Single-shot STEAM MRI with gradient and stimulated echoes (GRASTE)

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In single-shot STEAM MRI [1] each stimulated echo (STE) requires a slice-selective read-out RF excitation, a gradient rephasing the STE, and a phase-encoding gradient. Thus, the efficiency of the sequence, i.e. the time for data acquisition in relation to the total measurement time, is not optimal: the signal-to-noise ratio (SNR) per measurement time is reduced compared to most other single-shot techniques. To overcome this drawback, a few gradient echoes (GEs) in addition to the STE can be acquired in each read-out interval (Fig. 1a) (*gr*adient *a*nd *st*imulated *e*cho sequence, GRASTE). Thereby, two different k-space sampling schemes can be used. In the "standard" sampling scheme the upper and lower k-space parts are covered with the GEs, but the central part with the STEs (Fig. 1b) to minimise susceptibility-related artifacts due to GEs while maintaining most of the robustness of single-shot STEAM. In contrast, an "interleaved" sampling scheme, where GEs and STEs of a readout train represent successive k-space lines (Fig. 1c), has a major advantage: the flip-angle of the read-out RF excitation can be increased [2], and thus the signal-to-noise ratio (SNR) is improved.

Materials and Methods

Measurements were performed on a 3 T MR system (Siemens Magnetom Trio) with a standard transmit-receive head coil. Written informed consent was obtained from all volunteers prior to the examination. Single-shot STEAM acquisitions with one STE per read-out interval were compared to GRASTE measurements with two (Fig. 1a) or four additional GEs using the "standard" (Fig 1b) and "interleaved" (Fig. 1c) sampling scheme. For all protocols, the read-out flip angle was adjusted for grey matter according to [2].

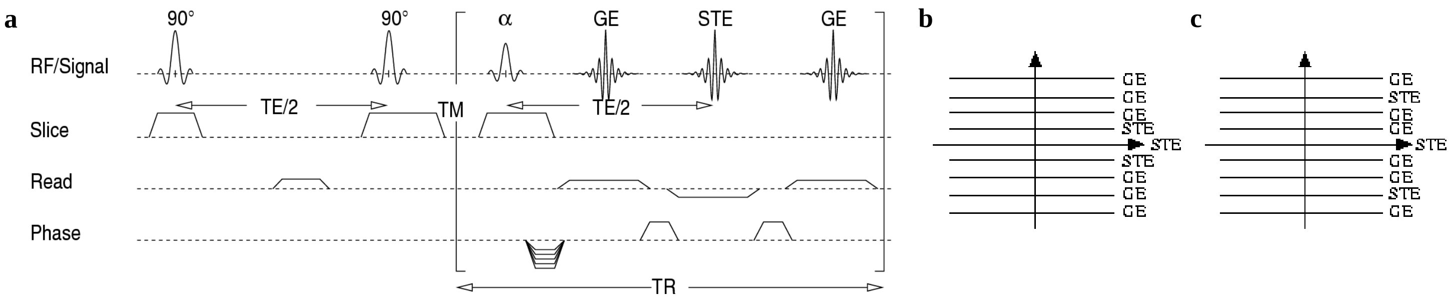

Figure 1: (a) Basic pulse sequence of "standard" GRASTE with two additional GEs and (b) "standard" and (c) "interleaved" k-space sampling schemes.

Results

Figure 2 shows the results obtained for a healthy volunteer and demonstrate that GRASTE allows a considerably reduced acquisition time. "Standard" GRASTE suffers from a slight SNR penalty due to the adapted read-out flip angle [2]. For example, four GEs per TR (Fig. 2c) can deliver 90% of the SNR obtained for STEs only (Fig. 2a) with an acquisition time reduced from 285 ms to 150 ms. The example for "interleaved" GRASTE (Fig. 2f) even has almost the double SNR compared to Fig. 2d due to a larger read-out flip angle for a similar reduction of the acquisition time (from 322 ms to 180 ms). However, this gain is at the expense of an increased sensitivity to susceptibility-related artifacts (not shown). For both GRASTE variants, the acquisition times of the images shown are well below the minimum time of 225 ms achievable without GEs for the used resolution and field-of-view.

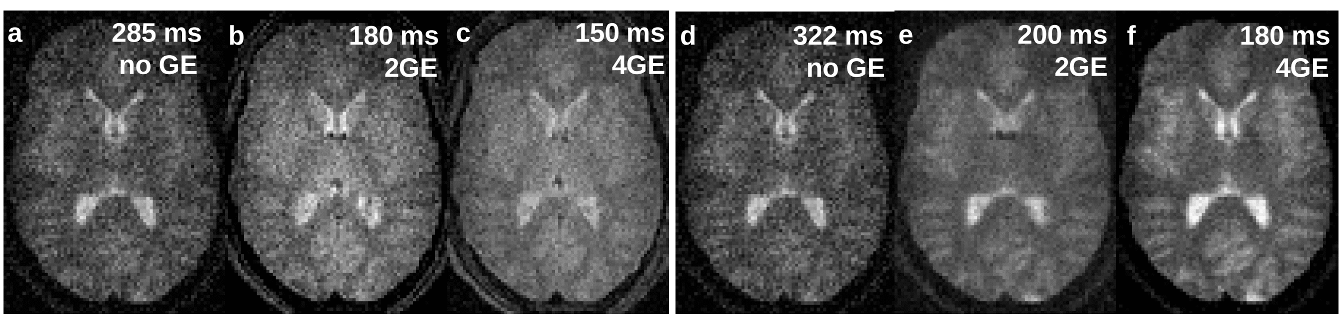

Figure 2: (a, d) Single-shot STEAM MR images, (b, c) "standard" GRASTE and (e, f) "interleaved" GRASTE images obtained with (b, e) two and (c, f) four GEs per TR, respectively; all images were acquired with a resolution of 2x2x5mm3.

References

[1] Frahm J et al, JMR 65, 130-135 (1985)
[2] Nolte UG et al, MRM 44, 731-736 (2000)