Multi-dimensional radial self-navigation with non-linear reconstruction for free-breathing coronary MRI

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Purpose/Introduction

The main challenge for cardiac MRI is motion. To account for respiratory motion, k-space-based self-navigation approaches have recently been introduced [1]. We took self-navigation to the next level by exploiting an image-based beat-to-beat respiratory motion correction algorithm [2] for coronary MRI. For each heartbeat, under-sampled sub-images (sub-sets of data used for final image reconstruction) are reconstructed and multi-dimensional respiratory motion parameters extracted. Non-linear reconstruction (related to Compressed Sensing) is proposed to generate the motion-corrected sub-images and the results are compared to those of a more conventional approach [3]. These studies include computer simulations and initial 3T human in vivo data.

Subjects and Methods

For motion estimation, all the sub-images were affine registered to a reference image. A relative in-plane displacement was then extracted from each sub-image prior to motion correction in k-space. Final conventional reconstruction of all combined motion-corrected k-space data was then performed. A MATLAB computer simulation mimicked heart and liver anatomy with superimposed cardiac and/or respiratory motion. Motion patterns as well as signal and contrast values were obtained from in vivo data. A 2D motion-corrected radial acquisition was simulated with A) a non-linear Total-Variation-based reconstruction [4,5] and B) a conventional reconstruction. The extracted displacement values of the sub-images were compared to the ground truth with linear correlation. The identical reconstruction pipeline was used for processing offline in vivo data obtained at 3T from 3 healthy adult subjects.

Results

In the conventionally reconstructed sub-images of the simulation, streaking artifacts were observed (Fig.1B). This adversely affected motion estimation as demonstrated by linear correlation (R^2=0.89, Fig.2A) and caused blurring of the heart and small coronary vessel in the final image (Fig.3C). However, using non-linear reconstruction, the anatomy in the sub-images (Fig.1C) is much better defined and motion estimation is substantially improved (R^2=0.99, Fig.2B). This directly led to a better depiction of the vessel in the final reconstruction (Fig.3D). In the in vivo coronary MRA (Fig.4), an improved visual delineation of the right coronary artery is obtained with the new approach (Fig.4B).

Discussion/Conclusion

We have developed and tested a new image-based self-navigation approach for free-breathing coronary MRI that extracts multi-dimensional motion-correction parameters directly from the sub-images while avoiding the need for a motion model or additional acquisitions. Using non-linear reconstruction, both the accuracy of motion estimation and image quality were consistently improved in a computer model and in preliminary in vivo data.

References

[1]MRM(2005)54:476-480 [2]MRM(2004)52:1127-1135 [3]IEEE-TMI(1991)10:473-478 [4] IEEE-TIP(2009)18:2419-34 [5]IEEE-JSTSP(2007)1,4:564-574

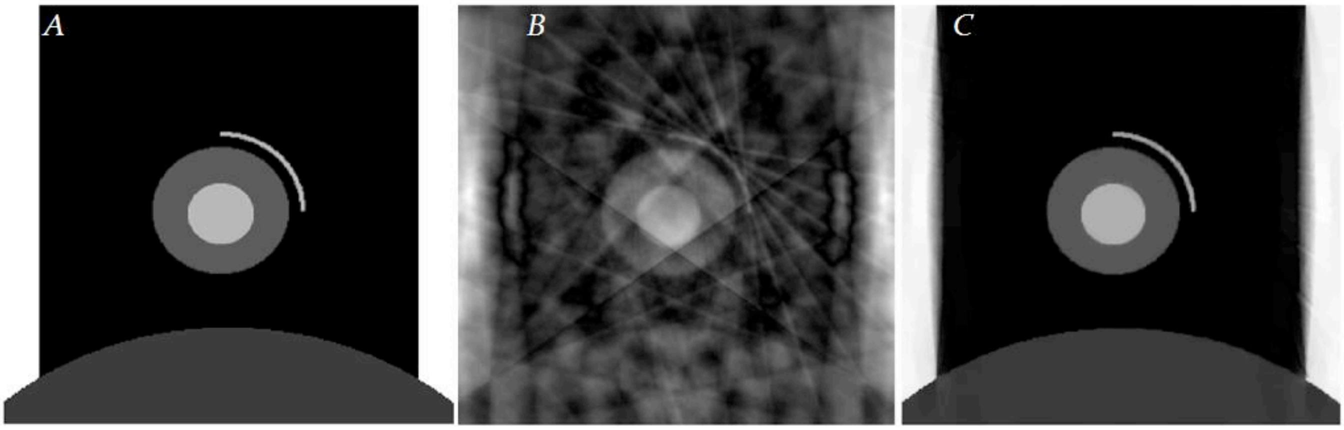

Figure 1 – Numerical simulation. A) Original image. **B)** Sub-image using 5% of the data (from one heartbeat) from image in A reconstructed with the conventional approach. **C)** Sub-image using 5% of the data (from one heartbeat) from image in A but reconstructed with the non-linear method.

