Synopsis  A new concept is proposed for generation of purely T2 weighted images, even in the presence of signal from longitudinal relaxation. This is accomplished by imaging in between non-equally spaced 180°-pulses which alternatively flip the magnetization into states parallel and antiparallel to B0. With optimized timing, magnetization courses are identical for different T1s, which removes T1 contrast, leaving only T2 contrast. This general idea was realized with TrueFISP readout between the 180°-pulses. Experiments on phantoms and volunteers confirmed the theory: TrueFISP images with essentially pure T2 contrast were obtained. More complex implementations are possible, e.g. by using varying timing patterns.

Introduction  MR images with T2 contrast are of high clinical relevance and can be obtained with long TE, long TR spin-echo (SE) imaging. Shorter scan times are achieved with turbo-spin-echo sequences (TSE and RARE). The main drawbacks of these methods are T1 effects due to imperfect pulses and a high SAR. Contrary to this approach we propose a concept for acquisition of pure T2 contrast images, wherein signal from longitudinal relaxation is allowed to enter the imaged signal, while T1 contrast is eliminated by a train of non-equally spaced 180°-pulses.

Methods  General optimized temporal patterns were derived from analytical calculations of relaxation characteristics. Simulations based on the Bloch equations helped to investigate the magnetization time course behaviour of specific sequence implementations. For a first realization, TOSSI sequences with TrueFISP [1] imaging blocks (TR=6.46) between the 180°-pulses were implemented on a whole body scanner (Siemens Vision, 1.5T). Each block was preceded by an $\alpha/2$- and concluded with an $-\alpha/2$-pulse [2,3]. Different timing schemes were realized, e.g. with durations of 91ms and 33ms for the parallel and the anti-parallel phase, respectively. TOSSI imaging experiments were performed on phantoms and on volunteers. The results were compared to images obtained with standard TSE and TrueFISP sequences.

Results  In Fig1 results from Bloch simulations are depicted for TrueFISP (left) and TOSSI (right) for a wide range of T1 and T2 values. Results are displayed for a TOSSI scheme that showed suitable for the separation of signal from compartments with different short T2 values, like white and gray matter of the human brain. While the TrueFISP signal time course depends on both T2 and T1, the TOSSI signal values for short T2 are separated independent of their T1, i.e. essentially pure T2 contrast is generated. The results of the phantom experiments were in good agreement with the theoretically expected behaviour (data not shown). In Fig2 images from a volunteer’s head are shown. While gray and white matter show uniform intensity in the standard TrueFISP image (a), the TOSSI image exhibits pure T2 contrast (b), very similar to the corresponding T2-weighted TSE image (c). Strictly speaking, the TOSSI contrast may be more accurate, since subcutaneous fat is correctly dark in the TOSSI image, while it is artificially bright in the TSE image due to its short T1. In this case purely T2-weighted images were obtained at a low flip angle of 50°, while exploiting the high SNR efficiency of the TrueFISP imaging sequence.

Conclusion  Both simulations and experiments showed that it is possible to suppress T1 contrast without removing signal from longitudinal relaxation, and thus, to generate pure T2 contrast. This general principle may be used in combination with a variety of different imaging sequences. It is of general importance that the 180°-pulses are implemented when no transverse magnetization is present in order to avoid the generation of unwanted spin-echoes. Although specific implementations will never be optimal for all possible T1 and T2 times, a wide range of values can be covered and optimized schemes can be found for various applications. Further optimization may be possible, e.g. by using combinations of different temporal patterns, or by slightly varying the flip angle within the up- and down-periods.

Acknowledgements  Support by Siemens Medizintechnik (Erlangen, Germany) is gratefully acknowledged.