Spiral PILS Coronary Artery Imaging

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Introduction: The goal of this study is to apply the partially parallel imaging with localized sensitivities (PILS) [1] technique to spiral coronary artery imaging. Like other parallel imaging techniques [2-5], PILS is designed to increase image acquisition speed. Some of the advantages of PILS are that it does not require complicated post-processing algorithms to reconstruct the image, it does not need additional time for measuring coil sensitivities or acquiring auto-calibration lines and it has the maximum possible SNR efficiency in parallel imaging. PILS was initially applied on Cartesian trajectories for 1D acceleration, but it also provides 2D acceleration for spiral trajectories with a fast, non-iterative image reconstruction [6].

Methods: While most parallel imaging techniques use combinations of coil data to reduce aliasing artifacts in the image due to k-space under-sampling, the PILS technique utilizes the fact that every coil element has a limited sensitivity profile, so that some degree of under-sampling in k-space would not cause significant aliasing artifacts that would otherwise occur if the whole body coil was used. For spiral imaging, the major source of aliasing comes from the first side lobe of the point spread function (PSF) of the spiral sampling function, which is a series of spiral arcs and can be approximated as a circle with a certain diameter. If the spiral trajectory is designed in such a way that the radius of the first side lobe is larger than the span of the largest coil sensitivity profile, then no aliasing interferes with the region of interest in each coil image. In this way, an under-sampling factor of two or larger can usually be achieved. It has been shown that under-sampling along the spiral trajectory requires separate demodulation hardware for each RF channel [7], which is not available on commercial scanners so far. In this study, we do not under-sample along the spiral trajectory. We use spiral trajectories that are under-sampled between interleaves by a factor of two and each coil image is reconstructed using gridding with a Kaiser-Bessel kernel. A Fermi window mask is applied to each of these coil images so that the aliasing energy in each coil image is suppressed and the resulting images are combined using square root of sum of squares.

Coronary artery images of normal volunteers were acquired on a Siemens 1.5T Avanto scanner using a spiral trajectory that was under-sampled by a factor of two between interleaves and the PILS reconstruction was implemented using Matlab (Mathworks, Natick, MA, USA).

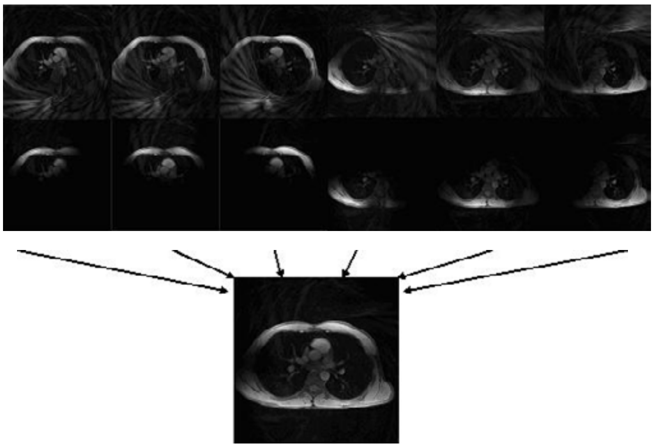

Figure 1: PILS reconstruction of spiral data with an under-sampling factor of two. A Fermi window is applied in each coil image to suppress aliasing artifacts and the resulting aliasing-free images are combined to give the full FOV of the final image.

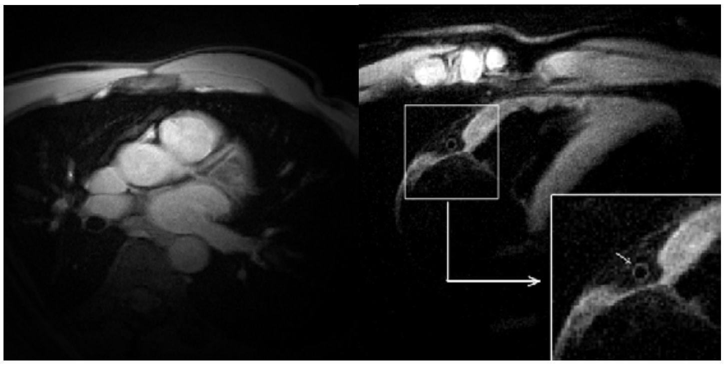

Figure 2: Coronary artery images reconstructed using PILS. The left image, acquired using three coil elements, delineates the proximal LAD and circumflex coronary arteries. The right image shows the application of PILS to black blood right coronary artery wall (arrow) imaging. In both images, no noticeable aliasing artifacts are observed and a factor of two reduction in imaging time was achieved.

Results: Figure 1 shows the steps involved in spiral PILS reconstruction. Because the aliasing pattern of a spiral trajectory is different from that of Cartesian trajectories, a circularly symmetric Fermi mask window is applied to each coil image so that the region with significant aliasing energy is suppressed. The resulting aliasing-free coil images cover different regions of the full FOV and are combined together using square root of sum of squares, generating the full FOV non-aliased image. Figure 2 shows two PILS images reconstructed for two example applications, one being spiral coronary angiography and the other being dark blood coronary wall imaging. In both images, no noticeable aliasing artifacts are observed and a factor of two in imaging time reduction is achieved.

Discussion: PILS has significant advantages for spiral scanning when the RF coils have localized sensitivity maps. In this work, the RF coil elements are relatively large compared to the human heart. A coil array with smaller coil elements and a larger number of coils is preferable for PILS, because of the more localized sensitivity profile for the coil elements. The increase in imaging speed provided by spiral PILS can be used to reduce the breath-holding interval or to increase the spatial resolution for spiral coronary artery imaging. As a high SNR parallel imaging method, PILS is a valuable tool in breath-held coronary artery imaging, which is typically SNR limited.

Conclusion: We demonstrated the successful application of the PILS technique to spiral coronary angiography and coronary artery wall imaging. Smaller and more localized coils may be used in the future to increase the speed-up factor for spiral PILS coronary artery imaging.

References:

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