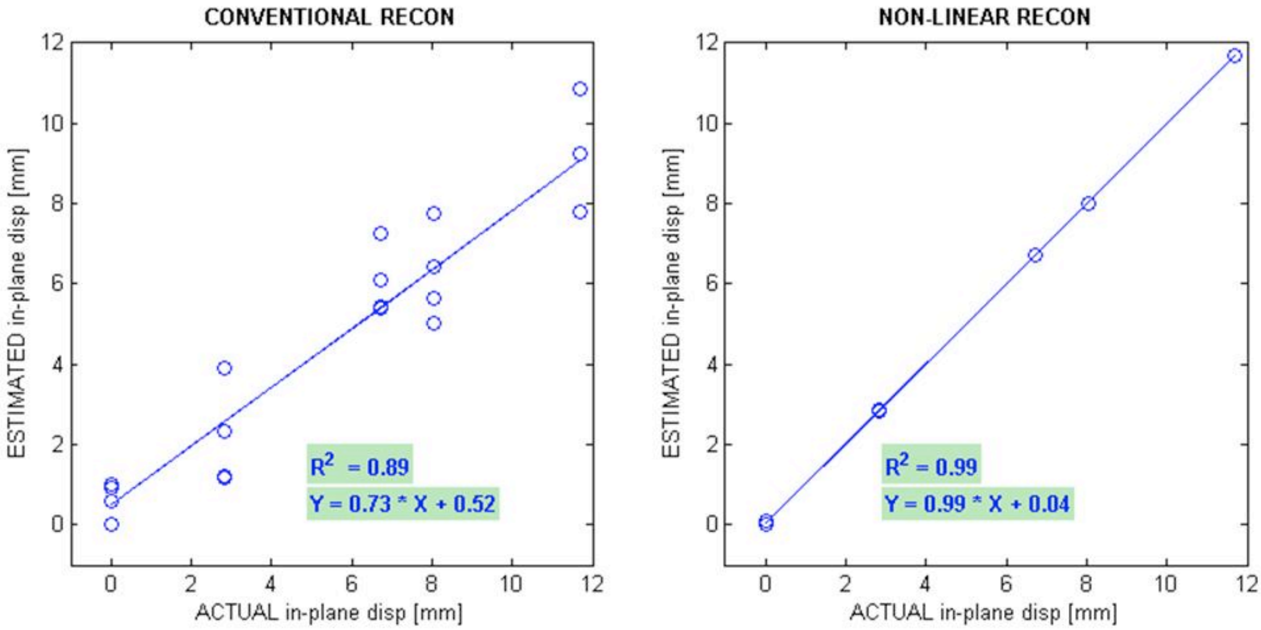

Figure 2 – Statistical analysis of the numerical simulation. Linear Regression analysis of in-plane displacements estimated by the motion correction algorithm (ESTIMATED in-plane disp) and the "known" displacements (ACTUAL in-plane disp). **A)** Results obtained with conventional reconstruction. **B)** Results obtained with non-linear reconstruction.

