FLOW-SENSITIVE SUSCEPTIBILITY-WEIGHTED IMAGING

T. Kimura[1], M. Ikedo[1], N. Furudate[1], and S. Takemoto[2]

[1]MRI development dept., Toshiba Medical Systems, Otawara, Japan, [2]MRI marketing dept., Toshiba Medical Systems, Tokyo, Japan

Introduction

Susceptibility weighted imaging (SWI) proposed by Reichenbach and Haacke [1,2] is a technique to enhance both effects of amplitude reduction and phase difference induced by susceptibility effects. In their technique, gradient flow rephasing for three axes was implemented due to enhance only susceptibility effects with eliminating flow effects. Here we call their technique a flow-insensitive SWI (FI-SWI) However, CNR between vein and background tissue is not sufficient especially in smaller veins with shorter TE and lower magnetic field. Here we proposed a flow-sensitive SWI (FS-SWI) where combined susceptibility effects with flow dephasing for the purpose of improving visibility of smaller blood vessel and assessed.

Methods

Imaging was performed on a 1.5 Tesla whole-body imager (EXCELART™ Vantage, Toshiba Medical Systems). 3D-gradients-echo sequence (FE3D) with TE=40 ms was used. Parallel imaging with reduction factor R=2 was used. In FS-SWI, flow dephasing gradients were employed for enhancing slower and smaller vessels. Several strengths of dephase gradients between b=0.1 to 32 s/mm^2 were compared. In FI-SWI, 2nd order gradient-moment-nulling (GMN) for 3-axis was applied. Images of the head for FI-SWI and FS-SWI were acquired in normal volunteers after obtaining informed consent. Higher frequency phase image ϕ was obtained by subtracting low-frequency phase components from the original phase images, negative phase mask defined as $M(\phi)=(\phi/\pi+1)^n$: $\phi<=0$, $=1$: $\phi>0$ was multiplied by amplitude image to reduce the voxel-intensity [1]. Finally, a minimum intensity projection (minIP) was performed on slicing encode direction same as the direction of static magnetic field.

Results and Discussions

Strength of the dephase gradients for FS-SWI was selected on b=4 s/mm^2 comparing from the view of balancing visibilities of blood vessels and motion artifacts. Figure 1 shows the comparison results. Although arteries as well as veins could be visualized in the FS-SWI image, amplitude (T2*W) image (**d**) could visualize veins sufficiently even compared to FI-SWI with phase-mask (**c**). In addition, smaller veins with slower flow such as medullary veins could be further visualized by applying phase-mask to FS-SWI image (**f**). Phase information was indispensable for FI-SWI to visualize veins, but stronger phase-mask with n=8 (not shown) induced significant SNR reduction.

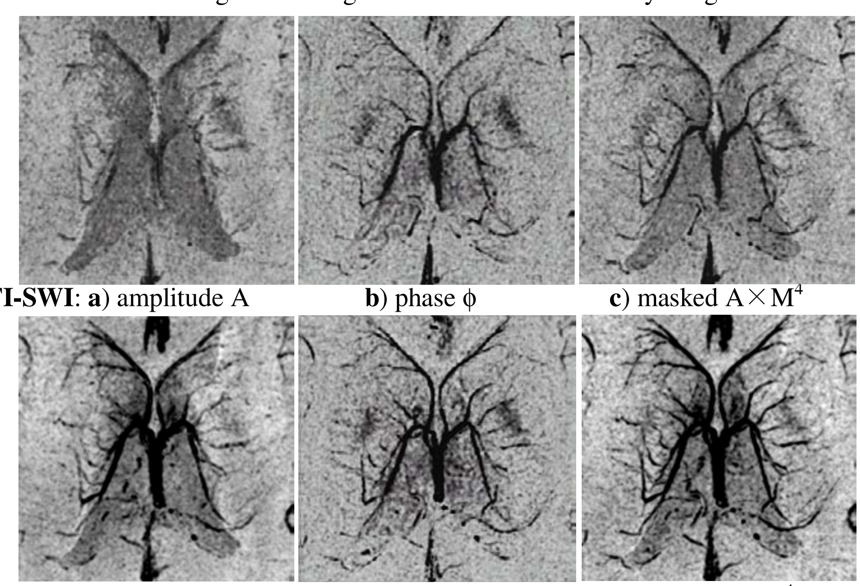
Complex signals of FI-SWI and FS-SWI sequence can respectively be described as $S_{FI}=kA_{sus}\exp[i\phi_{sus}]$ and $S_{FS}=k(A_{sus}A_{flow})\exp[i(\phi_{sus}+\phi_{flow})]$, where k is a proportionality coefficient, A_{sus} and A_{flow} are attenuation rates respectively induced by susceptibility and flow effects, and ϕ_{sus} and ϕ_{flow} are phase shifts respectively induced by susceptibility and flow effects. The amplitude of S_{FS} becomes smaller than the amplitude of S_{FI} as intra-voxel dephasing becomes stronger due to flow, but in phase of S_{FS}, phase cancellation and aliasing effects depending on flowing direction and speed may introduce artifacts. Comparing between both phase images in Fig. 1, those effects were not notable. The A_{flow} attenuation is more dominant than the A_{sus} in larger veins having comparatively higher flow-speed, and ϕ_{sus} is more dominant than ϕ_{flow} in smaller veins having slower flow. Hence, the FS-SWI image could well visualized veins including larger and smaller when phase-mask is applied. In addition, dephase gradients contribute to reduce internal signal in blood vessels. In ideal conditions, S_{FI} contains only veins and S_{FS} contains arteries as well as vein. As TE in FS-SWI become shorter, then not called SWI, venous components in S_{FS} will be reduced due to reducing susceptibility effects. Accordingly, the FS-SWI image with shorter TE and the FI-SWI image with longer TE come close to artery-weighted and vein-weighted images, respectively.

In conclusion, we proposed the FS-SWI technique and found that small veins were well visualized compared to the FI-SWI. The FS-SWI will be applied as a technique of black-blood MRA, which can visualize blood vessels with slower flow, and furthermore combination of both imaging techniques will make it possible to separate arteries from veins without using contrast materials.

references

[1] Reichenbach JR et al. JCAT 2000;24:949-57,

[2] Haacke EM et al. MRM 2000;52:612-8.



FI-SWI: **a**) amplitude A **b**) phase ϕ **c**) masked $A\times M^4$

FS-SWI: **d**) amplitude A **e**) phase ϕ **f**) masked $A\times M^4$

Fig.1 Comparison of axial brain FI-SWI images with 2nd order GMN (upper) and FS-SWI images with b=4 s/mm^2 (lower) shown as amplitude, phase and phase-masked amplitude images with n=4. TR/TE/FA=50ms/40ms/20°, FOV=21cm, acquisition matrix was 320x320x25, voxel size after sinc-interpolation was 0.35x0.35x0.75mm^3, acquisition time was 3m36s, and minIP thickness was 18mm.