

Weighted dual-echo T1-w Spin-Echo propeller with mutual cross-calibration

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Purpose

Recently, we introduced a T1-w Spin-Echo propeller sequence (SE-prop (1,2)) for T1-w imaging of the brain with similar image contrast as the classical T1-w Cartesian Spin-Echo (SE) sequence. Despite that many new pulse sequences have emerged for T1-w imaging, the type of MR contrast obtained from the classical Spin-Echo is often still preferred for post-Gd brain scans. With T1-w SE-prop, motion occurring between the blades is retrospectively corrected for like any other propeller sequence. However, due to that only one k-space line is read out every TR, one full blade is acquired in $N_{\text{phase}} \times \text{TR}$ s. Without parallel imaging, this time may be $\sim 10\text{-}20$ s depending on the blade width, why *intra*-blade motion may occur. With partial Fourier imaging and parallel imaging, the number of acquired lines can be reduced to shorten the temporal footprint of the blade. For a fixed scan time, one may therefore acquire more blades. However, using partial Fourier techniques on narrow blades ($N_{\text{phase}} < \sim 30$) does not shorten the blade scan time too much, since extra lines (a.k.a. ‘overscans’) are needed for the phase estimation in the half-Fourier reconstruction. Moreover, we have recently noticed that using less than $\sim 10\text{-}15$ overscans may lead to shading in the center of the image FOV due to the lack of this phase information. The same inefficiency applies to self-calibrating parallel imaging such as ARC, where the ACS lines within each blade limit the net acceleration for narrow blades. For these reasons, we here suggest parallel imaging accelerated blades (R=2) using cross-calibration and without the use of partial Fourier acquisition via an orthogonal dual-echo SE-prop approach.

Methods

A second echo, with swapped phase/frequency encoding direction, was added to the SE-propeller sequence (Fig. 1). Axial scans on a volunteer were acquired using a GE 1.5T Discovery MR450 system (GE Healthcare, Waukesha, WI) and an 8-channel head coil. The scan parameters were as follows: FOV = 24 cm, seven 5 mm slices, TE1/TE2/TR = 10/18/500 ms, receiver bandwidth = ± 50 kHz, matrix size of the blades = 320x28. Two scans were performed, one with 9 and one with 17 blade pairs, both with inferior saturation pulses to avoid pulsatile flow from the carotid arteries. An ARC acceleration of R=2 was used (no ACS lines), leading to a temporal footprint per blade pair of 8 s. ARC weights for each blade were calculated using its corresponding orthogonal blade. K-space weighting of the second echo according to Fig. 2b was performed for two reasons; first for better T1-weighting, by only use the 10 ms echo in the k-space center, and second to reduce the amount of colored noise inherent in propeller acquisitions by compensating the excessive averaging in the k-space center.

Results

In Fig. 3, two axial brain slices are shown. In Fig. 3a, the scan time was 1:03 min due to the 9 blades pairs, but (for illustration purposes) only the first echo was gridded with a k-space sampling corresponding to the green lines in Fig. 2c. Using both echoes (as intended) for gridding and with a data weighting of the second echo as in Fig. 2b, k-space becomes fully sampled (Fig. 3b). In Fig. 3c, the gridded image for the 17-blade scan is shown using both echoes, yielding a better SNR and yet reduced flow artifacts for twice the scan time (1:59 min).

Discussion & Conclusion

In this work, we have presented a dual-echo version of the SE-prop sequence, where the second echo contributes only to k-space outside its center for proper T1-w (minimal TE). This effectively compensates the excessive averaging in the center of k-space, and therefore will reduce the amount of colored (speckled) noise. At low SNR, colored noise becomes more disturbing, why this becomes more important for thinner slices. As SE-prop acquires one blade (pair) over several TRs, motion may occur within the blade, why the overall goal is to minimize this blade time, rather than the total scan time. We are therefore proposing to use R=2 with cross-calibration to cut this blade time in half. However, while R=2 is coupled with a low geometry factor for almost any head coil (no SNR penalty for a fixed scan time), the reduced amount of data (and scan time) leads to an SNR that we have found to be too low for daily clinical use. By using the same amount of blades as for a single echo scan (Fig. 3c), not only the SNR reaches the (in our opinion) desired level, but also flow artifacts are reduced significantly as they are spread out and averaged over more angular directions. The drawback of the dual echo scan is the reduction in the amount of slices per TR, and depending on the amount of slices needed, the interleaved slices may have to be collected in more batches (acquisitions), which increases the total scan time. However, this has also an advantage in that, for each batch (acquisition), the slices become more separated, which reduces cross-talk effects.

References

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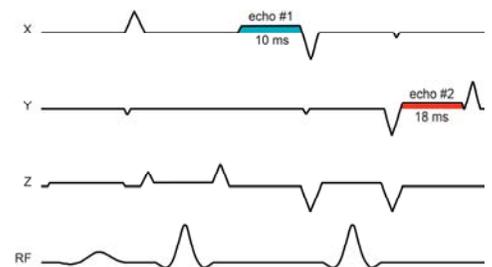


Figure 1. The orthogonal dual echo T1-w SE-propeller sequence. Not shown: Multiple slices are acquired each TR. One blade is filled in N_{phase} TRs until next blade is acquired.

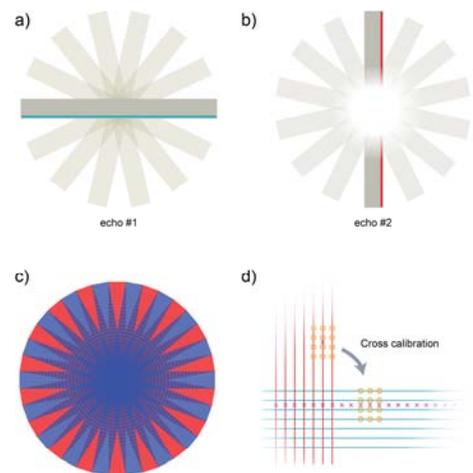


Figure 2. Two sets of propeller blades are built up in N_{phase} TRs: a) echo #1 and b) echo #2. Note that there is no contribution from echo #2 in the k-space center for T1-w image contrast purposes and reducing the colored noise. c) Example with nine blade pairs, each of size 320x28, building up k-space. d) ARC weights for echo #1 are estimated from echo #2, and vice versa, similar to Ref. 3.

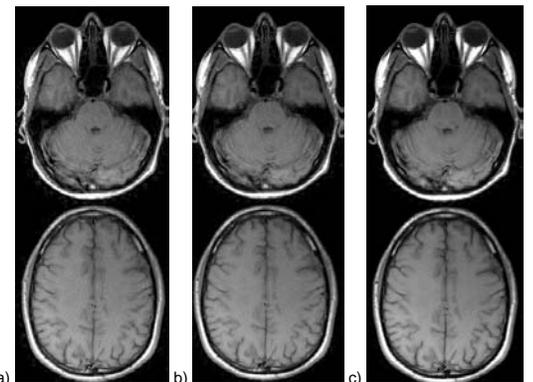


Figure 3. Gridded images for two slice locations on a healthy volunteer. a) 9 blades of the first echo only (angular undersampling, scan time: 1:03 min). b) 9 blade pairs (just fulfilling Nyquist at the k-space perimeter, same scan as in a). c) With the 17 blade experiment with almost 2x the minimum number of blades to fill k-space, flow artifacts are better controlled and SNR approaches the desired level. Scan time: 1:59 min.