T1-w SE-prop to overcome flow artifacts in post-Gd brain imaging

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Purpose For many brain MRI exams, tumor patients in particular, Gadolinium (Gd) is used for the detection of blood-brain barrier leakage. The primary MR tissue contrast of interest for this purpose is T1 weighting, acquired both pre and post Gd administration. The classical Spin Echo sequence (SE) has so far been the most widely used as the T1-w SE depict contrast enhancement more reliably than alternatives such as e.g. T1-FLAIR or MP-RAGE, both of which use a leading inversion pulse. The potential drawbacks of using an inversion preparation for T1-w contrast post-Gd are still under debate. Aiming for a motion robust sequence to replace the classical Cartesian SE for pre/post-Gd T1-w imaging, we have recently introduced a propeller based (3) T1-w SE-prop sequence (1,2). We have now developed this SE-prop sequence further, incl. adding support for spatial saturation pulses. To evaluate the performance of SE-prop, we have acquired T1-w images using both the Cartesian SE and SE-prop on selected patients undergoing brain MR exams with Gadolinium.

Methods To our standard brain MR protocol, one T1-w SE-prop scan was added before and after Gd administration to benchmark it against the classical Cartesian SE. At the time of this writing, 35 consenting patients have been enrolled. The exams were performed on GE 1.5T/3T Discovery MR450/MR750W scanners (General Electric Healthcare, Waukesha, WI) using standard head-neck coils. Common imaging parameters for the Cartesian SE and the SE-prop sequences were: FOV = 24 cm, slice thickness = 4 mm, image matrix 320x320, TE/TR = 10/500 ms. At 3T, the receiver bandwidth for the Cartesian SE was ±41 kHz and ±50-62.5 kHz for SE-prop. The higher bandwidth for SE-prop is due to that off-resonances from fat tends to be more disturbing for propeller trajectories (2). For SE-prop, the blade width was 32 lines, with one line acquired per TR. The blades were accelerated with an outer reduction factor (ORF) of 2 (and 8 ACS lines) to reduce the temporal footprint of each blade and to allow the use of more blades within the same scan time. 18-23 blades were used for SE-prop, scan time permitting. An inferior saturation pulse was used for both sequences to suppress incoming flow from the carotid arteries. Gradient 1st order moment nulling ('flow compensation') was however not used as it makes the vessels appear (undesirably) bright while it is still not sufficient to eliminate pulsating arterial flow and does also increase the echo time (TE), which degrades the T1-weighting.

Results In Fig. 1, two 3T post-Gd SE-prop scans with identical scan times are shown – one without parallel imaging and 15 blades (minimum) and the other with ORF = 2 and 20 blades. As the same amount of data has been collected in both cases, the SNR efficiency is similar, while it is clear that the use of more blades averages out the flow artifacts better (cf. black arrow), why this option was used for the remainder of the patient scans. Using the same matrix size, Fig. 2 shows axial Cartesian SE and SE-prop images before Gd injection, with the arrow pointing to a flow artifact from the lateral transverse sinuses that happened to coincide with the shape of the brain stem. This pre-Gd hyper intense area is not present on SE-prop (Fig. 2, right). In Fig. 3, a post-Gd example is shown of a patient with a meningioma, and where the white arrow points to a likely true lesion, which is difficult to distinguish from the surrounding flow artifacts on the SE image (left, cf. black arrow). Last, Fig. 4 shows post-Gd images from a selection of three patients acquired at 3T with SE (left) and SE-prop (right).

Discussion Propeller based pulse sequences have over the last decade shown to be very helpful against head motion artifacts for many image contrast types such as T2-w, T2-FLAIR, T1-FLAIR and DWI – recently also for T1-w Spin-Echo type imaging (1). While head motion is indeed a recurring problem in the clinical routine, flow artifacts in post-Gd Cartesian T1-w Cartesian SE scans is even more problematic. On nearly every clinical post-Gd Cartesian SE T1-w brain scan, flow artifacts in the cerebellum (from the transverse sinus) and in the brain stem region (from the carotid arteries) render these areas non-diagnostic. In this work we have shown that with SE-prop, these flow artifacts are reduced to thin radial streaks originating from each flow source. With more blades than the minimum to fulfill the Nyquist criterion at the k-space perimeter, these flow-induced streaks are essentially eliminated. What is more important is that these minor streaks (if visible) do not have a lesion like appearance and therefore less likely to mislead the radiologist (cf. e.g. Fig 3). For a fixed scan time, flow artifacts are better controlled by the use of more blades and parallel imaging. While we have primarily focused on the image quality of post-Gd scans, Fig. 2 shows an example of a *pre*-Gd flow artifact mimicking a lesion in the brain stem. However, without an inferior saturation pulse, even SE-prop produces strong (albeit not lesion-like) flow artifacts in the form of streaks from the pulsating MCAs (data not shown), why such saturation pulse has been used throughout the study for both sequences.

