The Local Effective Flip Angle in the Presence of Highly Inhomogeneous B1-Fields and Flow

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Introduction: Image contrast depends on relaxation times and imaging sequence, as well as on the effective local flip angle α. This is affected by inhomogeneities of the transmit coil but also and even more severely by metallic implants.

The effect of through-plane flow on a puls train can be modeled by introducing the effective flip angle that incorporates both all flow effects on transverse magnetization and the slice profile in a single value.

Knowledge of the effective flip angle can be used for proper quantification of e.g. first-pass measurements as shown in [1] or contrast optimization.

Methods: Calculation of the flip angle is based on the inversion recovery Snapshot FLASH presented by Deichmann [2]. T_1 Relaxation is derived from

$$T_1 = \frac{M_0}{M_{0SS}} T_1^*$$

with M_0 being the equilibrium magnetization, M_{0SS} the steady state magnetization and the time constant T_1^* from a 3-parameter exponential fit. According to [3] the flip angle α

$$\alpha = \arccos(\exp(\frac{T_R}{T_1} - \frac{T_R}{T_1^*}))$$

with T_R being the repetition time.A flip angle map can be calculated, as well as a spin density map in inhomogeneous B_1-field

$$SD = \frac{M_0}{\sin(\alpha)}$$

The effect of through-plane flow is covered only for transverse magnetization of pulse trains.

If puls shape and repetition time T_R are matched to the investigated sequence, these results can be directly transferred to all kinds of SSFP and gradient echo sequences to investigate *in vivo* behaviour.

Results: Figure 1 shows results from the inhomogeneous B_1-field induced by a thin wire in agar gel. The flip angle is elevated near the wire, whereas the spin density map is homogeneous. The measured flip angle in homogenous agar equals what is expected to be the nominal flip angle. Figure 2 shows flip angle maps of the human heart in the presence of through-plane flow. In addition, these measurements result in a quantitative T_1 map.

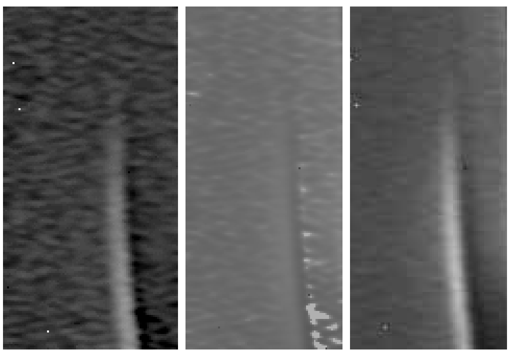

Fig. 1: Calculated flip angle α (a), spin density SD (b) and transverse magnetization M_0 (c) in inhomogeneous B_1-field induced by thin wire.

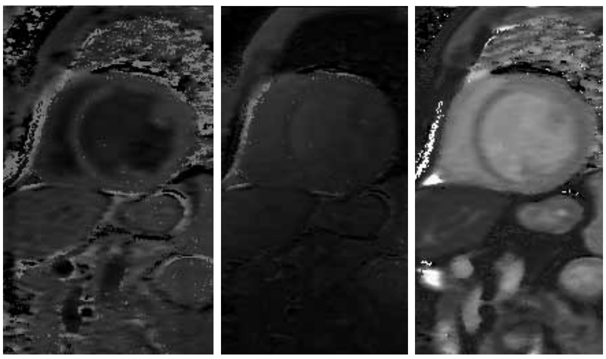

Fig. 2: Calculated flip angle α (a), transverse magnetization M_0 (b) and quantitative T_1 map in human heart.

Conclusion: The proposed method can easily access the local effective flip angle in the presence of highly inhomogeneous B_1-fields and flow. Measurement is fast and robust, and the resulting flip angle can be used for perfusion quantification based on the method proposed in [1].

[1] F Fidler Proc. ISMRM 11(2004) [2] R Deichmann JMRI 96:608-612(1992) [3] R Kaptein JMR 24:295-300(1976)