# EXPERIMENTAL ANALYSIS OF THREE SPOILING MECHANISMS USED IN VARIABLE-FLIP-ANGLE T1 MAPPING

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**Target audience:** physicists, clinicians

**Purpose**: Variable-Flip-Angle-methods (VFA) for T1 quantification are widely used [1]. The method employs a series of images acquired with a spoiled gradient echo sequence (FLASH) using different flip-angles. Assuming a signal model a pixel-by-pixel fit is performed to obtain a T1-map of the subject. However, the signal model is only valid when the remaining transverse magnetization is perfectly spoiled. The actual signal depends strongly on the RF-Increment Δφ used in the RF-spoiling mechanism [2]. As a consequence of insufficient spoiling, the signal depends on T1, TR, flip angle α and also on T2 and the RF-phase-increment Δφ.
In this work an experimental analysis of three VFA techniques is provided demonstrating the difficulties for obtaining correct T1 values.

**Methods**: Phantom bottles with different concentrations of CuSO4 and Resovist (Schering) were prepared to provide samples with T1 values in the range of 207ms and 2985ms and T2 values ranging from 169ms to 2321ms. Three VFA sequences were implemented on a clinical 1.5 T scanner:
(1) Standard-FLASH with adjustable RF-phase-increment. The RF-phase-increment was fixed to Δφ =117°.
(2) Radial FLASH with random spoiling gradient moments [3] for improved dephasing of the transverse magnetization. Both the RF-phase increment (between 0 and 2pi) and the gradient spoiling moment (between 20pi and 40pi) were randomly alternated for each TR.
(3) FLASH with diffusion effect spoiling [4]. Extremely large gradient moments (~1000mT/m) are applied to achieve diffusion effects which nearly completely spoil the transverse magnetization however on the expense of relatively large TRs.
For all sequences, a series of images with 14 different flip angles between 3° and 90° at were applied at TR times of 5ms/10ms/15ms/50ms depending on the methods used. Matrix-size was 128x128x32 and selective RF-pulses with a high time bandwidth TBW were used to ensure sufficiently rectangular slice profiles. Only the central slice was selected for analysis. The measured signals were fitted to the following standard signal model commonly used in the VFA approach: $M_0 \frac{(1-E_1)\sin(\alpha)}{1-E_1\cos(\alpha)}$ where M0 represents the equilibrium magnetization and E1=exp(-TR/T1).

**Results:** The plots in Fig.(a) to (c) show the measured signals as a function of the flip angle. The fitted signal model is plotted as a solid line. The resulting T1 values obtained from all three VFA sequences as well as the reference T1 values are shown in Fig. (d) to (f).

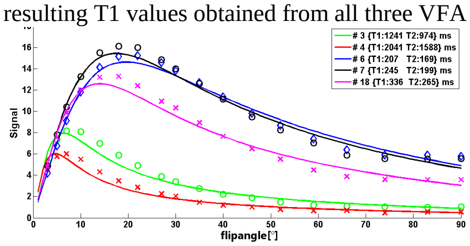


Fig. (a): Exemplary fit for different bottles for a standard FLASH-sequence (1)

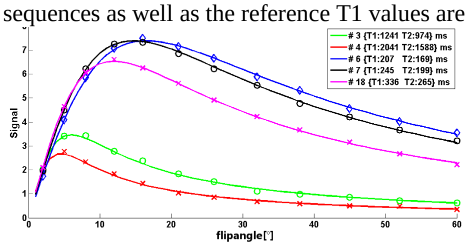


Fig. (b): Exemplary fit for different bottles for a FLASH-sequence with random spoiling (2)

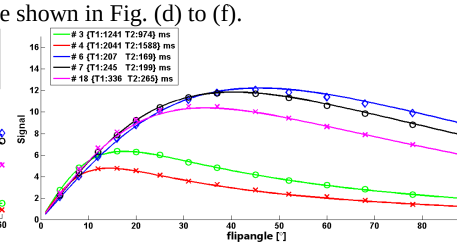


Fig. (c): Exemplary fit for different bottles for a FLASH-sequence with diffusion effect spoiling (3)

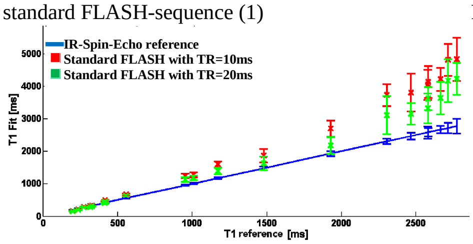


Fig. (d): Comparison of T1 vs. T1 reference for method (1). Two measurements with a TR of 10ms/20ms were performed

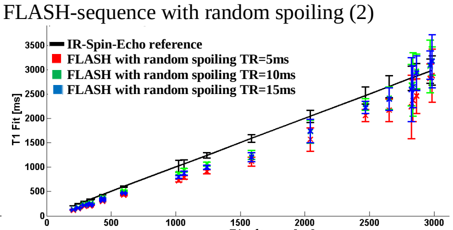


Fig. (e): Comparison of T1 vs. T1 reference for method (2). Three measurements with a TR of 5ms/10ms/15ms were performed

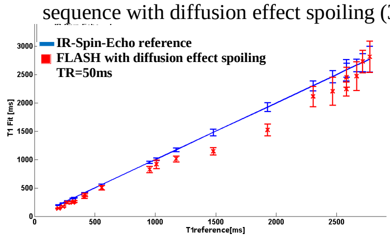


Fig. (f): Comparison of T1 vs. T1 reference for method (3). A TR of 50ms was used

The flip angle series obtained with measurement (1) show strong deviations from the signal model as can be appreciated in (a). The resulting T1 values deviate significant from the reference values especially towards larger T1 values. As expected, with increasing TR and thus allowing more time for dephasing the accuracy of the method improves. As can be seen in (b) for method (2) the data fit much better to the signal model used and thus more accurate T1 values are obtained. However, again towards larger T1 values a higher standard deviation can be observed especially if smaller TRs are used. Method (3) provides the best fit to the signal model (c), however the obtained T1 values still underestimate the reference values.

**Discussion:** As can be seen in the results, the standard VFA method using RF-spoiling does not match the reference data for a wide range of T1 values. This is particularly critical for T1 values larger than 600ms. The results suggest that care must be taken when VFA methods are used for T1 mapping even when improved spoiling mechanisms and many different flip angles are applied. In all cases the T1 values obtained are systematically over- or underestimated depending on the spoiling mechanism and TR used.

**Conclusion**: VFA is a robust method to get a fast estimate of T1 relaxation times, however for larger T1 values large deviations from the true T1 values can be obtained. While adding advanced spoiling mechanisms to the VFA sequence the accuracy of T1 estimation can be improved, however it still can significantly deviate from the true T1 values. Thus, T1 obtained with the VFA method should not be used as a reliable data source for reference measurements.

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**References:** [1] Fram et al, MRM (1987) 3:201–8 [2] Preibisch, Deichmann, MRM 61 (2009), Nr. 1, 125–35 [3] Lin, Song: MRM 62 (2009), Nr. 5, 1185–94[4] Yarnykh MRM 63 (2010) Nr. 6, 1610–26.