Cardiac MR fingerprinting with a short acquisition window in healthy volunteers and 62 consecutive patients referred for clinical CMR

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Synopsis

Cardiac magnetic resonance fingerprinting (cMRF) can be used to simultaneously acquire myocardial T_1 and T_2 maps in a single breath-hold. However, the common 250 ms acquisition window of cMRF might leave it vulnerable to motion artefacts. The goal of this study was therefore to compare the performance of cMRF with a short acquisition window (150ms) and low-rank reconstruction to that of routine cardiac parametric mapping techniques. In 7 healthy volunteers, and 62 cardiac patients, cMRF resulted in similar native relaxation times, but slightly different post-contrast T_1 and ECV values compared to routine techniques.

Introduction

Cardiac magnetic resonance fingerprinting (cMRF[1]) has been demonstrated to be a robust and accurate T_1 and T_2 mapping technique. However, the common 250ms acquisition window of cMRF might leave it vulnerable to motion artifacts in patients with high heart rates. A shorter acquisition window would thus be desirable, especially if the loss in precision due to less acquired signal can be compensated with a low-rank reconstruction. The goal of this study was therefore to compare the accuracy and robustness of a cMRF sequence with a short acquisition window and low-rank reconstruction[2] to routine T_1, T_2, and ECV mapping techniques. The comparison was performed both in a small cohort of healthy volunteers and in a heterogeneous group of consecutive patients referred for clinical CMR.

Methods

The accuracy of cMRF with a short acquisition window was first compared to reference and clinical routine parameter mapping techniques (MOLLI[3]; T_2-prepared bSSFP[4]) in the ISMRM-NIST phantom (QalibreMD) at 1.5T (Sola, Siemens). Reference T_1 and T_2 relaxation times were obtained with inversion-recovery TSE and multi-echo SE, respectively. Due to the sensitivity of the routine cardiac T_2 mapping sequence to short T_1 values, only those spheres with T_1>500ms were taken into the T_2 analysis. In vivo, cMRF was performed with the following parameters in both subject groups: 29 readouts/heartbeat, duration 15 heartbeats, pixel size=1.6x1.6mm2, slice thickness=8mm3, acquisition window=150ms. For each slice, a heart-rate dependent low-rank dictionary was created and used to reconstruct the parametric maps. The dictionaries were designed to take the slice excitation profile and B_1^+ inhomogeneity into account [2]. The human study was approved by the Institutional Review Board, and participants provided informed consent. In the healthy volunteers group (n=7, average age=27, 80% female), routine T_1 and T_2 maps and cMRF were acquired at three short-axis and a four-chamber orientation. In consecutive patients referred for CMR (n=62, average age=58y, 30% female), routine native T_1 (n=62) and T_2 (n=12) mapping as well as cMRF (n=62) were acquired in one basal slice; routine T_1 mapping (n=47) and cMRF (n=47) were also performed 20-25 minutes after gadolinium injection (0.2 ml/kg Dotarem). The parameter maps were manually segmented, and the synthetic ECV was calculated[6]. Linear regression against the reference values was used to assess accuracy in the phantom, while Student's t-tests and Bland-Altman analyses were used to assess differences between routine techniques and short acquisition window cMRF in vivo.

Results

The phantom mapping demonstrated similar or higher T_1 and T_2 accuracy of the cMRF over a wider range than the routine mapping techniques (Fig.1). In the healthy volunteers (Table 1), the cMRF myocardial T_1 and T_2 values showed small but non-significant differences compared to MOLLI (cMRF: 1019±90ms; Routine: 1001±48ms, p=0.28) and T_2-prepared bSSFP (cMRF: 43±4ms; Routine: 46±4ms, p=0.02). In the patients, both the native T_1 (cMRF: 1011±61ms; Routine: 1028±56ms, P=0.17) and T_2 (cMRF: 44±7ms; Routine: 46±3ms, p=0.53) values confirmed the good agreement (Fig.2). However, post-contrast myocardial T_1 values (Fig.2C-D, Fig.3B) were lower than the routine values (cMRF: 391±43ms; Routine: 441±43ms, p<0.001), while the blood pool values did not differ (cMRF: 268±42ms; Routine: 282±47ms, p=0.23). This was then reflected by slightly higher estimations of the synthetic ECV (cMRF: 28±4%; Routine: 26±3%; p=0.02).

