

3D TOF MRA of the intracranial arteries: effects of increasing magnetic field to 4.7T

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INTRODUCTION

TOF MRA has been successful at 3T (1,2) largely due to the increases in SNR and T1 relaxation times. The higher SNR at higher fields allows for higher resolution. The increase in T1 values will also allow for higher background suppression. However, increasing field also suffers from increasing RF field focusing due to shorter wavelength. At 3T, these effects are tolerable, but still noticeable (3). At the significantly higher field of 4.7T, the performance of TOF MRA is unknown. The purpose of this work is to evaluate the capabilities of TOF MRA at 4.7T for brain vascular imaging.

METHODS

In this study, 15 healthy volunteers were examined on both 3T and 4.7T magnets with identical Varian consoles. A 3D TOF pulse sequence was constructed with first order flow compensation applied to readout as well as slice selection gradients. Venous Saturation optionally precedes the sequence.

Experimental Protocol:

Imaging parameters were matched when possible between the two field strengths. A ramped excitation pulse was used with a 35:15 ratio between the flip angles at exit and entry of the imaging slab respectively, with 250 average. At 3T the TE/TR were 6.6/35 ms. The 4.7T TE was 5.85 ms with same TR. A 512 x 256 x 32 acquisition matrix was used with corresponding 20 x 20 x 3.2 cm FOV(s). Both systems used 100 kHz acquisition bandwidth with 75% fractional echo. Using the same flip angle and repetition time in both systems, the resulting CNR trend along blood vessel path was possible to measure for comparison.

Resulting source images were examined for CNR values along a blood vessel till its last visible point. Background values were measured in the same slice as the corresponding blood measurement.

RESULTS

The 4.7T system showed superior performance as compared to the 3T system. Using the above parameters, the CNR values from 4.7T were always higher than the corresponding 3T values with the implied increase of vessel visibility evident on the qualitative inspection. Moreover, when studied under different TR/Flip-Angle parameters, 4.7T system showed even higher CNR.

Theoretical considerations:

Using Bloch equations based simulation; a theoretical estimation was made about different parameters pertaining to blood visibility at 4.7T.

T1 relaxation changes: For 3.0T 1330, 830, and 1260 ms for gray matter, white matter and blood respectively. Those values become 1630, 1070 and 1800 ms in the same order for 4.7T.(1, 4). This parameter on its own would give 4.7T a somewhat constant advantage over 3T which will be of more relative weight by the end of the blood's pathway in the imaging slab.

RF focusing: The simulation studied the effect of RF power degradation towards the edges of axial imaging slab, an effect that's more severe at 4.7T. The graph below shows the RF excitation experienced by a hypothetical diagonally oriented vessel as the system tries applying a constant 25° pulse to it. This effect causes difference signal and contrast patterns exhibited by the moving blood.

For a blood vessel experiencing the RF inhomogeneity problem to its worst, (e.g. having a path that heads fast to the side of the brain and makes few turns in the area), 4.7 T simulation results had lower relative contrast than that at 3T where relative contrast is calculated as (blood-background)/background. In all other cases, 4.7T would start imaging at higher relative contrast while possibly lowering to a value very close to that yielded by 3T. In most cases, the higher SNR at 4.7T seems to be able to cover such shortcomings mainly accrued by the increased RF focusing at 4.7T.

DISCUSSION

From the background axial intensity variation, 4.7T images have an obvious RF focusing effect. This effect is reduced by utilizing local surface coils reception rather than the circumscribing coil used here. Nevertheless, the transmit variation remains which does affect image contrast. The shown image illustrates that the distal vessels are well seen at 4.7 T.

Using lower flip angles and moderate TR values, SAR problem of higher field is not of concern. But as one considers using magnetization transfer with TOF MRA, this issue has to be addressed.

CONCLUSION

As it offers unprecedented CNR images, 3D TOF MRA at 4.7T has the potential in pushing the performance limits of 3D TOF. More research is needed to fully address the high field issues with special emphasis on RF focusing effects on 3D TOF.

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