Polarity-Corrected TI Prep Tool for Delayed-Enhancement MR Imaging and T1 Mapping

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Target Audience: Radiologist, Radiologic technologist, Cardiologist

Purpose: It is essential to determine the optimal TI value in order to obtain satisfactory delayed-enhancement MR images. In the Look-Locker method for determining the TI value, an IR pulse is applied, single-shot acquisition is performed repeatedly to obtain multiple images, and the optimal TI value is determined visually. In the main delayed-enhancement MR scan, however, the IR + segmented field echo technique is used, and the determined TI value may not be necessarily optimal especially by the effects of magnetization recovery in each RR. In addition, the MR images are displayed as absolute values, and visual determination of the optimal TI value may be difficult near the null point. We have developed a new method for determining the optimal TI value, called Polarity-Corrected (PC) TI Prep tool, based on the IR + 2D segmented FE technique. In this new method, the acquired data is corrected to match the data points after magnetization recovery by phase correction, and curve fitting is then applied to determine the optimal TI value analytically. In addition, this method can be used to obtain the T1 values together with the TI value, and we therefore also investigated the applicability of this method to T1 mapping.

Methods: A 1.5-T MRI scanner (Excelart Vantage[TM] XGV, Toshiba Medical Systems, Otawara, Japan) was used for data acquisition. Scan conditions similar to those for the main delayed-enhancement scan were used for the PC TI Prep scan: TR/TE = 5/2 ms, parallel imaging factor = 2, number of segments = 2, matrix = 128×256, echo acquisitions per RR = 32 and k-space order = interleaved (from the center outward). An image was acquired for every 2-segment scan in the same cardiac phase during diastole, and a total of 7 or 8 images were acquired with different TI values in increments of ΔTI = 10 to 20 ms during breath-holding (14 to 16 RR). The phases of all acquired images were then corrected to the phase of the last acquired image, least-squares curve fitting was applied to the corrected data, the null point was determined analytically, and the TI value corresponding to the null point was determined as the optimal TI value. To correct for the effects of magnetization recovery in each RR, an RR correction term was added to the standard recovery curve and the equation below was used for curve fitting, where S is the signal, A is the scaling factor, and b is the inversion factor.[1] $S = A (1 - (1+b)\exp(-TI/T1) + \exp(-RR/T1))$. In addition, T1 maps were generated using the T1 values obtained by analysis. The main scan for acquiring delayed enhancement images was performed using the 3D segmented field echo technique with scan conditions of TR/TE = 5.2/2.2 ms and matrix = 128×256. To evaluate the TI value measurement accuracy, the TI values obtained using this method were compared against the optimal TI values corresponding to the minimum signal intensity of the main scan images acquired repeatedly with different TI values. The optimal TI values were also measured by changing the HR (Heart Rate) (40, 60, and 85). A multi-cylinder phantom with various Gd concentrations was scanned for this evaluation. To evaluate the T1 value measurement accuracy, the T1 values obtained using this method were compared against the T1 values obtained using the IR + SE method as the gold standard. For the TI Prep scan to measure the T1 values of the phantom, the conditions used were TR = 9.1 ms, TE = 3.6 ms, FA = 15°, SPEEDER = 2.0, and matrix = 120×256. The T1 values of the phantom measured using the IR + SE method were 283 ms, 326 ms, 370 ms, 456ms, 540 ms, 683 ms, 932 ms, and 1144 ms. In addition, T1 maps were created for patients with myocardial infarction.

Results: The optimal TI values determined using the main scans acquired with different TI values was changed by the different HR (Figure 1). Even though the TI values were changed by HR, good agreement was seen between the TI values determined using the main scan and the TI values determined by this method with RR correction（y = 1.01 x , $R^2 = 0.994$）(Figure 2). Figure 3 shows the T1 value measurement results. The measured values were in the range from 283 ms to 1144 ms and showed good agreement to the TI vales determined by the IR + SE method (y = 1.06 x, $R^2 = 0.962$). The measurement error was 7.4±3.8%. Figure 4 shows a T1 map for a patient with myocardial infarction. A reduction in the T1 values in the infarcted region is observed.

Discussion: The PC TI Prep method can measure the TI value accurately even with the effects of magnetization recovery in each RR and the T1 values with an error of approximately less than 10% for subjects with T1 values in the range from 238 ms to 1144 ms. This result suggests that this method should be useful in clinical practice. Only a single image is acquired after the application of each IR pulse in this method, and the effects of the readout segments for the magnetization recovery are therefore considered to be smaller than in conventional methods such as the Look-Locker, MOLLI,[2] and mPSIR[3] methods, in which single-shot data acquisition is performed repeatedly after the IR pulse is applied. In addition, since data can be acquired in the same cardiac phase for multiple images, the admixture of signals from surrounding tissues with different T1 values due to pixel shift is avoided. It is therefore considered that more accurate measurement of TI and T1 values is possible. The effects of magnetization recovery in each RR can be corrected for by adding the RR correction term proposed in this method to the standard recovery curve.

Conclusion: The PC TI Prep method can obtain the optimal TI value analytically and is not dependent on the operator's subjective judgment, and this method is therefore expected to be useful for performing more accurate delayed-enhancement MR imaging. This method can also be used to measure the T1 values together with the optimal TI value, which suggests that it should be suitable for use as a T1 mapping tool in commercially available MRI scanners.

References: 1. Kellman P, et al. ISMRM 2013; 21:1396   2. Messroghli DR, et al. MRM 2004; 52(1):141-146   3. Sanchez-Gonzalez J, et al. Abstract ESMRMB Lisboa 2012; 37
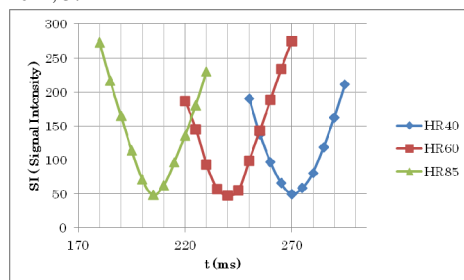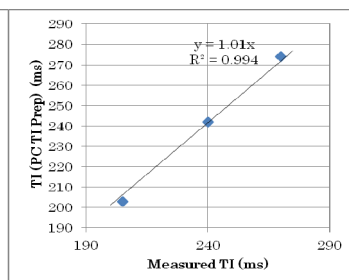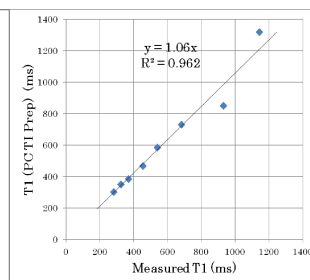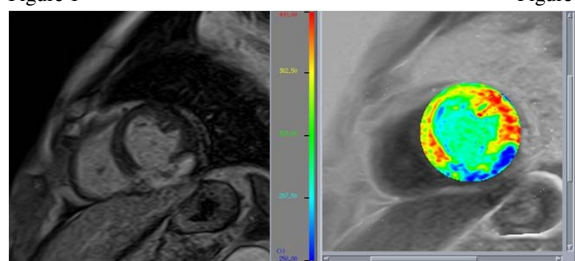
Figure 1

Figure 2

Figure 3

Figure 4