Discussion

cMRF with a short acquisition window and low-rank reconstruction performed similarly or better than routine techniques when tested against reference relaxation times obtained from the NIST phantom. In vivo, the overall average cMRF and routine relaxation times appeared to be highly similar in healthy volunteers and patients. The small but significant T_2 difference observed in healthy volunteers might be due to the small sample size. The difference in post-contrast myocardial T_1 is more significant, and might for example be caused by partial volume effects, through-plane motion, or a T_2 influence on the 4(1)3(1)2 MOLLI fit[7]. These findings warrant that ECV be measured with cMRF in a cohort of healthy volunteers in order to establish healthy reference values. Overall, we conclude that in 62 consecutive patients, cMRF with a short acquisition window and low-rank reconstruction resulted in comparable native cardiac T_1 and T_2 values when compared to routine techniques, but resulted in slightly different post-contrast myocardial T_1 and ECV estimations.

Acknowledgements

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References

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Figures

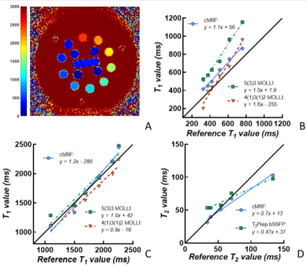

Figure 1. Accuracy of cMRF compared to reference techniques in the ISMRM-NIST phantom. A) T_1 map of the reference phantom obtained with short acquisition window cMRF. B) Linear regression plots of T_1 values in the phantom in the post-contrast myocardial T_1 range. C) Linear regression plots of T_1 values in the phantom in the native myocardial T_1 mapping range. cMRF is as accurate at the long and short T_1 values as the dedicated MOLLI sequences are. D) Linear regression plots for the T_2 values. The lower slopes are likely due to the contributions of stimulated echoes to the multi-echo SE.

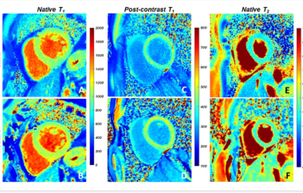

Figure 2. Representative T_1 and T_2 maps acquired with cMRF (top row) and routine technique in several patients. A,B) T_1 maps before contrast agent injection (72 y.o., male). The maps have comparable precision and accuracy. A small artefact from a stent can be observed at the posterior right ventricle insertion point in both maps. C,D) T_1 maps 20-25 minutes after contrast agent injection (27 y.o., male). The T_1 values are slightly higher in the centre of the myocardium of the routine maps. E,F) Native T_2 maps (57 y.o., female).

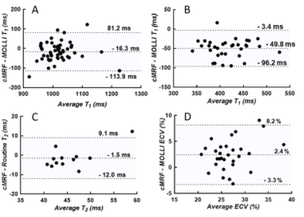

Figure 3. Bland-Altman analyses of cMRF and routine techniques for the entire myocardium in patients. A) Native T_1 relaxation times obtained with cMRF vs. 5(3)3 MOLLI. B) Post-contrast T_1 relaxation times obtained with cMRF vs. 4(1)3(1)2 MOLLI. A significant bias was observed, while the post-contrast LV blood T_1 was not significantly different between the two techniques. C) Native T_2 relaxation times obtained with cMRF vs. T_2-prepared bSSFP. D) ECV calculated with cMRF vs. the routine techniques.

	Healthy Volunteers			*Patients*		
	cMRF	*Routine*	*p value*	*cMRF*	*Routine*	*p value*
Native T_1 (ms)	1019 ± 90	1001 ± 48	0.28	1011 ± 61	1028 ± 56	0.17
Native T_2 (ms)	43 ± 4	46 ± 4	0.02	44 ± 7	46 ± 3	0.53
Post-contrast T_1 (ms)				391 ± 43	441 ± 43	< 0.001
ECV (%)				28 ± 4	26 ± 3	0.02

Table 1. The average myocardial relaxation times and ECV measured with cMRF and routine techniques. Similar native relaxation times were measured with all techniques and in both the healthy volunteers and patients. However, the post-contrast myocardial T_1 values differed between cMRF and MOLLI, which together with similar post-contrast blood T_1 values resulted in slightly different ECV estimations.