

Spin Echo Imaging

The Spin Echo (SE) sequence was introduced in 1950 by Hahn long time before the MRI era began. In a common SE sequence the excitation is always performed with a 90° pulse turning the longitudinal magnetization into transversal magnetization. Afterwards, the transversal magnetization decays with the time constant T_2^* due to a dephasing process of spins induced by magnetic field inhomogeneities. After half of the desired echo time (TE) a 180° excitation pulse is played out resulting in a rephasing process of the dephased spins by the **static** magnetic field inhomogeneities. Due to this rephasing process the signal reaches its maximum after TE, the so called Spin echo. Therefore, the effect of static magnetic field inhomogeneities is suppressed and the amplitude of the spin echo is given by the relaxation time T_2 – the effect of the non-static magnetic field inhomogeneities induced by the stochastic spin-spin-interaction (T_2) can not be reversed. The benefit of the SE sequence is therefore its insensitivity to magnetic field inhomogeneities. Drawback is given by the long scan time due the waiting interval until the next spin echo experiment can be performed (TR), i.e. longitudinal magnetization due to the T_1 relaxation process has recovered to be excited again. The SE sequence is schematically presented in Fig. 1 including all additional magnetic field gradients for the spatial encoding.

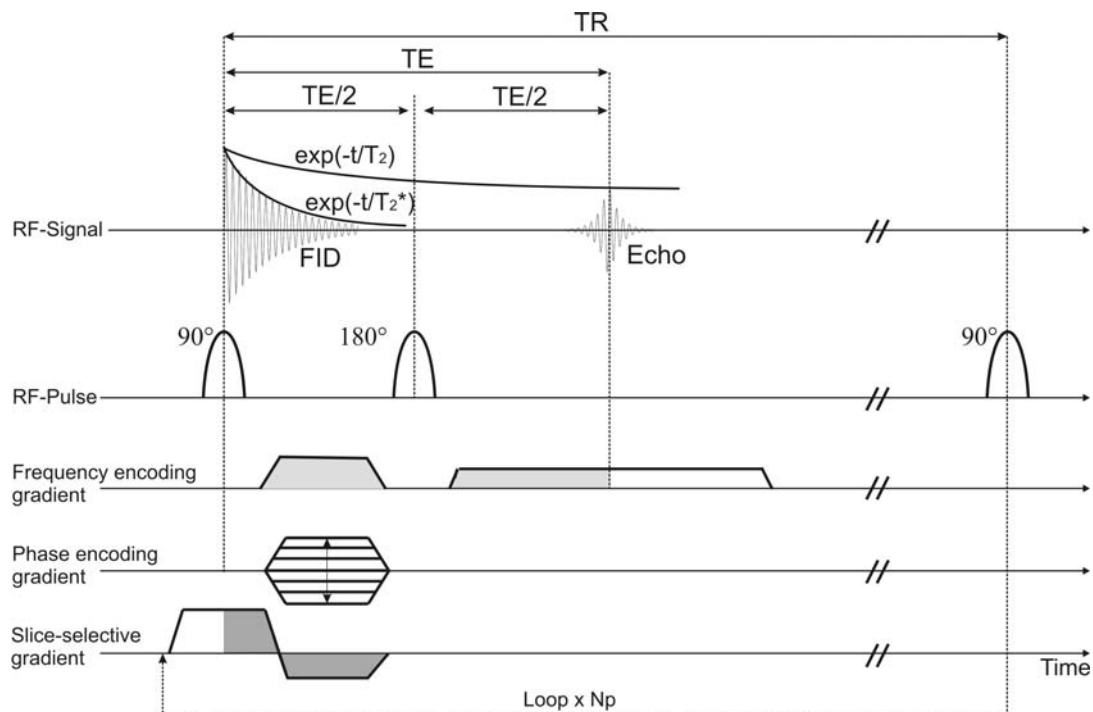


Fig.1: The spin echo sequence with all RF-pulses and magnetic field gradients for the spatial encoding. The sequence has to be repeated according to the matrix size in phase encoding direction to acquire the complete image. The echo amplitude is reduced due to the T_2 signal decay. The signal decay after the excitation with the 90° pulse is given by T_2^ and is called the FID (Free Induction Decay). Due to the 180° pulse the rephasing gradient in the frequency encoding direction has the same polarity as the dephasing gradient prior to the 180° pulse. The sequence has to be repeated according to the matrix size N_p in phase encoding direction.*

Since the echo amplitude is affected by the T2 relaxation time, the choice of TE short as possible minimizes the T2 weighting in the image. On the other hand, a longer TE (in the range of the T2 relaxation time of the tissue components) yields to a strong T2 weighting manifested in signal differences of the difference tissue components. Tissue with a short T2 have lost most of its signal intensity, tissues with a longer T2 show higher signal intensities. On the other hand, a short TR (in the range of the T1 relaxation time of the tissue components) introduces a T1 weighting in the image. A long TR results in a full relaxation of the longitudinal magnetization to its equilibrium state. Therefore, a T1 weighted image requires short TR and TE and a T2 weighted image long TR and TE. A long TR and a short TE minimizes the influence from both relaxation times T1 and T2, therefore resulting in an image of which the contrast is determined by its proton density (Pd). Typical values for T1-, T2- and proton density weighted SE images are summarized in Fig. 2.

