Free Breathing Whole Heart Coronary Angiography on a Clinical Scanner in less than 4 Minutes

K. Nehrke[1], P. Börnert[1], C. Stehning[2], R. Winkelmann[2], I. Grässlin[1], J. Overweg[1], P. Mazurkewitz[1], T. Rozijn[3]
[1]Philips Research Laboratories, Hamburg, Germany, [2]University of Karlsruhe, Karlsruhe, Germany, [3]Philips Medical Systems, Best, Netherlands

Introduction

Whole heart coronary MRA has become increasingly interesting over the last years [1,2]. Although, parallel imaging techniques have been employed in recent protocols [1], the total scan time is still rather long. However, with the introduction of a new MR scanner generation supporting up to 32 channels and corresponding reception coils, SNR can be slightly increased and further acceleration of these protocols becomes feasible. Thus, some approaches already address whole heart coronary MRA in a single breath-hold using massively parallel imaging [3]. However, these breath-holds are still rather long, not applicable for the majority of patients, and the resolution is limited by SNR. To increase patient comfort and to overcome the breath-hold restriction, free breathing highly accelerated whole heart CMRA is performed in this work.

Methods

All in-vivo experiments were performed on healthy adults (7 male) using a 1.5T whole body scanner (Achieva, Philips Medical Systems) equipped with 32 receive channels. The body coil was used for RF transmission, and a 32-element whole body phased array coil was used for signal reception. The receive-coil was arranged as two flexible 4×4 arrays, each of 37×37 cm² size, one placed at the back and one on top of the patient. After a short localizer-scan, the low-resolution 3D sensitivity maps of the 32 reception coils were measured with the body coil considered as a homogenous reference. The acquisition of the 3D sensitivity maps took 30 seconds divided over 3 breath-holds. For the whole heart scans an ECG triggered, free breathing, navigator-gated and -tracked (right hemi-diaphragm, window 5mm, tracking factor 0.6), fat suppressed 3D balanced FFE (flip angle: 70°, α/2-TR/2 start-up + 10 dummy cycles to approach the steady state, TR/TE: 4.2/2.1 ms, FOV: $180 \times 180 \times 150$ mm³, voxel size: $1.25 \times 1.25 \times 1.25$ mm³) sequence was performed. The cardiac acquisition window had duration of 120ms and was placed mid/late-diastole. The total scan time was below 4 minutes (at heart rate of 60bpm and 50% navigator efficiency). The three-dimensional acquisition with such large volume coverage allows for more efficient subsampling strategies, as to subsample k-space in two spatial frequency dimensions [4]. This enabled SENSE factors up to 3.5×2 for scan acceleration. Image reconstruction was performed on the scanner using the SENSE algorithm [5] including global sensitivity correction.

Results and Discussion

High contrast whole heart 3D images of high spatial resolution have been obtained in all volunteers. Figure 1 shows reformatted images of such a 3D data set of one selected volunteer. This illustrates the large volume coverage and the high spatial resolution of the scan. Although the multi-purpose array coil used in this work is not a dedicated cardiac array, high SENSE factors were achieved without noticeable SENSE artifacts (underlined by the low geometry factor). The use of 32 individual coils furthermore increases the SNR, which can be transformed into an accelerated acquisition. The entire workflow from data acquisition and reconstruction does not need any user interaction. The reconstruction time is about 30 seconds, while data acquisition for a scan to be performed subsequently is not blocked during this time. This reconstruction rate is rather fast, considering the workload of 32 receivers, and allows efficient clinical workflow. All scans were completed in total scanning times shorter than 4 minutes. Such short scan times can also have considerable impact on the image quality, because it minimizes bulk patient motion related artifacts.

Whole heart protocols considerably simplify the planning procedure. However, the effort formerly spent on precise planning is now necessary for post-processing as to ease the viewing for the physician e.g. by appropriate data reformatting.

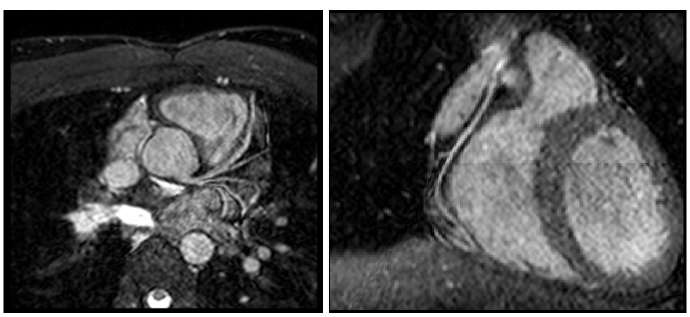

Figure 1: Reformatted images of a volunteer's whole heart data set. Left coronary system (LM, LCX) (left) and RCA (right).

Conclusion

Highly accelerated whole heart coronary MRA is possible on clinical systems supporting a large number of receive channels. Massively parallel imaging will have a great impact on cardiac exams in the future. The short total scanning time (<4 minutes) of this free breathing examination increases patient comfort and allows to add a whole heart coronary scan covering all major vessels to a routine cardiac examination, making a comprehensive patient study possible.

References

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