Spin-Echo Propeller (SE-prop): T1-w single-echo motion robust imaging without inversion pulses

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Introduction

T_1-weighted images are key in most clinical brain MR exams and are often used before and after Gadolinium (Gd) contrast administration to evaluate the regional contrast uptake. The conventional Cartesian *Spin Echo* sequence (SE) has so far been the most widely used sequence for this purpose. Other T_1-w pulse sequences often rely on an inversion pulse for the T_1-w contrast, such as for example the RF-refocused T_1-FLAIR and the gradient refocused MP-RAGE sequences, both of which produce an excellent WM/GM tissue contrast. To avoid motion artifacts, these two pulse sequences have also been implemented as motion robust variants (1, 2), similar to the original T_2-w PROPELLER sequence (3). However, in many radiologists' experience, the use of an *inversion pulse* based sequence after Gd administration sometimes makes the contrast enhancement less apparent.

Aiming for an unaltered tissue contrast compared with the classical SE sequence while alleviating motion artifacts commonly occurring in SE, we have in this work developed a new propeller-based T_1-w Spin-Echo sequence (SE-prop). Along with the expected benign motion and flow properties inherent in propeller acquisitions, we here also pay attention to off-resonance artifacts from fat in the context of propeller trajectories, noting that the chemical shift direction is different for each blade and that for T_1-w data the fat signal is particularly strong compared to the on-resonance water.

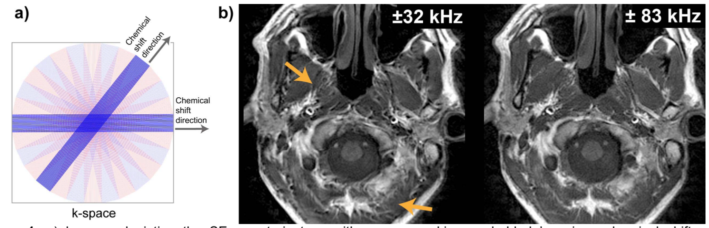

Figure 1. a) k-space depicting the SE-prop trajectory, with arrows marking each blade's unique chemical shift direction. b) SE-prop data on a healthy volunteer, acquired at 3T using bandwidths of ±32 and ±83 kHz. As the chemical shift direction rotates with blade angle, the artifact has a swirl-like appearance. At 3T, receiver bandwidths at or above ±62 kHz was found necessary for images to be diagnostic in these regions. Consequently, ±32 kHz was found enough at 1.5T (data not shown).

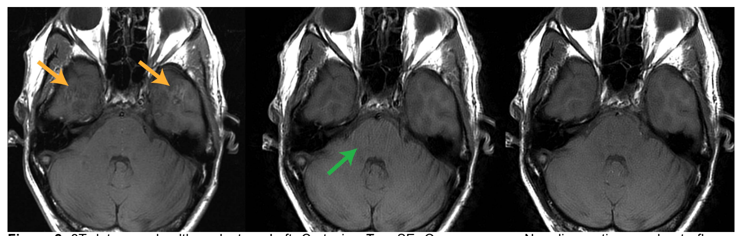

Figure 2. 3T data on a healthy volunteer. Left: Cartesian T_1-w SE. Orange arrows: Non-diagnostic area due to flow artifacts. Middle: T_1-w SE-prop. Green arrow shows moderate flow related streaks. Right: T_1-w SE-prop with flow comp. (no visible flow artifacts). 24 288x32 blades were used for SE-prop, 1 NEX for the Cartesian SE.

Materials and Methods

Most propeller-type sequences developed to date employ a single RF excitation followed by an echo-train to acquire a *k*-space blade (2-5). In SE-prop, the core sequence is identical to the classical SE sequence, with one RF excitation *per line* in a blade. While this introduces some risk of *intra*-blade motion, the time to acquire a blade consisting of e.g. 32 lines, using *TR* of 500 ms is only 16 s, which is short compared to the total scan time. The following sequence parameters were used in this study; FOV = 22 cm, sl. thk. = 4 mm, 24-28 blades of sizes 288 (or 448)×32, *TE*/*TR* = 8-15/500 ms, 8-channel head coil, GE 1.5T/3T DVMR 450/750 scanners. The raw data were reconstructed in MATLAB, compiled and deployed to a dedicated reconstruction server returning the gridded images to PACS.

To evaluate the lowest acceptable receiver bandwidth (*rBW*) to be used in SE-prop at 1.5T and 3T, respectively, SE-prop data were acquired at both field strengths using *rBWs* of ±32, 50, 63, 83 kHz. Finally, SE-prop's ability to suppress flow artifacts was investigated, with zero and first order gradient moment nulling, and compared to the Cartesian SE.

