Peripheral CE-MRA with Continuously Moving Table and SENSE

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INTRODUCTION

The continuously moving table (CMT) MRI technique [1] and the feasibility of its integration with SENSE have been recently introduced [2-3]. The CMT method dynamically acquires data as the table is moved through the scanner and potentially provides a seamless image over an extended longitudinal (S/I) FOV. In peripheral CE-MRA, spatial resolution along the phase encoding axes (L/R, A/P) is critical and is inherently limited by the continuous motion of the table. An advantage of SENSE is to improve spatial resolution without additional scan time, which can be valuable for CMT peripheral MRA. In this work, we present results from peripheral CE-MRA volunteer studies acquired with CMT and a SENSE acceleration of two along the L/R axis. We address several technical issues in the acquisition of sensitivity maps and image reconstruction.

METHODS

Fig. 1 illustrates a schematic of our CMT coil assembly and its placement about the volunteer. The multi-element setup is attached to the subject and moves with the scanner table during all image acquisitions. The elements are dynamically switched on and off during the CMT acquisition, beginning with pair 1 and ending with pair 4.

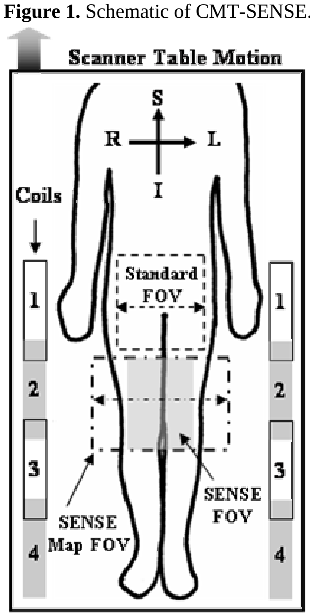

Figure 1. Schematic of CMT-SENSE.

Sensitivity Maps

Option 1

In a standard non-SENSE CMT peripheral MRA acquisition, the extent of the lateral FOV_Y (L/R) is typically prescribed such that it contains only the vasculature of interest (dashed box in Fig. 1). Layers of tissue and fat that fall outside of this prescribed FOV_Y will alias in the reconstructed image. However, these artifacts are removed during the subtraction of a mask from the contrast-enhanced data set, yielding an angiogram with only highlighted vessels.

Proper SENSE reconstruction requires full-FOV sensitivity maps. Therefore, the extent of the lateral FOV_Y for coil calibration in SENSE-CMT is necessarily increased to include the entire anatomy (dashed-dot box in Fig. 1). Subsequently, the two-fold SENSE accelerated acquisitions of the mask and contrast-enhanced image are performed with the FOV denoted by the gray box. It is evident that while SENSE is applied to achieve a factor of R = 2, the net gain in lateral spatial resolution is less than two when compared to a standard non-SENSE CMT peripheral MRA acquisition.

Option 2

To improve the efficiency of SENSE in CMT peripheral MRA, we propose that the sensitivity maps be acquired with a lateral FOV_Y that is typically used in standard non-SENSE acquisitions. With this scheme, the calibration images already exhibit wrap-around artifacts from the superficial fat and tissue layers. However, vessels of interest are not aliased. Subsequent two-fold SENSE accelerated acquisitions will introduce additional aliasing for fat and tissue voxels, whereas voxels containing vasculature will only undergo SENSE-induced aliasing.

SENSE reconstruction will successfully unfold pixels that were originally not aliased in the calibration images. On the contrary, erroneous unfolding will result for fat and tissue voxels that aliased in the sensitivity maps. However, since angiograms are typically obtained from a difference of mask and contrast-enhanced images, we expect that aliasing artifacts arising from the aforementioned fat and tissue voxels can be consistently removed by the subtraction process.

SENSE Reconstruction

In Fig. 1, the schematic illustrates that coils 1-4 on each side of the subject are overlapped along the S/I direction. This design ensures continuous coil coverage of anatomy along the longitudinal axis. SENSE reconstruction is performed individually for each of the four pairs of elements. As a result, voxels along the S/I direction are unfolded only if they are located within the sensitive region of the element pair being considered for reconstruction. Voxels located within the three overlapping regions are reconstructed twice by the two pairs of adjacent coils, and the results are subsequently averaged.

Figure 2. Volunteer results from CMT peripheral MRA with SENSE.

RESULTS

CMT peripheral MRA images were obtained using a 3D TOF-SPGR sequence with the following parameters: TR/TE (ms) = 5.8/1.8, $N_X/N_Y/N_Z$ = 256/128/16, $\alpha = 30^o$, R_Y = 2, a table velocity of 2.1cm/s, and 19mL of contrast injected at 1.5mL/s. Fig. 2a illustrates a SENSE reconstructed result using *Option 1*. Sensitivity maps were acquired with a full-FOV_Y of 42cm, and the effective FOV_Y is 21cm. Fig. 2b shows a SENSE reconstructed angiogram using *Option 2*. Sensitivity maps were obtained with a FOV_Y of 30cm, and the effective FOV_Y of the image is 15cm. Both images have been mask-subtracted.

In Fig. 2b, arrows denote residual pixels corresponding to superficial fat and tissue voxels that were aliased in the calibration images. These voxels are incorrectly reconstructed by SENSE. However, they do not affect visualization of the peripheral vasculature. In both Fig. 2a and Fig. 2b, note the banding appearance which corresponds to the overlapping regions between the coil elements. SNR is improved in these regions due to the averaging between SENSE reconstructions from two adjacent pairs of coils.

CONCLUSION

We have demonstrated SENSE with CMT in CE-MRA of the peripheral vasculature. While SENSE typically requires full-FOV sensitivity maps, we have identified that this approach is not necessary in CE-MRA, where the subtraction step between a mask and a contrast-enhanced image can remove irrelevant artifacts. Hence, the efficiency of SENSE to improve spatial resolution can be maximized. Imminent work will include additional volunteer exams and further studies in reconstruction to minimize the banding appearance of the images.

REFERENCES

[1] Kruger, et al. MRM 2002; 47:224-231.
[2] Keupp, et al. 12th Mtg. ISMRM, 2004, #324.
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