Assesing T_1 Accuracy for DCE-MRI Functional Imaging: The Effects of Measurement Sequence and Number of Flip Angles

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INTRODUCTION

Quantitative dynamic contrast enhanced MRI (DCE-MRI) requires sequences that provide fast imaging times, good SNRs and accurate T_1 calculations. There are many sequences that are utilised for this task, and the aim of these experiments is to compare the attributes of a selection of fast sequences, with the main attention focused upon T_1 calculations. The advantages and disadvantages, and hence suitability of each sequence will also be discussed.

METHODS

Four fast imaging sequences were compared: 2D and 3D Spoiled gradient echo (GRE) FLASH, saturation recovery (SR) FFE and magnetisation prepared inversion recovery sequences (MP-IR) turboFLASH. Sequences were compared on a 1.5 T Siemens Vision (GRE and MP-IR) or a 1.5T Philips Intera (SR), imaging a test object (Diagnostic Sonar) containing 11 gels with T_1 ranging from 221-992ms (+/- 3%) at 296K using a phased array body coil. The parameters of each sequence are as follows: 2D FLASH (TR/TE of 10.2/4.7ms), 3D FLASH (TR/TE of 3.8/1.4ms), SR FFE (TR/TE: 6/2.4ms) and TurboFLASH, (TR/TE of 5/2.3ms). SNRs and image acquisition times were recorded.

T_1 Calculation methods from the TurboFLASH sequence used were that of Jivan 1997 [1] using images acquired with and without the inversion pulse, the calculation method from the FLASH sequences was that of Wang 1987 using two flip angles ($\alpha_1/\alpha_2 = 5°/30°$) [2], and SR-FFE T_1 calculations were derived from the standard saturation recovery signal equation using multiple delay times (TD = 290, 300, 340, 500, 750, 1000, 1800) and a flip angle of 16°. T_1 calculations were repeated for the 3D FLASH sequence using three flip angles for comparison ($\alpha_3 = 48°$). The slice thickness for each sequence was kept at 8mm, and a field of view of 300mm^2

T_1 maps were created using IDL (RSI), and regions of interest (ROIs) were drawn around each of the gels in the images. The mean pixel value inside the ROI was taken to be the T_1 of the gel with an associated error assumed to be the standard deviation. These values were compared with the known values.

RESULTS

The SR-FFE sequence provided the highest temporal resolution at 1.108s (but has less phase encoding steps than the other sequences), produced the most accurate T_1 values as in figure 1, and had the highest SNR as in figure 2 (This high SNR is because of a filter applied on the Philips system). This sequence was, however, run on a more modern system than the other three sequences. The 3D FLASH sequence also produced accurate T_1 values compared to those calculated from the SR-FFE sequence and had SNRs greater then the 2D FLASH sequence but less than images acquired from the SR-FFE and IR-turboFLASH sequences. It also has an adequate imaging time for use in DCE-MRI, but it has the main advantage of being a 3D sequence, giving superior coverage of the sample that any of the other sequences examined, an attribute the 2D FLASH sequence lacks. For the same imaging time, the images yield a lower SNR, and lower accuracy T_1 values. IR-turboFLASH images give an improved SNR over the two GRE sequences and the accuracy of the T_1 values is comparable to those calculated from 3D FLASH. IR-turboFLASH also has a significantly faster imaging time than any of the other sequences.

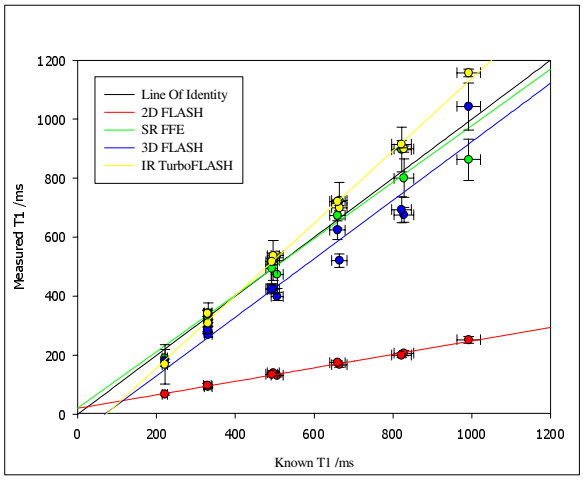

Fig 1: Graph showing the calculated T_1 values from the three different sequences as compared to the known values (the line of identity).

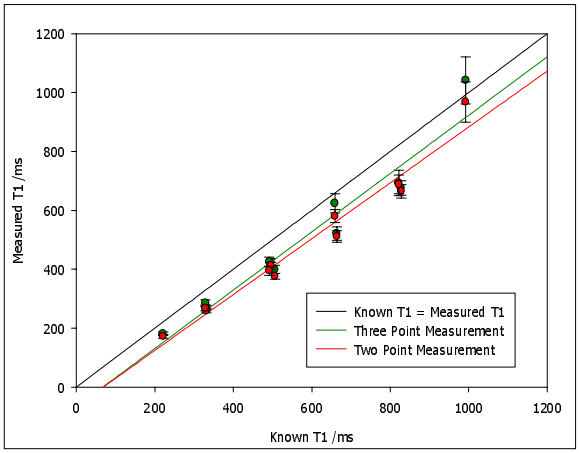

Fig 3: Graph comparing the T_1 values calculated from the 3D FLASH sequence from images acquired at 2 flip angles (dash-dot line) and three flip angles (dashed line).

DISCUSSION AND CONCLUSION

For faster imaging times with good SNR, the SR/IR sequences performed the best, but the disadvantage being they are only single slice sequences. If a wider sample coverage is required, then 3D GRE sequences would be more suitable as the accuracy of T_1 values calculated are comparable to those from the SR/IR sequences. From these experiments, 2D GRE sequences appear to offer no distinct advantages over SR/IR.

Figure 3 demonstrates that, when there is good SNR, as with the 3D FLASH sequence, taking more than two data points does not greatly improve the accuracy of the T_1 values. None of the sequences used produced perfect T_1 calculations, and so an experimentally derived calibration will still be required for high accuracy T_1 calculations. This must be considered when selecting a sequence to use for DCE-MRI.

ACKNOWLEDGEMENTS

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REFERENCES

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SEQUENCE	MINIMUM SNR	MAXIMUM SNR	SEQUENCE PARAMETERS USED	IMAGING TIME (S)
3D FLASH	22	42	• 160x256 Matrix • T1: 221ms • α = 30°/5°	3s
2D FLASH	11	44	• 160x256 Matrix • T1: 221ms • α = 30°/5°	2.06s
IR-TurboFLASH	51	67	• 160x256 Matrix • T1: 221ms • α = 8° • TI = 340ms	0.84s (read out) + 0.34s (TI) = 1.18s
SR-FFE	183*	250*	• 100x256 Matrix • T1: 221ms • TD: 340ms • α = 16°	0.768s (read out) + 0.340s (TD) = 1.108s

Fig 2: Table of the maximum and minimum SNRs found in phantoms, along with the imaging time for one image and a brief description of the sequence parameters used. (filter used on the Philips system)*