Accuracy, Precision, and Reproducibility Comparison of T_1 Mapping Sequences

Sébastien Roujol[1], Sebastian Weingärtner[1,2], Murilo Foppa[1], Kelvin Chow[3], Keigo Kawaji[1], Kraig V Kissinger[1], Beth Goddu[1], Sophie Berg[1], Peter kellman[4], Warren J. Manning[1,5], Richard B. Thompson[3], and Reza Nezafat[1]

[1]Department of Medicine, Beth Israel Deaconess Medical Center / Harvard Medical School, Boston, MA, United States, [2]Computer Assisted Clinical Medicine, University Medical Center Mannheim, Heidelberg University, Mannheim, Germany, [3]Department of Biomedical Engineering, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada, [4]National Heart, Lung, and Blood Institute, National Institutes of Health, Bethesda, MD, United States, [5]Department of Radiology, Beth Israel Deaconess Medical Center / Harvard Medical School, Boston, MA, United States

Target Audience

Scientists and clinicians who are interested in myocardial tissue characterization.

Purpose/Introduction

Quantitative myocardial T_1 mapping can characterize myocardial tissue composition in various cardiovascular diseases. The extracellular volume fraction (ECV) can be calculated from pre and post-contrast T_1 maps and shows promise for the detection of diffuse myocardial fibrosis. Several techniques have been recently proposed for myocardial T_1 mapping [1-4], which relies on different sampling scheme of the T_1 recovery curve. However, no comprehensive comparison has been performed across these methods yet. In this study, we sought to analyze T_1 and ECV measurements in term of accuracy, precision and reproducibility from four T1 mapping sequences of Modified Look-Locker Inversion Recovery (MOLLI)[1], Shortened MOLLI (ShMOLLI)[2], Saturation recovery single-shot acquisition (SASHA)[3], and SAturation Pulse Prepared Heart rate independent Inversion-REcovery sequence (SAPPHIRE)[4].

Materials and Methods

All data were acquired on a 1.5 T Phillips scanner.

Phantom experiment: Each T1 mapping sequence was acquired 10 times using a b-SSFP readout (TR/TE=3.1/1.5ms, FOV=360×337 mm^2, voxel size=1.9×2.5 mm^2, slice thickness=8 mm, SENSE factor=2, flip angle=35°(MOLLI & ShMOLLI) / 70°(SASHA & SAPPHIRE)) in a phantom containing 14 vials ($NiCl_2$ doped agarose) with different T_1 values. A 5-(3)-3 scheme was used for MOLLI. T_1 measurements were compared to gold standard T_1 measurements obtained from spin echo (SE) acquisitions (inversion times from 100ms to 3000ms).

Healthy subject experiment: 8 healthy subjects (38±19y, 4 males) were recruited and scanned with the same four sequences. Pre-contrast imaging was initially performed twice and was followed by two post-contrast imaging at 15 and 30 minutes after contrast injection of 0.1 mmol/kg of Gd-BOPTA.

Data Analysis: T_1 maps were reconstructed offline using an in-house platform. Conditional reconstruction was used for ShMOLLI. Accuracy, precision and reproducibility were analyzed using the phantom. Accuracy was measured as the average (over the 10 repetitions) of the absolute difference between spin echo values and average T_1 within an ROI. Reproducibility was computed as the standard deviation (over the 10 repetitions) of the average T_1 within an ROI. Precision was measured as the average (over the 10 repetitions) of the T_1 standard deviation within an ROI.

In-vivo data were analyzed by a blinded observer who manually delineated both septum and blood pool in all T_1 maps. A single ECV value was then generated for each pair of pre and post contrast maps. The absolute difference of T_1 means between the two sets of pre-contrast maps and the absolute difference of ECV measurements generated from the second pre-contrast T_1 and each of the two post-contrast T_1 data were examined.

Results

Tables 1 and 2 show the results obtained in phantom studies. All methods had similar accuracy for low T_1 values (<1000ms) while SASHA and SAPPHIRE had higher accuracy than MOLLI and ShMOLLI for high T_1 values (>1000ms). Overall, SASHA and SAPPHIRE were less precise and reproducible than MOLLI and ShMOLLI. SAPPHIRE had similar accuracy and reproducibility than SASHA but higher precision for large T_1 values (>1000ms). SASHA and SAPPHIRE had lower reproducibility than MOLLI and ShMOLLI for in-vivo pre-contrast T_1 mapping (Figure 1). ECV reproducibility is similar with all methods.

Conclusions

Both SASHA and SAPPHIRE T_1 sequences yield consistent excellent accuracy, but with lower reproducibility and precision compare to MOLLI and ShMOLLI. Reproducibility of ECV measurements is similar with all methods.

