Title: Contrast Adjustment for MR Images at 7 T

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Introduction:

MRI is capable of generating a variety of contrast mechanisms. The acquired signal used to generate the image, depends on a range of parameters, where each of them is either object specific or method specific. Knowledge of this dependency provides the possibility to adjust the signal intensity of any spin isochromat by modifying method specific parameters in the dependency. As this reliance is known for a sequence that is employed to generate the image, the signal intensity of and therefore the contrast between different isochromats in MR images are adjustable. In this work we present proof of this concept to UHF-MRI (7 T) aiming for applying it to knee imaging.

Methods:

The signal generated by Spin-Echo (SE) sequence [1] was simulated using in-house MATLAB scripts [2], based on the closed-form solution of the Bloch equations for SE signal. Considering a specific range of TRs and TEs given to the simulation while other parameters are known, the outcome is the range of TRs and TEs at which a certain level of contrast between two spin isochromats will be generated.

Attaining the desired level of contrast was verified on a phantom. The phantom consisted of an apple, a potato and a citrus. Images were acquired using SIEMENS 7T MR Imager (MAGNETOM Terra) equiped with a dedicated knee coil (1Tx 28Rx Knee Coil, 7T Clinic). Due to images of each of the three objects being not isointense, relatively homogeneous regions were selected for relaxation times calculation. Using inversion recovery acquisition method (TIs=40, 100, 300, 600, 1000, 1500, 3000, 5000ms, TRs=TI+10000ms) and an exponential fitting to the acquired data, we estimated the T1 value of apple and potato in a relatively homogeneous region (7 slices(apple),19 slices(potato),30 slices(total),2.5/0.5 mm thickness/gap). SE acquisition method applied at multiple TEs (TEs=6, 8, 12, 15, 30, 45, 65, 95, 120, 150, 180ms, TR=7500ms) and an exponential fitting were performed to measure T2 of the two objects in almost the same regions (8 slices(apple),18 slices(potato), 40 slices(total), 2.5/0.5 mm thickness/gap). SE acquisition with very short TE and very long TR (TE=6ms, TR=15000ms) to leave the signal weighted only by proton density was used where relative signal intensities of the two objects from regions of equal size delivered relative

spin density which was then averaged across selected slices. The Contrast between apple and potato was calculated in two adjacent slices (2.0/0.1mm thickness/gap), chosen from within the range of slices used for relaxation time measurements.

Our evaluation of contrast adjustment was performed in two sets of SE imaging, one with long TR=5580ms (with five contrast levels from 95±5% down to 15±5%) and the other with relatively shorter TR =1780ms (with four contrast levels from 95±5% down to 65±5%). By feeding the simulation with the relaxation times, spin density ratios of the two objects, and the TR and the flip angle of the sequence refocusing pulse, we calculated TEs at which the contrast lies within the desired level and range. The range of TEs given to the simulation was 10 to 120ms with resolution of 50 points equally spaced. These TEs were given to the sequence to generate images with adjusted contrast.

Results:

Figure 1 shows the result of simulation for a specific TR of 5580 ms. For each level and range of contrast the calculated TEs are presented in the corresponding plot.

