DCE-MRI Functional Imaging Using an Endorectal Coil: Limits on Measurement Accuracy

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INTRODUCTION

The use of small receiver coils such as endorectal coils plays an important diagnostic role in cervical, rectal and prostate MR imaging because of their higher sensitivity [1]. However, higher signal to noise ratio (SNR) is compromised by the spatial range over which these coils are sensitive. Signal reduces with distance from the centre of the coil, making the signal data increasingly noisy with distance and likely to be unsuitable for parametric measurements arising from functional T_1W DCE-MRI [2]. This study aims to utilise simulations based on measured endorectal coil geometry and experimental data, to determine the distances from the centre of the coil at which the signal data can be still considered useful. This study estimates errors in the calculated T_1 value from simulated data.

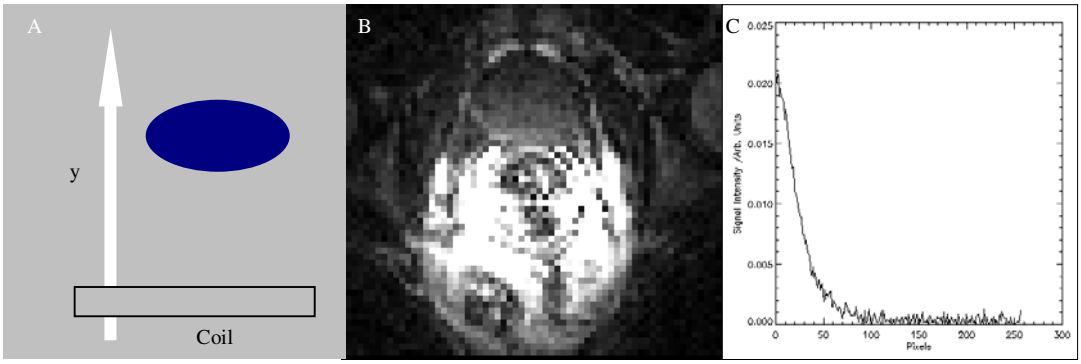

Fig1: A shows the position of the coil, and the area of interest when imaging transversely. B is an image of the prostate, where the positions of the coil and the prostate are visible. C is a profile through the y direction of the simulated signal data

METHODS

Signal data, as from a spoiled gradient echo sequence at multiple flip angles was simulated with a signal dependence based on experimental measurements performed on a Philips Intera system. Using the Biot-Savart equation, a spatial dependence (denoted y as in figure 1 A. Only signal variation in the y direction assumed) on the signal strength (as derived from patient data) was introduced (see figure 1 C). Gaussian distributed noise was added to create SNRs found in typical experimental data with the endorectal coil. T_1 maps of 256 x 256 pixels were calculated by the method of Wang 1987 [3] in which T_1 is calculated from signal data at multiple flip angles (α). This was repeated 256 times with different noise distributions to produce the T_1 map. Parameters were based on values used experimentally: α_1/α_2/TR of 2°/30°/4ms with a pixel size of 2mm^2 and a simulated T_1 value of 1200ms (value of the prostate).

T_1 maps were calculated with SNRs at the centre of the coil of 1000, 500, 200, 100, 75, 50, 40, 30, 20 and 10 (SNR in the centre of the coil In-vivo is approximately 50 for the sequence used) From these maps, the distance from the centre of the coil to the position where the uncertainty in the T_1 value is 5%, 20% and 50% was determined. The uncertainty in the T_1 value 60mm in the y direction from the centre of the coil (the approximate position to the edge of the prostate furthest from the coil) was also determined.

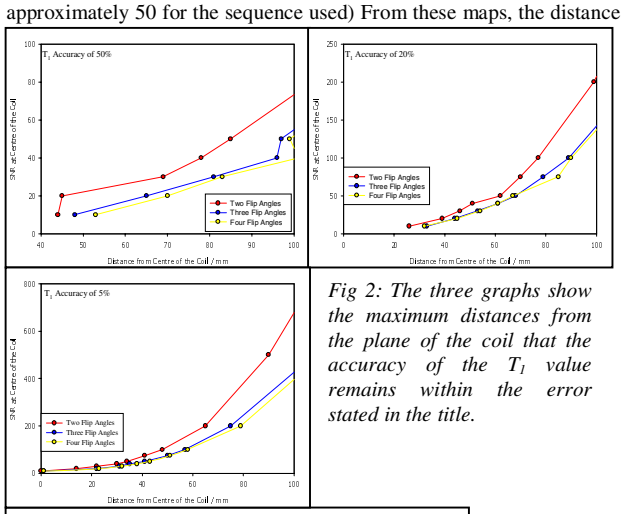

Fig 2: The three graphs show the maximum distances from the plane of the coil that the accuracy of the T_1 value remains within the error stated in the title.

These simulations were then repeated for three flip angles of 3°, 10° and 30° and then 4 flip angles of 3°, 10°, 20° and 30° to determine any increase in accuracy of the simulated T_1 values.

RESULTS

The simulations have shown that, the distance from the centre of the coil in which the calculated T_1 remains within a desired accuracy increases with increasing SNR at the centre of the coil (figure 2). At lower SNRs, a greater increase in the uncertainty in the T_1 value can arise from a small decrease in SNR. Figure 3 shows how the uncertainty in T_1 changes for a fixed position at 60mm. As expected the uncertainty in the T_1 value decreases with increasing SNR.

DISCUSSION

These simulations highlight the range over which a small receiver coil can be considered effective for T_1 calculations. The results give an indication of the range (in the y direction) from the coil that accurate T_1 values can still be produced.

Increases in accuracy of the calculated T_1 values can be achieved by increasing the number of data points acquired (e.g. at more flip angles) before T_1 calculation, and there would be benefits to using higher field strength magnets because of the increased SNR. With particular reference to prostate imaging, at a distance from the coil of 60mm, where the furthest edge of the prostate from the coil approximately lies, when observing SNRs < 100, any small decrease in SNR can result in a very large increase in the error in the T_1 value (figure 3).

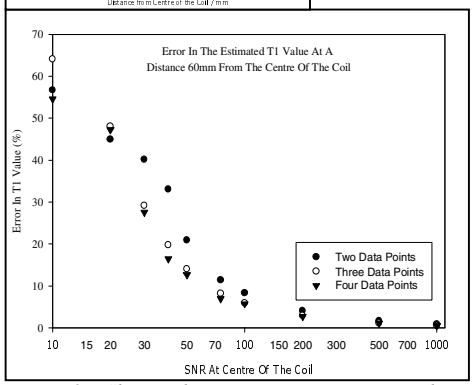

Fig 3: Shows the percentage error in the simulated T_1 value at a point 60mm from the centre of the coil. This is approximately where the furthest edge of the prostate would lie relative to the coil.

CONCLUSION

These experiments highlight the importance of achieving the highest possible SNR. This must be considered, if necessary, at the expense of other acquisition parameters such as resolution and acquisition time. With respect to the clinical example above (figure 1 B), the T_1 of the prostate could be calculated to an accuracy of 20% at the furthest edge of the prostate from the coil.

ACKNOWLEDGEMENTS

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