Variable Sampling Density Spherical Navigator Echoes (VSD SNAV) for Prospective 3D Alignment

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Introduction: Manual patient repositioning may introduce significant inter-operator and intra-operator variability in longitudinal MR imaging or spectroscopy studies. To achieve fast, accurate and automatic inter-scan registration, Welch et al. described a navigator-based method [1], where a combination of linear and spherical navigators (SNAV) were used; a limitation of the approach was the long acquisition time (~ 19 s to acquire a set of orbital trajectories) and the inability of the technique to measure translations larger than a few mm (thereby requiring a separate 1D navigator acquisition). In this work, we modified the original navigator-based realignment technique by using a variable-sampling-density spherical navigator echo (VSD SNAV) acquisition method [2]. This improved technique eliminates the need for a linear navigator and reduces the acquisition time from 19 s to 50 ms. The performance of this technique was verified through both in vitro and in vivo experiments.

Methods: All experiments were performed on a General Electric 3.0-T whole-body MRI scanner, using both a bird-cage head coil and an 8-ch phased array coil. A fast gradient recalled echo pulse sequence was customized to acquire the VSD SNAV data [2] and modified to accept rotation and translation parameters to transform the SNAV coordinate system with respect to the scanner's physical coordinate system. For all experiments, VSD SNAVs were acquired along the surface of a sphere (radius 0.6 cm^{-1}) in 50 ms (TR = 25 ms); a two-shot approach was used, collecting 1328 sample points over a hemisphere for each shot. The remaining sequence parameters were: TE = 1 ms, flip angle = 10° (human) or 20° (phantom), slab thickness = 30 cm. When the multi-channel phased array coil was used, the phase alignment method was used to combine the data from all coils into one SNAV data set [3]. For large translations, phase unwrapping was implemented in the frequency domain.

To quantify the accuracy of VSD SNAVs to detect large translations, VSD SNAV data sets were collected from an agarose-gel-filled skull phantom at 11 different positions over a range of ±20 mm from a baseline position. Translation in the SI direction was achieved by changing the scan prescription so that the scanner table would move by a prescribed amount.

To demonstrate *in vivo* 3D misalignment correction, using the VSD SNAV technique, a healthy volunteer was scanned. First, a baseline SNAV data set and three sets of orthogonal images were collected (Fast gradient echo, TE/TR = 10 ms/500 ms, flip angle = 45°, FOV = 26 cm, thickness = 3 mm, matrix: 256*256*24). The volunteer was then moved out of the scanner and repositioned on the scanner bed. A second VSD SNAV was acquired and used to determine the three rotation angles by registering the magnitude profile with the baseline SNAV. To achieve higher accuracy of translation detection, another SNAV – rotated by the calculated rotation angles – was acquired. After the translation between the two patient positions was determined, SNAV-aligned images were collected to visually demonstrate the success of the realignment technique. Finally, the unaligned images were acquired for comparison.

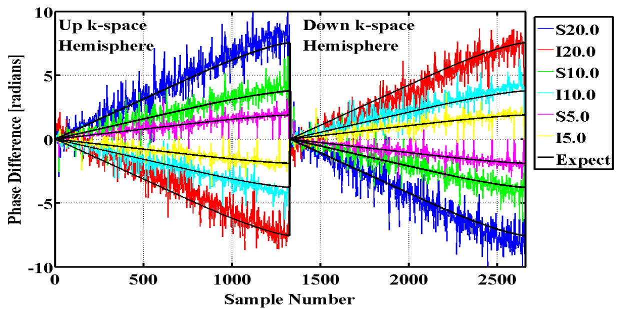

Figure 1. Phase difference plots caused by translation in the SI direction. Data were acquired with an 8-ch phased array coil.

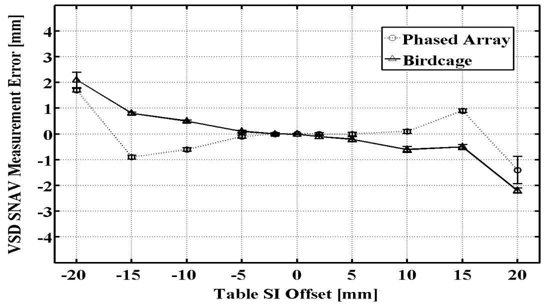

Figure 2. Translation measurement error derived from phantom experiments performed using bird-cage and phased array RF coils. . The error bars are the standard deviation across 32 repetitions.

Results and Discussion: The measured and expected phase differences between the trial (S/I position ≠ 0) and baseline VSD SNAVs are plotted in Figure 1. Excellent agreement was observed between the measured and expected phased differences over the entire range of ±20 mm. The measured translation errors are shown in Figure 2. For both coils, a high accuracy (0.1 ± 0.1 mm) was achieved for translations less than ±5 mm. At translations of ±20 mm the accuracy is decreased to a level similar to that achieved using linear navigators [1]. Figure 3 visually demonstrates the ability of the VSD SNAV to prospectively correct 3D misalignment *in vivo*.

In conclusion, the spherical navigator-based alignment technique has been improved and successfully implemented using both a standard bird-cage coil and a multi-channel phased array coil. The accuracy of detecting large translations can be further improved by reducing the radius of the VSD SNAV. Following further development and optimization, this technique has the potential to reduce the variability of quantitative MR in longitudinal studies through inter-exam, inter-series, and intra-image realignment.

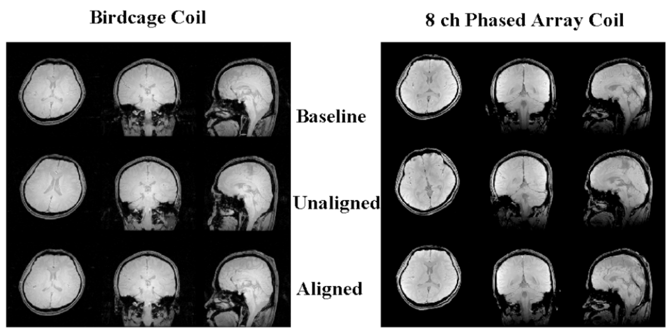

Figure 3. Axial, coronal and sagittal images of a healthy volunteer at baseline, following misalignment, and realignment using the VSD SNAV technique.

References: [1] Welch, et al., MRM 52:1448-1452, 2002. [2] Petrie, et al., MRM 53:1080-1087, 2005. [3] Debbins, et al., MRM 38:1003-1011, 1997.