Ramped RF Excitation in 3DTOF MR Angiography at High Magnetic Field

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Introduction

Three-dimensional time-of-flight MR Angiography (3D TOF MRA) often makes use of a ramped RF excitation pulse in order to keep the blood signal and blood-to-background contrast sufficiently high over the entire vessel pathway (1). In particular, the ramped RF pulse can be beneficial for improving the visibility of distal middle cerebral arteries which are medically significant for the diagnosis of brain vascular problems like stroke. A ramped excitation pulse applies a lower flip angle to the bottom of the imaging slab where the fresh arterial blood enters and increases the flip angle until it delivers the maximum intended flip angle as blood leaves the slab. A linear ramp serves to reasonably achieve the above mentioned goal, although the best choice would be a non-linear ramp as shown in previous work on the carotid arteries (2).

However, at higher magnetic fields (3 T and greater), the shorter RF wavelength can lead to wave effects that significantly deform the excitation profile across the head, whereby the RF intensity drops off as one moves away from the center of the head. The actual RF excitation profile as seen by blood will now depend not only on the blood's pathway and on the applied RF pulse, but also on the effects of the RF profile distortion. This can lead to reduced visualization for the distal middle cerebral arteries, because these vessels are in an area of reduced RF profile near the edge of the head. In this study, we investigate the effect of the transverse RF profile variation at 3T on the shape of the RF ramped excitation along different blood vessel pathways. In particular, we demonstrate how to improve the profile for application to distal cerebral arteries in the brain at 3T.

Methods

All experiments were performed at 3.0 T. Phantom studies of RF excitation profile made use of a cylindrical saline phantom with 50 mM NaCl solution which has dielectric properties close to the brain's average (3). Intensity profiles were measured using a short TE and long TR (10 sec) to avoid effects on the signal from T_1 and T_2 relaxation. The intensity profile across the image was converted to a flip angle "transverse" profile with the maximum intensity referring to 90^o and other values appropriately calculated. The Bloch equations were used to estimate the expected intensity of blood along its pathway through slab as it receives successive number of excitations. Steady state background signal was also calculated for both gray and white matter.

The following parameters were used in the calculations: T1 for: Gray matter 1330 ms, White matter 830 ms, Blood 1260 ms. In addition, several ramp pulse profiles with different slopes were prepared and tested on volunteers with TR=36 ms, TE 7 ms and Flip Angle 25^o.

Results and Discussion

Figure 1 shows the RF profile across the imaging plane due to RF inhomogeneity. Figure 2 shows a coronal maximum intensity projection from a 3D TOF data set acquired at 3T. The white drawn line, was used in the calculations that are demonstrated in later figures. Figure 3 shows the results of the calculations for Gray matter. As shown here, the double sloped ramp pulse raises the distal blood contrast without sacrificing much of it at the slab bottom. The theoretical calculations showed that a vessel that goes from the middle to a distal area is expected to have a poor contrast level and that the situation worsens even more because of the RF inhomogeneity problem at higher field.

Conclusion

Changing the ramped RF excitation pulse to account for the non-uniformity of the high field RF profile is a promising method for enhancing visibility of distal middle cerebral arteries. This method is of increasing importance as one goes to higher field where the RF profile increasingly deforms.

References:

1- Purdy D, et al, SMRM 1992.
2- Priatna, A et al, JMRI 1995; (4):421-427.
3- Qing X Y, et al, MRM 2002; (47): 982–989.

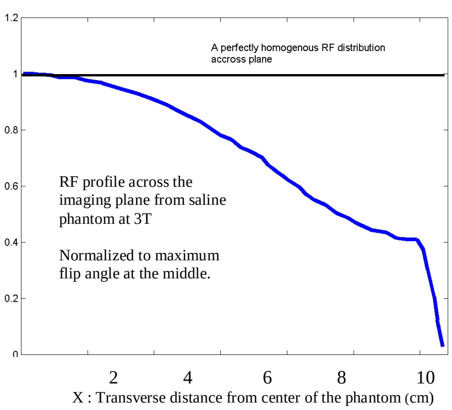

Figure 1 : right half of the RF distribution along X, as calculated from intensity "transverse" profile of a saline phantom

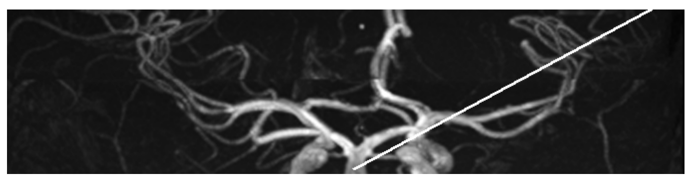

Figure 2 : Coronal image with contrast agent for the brain arteries, showing how some vessels branch off the center to reach distal brain areas. The drawn line shows the "diagonal vessel" depiction that we used for theoretical calculations.

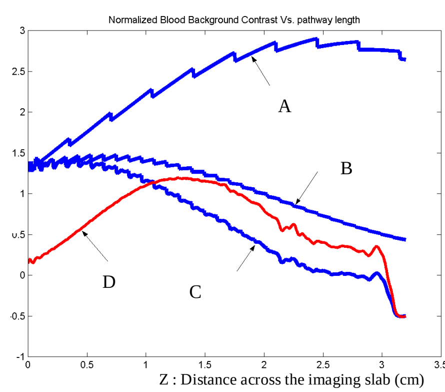

Figure 3 : Blood-Background contrast for ; (A) A vessel going straight in the middle of the slab, (B) Diagonal vessel with RF profile completely homogenous, (C) Diagonal vessel with real RF profile (the one from figure 4 is applied). (D) Same vessel in C, but with a double sloped ramp pulse.

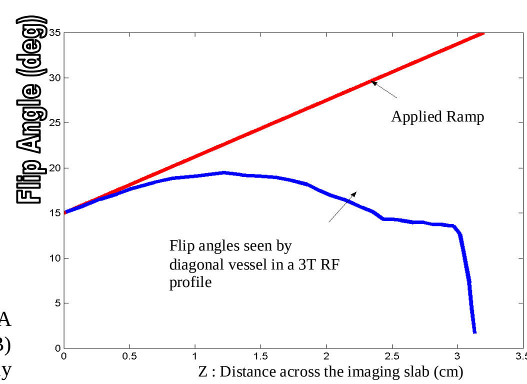

Figure 4 : RF profile: (A): As applied, (B) Reality after applying the RF inhomogeneity condition.

Acknowledgements

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