Acknowledgements

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References

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		T1 measurements [ms]				Accuracy [ms]			
Vial	SE	MOLLI	ShMOL.	SASHA	SAPP.	MOLLI	ShMOL.	SASHA	SAPP.
#1	268.1	281.1	280.9	274.8	278.4	12.9	12.8	6.7	10.3
#2	327.4	323.1	323.1	335.8	336.5	4.2	4.2	8.4	9.1
#3	425.3	435.6	434.4	429.7	442.5	10.3	9.1	4.4	17.2
#4	569.2	564.4	528.9	590.9	596.8	4.7	40.2	21.7	27.6
#5	594.3	598.8	544.1	592.7	613.6	4.5	50.2	1.9	19.3
#6	705.4	679.1	566.7	730	725	26.3	138.7	24.6	19.6
#7	821.3	821	809.5	814.4	847.4	1.3	12.4	7	26
#8	939.9	880.9	840.9	955.7	961.2	59.1	99.1	15.8	21.3
#9	983.8	966.5	954	970.3	1007.7	17.4	29.9	13.6	23.9
#10	1110.1	1036.4	1003.3	1120.2	1119.4	73.7	106.7	10.1	9.3
#11	1127	1066.4	1039.1	1132.4	1152.6	60.6	88	5.6	25.5
#12	1133	1087.1	1064.9	1131.3	1163.2	45.9	68.1	2.4	30.2
#13	1141.2	1054.6	1005.5	1137.1	1144.3	86.5	135.6	8.8	5.5
#14	1465.1	1406	1401	1409.1	1487.4	59.2	64.2	56	22.3

Table 1. *Measurement and accuracy obtained in phantom studies with the four T_1 mapping methods. Excellent accuracy was achieved using SASHA and SAPPHIRE (SAPP.) for all studies T_1 ranges while MOLLI and ShMOLLI (ShMOL.) showed lower accuracy for large T_1 values (> 1000ms).*

		Precision [ms]				Reproducibility [ms]			
Vial	SE	MOLLI	ShMOL.	SASHA	SAPP.	MOLLI	ShMOL.	SASHA	SAPP.
#1	268.1	2.1	2.1	3.1	2.8	0.5	0.7	1.1	2.6
#2	327.4	2.6	2.4	4.6	4.5	1	0.5	1.9	1.8
#3	425.3	2.8	2.2	4.2	4.3	0.7	0.4	2.1	1.3
#4	569.2	2.6	2	6.1	4.4	1.3	0.6	1.8	1.8
#5	594.3	3.1	2.3	4.6	3.9	0.7	0.7	1.9	1.7
#6	705.4	3.8	2.1	9	8.1	1.2	0.4	4.1	2.6
#7	821.3	3.8	19.1	6.9	6.2	1.9	9.9	1.9	2.8
#8	939.9	4.2	5.2	9.8	7.4	1.6	2.3	5	2.6
#9	983.8	3.7	3.7	6.4	7.7	2.9	3.4	3.7	6.1
#10	1110.1	5.5	6.5	15.4	12.3	3.3	3.3	4	6.1
#11	1127	4.8	6.7	14.7	8.8	3.1	3.2	4.2	3.9
#12	1133	5	6.7	12.5	8.5	2.8	4	2.6	4.2
#13	1141.2	8	15.3	12.3	8	3.2	5.1	9.9	5.9
#14	1465.1	3.9	4.7	12.4	9	4.1	5.2	8	10

Table 2. *Precision and reproducibility of T_1 measurements obtained in phantom studies with the four T_1 mapping methods. MOLLI and ShMOLLI (ShMOL.) provided improved precision compared to SASHA and SAPPHIRE (SAPP.). Similar reproducibility was obtained with the four methods for low T_1 ranges while MOLLI and ShMOLLI showed better reproducibility for higher T_1 ranges.*

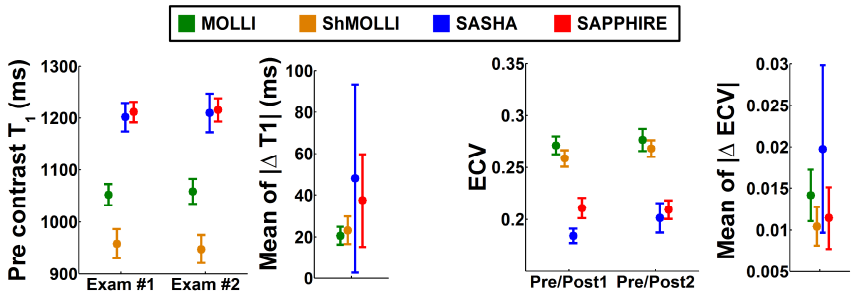

Figure 1. *Reproducibility of T_1 and ECV measurements in healthy subjects. MOLLI and ShMOLLI tend to be more reproducible than SASHA and SAPPHIRE for pre-contrast T_1 mapping. All methods shows similar reproducibility in term of reproducibility of ECV measurements (p=NS).*