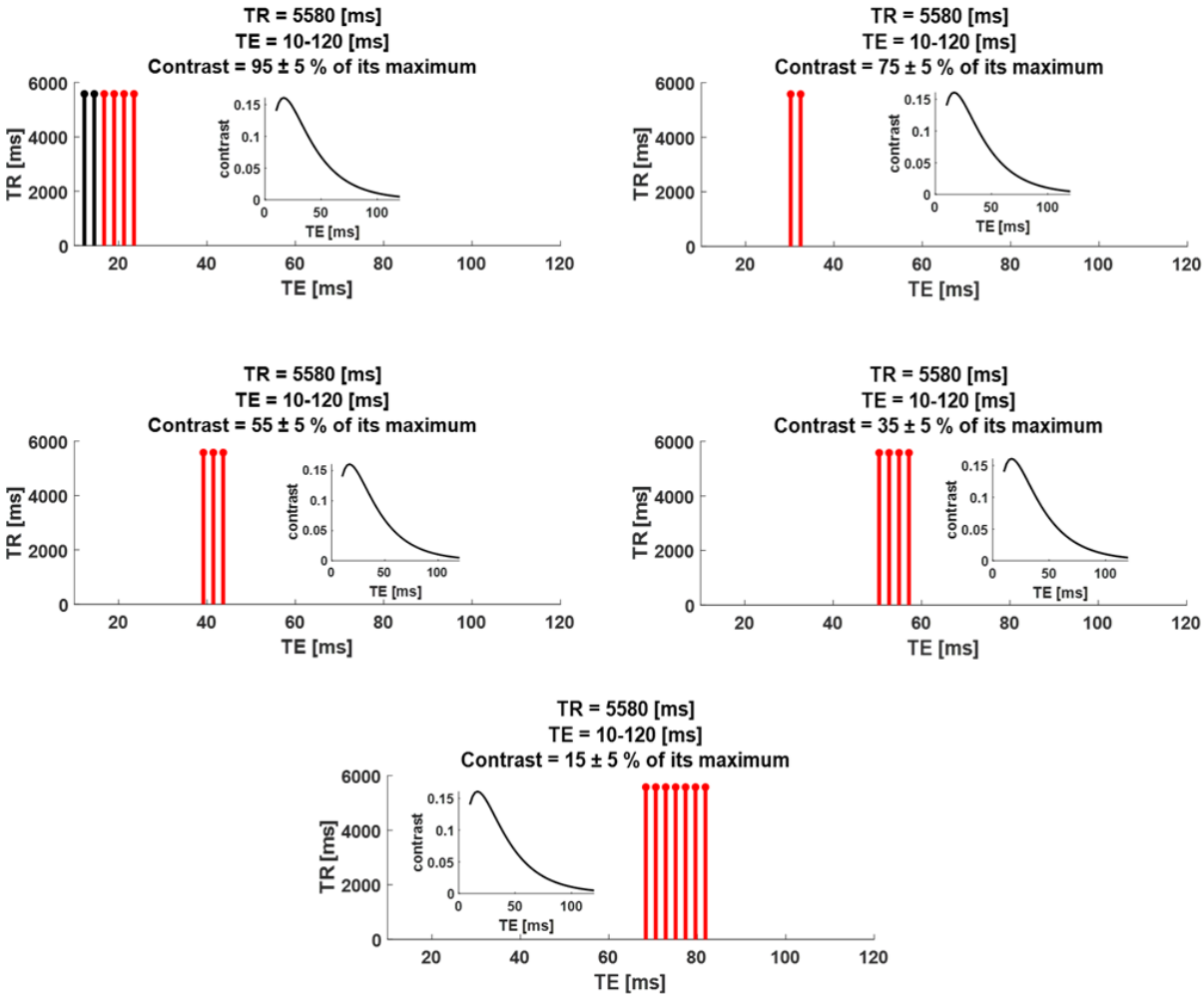

Figure 1 - Calculated TEs to gain five different contrast levels between apple and potato descending from 95±5% down to 15±5% for a specific TR.

The measured relaxation times of the two objects and their relative proton density ratios normalized to that of apple are given in Table 1.

Table 1		
7 T	Apple	Potato
T_1 (*) [ms]	698.3 (558.6, 838.0)	737.2 (598.6, 875.7)
T_2 (*) [ms]	9.3 (8.9, 9.7)	26.3 (24.7, 27.9)
PD (norm)	1	0.88
*95% confidence bounds		

Table 1 - Measured T_1 and T_2 relaxation times and relative spin density for apple and potato at main magnetic field strength of 7 T.

Tables 2 and 3 manifest the desired levels of contrast, the TEs that were calculated and entered into the SE sequence for each level, the measured CNR and its level relative to the reference (ref) for two sets of SE image acquisitions with different TRs. The levels are given in percentage relative to the maximum achievable contrast.

