Cerebral Cortex and Thalamic Sub-Region Contrast at 7T: Magnitude, Phase or Susceptibility?

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INTRODUCTION: Image phase contains unique tissue information. Previously, Duyn et al have shown that image phase can reveal cerebral cortex structures with better contrast than magnitude at high field (1). These results demonstrated the superior sensitivity of image phase to delineate brain anatomical details than the magnitude. However, image phase is intrinsically limited by its non-local and orientation-dependent properties. The recent advancement in high resolution susceptibility mapping using phase has provided a unique opportunity to examine those structures that are not easily to visualize with magnitude. In this study, we reconstructed susceptibility maps with high spatial resolution at 7T. The resultant susceptibility maps showed excellent gray and white matter contrast at cerebral cortex. More importantly, the anatomical structures revealed by susceptibility were not always the same as those from the corresponding phase maps. Since tissue phase is nonlocal and orientation dependent, and since susceptibility map shows more similar structures as the magnitude, susceptibility may be more accurate for visualizing the structures than phase. We also showed that phase and susceptibility maps showed much higher contrast at sub-thalamic regions than its corresponding magnitude, further demonstrating the value of susceptibility mapping for visualization of brain structures.

MATERIALS AND METHODS

High field brain imaging: High resolution gradient-echo images were acquired from a healthy subject on a GE 7T scanner equipped with a 16-channel head coil. The sequence used a flow-compensated SPGR sequence with TE = 11 ms, TR = 25 ms, flip angle = 12º, FOV = 26x19.5x9.6 cm^3 and matrix size = 512x384x64.

Image processing: The dataset was cropped or zero-padded in different directions to make an isotropic resolution of 0.75x0.75x0.75 mm^3. The background phase was removed with the phase wrap insensitive background removal method (2, 3), and the resulting phase was further used to reconstruct the magnetic susceptibility map of the brain tissue using the LSQR method with minor modifications (2).

RESULTS: Fig. 1A&D shows the magnitude images of brain regions that covers the cerebral cortex and the thalamus. Although the signal to noise ratio is great, however, the contrast is not as good. In contrast, the phase and susceptibility maps display much better contrast. Both phase and susceptibility maps allow a clear visualization of the gray matter and white matter (Fig. 1 B&C). The major anatomical structures look similar between phase and susceptibility. However, upon careful examination, there are quite a few differences in the structures, such as those pointed by the green arrows. Further, the structures revealed by susceptibility map are more similar to the corresponding magnitude than phase. We think that these differences between phase and susceptibility are caused by the non-local property of phase, and the structures revealed by susceptibility are more accurate than phase. In Fig. 1 E&F, we can appreciate the signal intensity variations in the thalamus region. Especially, there is a horse shoe structures, as pointed by the arrow, which can be easily seen in both phase and susceptibility maps. This structure was also visible in the magnitude image, but with a much smaller contrast. In addition, there are some other structures in the thalamus region, which was visible in the phase and susceptibility maps but cannot be seen from the magnitude images.

DISCUSSION AND CONCLUSION

In this study, we applied the state-of-the-art phase processing and susceptibility mapping methods to analyze the gradient echo images acquired at 7T. Both phase and susceptibility shows excellent gray and white matter contrast at cerebral cortex. More importantly, the structures from phase and susceptibility were not the same. We think susceptibility contrast is more genuine due to its local property. Susceptibility map also shows great sub-thalamus contrast that is typically difficult to visualize with other methods. Visualization of sub-regions and nuclei of the thalamus is important for neurologic and psychiatric studies, as it has been shown that psychiatric disorders may only affect certain thalamic sub-regions [4]. These results demonstrated that high resolution susceptibility map provided a promising contrast for visualization of brain structures.

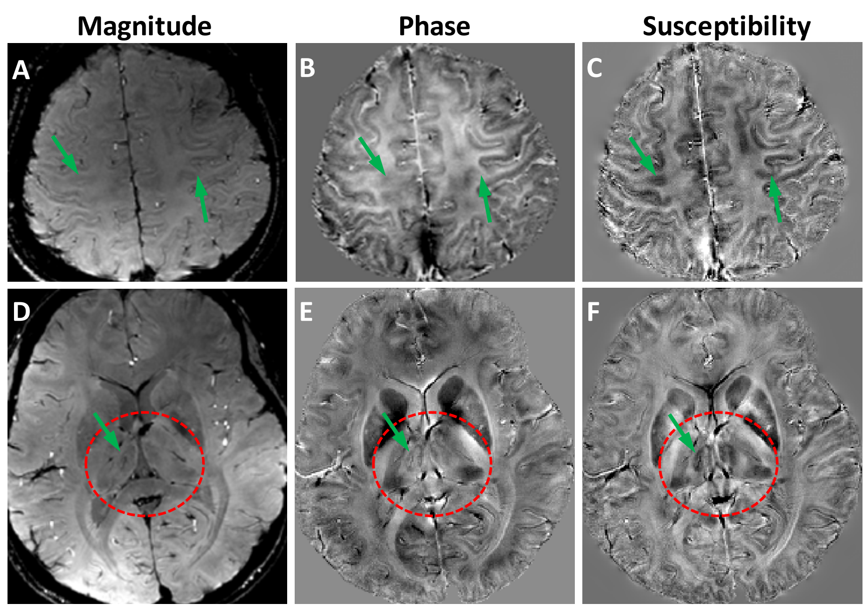

Fig. 1. Magnitude, phase and susceptibility maps of *in vivo* brain at 7T. Note: For phase, white (higher intensity) means negative frequency shift. For susceptibility, white means diamagnetic.

REFERENCES

(1) Duyn et al, PNAS, 2007. (2) Li et al, manuscript in revision. (3) Schweser et al, NeuroImage, 2010 (4) Hazlett et al, Am J Psychiatry, 1999