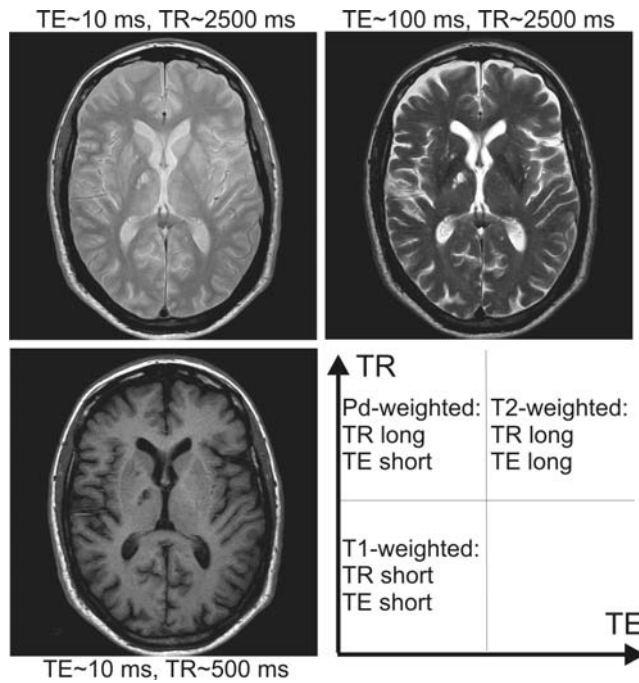


Fig.2: Different contrasts of a spin echo sequence according to TE and TR.

The waiting time due to T1 relaxation between successive excitations (TR) can be used to excite and acquire other imaging slices. The number of slices in this interleaved acquisition scheme is therefore given by TE and TR.

One specific appearance of the SE sequence is the Outflow-effect. This effect is responsible that vessels typically provide almost no signal and are therefore black in SE images. The reason is because during the time between the 90° and the 180° pulses the blood flows completely or particularly out of the imaging slice and therefore the spins do not see the 180° pulse. The outflow effect is less pronounced for slow flowing blood, i.e. excited spins (blood) stay within the slice and yields some signal. The same effect can be observed if the vessel is located within the slice for a certain distance. Further, a fresh thrombus also leads to a bright signal within the vessel. In contrast, gradient echo sequences demonstrate an enhanced signal for inflowing blood, the so-called inflow effect.

An additional 180° pulse applied before the SE sequence introduces an additional T1 weighting in the image. If the time between this inversion pulse and the 90° pulse of the SE sequence (inversion time TI) is chosen that the longitudinal magnetization of a tissue is zero no signal is provided by this tissue. Such a sequence is called an inversion recovery sequence. The most common types of this inversion sequences are the STIR (Short Tau Inversion Recovery) sequence where the signal of the fast T1 relaxing fat tissue is suppressed by using a short TI (160ms @ 1.5T), and the FLAIR (Fluid Attenuated Inversion Recovery, see Fig. 3) sequence where the signal of the slow T1 relaxing liquor is suppressed by using a long TI (2500ms @ 1.5T).

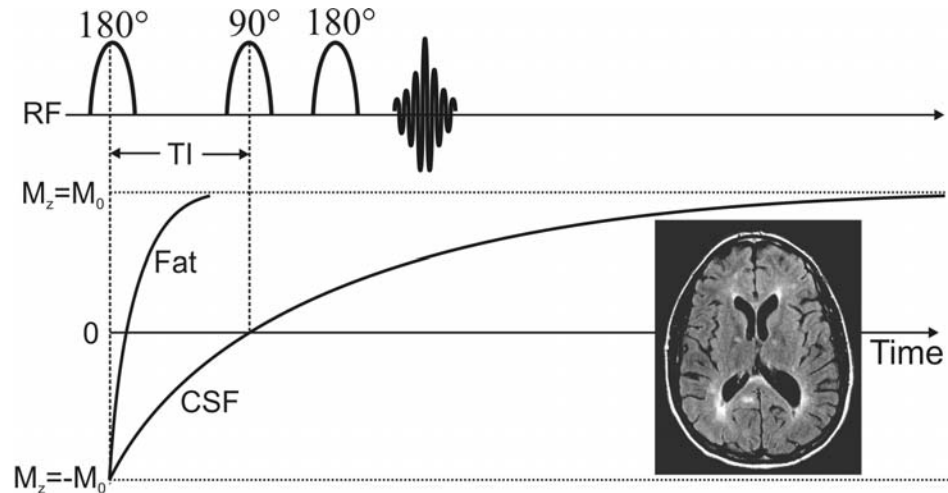


Fig.3: FLAIR-sequence - if the time of inversion (TI) is chosen that the longitudinal magnetization M_z of the CSF is zero during its T_1 relaxation, the CSF-signal in the subsequent SE-sequence is suppressed.

Literature:

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