODS

Cardiac Phantom

A 24 × 32 cm elliptic cardiac phantom (Data Spectrum, Chapel Hill, NC) was scanned using an MRI scanner, and the resulting MR images were segmented into a 10-mm-thick left ventricle (LV)

Received Aug. 10, 1999; revision accepted Nov. 2, 1999.

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Representative Results:

TABLE 2
Performance of Combined Corrections of Acquired and Simulated Data

Combined corrections	BEM uniformity (%)	Contrast	Spatial resolution (mm)	SNR	Quantitation error (%)	
					In LV	In liver
None (I20 + FBP)	75 ± 13	0.66	13.5 ± 1.2	4.9	−93 ± 3	−88 ± 4
	78 ± 14	*0.60*	*13.3 ± 1.1*	*4.7*	*−92 ± 2*	*−86 ± 3*
Attenuation (I20 + MR)	88 ± 8	0.68	13.4 ± 1.5	5.2	−24 ± 6	13 ± 3
	89 ± 7	*0.63*	*13.1 ± 0.9*	*5.0*	*−22 ± 5*	*16 ± 2*
Scatter + attenuation	89 ± 8	0.77	12.8 ± 2.0	4.4	−28 ± 3	−2 ± 3
(JAS + MR)	*91 ± 7*	*0.73*	*12.4 ± 0.9*	*4.2*	*−31 ± 5*	*−3 ± 3*
PSF + attenuation	86 ± 7	0.80	10.2 ± 1.7	4.0	−8 ± 4	16 ± 5
(I20 + FDP + MR)	*90 ± 3*	*0.78*	*9.5 ± 1.3*	*3.2*	*−7 ± 2*	*18 ± 4*
Scatter + PSF + attenuation	89 ± 8	0.90	9.6 ± 1.8	3.5	−19 ± 6	−3 ± 4
(JAS + FDP + MR)	*95 ± 4*	*0.89*	*9.2 ± 1.4*	*2.8*	*−18 ± 4*	*−2 ± 3*
Scatter + PSF + attenuation + FSR	89 ± 8	0.90	9.6 ± 1.8	3.5	−4 ± 3	−3 ± 4
(JAS + FDP + MR + R)	*95 ± 4*	*0.89*	*9.2 ± 1.4*	*2.8*	*−2 ± 3*	*−2 ± 3*

Acquired data are in roman type; simulated data are in italic type.