# Self-calibrated Spiral SENSE

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## Introduction

Currently, sensitivity encoding (SENSE) imaging (1) uses a calibration scan to map coil sensitivities, which increases total scan time and may introduce spatial misregistration due to motion. Self-calibration by replacing sensitivity maps with a low resolution image constructed from the k-space center has been developed in SMASH imaging (2,3). Here, we extend the self-calibration strategy to spiral SENSE reconstructions. The densely sampled k-space center in spiral imaging is an inherent candidate for self-calibration.

## Methods and Materials

The self calibration algorithm is to replace the normalized coil sensitivity map $C_l(r)/\sqrt{(\sum_l|C_l|^2)}$ with a normalized low resolution image $L_l(r)/\sqrt{(\sum_l|L_l|^2)}$, where $L_l$ is constructed from the k-space center data using discrete Fourier transforms. This replacement is a decent approximation due to the smooth spatial variation of coil sensitivities. In our implementation, a threshold was applied to $\sum_l|L_l|^2$ to condition division, and the low resolution images were input into the conjugate gradient (CG) algorithm (1).

Phantom/human experiments were performed to validate the self-calibrated SENSE method: 1) coil sensitivity maps were compared directly with lower resolution images in phantom; 2) various sizes of "k-space center" were compared to identify optimal low resolution on both phantom and human data. Experiments were executed with uniform spiral trajectories (TE/TR = 1.1/11.7msec, 24 interleaves with 1898 pts/interleaf) and 4-element cardiac coils on 1.5T GE MRI scanner.

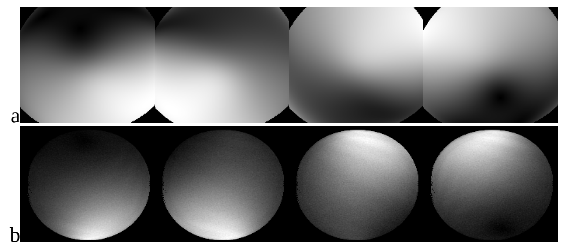


Fig.1. a) normalized low resolution images from self calibration. b) sensitivity maps measured using a uniform phantom.

## Results

The self-calibrated spiral SENSE imaging with 2x reduction was performed on phantom and human. The normalized low resolution images (Fig.1a) demonstrated spatial variation similar but not identical to the normalized sensitivity maps (Fig.1b). The SENSE image using low resolution image input (Fig.2c) is almost identical to the SENSE image using sensitivity map input (Fig.2b) (there was a small misregistration in the coil sensitivity map Fig.2b).

The effects of k-space center size characterized by the image error (RMS between the self-calibrated SENSE image and the standard full k-space image) are illustrated in Fig.3, indicating an optimal k-space diameter of 4/FOV for the self-calibration algorithm.

An example of human self-calibration SENSE imaging is depicted in Fig.4. The 2x reduction self-calibrated SENSE image provided image quality similar to the full k-space data set.

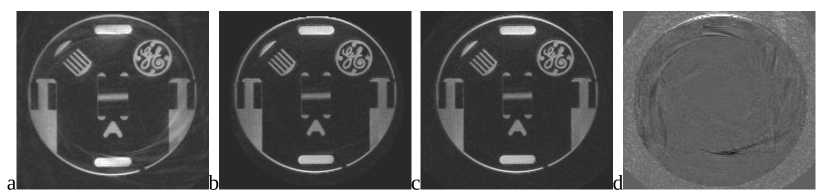


Fig. 2. Phantom images from a 2x reduction data: a) before and b) & c) after 3 iterations of the SENSE conjugate gradient (CG) algorithm, with (b) from sensitivity maps and (c) from self-calibrated low resolution images. (d) is the difference between (b) and (c).

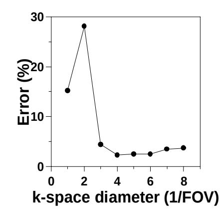


Fig.3. Error in self-calibrated SENSE image vs k-space size of the lower resolution image

## Discussion

Our preliminary data demonstrate that the self-calibration algorithm is feasible for SENSE spiral imaging. The optimal k-space center size is about 4/FOV for constructing the low resolution images in the self calibration algorithm. Through the conjugate gradient iterative inversion, the low resolution images provide similar SENSE image as the coil sensitivity maps.

## References

1. Pruessmann KP, et al. MRM 2001; 46:638-651.
2. McKenzie CA, et al. MRM 2002; 47:529-538.
3. Yeh EN, et al, ISMRM 2002, 2390.


Fig. 4. Human cardiac reconstructions from (a) full data set and (b,c) 2-fold reduced data set. (b) is the CG reconstruction after 3 iterations and (c) is before iteration.