A New Look at an Old Mechanism: Principles and Applications of Superstimulated Echo TSE

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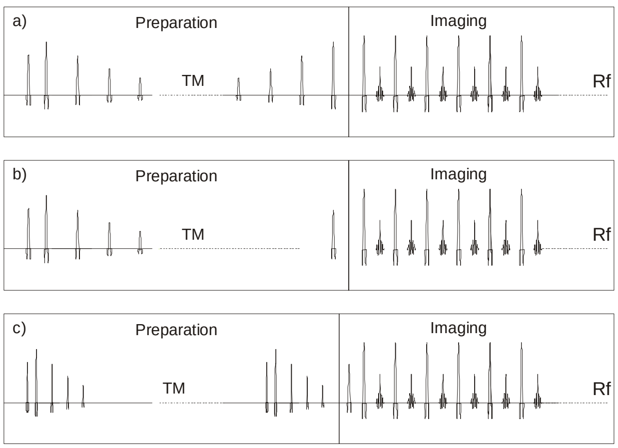
Purpose

The stimulated echo - mechanism is based on the preparation of sinusoidally modulated z-magnetization. Due to the long T1-relaxation time of protons in biological tissues, the preparation interval TM can be in the order of several hundreds of milliseconds without significant T1-attenuation. The disadvantage of the stimulated echo-mechanism lies in its inherent signal loss by 50%.

The superstimulated (ss) -echo mechanism has been suggested as a means to overcome this inherent signal loss (1). By preparing z-magnetization with a periodic rectangular modulation of +/- z-magnetization it could be shown, that – at least in principle – all of the magnetization will be available for formation of a superstimulated echo. The practical implementation of this mechanism has been prohibited, however, by the lack of an efficient way to prepare z-magnetization with a sufficiently well defined modulation pattern. Recently it has been shown, that such a modulation corresponds to the static pseudosteady state in a CPMG-sequence for the limiting case of zero refocusing flip angle (2). It has also been shown, that such a modulation can be achieved very efficiently by use of the TRAPS-mechanism(3). The purpose of this paper is to implement a TSE-sequence with preparation modules leading to superstimulated echo formation and to demonstrate its efficiency for some basic applications.



Materials and methods

Some basic approaches for implementation of a ssTSE-sequences are shown in Fig.1. The TSE-imaging module is preceded by a preparation interval consisting of a CPMG-sequence, where magnetization is first transformed into rectangular modulated z-magnetization. In variant a) z-magnetization is first prepared and retrieved later on by a time-reversed sequence of pulses. In the asymmetric variant b) a shorter retrieval sequence is used. In c) finally the sequence used for retrieval of z-magnetization is identical to the initial preparation sequence. This will lead to recovery of z-magnetization, which is then submitted to a regular TSE-sequence for image generation. For variants a) and b) it is advisable (although not strictly necessary) to use identical timing and gradients for the CPMG-sequence used during preparation and imaging, whereas variant c) allows to use echo trains with different timing and gradients, which is especially useful for diffusion/flow encoding.

Experimental

All experiments were performed at 3T (Siemens Magnetom Trio). Typically 5 refocusing periods were used for optimum preparation of rectangular z-modulation. For diffusion weighted imaging a HASTE-sequence was used for the imaging module in order to minimize motion artefacts, all other implementation were performed with echo train length comparable to those used in clinical routine (ETL = 11-35). Typically a preparation sequence with n=5 was used.

Results

Fig.2 shows examples of ssTSE-images used to determine T1. Results of fitting data to measurements with 10 different TM-values yields yield T1=1210 ms (grey matter) and T1=752 ms (white matter).

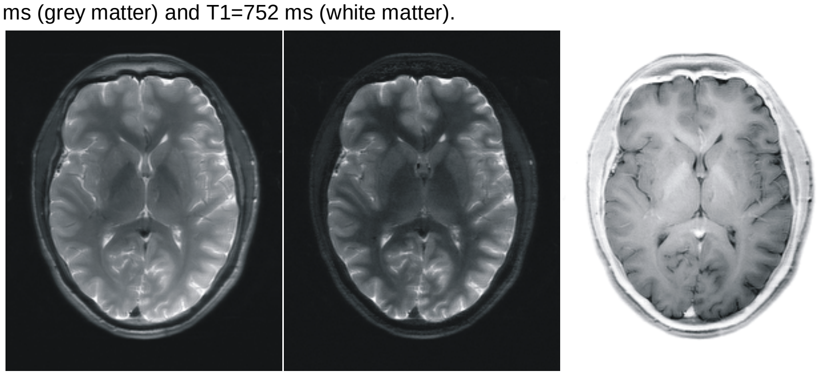


Fig.2 ssTSE-image with TM=90 ms (left), TM=1224 ms(middle) and difference image(right). (ETL=35, Half Fourier, TR/TE= 4000/27, 20s acquisition time, 13 slices.

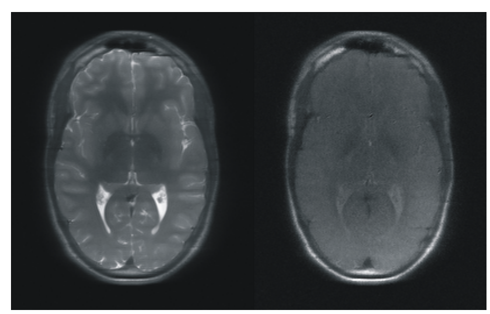


Fig.3 Diffusion weighted single shot ssHASTE with effective b-factor of ~30 (left) and ~300(right)

Examples of diffusion weighted single shot ssHASTE are shown in Fig.3. Due to the superposition of different refocusing pathways T2-weighting cannot be characterized by a singular b-value, the resulting signal attenuation will depend on T1 and T2 as well as on the ADC (1,4). The values given are therefore estimates based on the observed signal attenuation.

Conclusion

The superstimulated echo mechanism is demonstrated to yield high resolution T1- and diffusion weighted images without the inherent SNR-penalty of conventional stimulated echoes. This can be used for T1-weighted imaging(s.Fig.2) as well as for diffusion weighted imaging. Potential applications are especially the detection and characterization of infarcts in the brain stem and other areas, where EPI-based diffusion imaging suffers from EPI-artifacts. The overall image acquisition time of ~500 ms/image appears to be, however, prohibitive for use of ssTSE in diffusion tensor imaging. Further potential applications are measurements of brain motion with ECG-gated ssTSE and the use of z-modulation in the z-direction for arterial spin labeling.

References

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