Table 2					
Contrast adjustment – Apple vs. Potato					
TR = 5580 [ms]					
Contrast-Desired (%)	95±5%	75±5%	55±5%	35±5%	15±5%
TE [ms]	16	30	40	51	67
CNR-Measured	455±36*	451±1	332±31	222±1	128±3
Contrast-Adjusted (%)	-	75±8% (ref)	55±13%	37±4%	21±3%
*The measured CNR for this level was comparatively low and was excluded from the analysis					

Table 2 - TEs derived from simulation and entered into the sequence to deliver five different contrast levels between apple and potato at a specific TR. The measured CNR at each level and the actual adjusted level of contrast are given.

Table 3				
Contrast adjustment – Apple vs. Potato				
TR = 1780 [ms]				
Contrast-Desired (%)	95±5%	85±5%	75±5%	65±5%
TE [ms]	14	10	9	8
CNR-Measured	260±33	207±9	183±1	175±21
Contrast-Adjusted (%)	100% (ref)	80±7%	71±9%	67±1%

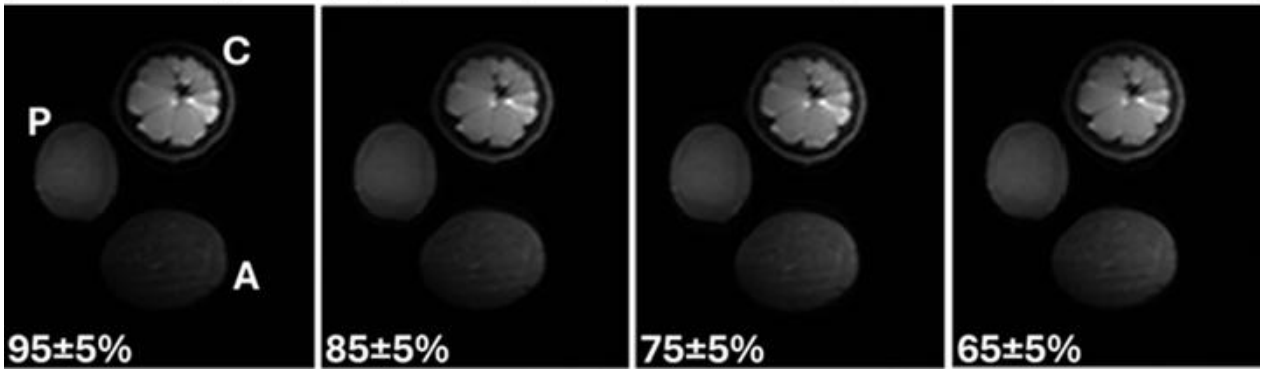

Table 3 – (Top) Table presenting TEs derived from simulation and entered into the sequence to deliver four different contrast levels between apple and potato at a specific TR. The measured CNR at each level and the actual adjusted level of contrast are given. (Bottom) Images of the phantom consist of apple (A), potato (P) and citrus (C) acquired with SE sequence to assess the adjustment of the contrast between apple and potato at four levels.

Measured mean CNRs lie within the range of 10% which was set for each level of contrast.

Discussion:

This work is an initial step towards generating contrast between tissues at any desired level in MR images, e.g. in knee MR images generated at UHF (Ultrahigh Field). To achieve this, all parameters that affect the MR signal intensity must be considered in the whole process of contrast adjustment. The type and number of some of these parameters are dependent on the sequence which is employed to generate the images. The accuracy of the calculations could also be affected by the applied reconstruction technique e.g. when parallel imaging is employed to accelerate the acquisition. Knowledge of precise values of relaxation times of the spin isochromats that are imaged elevates the accuracy of the contrast adjustment.

Conclusion:

In this work we present a proof of concept of the possibility to gain specific levels of contrast between different objects in MR images with the support of simulation. The approach could be applied to a variety of sequences and paves the way for establishment of a fully automated contrast adjustment for MR images.

Data and Code Availability:

Code is available on https://github.com/CyclotronResearchCentre/ESMRMB2025_ContrastAdjustment

Data is available upon request to Seyedmorteza Rohani Rankouhi (seyedmorteza.rohanirankouhi@uliege.be).

References:

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