Simultaneous Spin/Gradient Echo Acquisitions in Conjunction with Arterial Spin Labeling For Quantification of T2* by Single Shot 3D Spiral GRASE Imaging

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Quantification of local T2*, which is used in fMRI as a surrogate for neuronal activity, can be difficult because static (R2') and irreversible (R2) effects contribute to the decay. In this work, we developed a 3D mapping scheme based on GRASE [1], in which two spiral-out planar readouts per k-space partition are used to acquire a spin echo (governed by R2) and a time-shifted gradient echo (governed by R2') on the ascending slope of the corresponding spin echo. From a combination of R2 and R2', local T2* variations can be quantified. Measurements were also performed in conjunction with arterial spin labeling allowing to selectively measure T2* of labeled water.

Theory:

GRASE is principally a CPMG sequence with a 90° excitation pulse followed by a train of refocusing pulses, generating a series of spin echoes.

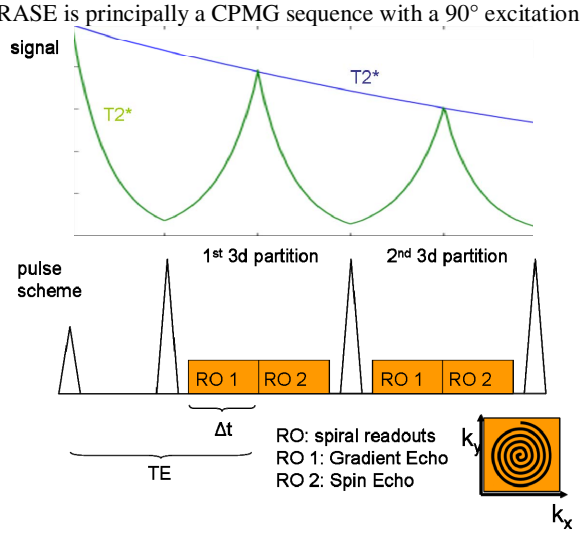

Fig.1: signal curves and pulse/readout schemes; for each partition, two spiral readouts are performed, starting in the k-space-center of the 3d partition at TE- Δ t and TE.

Conventionally, each spin echo is spatially encoded by EPI readouts for each slice of k-space, where the center of the k-space slice is reached synchronously with the spin echo. To acquire dual echoes for each segment, we replaced the cartesian EPI readouts by two successive spiral readouts, in which the center of the first spiral lies on the ascending signal slope, and the second spiral coincides with the spin echo [Fig. 1]. Conventional blipped phase encoding gradients are used to encode the 3rd spatial dimension. Under the assumption that the readouts of each segment do not interfere with each other and the modulation transfer function of the spiral readouts is the delta function, the signal from the second spiral at echo time TE is given by $s(TE) = s_0 \cdot e^{-TE \cdot R2}$. In contrast, the signal from the first spiral at $TE - \Delta t$ is governed by $R2$ and by a superposed refocusing slope due to $R2'$, thus $s(TE - \Delta t) = s_0 \cdot e^{-(TE-\Delta t)\cdot R2} \cdot e^{-\Delta t \cdot R2'}$. Here, $R2'$ is the part of $R2*$ decay which can be completely refocused: $R2' = R2* - R2$. Defining $R2^+$ as the recovery rate of the spin echo by $s(TE - \Delta t) = s_0 \cdot e^{-TE \cdot R2} \cdot e^{-\Delta t \cdot R2^+}$ the relationship $R2* \equiv 2 \cdot R2 + R2^+$ follows. $R2^+$ can be measured from the ratio of the first to the second echo. $R2$ can be obtained – and thus $R2*$ and T2* computed - by repeating the experiments with shifted echo time TE.

Methods:

Measurements on a 4T scanner (Bruker/Siemens) have been performed on two healthy volunteers, age 23 and 26. The sequence had an echo time of 26ms (first refocused echo), turbo factor (echo train length) 16, Δt = 12ms, 12 averages. One single spiral readout per partition took 10 ms, with a FOV of 250mm and an isotropic inplane resolution of 3.8mm. In the framework of a pulsed arterial spin labeling sequence, inflow time 1500ms, perfusion weighted difference images were obtained with two averages and a measurement time of 16sec. For the calculation of the R2* maps literature values have been used for T2 of tissue (T2=50, [2]).

Results:

Maps of estimated T2* were obtained with whole brain coverage and 3.8mm resolution. The values found were in the order of literature values (0.031[1/ms], [2]). Strong local variations can be seen in lower slices [Fig. 2]. Diffusion weighted images have also been obtained [Fig. 3].

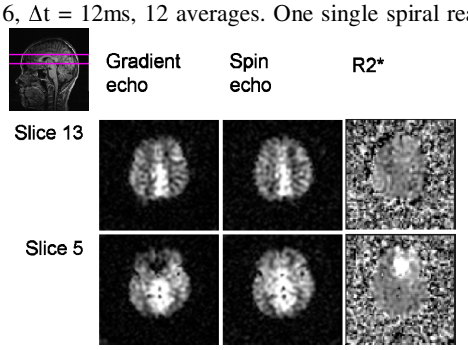

Fig.2: Gradient echo, spin echo and R2* maps; values found ranged from 0.2[1/ms] (slice 5) to an average of 0.06[1/ms] for slice 13.

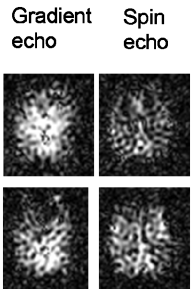

Fig.3: Perfusion weighted difference images for gradient and spin echo

Conclusion :

A method has been presented to acquire spin and gradient echoes in one shot, allowing absolute quantification of T2' and T2*. The applicability for ASL experiments has also been shown. This sequence should be useful to improve quantification of fMRI, either conventional or in combination with ASL. Furthermore, when combined with ASL, this novel sequence could be useful to measure compartmental effects of local T2*.

Acknowledgments:

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References:

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