Quantitative Bias from Respiratory Motion and Finite System Resolution for SPECT Imaging of Kidneys – A Simulation Study

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Aims:

Accurate quantitative SPECT images are critical for personalized dosimetry of patients undergoing Lu-177 therapies. Blurring due to the finite resolution of the SPECT system is responsible for inducing quantitative bias on reconstructed images in small objects or at the edges of larger ones. However, respiratory motion imposes blur as well and may further add to this bias. The organ of interest during Lu-177 dosimetry most affected by respiratory motion is the kidney. In a collective of seven patients, prior work by our group using data-driven respiratory gating found head-foot breathing motion in the left and right kidneys to be 7.2±3.8 and 5.8±4.1mm, respectively [1].

The goal of this work was to assess the amount of bias resulting from such motions and compare it to that due to the finite system resolution.

Methods:

A patient CT was selected, and left and right kidneys were manually segmented to create a binary image. A respiratory surrogate signal obtained via data-driven means from the corresponding SPECT acquisition [2] was then scaled to create a head-foot motion waveform with magnitudes of 1.7, 3.4, 5.8, 7.2, 9.9, and 11.0mm. These magnitudes correspond to the mean translations ±SD measured in a previous study mentioned above. The motion waveform for each magnitude was sampled at 0.5mm increments and used to shift the kidney image to create a set of images with varying extents of motion blur. Each of these was then further blurred with a set of isotropic Gaussian kernels with FWHMs of 9, 12, and 15mm to simulate the system's reconstructed resolution. Including unblurred images, a total of 28 were generated.

The sum of voxels in blurred images belonging to original kidney regions was computed. The ratio of this sum to that in non-blurred images yielded a coefficient C describing the amount of bias caused by the system resolution and motion blurring.

Results:

Results are summarized in Figure 1. Blur from the system resolution alone caused substantial bias, with C = 0.80 for the conservative 9mm system resolution, and less than 0.75 for the other two. With no system blur, C=0.97, 0.94, 0.90, 0.88, 0.85, and 0.84 for motion magnitudes of 1.7, 3.4, 5.8, 7.2, 9.9, and 11.0 mm, respectively. With finite system resolution of 9mm, C=0.79, 0.79, 0.77, 0.76, 0.74, and 0.73 for the same motion magnitudes.

Conclusion:

In this relatively simple simulation study, system resolution was the dominant factor determining quantitative bias. However, additional bias exceeding 5% due to respiratory motion blur was observed for realistic motion magnitudes and system resolutions. Furthermore, only head-foot motion was considered here, and true 3D motion could be expected to result in further loss of accuracy.

References:
[1] J.C. Sanders, T. Kuwert, A.H. Vija, and P. Ritt, "Effect of data-driven respiratory gating on Lu-177 SPECT/CT scans", *29th Annual Congress of the EANM*, 2016, Oct.15-19, Barcelona, Spain.

[2] J.C. Sanders, P. Ritt, T. Kuwert, A.H. Vija, and A.K. Maier, "Fully automated data-driven respiratory signal extraction from SPECT images using laplacian eigenmaps," *IEEE Trans. Med. Imag.*, 45(11), pp. 2425-2435, 2016.

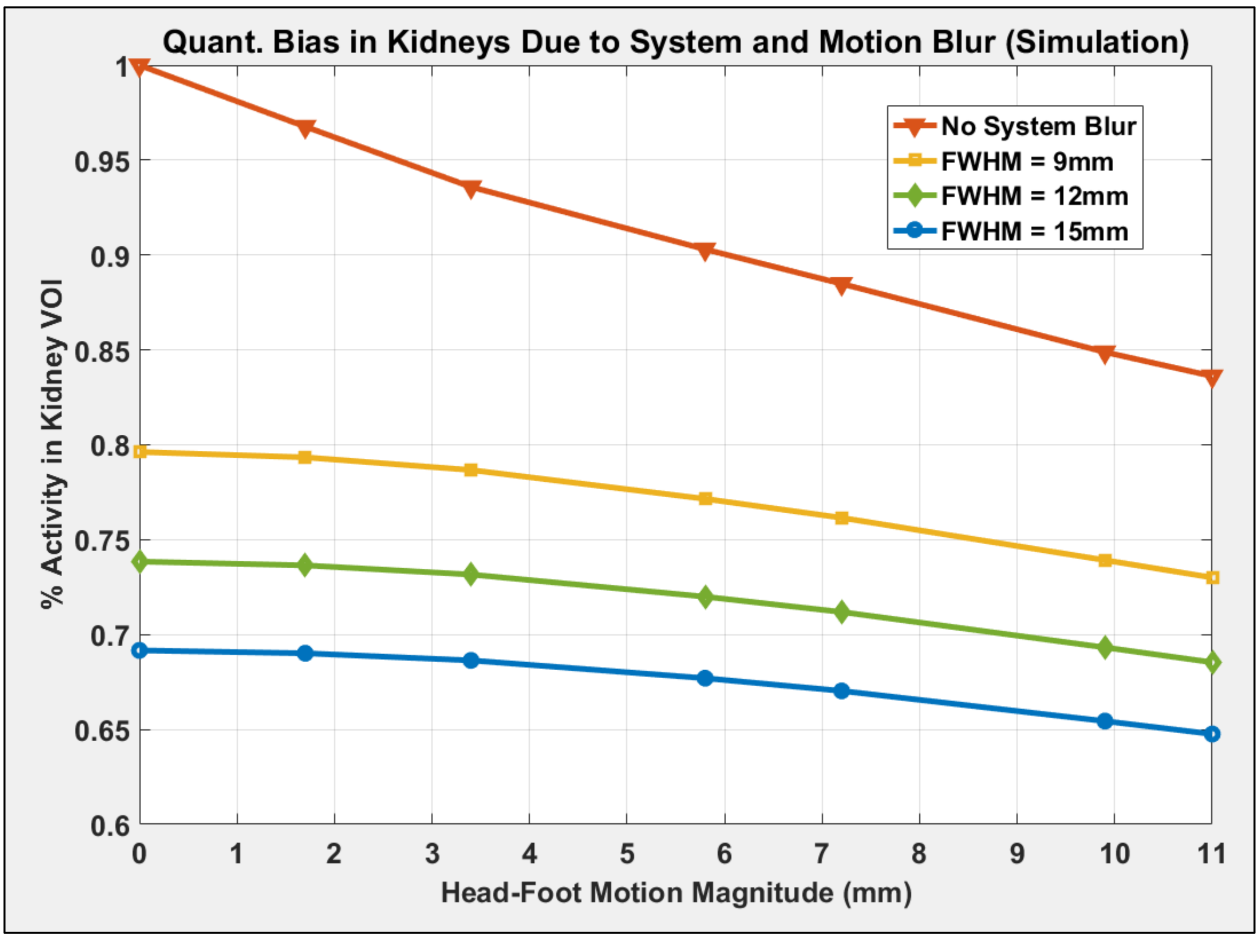

Figure 1. Percent of activity recovered in the kidney VOIs as a function of Head-Foot motion magnitude for each system blur level.