Single Breath-Hold Whole-Heart 3D CINE Imaging Using kt-BLAST and kt-SENSE

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Introduction

Conventional breath-held 2D CINE imaging of the heart can be time consuming and bears the risk for slice registration errors due to the use of multiple breath-holds. The speed advantage inherent to parallel imaging can be used for streamlining cardiac functional assessments[1, 2, 3]. This is of profound importance for addressing the problem of long examination times in conventional 2D CINE imaging. Accelerated CINE imaging also yields the potential to use large imaging volumes, which may render localizer scans obsolete and increase patient comfort by substantially improving scan efficiency. This study examines the feasibility of up to 8-fold accelerated single breath-hold whole-heart coverage imaging for global cardiac function assessment by taking advantage of spatiotemporal correlations. For this purpose the kt-BLAST and kt-SENSE[4] approach was incorporated into a 3D steady-state free-precession (SSFP) based imaging technique. For comparison, conventional 2D CINE imaging was performed, which requires 8-12 breath-holds and rest periods to cover the entire heart.

Material and Methods

In seven subjects (5 male, 2 female, 28.3 ± 4.1 years) accelerated ECG-gated whole-heart 3D SSFP CINE imaging (TR/TE: 3.4/1.7 ms, flip angle: 45°, FOV: 350 mm, matrix: 144) was performed on a 1.5 Tesla whole-body MR system (Achieva, Philips Medical Systems, Best, NL) with simultaneous accelerations along both phase encoding directions. Acceleration factors ranged from R=5 (20 cardiac phases) to R=8 (24 cardiac phases). Large 3D short axis slabs consisting of 12 slice partitions covering a volume of 9.6 cm (interpolated voxel size of 1.3 x 1.3 x 4.0 mm^3) were acquired in a single breath-hold (breath-hold duration: 22 sec for R=5 and 20 sec for R=8). Low spatial resolution training data were acquired using a short separate scan (scan time: 5 and 6 sec, respectively). At first, image reconstruction was performed using kt-BLAST. Afterwards, kt-SENSE images were reconstructed using coil sensitivity maps obtained from a reference scan. Image quality was compared to 2D SSFP CINE images (TR/TE: 3.7/1.85 ms, flip angle: 60°, FOV: 350 mm, matrix: 192, reconstructed to 384, number of slices: 9, slice thickness: 8 mm, breath-hold duration: 14 sec per slice) consuming single breath-hold per slice. End-diastolic and end-systolic volume (EDV, ESV), stroke volume (SV), ejection fraction (EF), and the left ventricular mass (LVM) were analyzed. Statistical significant differences ($p<0.05$) between the accelerated and conventional approach were analyzed using non-parametric *Wilcoxon* test.

Results

3D SSFP CINE imaging of the entire heart was successfully performed in all subjects. Representative short axis views and reformatted four-chamber views are shown in Fig. 1. The myocardial boarders are clearly delineated in both, short axis views and reformatted four-chamber views derived from 3D CINE acquisitions. For comparison, severe slice registration errors are present in the reformatted four-chamber view obtained from 2D CINE imaging. The use of accelerated volumetric imaging resulted in a decrease of the blood/myocardium contrast due to saturation effects. Furthermore, the contours of the myocardium are more blurred in the original short axis views compared to the conventional 2D CINE approach. This can be attributed to the (i) reduced in-plane spatial resolution and (ii) the increase in the acquisition window length per cardiac phase. Differences ($p<0.05$) were found for the measured EDV, SV, EF, and the LVM as illustrated in Fig.2. Image quality was comparable between kt-BLAST and kt-SENSE as well as between an acceleration factor of 5 and 8.

Discussion and Conclusion

The feasibility of single breath-hold whole-heart 3D CINE imaging with up to eight-fold acceleration has been demonstrated. The spatial resolution used for 3D imaging facilitates arbitrary reformatted multi-oblique views while preserving image quality and slice registration. The accelerated whole-heart coverage paradigm presented here promises to extend the capabilities of routine CINE imaging from multiple slices to single large volumes. This reduces the demands for precise localization while improving both operator convenience and patient comfort. Despite the clear SNR advantage of the kt-BLAST approach vs. coil sensitivity encoding, the effective temporal resolution remains a challenge as very large accelerations are explored. In this preliminary study, decreased EDV, SV, EF, and LVM were observed. A recognized limitation of this study is its assessment in a limited number of subjects. Therefore, efficacy of the described accelerated 3D methods in the clinical routine environment awaits further study.

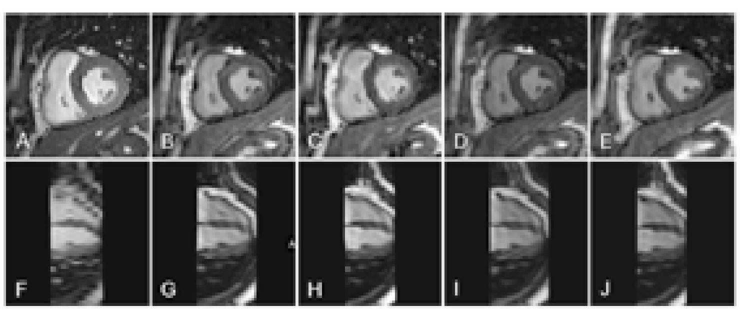
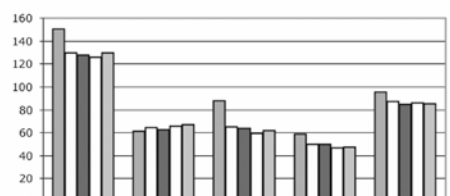


Fig. 1:
Original short axis views (A-E) and reformatted four-chamber views (F-J) using 2D cine imaging (A, F), 5-fold accelerated 3D cine imaging with kt-BLAST (B, G) and kt-SENSE (C, H), and 8-fold accelerated 3D cine imaging with kt-BLAST (D, I) and kt-SENSE (E, J), respectively.



	EDV	ESV	SV	EF	LVM
2D Cine conv.	150.5	61.4	88.2	58.8	95.8
3D kt-BLAST 5	129.7	64.3	64.9	49.9	87.3
3D kt-SENSE 5	127.6	62.8	64.2	50.3	84.8
3D kt-BLAST 8	125.7	65.7	59.2	47.0	86.3
3D kt-SENSE 8	129.4	66.9	61.7	47.7	85.1

Fig. 2
Summary of the left-ventricular physiological parameter

References

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