2D Nose Navigators (NoseNav) for real-time correction of nodding motion in brain MRI

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Purpose Real-time motion correction techniques are very promising for correction of patient head motion (1-2). With a real-time feedback loop, the slice locations are constantly updated to follow the patient's head, thereby avoiding both spin-history effects from crossing slices and more importantly image ghosting for multi-shot sequences. On the other hand, with the wider use of propeller (3) sequences that now serve multiple image contrasts (T2-w, T1-w, T1 & T2-FLAIR, etc.), the issue of motion-induced image ghosting is less of an issue in the clinical practice. However, the retrospective correction in the propeller reconstruction is typically performed in-plane only. For non-sagittal slices, this leaves nodding motion uncorrected, which is also very difficult to restrain in a clinical setting and at the same time commonly occurring, not the least due to patient breathing. In this work, we propose a new type of 2D navigator that tracks the patient's nose (assumed to be of no diagnostic interest) for real-time correction of nodding motion and integration with e.g. axial/coronal propeller scans.

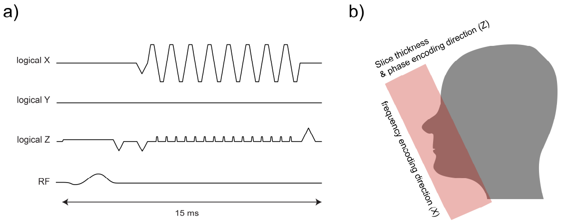

Figure 1. a) The Nose Navigator pulse sequence consists of a non-spectrally selective minimum phase RF excitation pulse and an EPI-readout with blips on the slice-encoding axis. b) With a (tilted) coronal 40-80 mm thick slice, the full left-right extent of the nose (and jaw) is excited. The sagittal EPI readout will hence show a lateral projection of the noise (and jaw).

Methods A GE-EPI based 2D nose navigator sequence module was developed (Fig. 1a). To be prescribed as a single tilted thick coronal slice (red area, Fig. 1b) over the patient's nose and jaw area (to leave the brain magnetization untouched), but with a sagittal EPI readout (to see the nose in a sagittal view), the phase encoding blips were moved from the logical Y to the logical Z axis (Fig. 1a). Thanks to the coronal(ish) excitation, no aliasing will occur in the phase encoding direction (A-I/P-S). Due to concerns with chemical shift artifacts from fat (common problem in EPI), we first investigated the water/fat content of the nose. In Fig. 2, three nose scans are shown with a) non-spectral ('normal') excitation, b) fat-saturated excitation, c) water-saturated excitation. From the very low fat signal in c) it was concluded that a standard minimum phase RF pulse could be used for the Nose Navigator (NoseNav) sequence, allowing the RF excitation duration to be 1-3 ms instead of ~8-16 ms (common for EPI). Furthermore, as the olfactory region is subject to significant susceptibility gradients from tissue-air boundaries, geometric distortions and signal dropouts are to be expected from a GE-EPI readout. To reduce geometric distortions, the frequency encoding resolution was low (here 48), the phase FOV 50% (here 10x5 cm), and a high parallel imaging factor should be used (coil dependent). While an increased phase encoding resolution does not increase the distortions, it does increase TE (and signal dropouts from dephasing). Therefore, NoseNav scans with R=1-3 with matrix sizes of 48x24-96 (freq x phase) was performed on a volunteer using a 1.5T Discovery MR450 MR system (GE Healthcare, Waukesha, WI) and an 8-channel head coil. The most appropriate selection of R and phase encoding resolution was subsequently used for a motion experiment involving 40 time frames. The flip angle was 35 degrees, the TR 150 ms, and the slice thickness 40 mm. The single slice nose navigators were 2D realigned using SPM5 (FIL, London, UK) and the mean image before and after realignment was calculated as a visual measure on how well the motion correction performed.

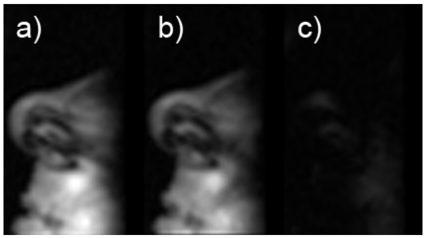

Figure 2. EPI normally needs spectral excitation to avoid chemical shift artifacts from fat. Above shows a 24-shot (distortion free) 48x24 EPI scan (FOV 10x5 cm) with: a) non-spectrally selective excitation, b) fat-sat, c) water-sat. The lack of fat signal allows the use of a short non-spectrally selective RF pulse (Fig. 1a) in the interest of minimal TE.

