The Application of vGRASE to Scan Time Reduction in T2-Weighted Imaging of the Brain

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Introduction

A standard way to reduce scan times with Turbo Spin Echo (TSE) imaging sequences [1] is to increase the turbo factor, i.e. the number of lines of *k*-space that are sampled at each spin excitation. This is achieved by increasing the number of RF refocusing pulses by a combination of reduced spin-echo-spacing and increased readout time. A longer readout time results in signal loss in the later echoes due to T_2 decay, leading to image quality degradation, whilst a shorter spin-echo-spacing causes an increase in SAR and loss of scanning efficiency as the proportion of time used for data sampling is reduced. These problems can be overcome by using the GRASE sequence [2] to acquire multiple lines of data at each spin echo. However, the standard GRASE acquisition scheme suffers from the drawback that complex signal modulations due to a combination of T_2 decay, T_2^* decay and off-resonance produce ringing and ghosting artefacts in the image [3-4]. A potential solution to this problem is to use the vGRASE sampling scheme [5], which has the effect of separating the T_2 decay effects from the T_2^* and off-resonance effects in such a way that their respective signal modulations take place along different *k*-space axes. The resulting image-domain point spread function (PSF) has a smooth behaviour without the sidebands that are characteristic of the PSF with standard GRASE. Despite these potential advantages, vGRASE has received little attention since the initial description of the method. This paper investigates the application of the technique to T_2-weighted imaging of the head and demonstrates how the method can be used to perform high turbo-factor imaging, whilst preserving the characteristics of the spin-echo-train used in a standard TSE readout.

Methods

Sequence Design: Fig. 1 shows the sequence diagram for a single RF excitation (or shot) for a spin-echo-train of length 5. An EPI-echo-train is used to sample a contiguous set of data points (or readout segment) in the k_x direction at each spin echo. The pre- and de-phasing readout gradients (solid blue colour in fig. 1) are used to vary the k_x offset of the readout segment as a function of spin echo number, such that data sampling starts at the first spin echo at the most negative k_x offset and steps through k_x as the spin echo number increases. The centre of *k*-space is sampled at the central spin echo in the spin-echo-train. Instead of the constant phase-encoding gradient used in the original vGRASE sequence, a blipped phase-encoding gradient is used to step through k_y data points during each EPI-echo-train. A different set of k_y points are sampled at each shot using a standard interleaved segmentation scheme, in which the pre- and de-phase gradients (orange stripes in fig. 1) are varied from shot to shot. The technique relies upon a good match at the interface between k_x segments, which places requirements on the gradient and data sampling systems to provide a precise *k*-space trajectory. To minimise the potential problems associated with imperfect *k*-space trajectories, instead of the trapezoidal gradient pulses used in the original vGRASE implementation, a smoothly varying sinusoidal readout gradient pulse shape is used, along with a small overlap between readout segments.

Volunteer Measurements: Images were acquired from healthy volunteers using a Siemens 1.5T MAGNETOM Avanto system with the standard head matrix coil and the following imaging parameters: FOV 173x230mm; matrix 192x256; pixel size 0.9x0.9mm; slice thickness 5mm; number of slices 24; TR 4000ms; number of spin echoes 9; spin-echo-spacing 16.5ms; number of EPI-echoes (number of lines of *k*-space per shot) 32; EPI-echo-spacing 0.36ms; number of spin echoes 9; total length of readout 153ms; effective echo time 82ms; number of shots 6; scan time including phase-correction scan 28 seconds. Images were generated on the MR scanner using a modified version of the standard image reconstruction software.

Results and Discussion

Images from the study demonstrated good image quality with respect to the low level of artefact and clear contrast between grey and white matter. An example image is shown in fig 2. This study has confirmed that it is technically feasible to use the vGRASE technique to acquire T_2-weighted images with similar contrast properties to standard TSE protocols. This is possible because the higher turbo factor does not result in a corresponding increase in the number of RF refocusing pulses or overall readout time. Some additional flexibility also exists for controlling the spin-echo-spacing for a given turbo factor, as there is a relationship between the number of refocusing pulses and the width of each readout segment, which in turn determines the EPI-echo-spacing. The method is likely to be of particular interest for measurements at higher fields, for which the penalties associated with an increased number of RF refocusing pulses are more severe due to the increased SAR and reduced T_2. Despite the low level of artefact observed in this study, the sensitivity of the technique to small imperfections in the *k*-space trajectory may mean that a routine implementation will require some additional dedicated adjustment procedures to ensure consistent image quality.

References

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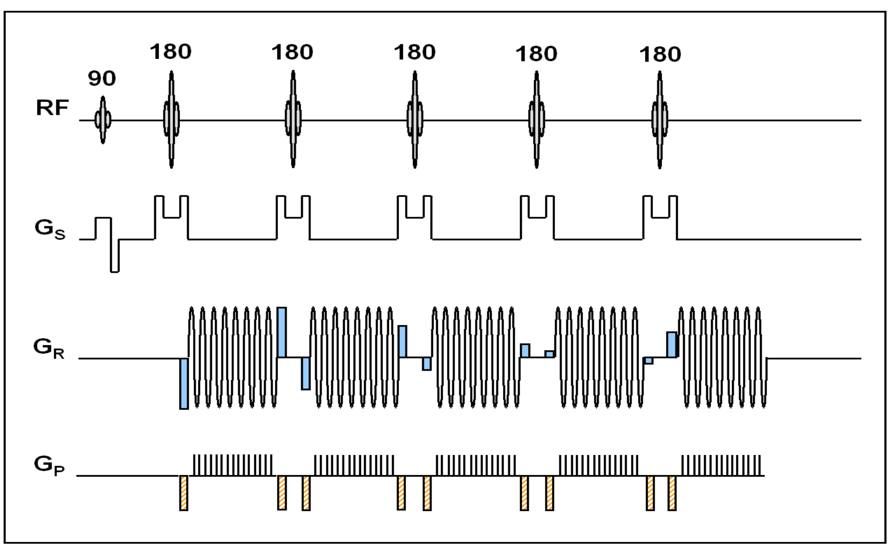

Figure 1: Sequence diagram.

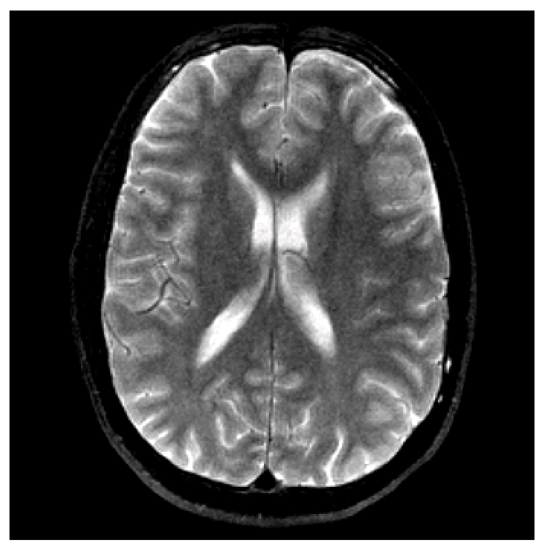

Figure 2: 256 matrix T_2-weighted image acquired in 28s.