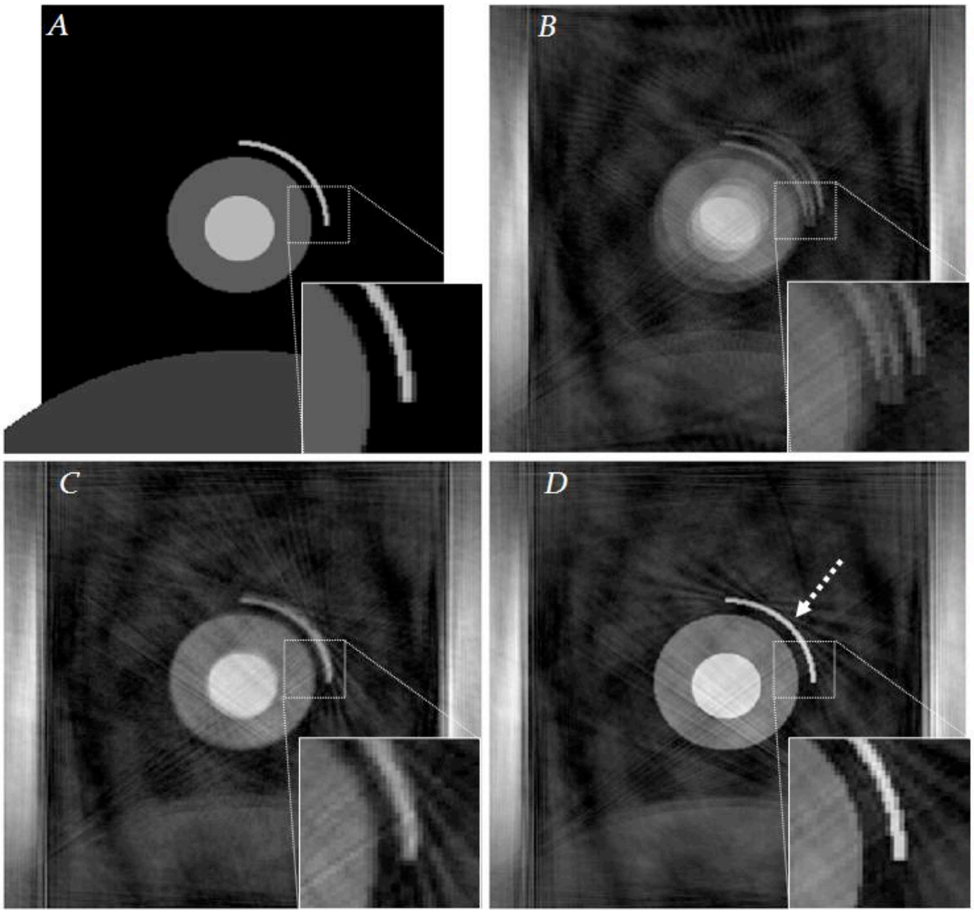

Figure 3 – Numerical simulation: 2D radial self-navigated reconstruction results. A) Original simulation. **B)** Motion corrupted image without any motion correction. **C)** Motion corrected image using conventional sub-image reconstruction. **D)** Motion corrected image using non-linear sub-image reconstruction, with which a better visualization of the coronary vessel can be obtained (dotted arrow). The following parameters were used: 20 interleaves, 300 projections in k-space, 15 projections per interleave, 256 matrix, 256x256mm FOV, regridding on a 256x256 matrix.

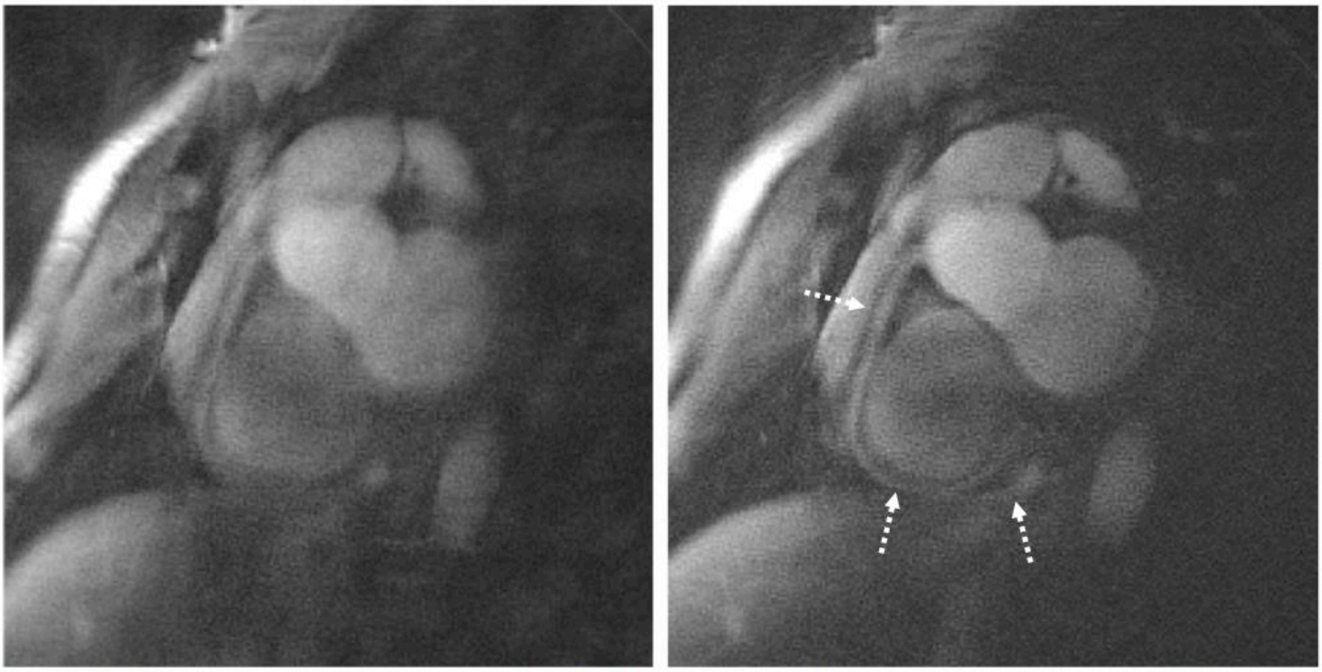

Figure 4 – *In vivo* result: right coronary artery. A) Motion corrupted image without any motion correction. **B)** Motion corrected image using non-linear sub-image reconstruction, with which an improved visual delineation of the coronary artery can be obtained (dotted arrows). Acquisition parameters: 368 sample per projection, 364 projections in k-space, 26 interleaves, 14 projections per interleave, 368 matrix, 0.8x0.8mm resolution, 5mm slice thickness, 300x300mm FOV, TE=3.26ms, TR=7.2ms, T2prep=50ms, α=15deg, BW=234Hz/pixel.