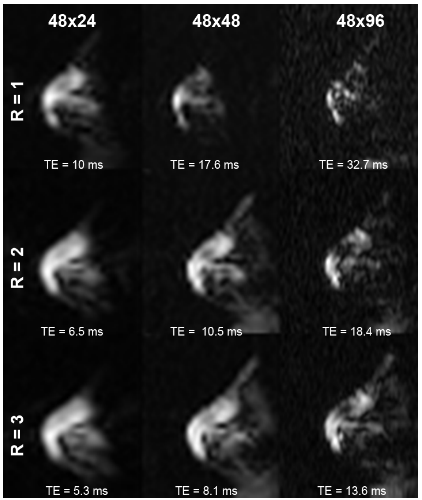

Figure 3. The nose navigator acquired with different matrix size and parallel imaging acceleration. Both geometric distortions and prolonged TE leading to signal dropouts are concerns, of which the latter appear to be more important. With FOV = 10x5 cm, the left-most images have square pixels. It was assumed that the upper part of the nose needs to be clearly visible for proper realignment. Hence 48x48, R=3 was used for the motion experiment (Fig. 4).

Results The best trade-off between TE, in-plane resolution, and signal dropouts were found to be R=3 using a 48x48 matrix (Fig. 3), resulting in a TE of 8.1 ms. For TEs over ~10 ms, the nose started to vanish due to dephasing. For the lowest phase encoding matrix (left column), it was difficult to depict the upper part of the nose, which was expected to be important for accurate rotation estimation. The result of the nodding motion experiment, using R=3 and 48x48 (over FOV 10x5 cm) is shown, with: a) the first time-frame, the mean of all 40 time-frames b) before realignment, and c) after realignment. In Fig. 4d, the mask used in the realignment process is shown, excluding the mouth and jaw that may not always move rigidly.

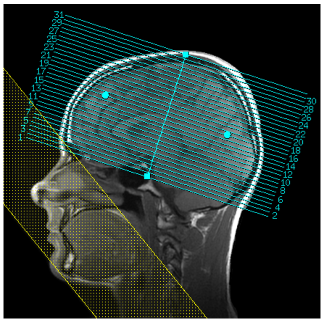

Figure 5. Future implementation as a graphical saturation plugin, supported via the scanner's user interface (yellow). Thereby making it compatible with other sequences, and slices covering most of the brain (blue) may be prescribed without interferences. The motion estimates from the nose navigator will in real time update the slice locations of the main sequence (blue).

Discussion & Conclusion We have here shown, as a proof of concept, a new approach towards real-time correction of nodding motion in MRI. Next, the sequence will be optimized further for improved image quality and efficiency, potentially with higher R or the use of an RF refocusing pulse to avoid signal dropouts. To be of practical use, the NoseNav sequence will be re-implemented as a spatial saturation plugin, to allow the clinical staff to graphically prescribe both the slices of the main sequence (Fig. 5, blue) and the thick axial-coronal NoseNav slice plane (Fig. 5, yellow). As seen in Fig. 5, it is feasible to acquire most of the brain without either the imaging slices to saturate the nose area, or vice versa. Next, a real-time feedback process will be implemented to continuously feed the main sequence with motion estimates (A/P translation, S/I translation, and L/R rotation) for real-time slice adjustments.

References [1] Maclaren J *et al.* Magn Reson Med 2012. [2] White N *et al.* Magn Reson Med 2010;63(1):91-105. [3] Pipe JG. Magn Reson Med 1999;42(5):963-969.

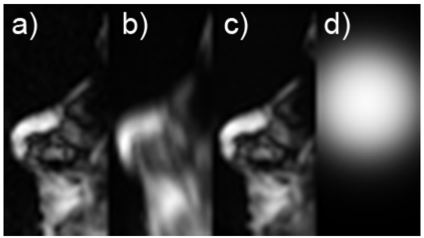

Figure 4. FOV = 10x5 cm, 48x24 matrix, R=3, 40 mm slice thickness. Nodding motion performed by volunteer over 40 time frames. a) First time frame (reference). The average over the 40 frames are shown without realignment (b), and with realignment (c). d) Mask used during estimation.