# The Accuracy of Myocardial T2-Mapping Techniques

### S. Giri[1], G. Mihai[1], Y-C. Chung[2], and O. P. Simonetti[1]

[1]The Ohio State University, Columbus, Ohio, United States, [2]Siemens Medical Solutions USA, Inc., Columbus, Ohio, United States

**Objective:** 1. To evaluate different pulse sequence options available for T2 Mapping of human myocardium vis-à-vis accuracy of T2 measurements in phantoms. 2. To propose a practical approach to T2 evaluation that can be used in clinical setting to distinguish tissues with T2 differences 3. To get a range of values for human myocardial T2 values using the most accurate and practical approach. 4. To study the inter-subject variability of myocardial T2 values in healthy subjects.

**Background:** The MR T2 relaxation time of human myocardium is an important parameter in detection of myocardial edema and inflammation. These pathologic changes in myocardium can be detected using either a T2 Weighted (T2W) sequence or by directly quantifying the T2 values in a T2 Map. Past literature has reported a wide range of normal myocardial T2 values (in ms): 57(1), 44.3(2), 54(3), 56.9(4), 52(5), 58(6).

In this work, we evaluate 2 different sequences for T2 Maps, Turbo Spin Echo (TSE) and T2-prepared TrueFisp (T2P-SSFP), each with different protocols.

## Methods:

**Phantom study:** We prepared 2 phantoms using different proportions of Agarose and $NiCl_2$ to simulate T1 and T2 values in the range for normal myocardium (T1, T2) and edema (T1, T2). We evaluated the T2 values of these 2 phantoms using the traditional spin echo technique with a TR of 6 seconds and 9 images at the following TEs (in ms): 11, 25, 40, 60, 90, 120 160, 200, 250. After accounting for random noise in the received signal, the MR spin echo signal decays as follows: Signal = $M_0$ exp(-t/T2) + N, where $M_0$ is the initial magnetization and N is the random noise. We fit all three parameters to obtain accurate T2 values. We then tested 4 different protocols to generate T2 Maps, 2 each with T2P-SSFP and TSE sequences: TSE with 2 TE's, TSE with 3 TE's, T2P-SSFP with linear k-space re-ordering and 3 TE's, T2P-SSFP with centric k-space re-ordering and 3 TE's. We optimized these 4 protocols and used them to generate the T2 maps of phantoms using a 2 parameter model. The optimized protocol and imaging parameters are given in Table 1.

**In-vivo:** 6 healthy volunteers were scanned in the study comprised of 2 parts: (1) To compare the performance of TSE and T2P-SSFP protocols, we generated T2 Maps of mid-ventricular SAX slice (2). Using the results of (1) and of phantom study which established the superiority of T2P-SSFP techniques, we acquired the T2 maps of the AHA recommended 16 segments (apex was not used) using T2P-SSFP (both linear and centric ordering) to compare for inter-subject variability (centric reordering) and more accurately compare centric vs linear ordering. ANOVA test was used to study the variability in T2 measurement with different techniques (n=36, 6 mid-ventricular SAX segments for 6 subjects) and also to study the inter-subject T2 variability (n=16 segments for each subject); in addition, we compared linear and centric ordering using a paired t-test (n=96, 16 segments in 6 subjects); Tuckey's correction was used for multiple comparison. p-value < 0.05 was considered significant.

## Results:

**Phantom:** From Table 2, T2P-SSFP with centric ordering provided the most accurate T2 measurements, followed by T2P-SSFP with linear ordering. Both TSE methods significantly overestimated T2 values.

**In vivo:** The differences in T2 values measured with the 4 protocols were statistically significant (p-value < 0.001). Pair-wise, only the 2 TSE techniques were similar (p-value=0.98, paired t-test)

The T2 values in the 6 subjects from Centric ordered T2P-SSFP showed statistically significant variation (p-value < 0.001). Thus, instead of reporting a mean and SD, we report a range of observed values: 40.5 to 54.8 ms.

The T2P-SSFP with linear ordering gave a T2 value higher than that given by centric ordering (paired t-test, p-value < 0.001).

Although T2P-SSFP with centric ordering gave the highest accuracy in determining T2 values (based on the phantom study), the raw images with centric ordering had some artifact in blood pool which showed up in T2 Maps. This problem was not observed in linear ordering (Fig 1).

## Conclusion:

We investigated 4 different protocols with 2 pulse sequences which can be used for T2 mapping of human myocardium. T2P-SSFP measured phantom T2's more accurately than the TSE based techniques which overestimated T2; the possible reasons could be stimulated echoes and insufficient TR; increasing the TR is not feasible for subject breath-hold. Moreover, being single-shot, the imaging time is within acceptable breath-hold duration (7 RR intervals). Thus T2 mapping is an accurate and practical technique to detect T2 values across myocardium. Clinically, this technique can be used to detect subtle myocardial T2 changes due to edema associated with acute coronary syndrome.

## References:

1.  Bottomley PA, et al. Med Phys. 1984; 11(4):425-48.
2.  Mavrogeni SI, et al. MAGMA. 1998; 6(1):7-12.
3.  Huang TY, et al. Magn Reson Med. 2007; 57(5):960-6.
4.  He T, et al. J Magn Reson Imaging. 2006; 24(3):580-5.
5.  Foltz WD, et al. Magn Reson Med. 2003; 49(6):1089-97.
6.  Papanikolaou N, et al. Acta Radiol. 2000; 41(4):348-51.

**Table 1: Imaging parameters**

| Parameter | T2P-SSFP | TSE |
|---|---|---|
| Effective Echo times (ms) | 0, 24, 55 | {4.4, 53}, {4.4, 44, 84} |
| Matrix | 96 x 160 | 80 x 128 |
| Slice (mm) | 8 | 8 |
| Flip angle (degrees) | 40 | 90/180 |
| TR | 3 RR | 3 RR |
| PAT (acceleration/ref lines) | 2/24 | 2/27 |
| Imaging time | 7 RR intervals | 21 RR intervals |

**Table 2: Phantom study results; T2 (ms) from different protocols**

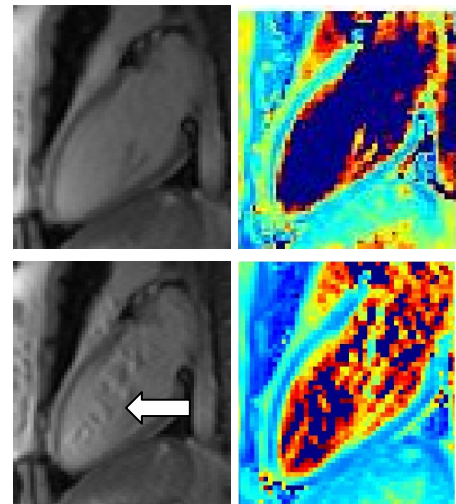| | T2 (from SE) | T2 Map | | | |
|---|---|---|---|---|---|
| | | T2P-SSFP | | TSE | |
| | | Centric | Linear | 2 Echo | 3 Echo |
| Phantom 1 | 51.6 | 53.8 | 61.5 | 69.2 | 66.8 |
| Phantom 2 | 101 | 101.9 | 112.2 | 150.8 | 136.8 |



Fig 1: VLA images (left column) and T2 Map (right column) acquired with Linear (top row) and Centric (bottom row) ordering. Note the artifact (arrow) in centric ordered raw image and the corresponding T2 Map.