Optimised FLASH sequences for examinations of the human lung at 0.2 Tesla

M. Oechsner[1], M. Beer[2], E. D. Pracht[1], H. Köstler[2], D. Hahn[2], M. Weininger[2], M. Beissert[2], P. M. Jakob[1]

[1]Experimemtal Physics 5, University of Würzburg, Würzburg, Bavaria, Germany, [2]Institut für Röntgendiagnostik, University of Würzburg, Würzburg, Bavaria, Germany

Introduction: MRI investigations of the human lung are challenging for several reasons: the low proton density of lung parenchyma produces a weak signal and multiple air-tissue interfaces with different magnetic susceptibilities may lead to artefacts. At lower magnetic fields, susceptibility artifacts are less pronounced, resulting in a longer relaxation time T_2^*. Furthermore, examinations at lower fields produce lower costs. In the present work, we optimised a 2D- and 3D FLASH sequence [1] for investigation of the human lung at 0.2 Tesla. For signal optimisation, we measured the relaxation times T_1 and T_2^*. The sequence parameters were calculated to gain the highest SNR in lung parenchyma and simultaneously to acquire an adequate number of images in one breath-hold. The sequences were tested on healthy volunteers and preliminary examinations were performed with lung patients.

Methods: The highest SNR for the acquisition time T_{ACQ} of a gradient echo is given by the expression $T_{ACQ} = 1.26 * T_2^*$ [2]. In FLASH sequences, the maximum signal for a given TR and T_1 can be detected by excitation with the Ernst angle: $\cos \alpha_{ernst} = e^{-TR/T1}$ [3].
All measurements were performed on a 0.2 Tesla scanner (Siemens Magnetom Open, Erlangen, Germany). Data analyses were done using Matlab (the MathWorks, Inc., Natick, MA, USA). Relaxation time T_1 was measured with an IR-Snapshot FLASH sequence [4] (TE/ TR/ α = 1.4ms/ 3.6ms/ 7°; 20mm slice thickness; matrix 64 x 128 zero-filled to 128 x 256; FOV = 500mm^2, TA = 3.3s) with detection of a series of 14 snapshot flash images after a non-selective inversion pulse.
Relaxation time T_2^* was measured with a multi-gradient echo sequence with 10 consecutive echoes (TE_{first}/ TE_{inter} / TR/ α = 2.3ms/ 4.6ms/ 45.1ms/ 20°, slice thickness 20mm, matrix 64 x 128, zero-filled to 128 x 256, FOV = 500mm^2, TA = 2.9s). With the T_1 and T_2^* values, the appropriate acquisition time and flip angles were calculated. The sequence parameters were choosen as follows: interleaved multi-slice 2D FLASH: TE = 3.7ms, $TR_{effective}$ = 13.0ms * number of slices, α = 40° - 45°, readout bandwith = 97.7Hz/ pixel; 3D FLASH: TE = 3.7ms, TR = 13.0ms, α = 12°, readout bandwith = 97.7Hz/ pixel. The gradient echoes were acquired with 25% asymmetric echo readout. Volunteers and lung patient investigations were carried out in inspiration breath-hold and supine position. All FLASH images were acquired with 12 - 16 slices/ partitions within one breath-hold (matrix: 64 - 112 x 256, FOV = 450 – 500 mm^2, 10mm slice thickness).

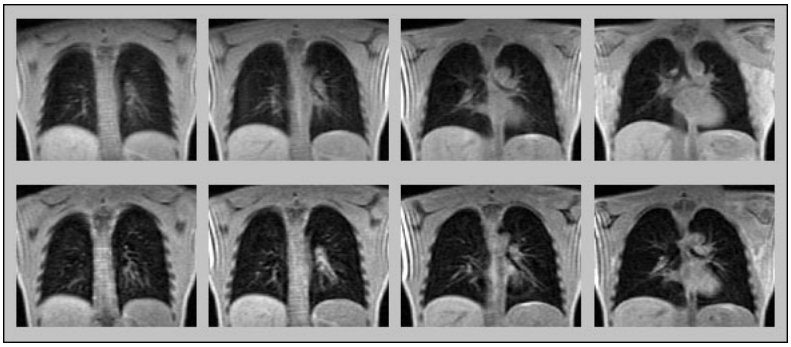

Fig.1: 2D FLASH (top) and 3D FLASH (bottom) coronary images of series of 12 - slices/ partitions of a healthy volunteer (FOV = 450mm^2, matrix: 96 x 256, slice thickness 10mm, TA = 15.0s).

Results: The mean T_1 value in lung parenchyma was 612.7 ± 82.3ms, the mean T_2^* value was 8.6 ± 3.3ms .With these results, the optimised sequence timing was calculated. The FLASH sequences show a good SNR in lung parenchyma and also a clear contrast of greater vessels (Fig. 1). The 3D FLASH produced a SNR in lung parenchyma of 5.89 - 6.89, the 2D FLASH 6.17 - 7.20. In both sequences, only small flow artefacts are visible and they are more pronounced in the 2D FLASH due to the longer effective TR. The investigated disease (cystic fibrosis, Fig. 2) in the lung patients can be clearly identified and shows good contrast to lung parenchyma.

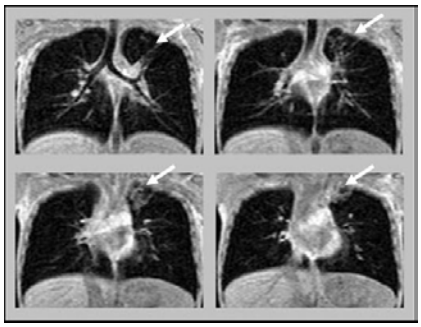

Fig.2: 3D FLASH coronary images of a patient suffering cystic fibrosis. The disease can be identified (arrows) in the upper left lung (FOV = 450mm^2, matrix: 96 x 256, slice thickness 10mm, TA = 15.0s).

Discussion: We measured the relaxation times T_1 and T_2^* and calculated the optimised parameters for a 2D and 3D FLASH sequence at 0.2 Tesla. Because of the longer T_2^* at low magnetic fields, the bandwidth of the FLASH sequences was reduced to gain the highest SNR. FLASH sequences allow a low bandwidth without major losses in image quality. Both sequences show only minor flow artefacts. In 2D FLASH, the longer $TR_{effective}$ of the interleaved acquisition mode allows a larger flip angle and compensates for the signal advantage of the 3D excitation [5]. With the optimised sequences, an adequate number of images could be aquired to cover the whole lung in one breath-hold. With a slice thickness of 10mm, both FLASH sequences achieved a high SNR in lung parenchyma and also a good contrast for the examined disease (cystic fibrosis). To study the value of low field examinations of the human lung, more patients with various diseases should be examined. Up-to-date hardware and further sequence optimisations provide further possibilities to improve contrast, signal and acquisition time, and make examinations of the human lung at low magnetic fields more attractive.

References:

[1] Haase et al., JMR 67:258 (1986)
[2] Pohmann et al., JMR 129:145 (1997)
[3] Ernst et al., Rev. Sci. Instrum. 37:93 (1966)
[4] Jakob et al., JMRI 14:795 (2001)
[5] Johnson et al., MRM 41:824 (1999)