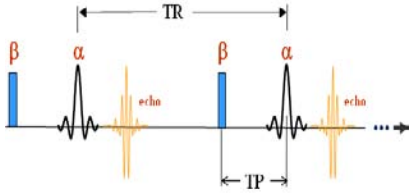
True T1 weighted MR Imaging by a Non Selective and Selective RF Sandwich Pulse Scheme: TOBAC [T One Beta Alpha Contrast]

M. Deimling[1], A. Stemmer[1]

[1]Siemens Medical Solutions, Erlangen, Germany

Introduction: Since the early days of MRI, pulse sequences have been suggested to enhance the T1 weighting by preparing the Mz magnetization due to inversion of Mz (e.g. Inversion Recovery or snap-shot FLASH). Each of these methods has its inherent disadvantages; the classical IR sequence needs relatively long measurement times, whereas the single shot variant suffers from S/N and point spread effects. In addition both cases are hampered by the suppressed signal of the contrast media. The application of RF spoiled gradient echo sequences with a high excitation flip angle α and a short repetition time TR results in a disappointing T1 contrast. In the comparable 3D sequence a strong signal variation along the slice direction is observed in form of an M shape. Both effects are explained by the deviation of the excitation profile from a rectangular profile; at a very short TR time << T1 and an excitation angle α ω 90 deg., the magnetization at the boundary provides a substantial contribution to the overall signal from this slice. This leads to a partial volume effect and therefore to a reduced T1 contrast in 2D imaging, in a 3D application e.g. the Grey-White matter contrast varies from medial to lateral in sagittal orientation. Beyond these effects, the aliasing artefact in 3D imaging is more pronounced due to the high edge signal – all this shortcomings are addressed by this sequence. The basic idea to overcome those problems was already mentioned by Haase two decades ago [1, 2]. The purpose of this work was to explain theoretically the magnetization behaviour and the demonstration of the improved T1 tissue contrast obtained by a simple pulse scheme composed by a time separate non selective β - and a slice selective α - RF excitation.

Material and Methods: Measurements were performed on a Magnetom Espree system at 1.5T using a 12 element head coil. A standard Rf-spoiled gradient echo sequence was modified with respect to a magnetization preparing module. An extremely short non selective RF pulse width τ = 200 µsec is required to partially saturate spins over a large area, even under such conditions the Rf pulse amplitude and therefore the added SAR is small compared to the selective excitation pulses. Because of the non ideal slice profile the flip angle across the slice became a function of the position $\alpha(z)$ and consequently the longitudinal as well as the transversal magnetization. For a homogeneous tissue at a given T1 and TR the Ernst angle α_E determines the form of the slice. For the 3D case a solution of the 3rd Bloch equation are derived easily for the steady state of Mz under the Rf pulse string illustrated in **Fig.1:**

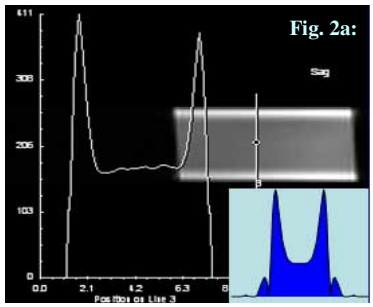


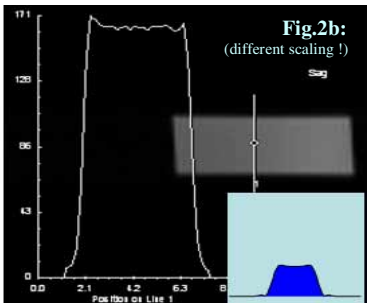
$$M_z = M_o \frac{1-\cos(\beta)E1 - EP(1-\cos(\beta))}{1-\cos(\alpha)\cos(\beta)E1}$$ with $E1 = \exp(-TR/T1)$ and $EP = \exp(-TP/T1)$

Using this formula the simulated slice profile is depicted in the insert of Fig.2.a and 2.b. The 3D-plot in Fig.3 gives a impression of the working of the pre pulse β for a large range of T1 values. The 2D multi (= N) slice TOBAC steady state experiment is more complicated to describe. This is because (i) of the rapid repetition time tr = TR/N of the non selective β pulses which have a cumulative effect and (ii) the effect of the selective α pulse every TR time. The theoretical description of the TOMROP sequence is given in [3]; this formalism is well suited for the description of the 2D sequence variant.

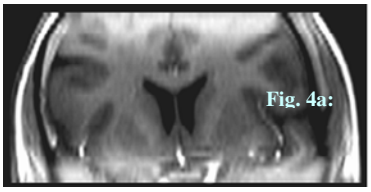
Results and Discussion: The theoretical description of the combined effect of the sandwich RF pulse and the experimental results are in good accordance, especially the results from the 3D experiment. Residual image artefacts in the 2D TOBAC sequence needs to be analyzed further with respect of the spoiler strategy. The high bandwidth β pulses have generally a distinct lower flip angle than the α and do therefore not limit applications. We propose again a simple, but effective RF pulse technique to improve the T1 image contrast in 2D as well as the signal homogeneity in 3D applications. This TOBAC technique allows creating a nearly optimal slice profile even under steady state conditions; therefore fast T1 image calculation seems possible without further slice profile corrections [4, 5].

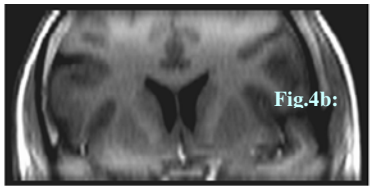
References: [1] Haase A., Matthaei D. SMRM 1987, p.441 [2] Heid O. Dissertation 1998 [3] Brix G. et.al. MRI Vol. 8, 351-356 (1990)
[4] Deimling M. et.al. SMRM 1986, p.926 [5] Parker GJM et.al. MRM 45 :833-845 (2001)



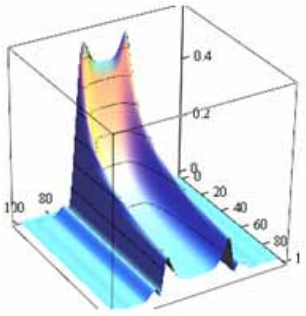


Transversal measurements, coronal reformatted and slice simulation (graphic insert). Profile along the 3D dimension.
TOBAC sequence: TR= 12 ms. Phantom fluid: T1 = 350 ms, T2 = 300 ms
β = 0 deg / α = 60 deg. **v.s.** **β = 40 deg / α = 60 deg.**



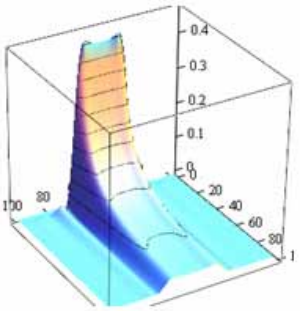


Volunteer measurement: Profile along the 3D dimension. TOBAC sequence:TR = 12 ms
β = 0 deg / α = 60 deg. **v.s.** **β = 40 deg / α = 60 deg.**



a.) β = 0 deg. / α = 50 deg.

Fig. 3
Plot of the slice profile magnetization as a function of the relaxation time T1 in the range: 100 ms < T1 < 3000 ms for a TR of 20 ms:



b.) β = 40 deg. / α = 60 deg.