Coil Design for Highly Accelerated 2D SENSE MRA of the Lower Legs

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INTRODUCTION: There has been considerable interest recently in the application of parallel acquisition to contrast-enhanced MRA (CE-MRA) using acceleration in either one [1] or two [2] directions. When 2D SENSE is applied to the legs, the typical directions for acceleration are left-right (L/R) and anterior-posterior (A/P). However, unlike axial sections of other regions of the body, such as the head, the fields of view of the legs along the L/R and A/P directions can differ from each other by a factor as high as three. This means that a coil array placed circumferentially around the legs and consisting of uniformly-sized coil elements will in general not be optimum for both L/R and A/P acceleration. In this work we describe an eight-element array in which the anterior and posterior elements are designed to have reduced depth of response compared to the left and right elements, accounting for the FOV differences. Compared to an eight-element array with uniformly-sized elements, the new design typically provides a 25% reduction in the g-factor for 2D SENSE acceleration factors which exceed seven. 2D SENSE CE-MRA of the lower legs at these high accelerations is of high quality and is not limited by degraded SNR.

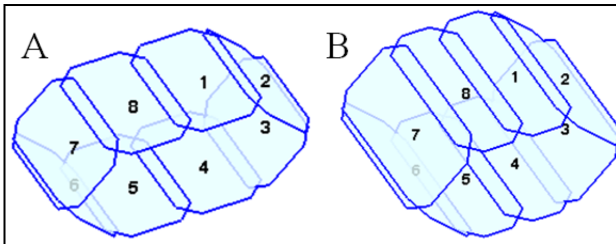

Figure 1. (A) Original coil comprised of eight identical elements. (B) New coil with A/P elements (#1, 4, 5, 8) designed for less depth of sensitivity than lateral elements (#2, 3, 6, 7).

METHODS: ***Background:*** After seeing good quality results demonstrated using 2D SENSE in MRA of the brain at 3.0T [2], we investigated the application of 2D SENSE to CE-MRA of the lower legs. Initial studies used a prototype eight-element array placed circumferentially around the legs (Figure 1A). All elements had equal size: 21.4 cm long x 14.4 cm wide with about a 2.5 cm overlap. CE-MRA results were formed using 2D SENSE with accelerations as high as 7.3. Although the SENSE-induced noise amplification was not severe, inspection of the g-factor maps indicated that much of the contribution to large g-values was due to limited falloff in the sensitivities of the coils placed anteriorly and posteriorly. This led us to question whether the size and thus sensitivity of these coils could be better matched to the A/P FOV.

Coil Design: Simulations of coil response and considerations of the typical A/P and L/R FOVs led to design of a new eight-element coil (Figure 1B). All elements were made longer than in (A) for improved S/I coverage. The laterally placed elements were 27.1 cm long x 14.4 cm wide and the anterior and posterior elements were 27.1 cm long x 10.5 cm wide, with about 2.85 cm overlap between elements. Element conducting strip thickness was 0.90 cm for all elements. Elements were tuned to ~128 MHz, and their overlap was optimized for SNR. The coils were connected to the imaging system via an eight-channel gateway.

SENSE g-Factors Using In Vivo Acquisitions: The lower legs of three volunteers were imaged using both coils on a GE 3.0T (V14.0) imaging system using a coronal fast GRE sequence with parameters: TR/TE = 8.5/4.12 ms, flip angle = 10°, BW ± 31.25 kHz, FOV 40 (S/I) x 32 (L/R) x 13.2 (A/P) cm^3, and sampling matrix of 400x160x66 yielding 1x2x2 mm^3 resolution. Sensitivity profiles were obtained by dividing each coil element image by the root-sum-of-squares image and thresholding to remove background noise. Coil sensitivity profiles were then used to calculate full-volume g-factor maps for 2D SENSE accelerations along the L/R and A/P directions.

7.3x 2D SENSE Time-Resolved CE-MRA Study: The lower legs of a fourth volunteer were imaged using the new coil. The scan was done using CAPR [3] with a coronal fast GRE sequence on a GE 3.0T (V14.0) imaging system. Scan parameters were: TR/TE = 5.85/2.7 ms, flip angle = 30°, BW ± 62.5 KHz, FOV 40 (S/I) x 32 (L/R) x 13.2 (A/P) cm^3, and sampling matrix 400x320x132 yielding 1 mm^3 resolution. A calibration scan identical to that previously described for the other three volunteers was acquired prior to the intravenous injection of 20 mL of Multihance® contrast at 3 ml/sec + 20 ml saline at 3 ml/sec. 7.3x 2D SENSE was performed in both phase encoding directions with accelerations of 3.64 (L/R) x 2.0 (A/P).

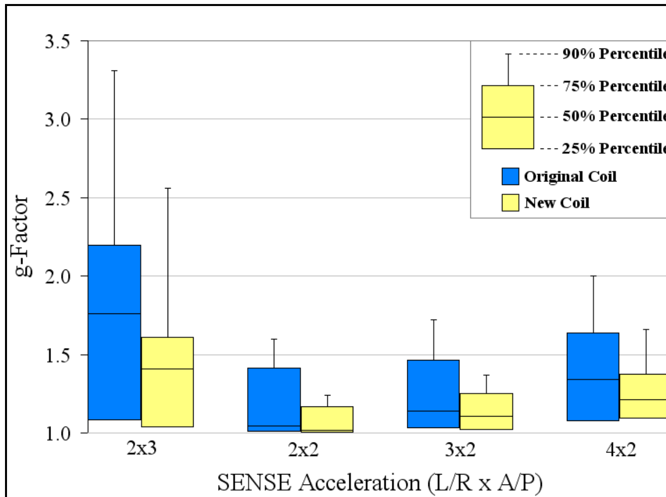

Figure 2. Comparison of g-factor plots for original (dark) and new coil (light) for various 2D SENSE accelerations.

RESULTS: Percentile values for the g-factor are shown in Figure 2 for one volunteer scanned with the two coils. A significant decrease in the 50%, 75%, and 90% g-factor percentiles is evident for all SENSE accelerations when the new, varying-sized-element coil is compared to the original coil with uniformly-sized elements. Qualitative assessment of the g-factor maps indicates improvement mostly occurs in regions affected by acceleration in the A/P direction, as predicted. G-factor maps from Volunteers 2 and 3 showed similar improvement with the new coil. Figure 3 shows an A/P maximum intensity projection from the CE-MRA study using the new coil. This is one frame from a series reconstructed at 5 sec intervals, each frame formed from data collected over a 20 sec long temporal duration or "footprint." The image quality is considered to be excellent.

Figure 3. Contrast-enhanced MR angiogram of lower legs formed using new coil and 2D SENSE acceleration R = 3.64 x 2 = 7.28.

DISCUSSION AND CONCLUSIONS: 2D SENSE can be applied to CE-MRA of the lower legs for generating high quality images using acceleration factors of seven or higher. Contributing to the retention of SNR at such high R-values is the use of coil arrays which are matched to the typically asymmetric L/R vs. A/P fields of view.

[1] Maki JH, JMRI, 2002. [2] Hu HH, Radiol., 2007. [3] Haider CR, 15th ISMRM, 2007, #3117.