Results

In Fig. 1a), the SE-prop *k*-space trajectory is depicted, with arrows indicating the chemical shift direction for two of the blades. After gridding, the final image will be contain fat-signal shifted along all blade directions. This is shown for 3T data in Fig. 1b), for *rBWs* of ±32 and ±83 kHz, respectively. The orange arrows points to fatty structures subject to "swirl-like" chemical shift artifacts. It was found that a *rBW* of about ±63 kHz was necessary to keep the chemical shift under control for future clinical reading of the images at 3T. Consequently, ±32 kHz was found adequate for 1.5T.

Fig. 2 shows an axial slice at the level of the in-flowing cerebral arteries. In the left panel, the Cartesian SE image is shown with apparent flow artifacts in the temporal lobes resulting in a partly non-diagnostic image (orange arrows). For the corresponding SE-prop image (middle panel), the flow artifacts are spread out and reduced in amplitude, leaving the temporal lobes artifact free while introducing some flow related streaks in the brain stem (green arrow). Combining SE-prop with first order moment nulling gradients, the residual flow artifacts disappear as expected. High resolution SE-prop scans are shown in Fig. 3 acquired at 1.5T and 3T using 28 448×32-wide blades, leading to a 7:30 min scan time and a nominal resolution of 448×448 (0.49×0.49 mm^2). Finally, Fig. 4 shows comparative post-Gd patient data acquired at 3T with Cartesian SE and SE-prop, respectively.

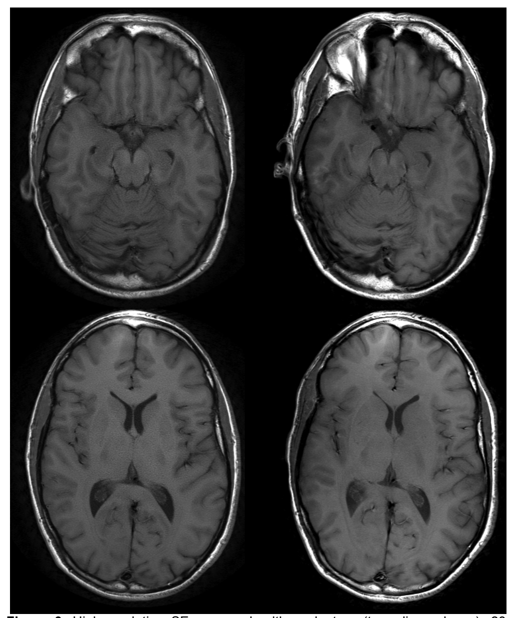

Figure 3. High-resolution SE-prop on healthy volunteer (two slices shown). 28 blades of size 448x32. Left/Right: 1.5T/3T. Scan time: 7:30 min.

Discussion

Similar to how T_2-w PROPELLER is a motion robust variant of the Cartesian T_2-w FSE sequence, we have in this work presented a T_1-w propeller variant of the Cartesian T_1-w SE sequence. With that, one comes one step closer to a comprehensive motion robust everyday clinical brain exam.

In this work, we have presented classical SE and SE-prop images subject to flow and off-resonances (fat). While these results extend also to e.g. T_2-w PROPELLER, these effects appear stronger in T_1-w data and hence need to be addressed more carefully. Our recommendation of higher receiver bandwidths to control the presented "chemical swirls" may be ignored if the tissue of interest lies outside the orbital and head & neck regions, for the sake of an increased SNR efficiency. The details regarding motion-correction of int*ra*- and int*er*-blade motion is subject to a parallel investigation, but is of outmost importance for T_1-w SE-prop to become as regularly used as the well-established T_2-w PROPELLER sequence. Next, a prospective patient study will begin that will benchmark the Cartesian SE against SE-prop.

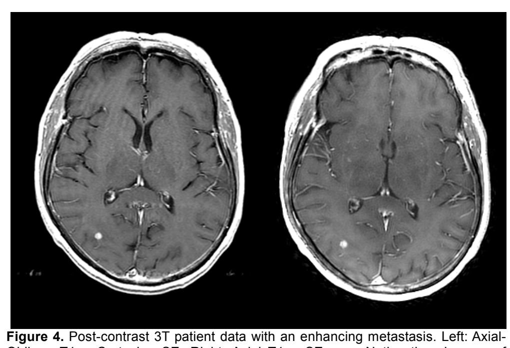

Figure 4. Post-contrast 3T patient data with an enhancing metastasis. Left: Axial-Oblique T1-w Cartesian SE. Right: Axial T1-w SE-prop. Notice the absence of motion artifacts for SE-prop, despite no motion correction being performed.

Acknowledgements

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References

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