DCE-PWI: 3D T1-measurement as function of time or flip angle?

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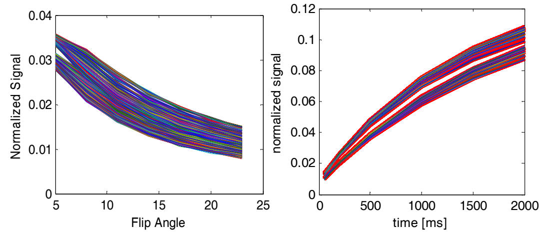
Introduction: Dynamic Contrast Enhanced Perfusion Weighted Imaging (DCE-PWI) and the preceding T1 measurement is usually performed with a FLASH sequence. For the sake of speed, the 3D T1 measurement is often performed by measuring the signal for a range of flip angles instead of as a function the inversion (or saturation) time [1,2]. This work investigates how off-set in flip angles in the presence of B1 inhomogeneities propagates into large errors in the T1 estimates. The errors are markedly reduced when the measurement is performed as a function of time, however this requires signal preparation.



Methods: A signal equation was developed describing the steady state from a preparation pulse with flip angle, *p*, (which may be 0°) over the pre-FLASH delay, T_d, and the FLASH train of small flip-angle pulses, α, with an inter-pulse delay, T_R. The signal was measured at the k-space center line, *n*. For large *n*, the signal approaches the FLASH steady state.

The simulated object had a T1 map with value 1800 in the left side and 1400 in the right side (fig 3, h). M0=1 in the entire image. Two data sets were simulated with *n*=20, T_R=3.5ms: A) Signal as a function of flip angle (fig.1,a), α=[5:3:25], with *p*=0°, T_d =0ms. B) Signal as a function of time after a saturation preparation pulse (fig.1,b), T_d=[50 100 200 500 1000 1500 2000]ms, with *p*=90°, α=15°. Noise was added representing a human measurement.

To investigate the effect of B1 inhomogeneity, a B1 scale factor, *B1sf*, map was constructed (fig.2,b), with a range complying a human measurement (fig.2,a). The nominal flip angle was scaled with the *B1sf* and the effective flip angle was used when generating both data sets. C) A third data set was generated where the saturation pulse was also scaled with *B1sf*, even though the effect on this harder pulse is expected to be moderate. The signal equation was then fitted to the three data sets both with the nominal alpha and the 'measured' effective flip angle to simulate B1 inhomogeneity correction.

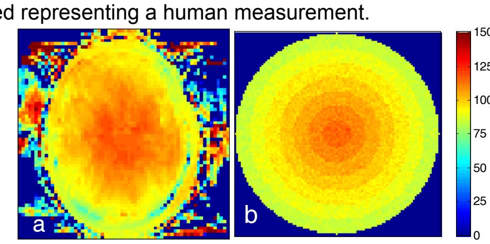
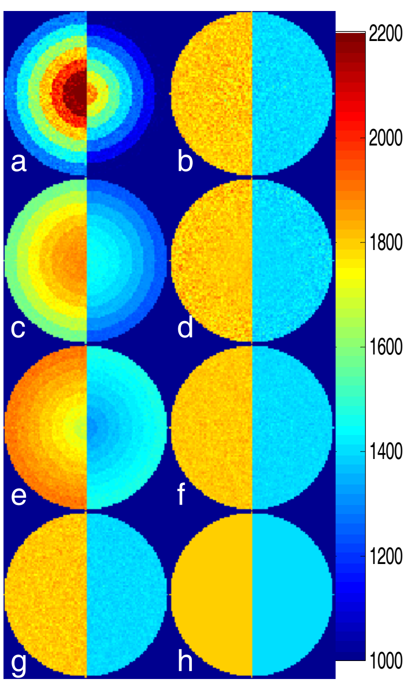


Fig. 2: ***a****: B1sf measured in human: the effectiveness of the flip angle in percent.* ***b****: simulated B1sf.*



Results: The fitted values are displayed in fig.3, a-g. The concentric circles from the B1 inhomogeneity map are pronounced in the T1 estimates when measured as a function of flip angle (fig.3,a); The values are more accurate when measured as a function of time, both when the saturation pulse was affected by B1 (fig.3,c) and when not affected (fig. 3,e). If the effective flip angle is also estimated from the T1 measurement acquired as a function of time, then the T1 estimate further improves (fig.3,g). With B1 inhomogeneity correction (here perfect correction, since no bias but only variance was simulated in the B1 measurement), the noise level in the T1 estimates is larger when measured as a function of alpha (fig.3,b) than measured as a function of time especially when the saturation pulse was not affected by inhomogeneities (fig.3,f).

Discussion: Although the nominal flip angle has a distinct value, the effective flip angle varies with B1 inhomogeneities. Thus, acquiring a T1 measurement as a function of flip angle also introduces an uncertainty along the x-axis (fig.1,a). The delay from excitation to readout is an accurate and precise measure, which makes T1 measurement as a function of time a more robust method, and hence it provides more accurate and precise T1 estimates. The accuracy increases if the pre-pulse is insensitive to B1 inhomogeneities. Moreover, this also allows for the flip angle to be estimated in the fit to data (fig.3,g), which may further improve the T1 estimate. The recommendation is therefore to perform T1 measurement as a function of time, also for the 3D sequence.

References: [1] Sourbron. *E. J. Rad.* 76:304-312 (2010) [2] Li et al *J. MRI* 12:347–357 (2000)

Fig. 3: Left column, no inhomogeneity correction. ***a,b****: fitted T1 map from measurement as function of flip angle.* ***c-g:*** *fitted T1 map from measurement as function of time.* ***c,d****: saturation pulse also affected by B1.* ***e,f,g****: saturation pulse not affected.* ***g:*** *flip angle also estimated during the T1 estimation.* ***h:*** *underlying T1 values.*