Fully Automated Measurements of Longitudinal and transverse Relaxation Times of MRI Contrast Agent

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INTRODUCTION: Contrast agents for tissue contrast enhancement are widely used in MRI [1]. Measurements of longitudinal and transverse relaxation times (T1 and T2) of solutions of MRI contrast agent samples are essential for their characterization and comparison in clinical diagnosis and biomedical applications [2-4]. Regions of interest (ROI) of samples are drawn manually in every image acquired from different time points, which is time consuming and subjective. A fully automated software-based measurement method is proposed that locates tubular samples, draws ROIs and calculates T1 and T2 relaxation times without user intervention.

MATERIAL AND METHODS: 77 samples (50 for T1 measurements) stored in 15 ml plastic tubes with 15 mm diameters were prepared in deionizer water solutions of Gd-DTPA with different concentrations ranging from 0.01 to 3.8 Mm. Data at 3.0T (SIEMENS, TRIO3) from these 77 samples were analyzed: (a) T1 measurement: Inversion recovery (IR) sequence, TR 9 s, TE 12 ms, flip angle 150°, matrix 416×640, FOV 78×120 mm, receiver bandwidth 250 kHz, slice thickness 5 mm, 10 TIs ranging from 24 ms to 5 s. (b) T2 measurement: Carr-Purcell-Meiboom-Gill (CPMG) sequence, TR 3 s, TE 27.6 ms, 11 equidistant spin echoes, refocusing flip angle 180°, matrix 256×104, FOV 40×120 mm, receiver bandwidth 190 kHz, slice thickness 5 mm. Measured signals S(T1) and S(TE) respectively from IR and CPMG at a certain time points can be written as [4]

\[S(T1) = S0*(1-2*\exp(-T1/T1)) + C\]

\[S(TE) = S0*\exp(-TE/T2)\]

Where, S(T1) and S(TE) were measured signals at T1 and TE; S0 was a constant determined by equilibrium magnetization. C was a constant. S0 and T1 or T2 values were extracted using our fully automated method as follows:

Our fully automated method for measurement of relaxation times of samples stored in plastic tubes involved the following steps: (1) Estimate the center (C) and the radius (R) of each sample at the image with maximum mean intensity based on circle Hough transform [5], shown in Figure 1; (2) define the circle with center C, and radius 0.5*R, as the ROI; (3) Calculate mean values and standard deviations of ROI; (4) Quantify relaxation times using a nonlinear two-parameter least-squares fitting based on Levenberg-Marquardt algorithm [6].

Fully automatic measurements of relaxation times (T1 and T2) are compared with measurements obtained manually by an experienced user and calculated using MIRio software. Linear regression and Bland-Altman analysis were used to compare the relaxation estimations.

RESULTS: Figure 2 shows the scatter plots of of T1 and T2 measurements obtained with automatic (Auto) and manual (Manu) methods, demonstrating excellent correlation (R²=0.9999). Bland-Altman plots (Fig.3) also reveals close agreements between the two methods with minimal bias. The typical manual measurements on 10 samples with 10 time points took more than 10 minutes, while the automatic measurements took only around 1 second.

DISCUSSION: This fully automated methods based on circle Hough transform effectively locates the samples and accurately calculate the relaxation times. A blinded study on these samples is warranted for assessment of performance. In summary, this method is effective and accurate in measurements of relaxation times of MRI agents.