Conclusion In summary, flow artifacts in the basal parts of the brain are present on nearly every T1-w post-Gd brain scan – regardless of the patient – and renders large parts of the images non-diagnostic. This preliminary study suggests that SE-prop will, in addition to its motion correction abilities, play a strong role for T1-w imaging of tumors around the brain stem and cerebellum, despite its slightly prolonged acquisition time due to the propeller trajectory.

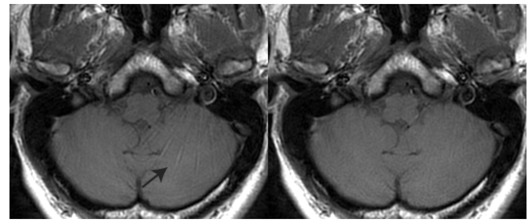

Figure 1. 3T T1-w SE-prop data on a patient pre-Gd. Both images acquired with identical scan time, image resolution, and blade width. Left: Using 15 blades (= minimum to cover the k-space perimeter). Right: Using 20 partially accelerated blades (ORF=2), with reduced flow artifacts.

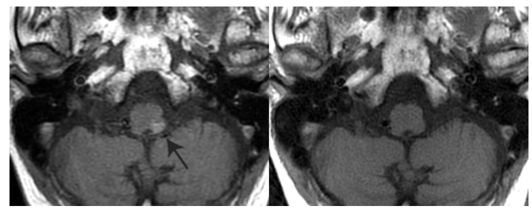

Figure 2. 1.5T T1-w data on a patient pre-Gd. Left: Cartesian SE. Right: SE-Prop. Black arrow: Flow artifact from the lateral veins, which may be mistaken for a lesion. Both images were acquired with 320x320 final matrix size. For SE-prop, 22 blades of size 320x32 were used.

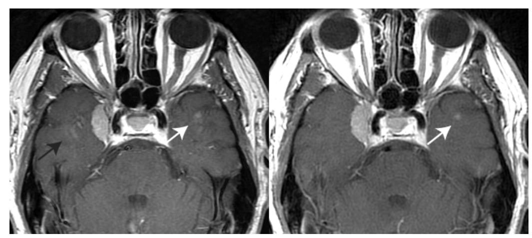

Figure 3. 3T T1-w post-Gd images of a patient with meningioma. Left: Cartesian SE. Right: SE-Prop. Black arrow: Flow artifacts. White arrows: A hyperintense lesion. In the left image (SE), it is harder to separate the flow artifacts from enhancing lesions.

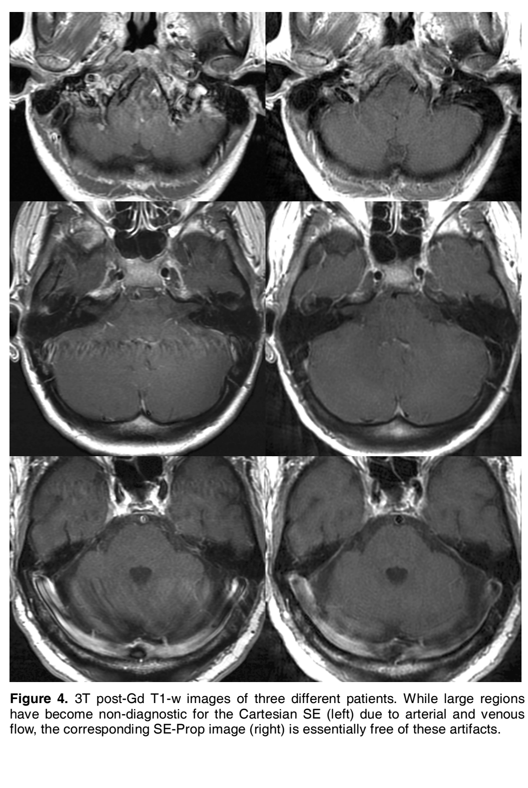

Figure 4. 3T post-Gd T1-w images of three different patients. While large regions have become non-diagnostic for the Cartesian SE (left) due to arterial and venous flow, the corresponding SE-Prop image (right) is essentially free of these artifacts.

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References

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