On moving coil encoding and calibration in dynamic imaging

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Introduction: Image reconstruction of multi-channel coil data is based on sensitivity maps [1] for each receive antenna. Sensitivities are typically derived from either a pre-scan [2] or by autocalibration from fully sampled or composite k-space profiles [3,4]. Both approaches inherently assume a static object or negligible motion relative to the spatial variation in coil sensitivities. As coil diameters have become smaller in the wake of ever larger coil arrays, this assumption may not hold in all cases, in particular when bulk motion can be expected. It has already been demonstrated that rigid motion of an object relative to a static coil causes inconsistencies and requires incorporation of time-varying sensitivity maps in object coordinates [5].

In the present work, the impact of breathing motion on myocardial perfusion imaging is studied including both a moving object and moving receive coils fixated to the chest exhibiting respiratory motion. Reconstruction results taking into account moving coil sensitivities relative to the true, static and autocalibrated sensitivity maps are compared.

Methods: A deformation field with realistic amplitudes was applied to a three-dimensional myocardial perfusion phantom to simulate breathing motion. The dynamic frames of the contrast enhanced images were non-rigidly warped such as to exhibit cyclic respiratory motion (Figure 1). Coil encoding was based on two opposing coils with a spatial dependency of sensitivity according to Biot-Savart's law. While the posterior coil remained static, the anterior coil was moved according to the chest wall motion pattern. Three data sets were reconstructed including a) moving coil sensitivities used for encoding (representing the ground truth), b) static sensitivities, and c) using auto-calibrated sensitivities. The auto-calibration data was derived from the image mean over time divided by the sum of squares reconstruction of this mean [6]. Motion was corrected using the a priori motion field imposed on the data. Image reconstruction was implemented in Matlab (Mathworks, Natick, USA) and performed on standard PC hardware.

Results: In Figure 3 image profiles over time are shown for moving coil, static coil and autocalibrated reconstruction. It is seen that for the static coil sensitivities, the errors are biggest near the moving coil. For the autocalibrated reconstruction, errors also increase in regions where coil sensitivities overlap due to the spatially non-homogeneous combination of coil sensitivities. Signal intensity (SI) profiles of simulated cardiac perfusion are demonstrated in Figure 4. SI curves for the given position in myocardium and blood pool differ by up to 10% for the reconstruction with static sensitivities relative to ground truth. Using autocalibration, errors up to 15 % are found relative to the reference.

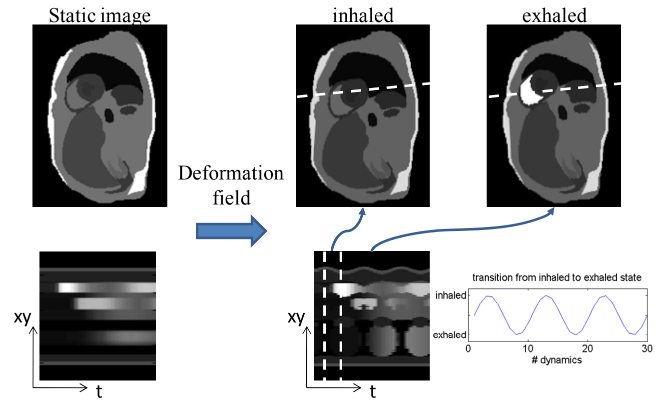

Figure 1: A static contrast enhanced perfusion phantom was non-rigidly warped according to a cyclic breathing pattern.

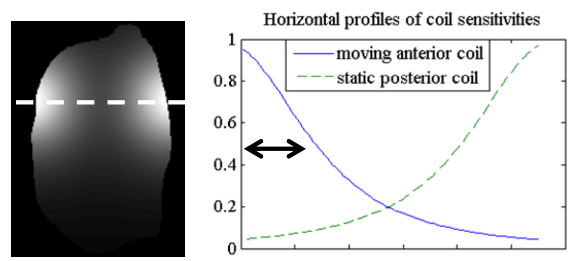

Figure 2: Sum-of-squares reconstruction of coil sensitivities (left) and profiles (right) of a static posterior and a moving anterior coil. Spatial dependence of coil sensitivity maps are based on Biot-Savart's law.

Discussion: It has been demonstrated that moving coils may impair image reconstruction if the motion induced changes in coil sensitivities are not taken into account. Although overall perceived image quality remains acceptable, the quantitative evaluation of signal intensity curves shows errors of up to 15 % in absolute signal compared to the ground truth if coil motion is not taken into account. With large arrays of small coils becoming standard, reconstruction performance of autocalibrated methods is degraded when motion is present.

References:

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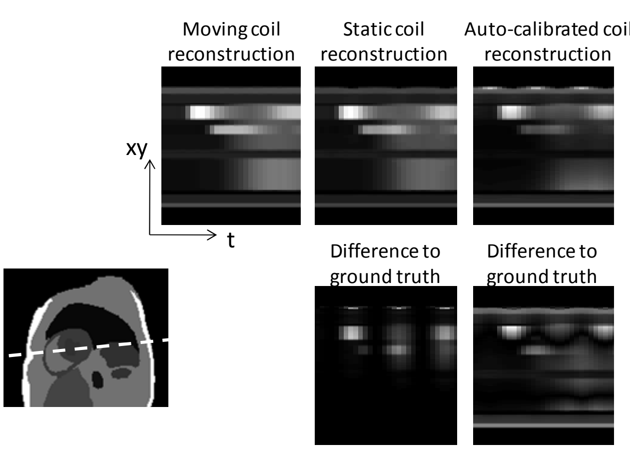

Figure 3: Image profile over time taken along the dashed line for moving coil, static coil and autocalibration reconstruction. The impact of coil motion on reconstruction accuracy is clearly seen.

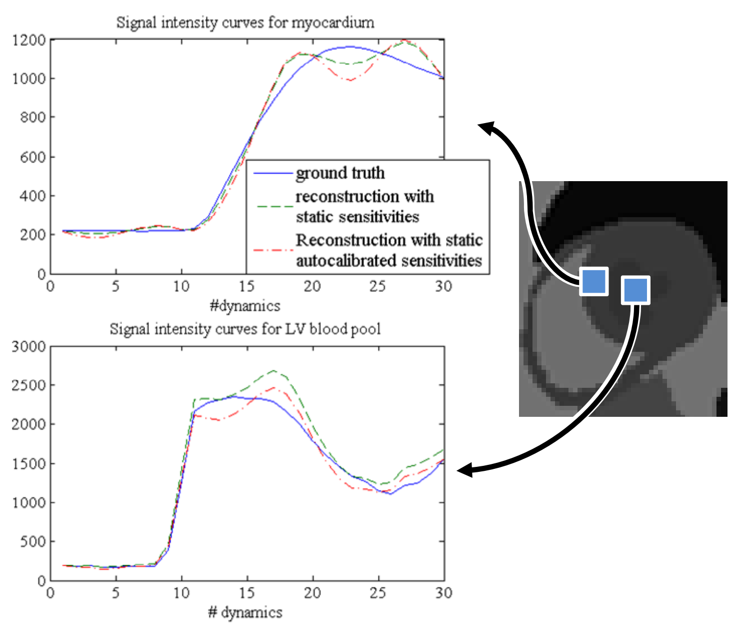

Figure 4: Signal intensity curves for mycoardium (top) and left ventricular blood pool (bottom) for true, static and autocalibrated sensitivity maps.