Myocardial T1 mapping at 3T by sampling inversion recovery with real time turboflash

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INTRODUCTION T1 mapping is useful in the diagnosis of non-ischemic cardiomyopathies such as myocardial fibrosis [1] and is commonly performed using MOLLI [2]. However, MOLLI and its variants are sensitive to arrhythmia, tissue T2 values etc. and underestimate T1 [3]. Use of saturation recovery for magnetization preparation reduces a technique's sensitivity to heart rate, but it also reduces the signal's dynamic range [4]. At 3T, balanced SSFP readout is also susceptible to banding artifact. In this study, we propose an arrhythmia insensitive myocardial T1 mapping technique at 3T with scan time less than 6 seconds.

THEORY AND METHOD Theory The sequence, IR-rttfl, performs realtime turboflash acquisition after an inversion pulse to sample the recovery of inverted magnetization (see Fig.1). Diastolic images are selected retrospectively based on time stamps of raw data for T1 calculation using formula in [5]. A trigger delay (about 400-500ms) is applied before the inversion pulse to ensure that initial magnetization recovery is sampled during the diastole of the first heart beat. Parallel imaging improves temporal resolution and asymmetric echo shortens TR. The sequence was implemented on a 3T scanner (TIM Trio/Verio, VB17A, Siemens, Erlangen). Phantom and healthy volunteer study were performed on Trio while patients study was done on Verio. Experiments The accuracy of IR-rttfl was first tested on phantoms doped with gadolinium with known T1 and T2 values measured by spin echo sequence (TR=10s). Parallel imaging was not used to keep temporal resolution consistent with *in-vivo* experiments later. The technique was then evaluated in ten healthy volunteers (IRB approved with informed consent) on three mid-ventricular short-axis slices. In four of them, MOLLI was also acquired for comparison. Finally, gadolinium contrast study was performed on three patients with myocardial infarction using both IR-rttfl and MOLLI. Imaging parameters used were: TR/TE=2.3ms/1.1ms, flip angle=5°, base matrix=192, TGRAPPA rate 3, temporal resolution=80-100ms (subject dependent). 60 measurements were acquired (scan time < 6s). Scanning was performed with breathhold.

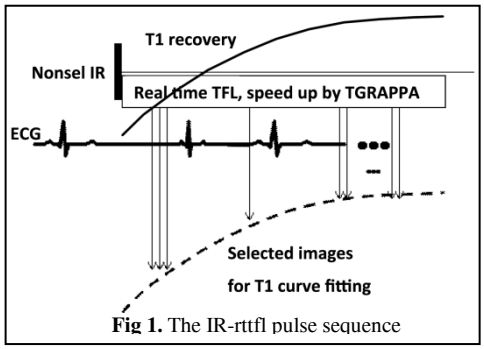

Fig 1. The IR-rttfl pulse sequence

RESULTS AND DISCUSSION The T1 values estimated by IR-rttfl and MOLLI were plotted against reference values measured by spin echo in the phantom study (Fig 2). The simulated heart rate for MOLLI was 60bpm. T1 values of IR-rttfl were comparable with spin echo while the T1 values of MOLLI are slightly underestimated when T1>1000ms. In healthy volunteers, T1 values of myocardium and blood averaged over all the volunteers and slices were 1254ms±81ms and 1727ms±52ms. In four of them, T1 values of myocardium and blood from MOLLI were 1157ms±68ms and 1652ms±37ms respectively. For patient study, one slice with infarction was selected for analysis from each patient based on the phase-sensitive inverse recovery (PSIR) images. The averaged RR intervals for the three patients were 1066, 919 and 1294ms. MOLLI failed in one patient due to long breathhold times. Typical T1 maps from a patient before and after contrast using these two methods are shown in Figure 3. The myocardium was then segmented according to the AHA model [6]. Table 1 shows the T1 values of each segment using IR-rttfl and MOLLI. The T1 values of normal myocardium measured by IR-rttfl were generally slightly higher than the MOLLI values. This may be due to the underestimation of myocardial T1 values by MOLLI [3]. Imperfect image registration and contouring might also affect the accuracy of the segmental T1 values. In the post-contrast study, the T1 values of the two methods were different due to different acquisition times. The averaged partition coefficients of normal myocardium and infarct using IR-rttfl were 0.39 and 0.54. The corresponding values for MOLLI were 0.42 and 0.59.

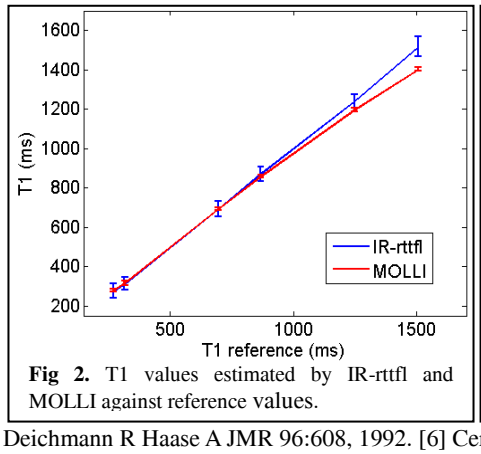

Fig 2. T1 values estimated by IR-rttfl and MOLLI against reference values.

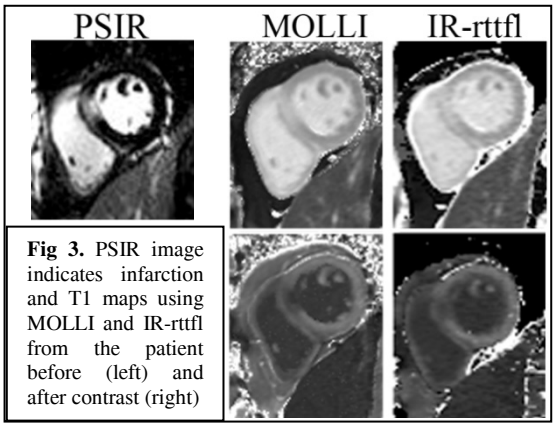

Fig 3. PSIR image indicates infarction and T1 maps using MOLLI and IR-rttfl from the patient before (left) and after contrast (right)

CONCLUSION The arrhythmia insensitive IR-rttfl performs myocardial T1 mapping in a short breathhold. It is more accurate than MOLLI in phantoms. The results are comparable to MOLLI in healthy volunteers and patients with myocardial infarction. Results from the contrast studies are promising.

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Table 1 Comparison of results of IR-rttfl and MOLLI in patient study

Pre-contrast	IR- rttfl						MOLLI					
	1	2	3	4	5	6	1	2	3	4	5	6
Patient1	1489±60	1306±80	1224±67	1197±44	1219±115	1309±176	1382±92	1269±77	1174±74	1081±45	1103±35	1098±28
Patient2	1400±78	1314±61	1269±47	1308±49	1288±74	1367±164	1331±78	1264±89	1192±58	1133±51	1029±86	1160±128
Patient3	1353±152	1267±68	1366±95	1505±71	1127±109	1024±126	Failed due to unsuccessful breathhold					
Post-contrast	IR- rttfl						MOLLI					
	1	2	3	4	5	6	1	2	3	4	5	6
Patient1	323±41	375±58	435±35	433±45	409±58	438±49	319±28	358±43	438±30	451±34	469±51	436±37
Patient2	369±24	428±34	408±40	399±26	432±30	455±35	291±33	340±49	354±29	362±20	349±38	348±39
Patient3	357±95	422±51	425±58	324±124	408±60	421±59	Failed due to unsuccessful breathhold					

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