High Resolution PWI of the Brain; Comparison with SWI, MRA, and T1-CBV images

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Purpose:

Perfusion-weighted imaging (PWI) using dynamic susceptibility contrast (DSC) is useful tools to evaluate various diseases of the brain. Cerebral vasculature, regional blood flow and hemodynamic state can be quickly evaluated by perfusion maps, such as cerebral blood flow (CBF), cerebral blood volume (CBV) and mean transit time (MTT) maps. Susceptibility weighted imaging (SWI) has a potential in providing a regional oxygen saturation map and high resolution MR venography (MRV). MR angiography (MRA) gives us information about arterial blood flow and vasculature. CBV maps can be also calculated from pre and post contrast T1 weighted images (T1WI). Information about macro circulation (arterial and venous blood flow), micro circulation (capillary blood flow), and oxygen consumption can be obtained from the combinations of these maps. However, current PWI method has a limitation in spatial resolution (usually the resolution of PWI is more than 2 x 2 x 4 mm), to compare with SWI, MRA and T1-CBV (the resolutions of these maps are typically less than 0.5 x 0.5 x 1 mm). The purpose of this study is to achieve high resolution PWI with resolution of 0.5 x 0.5 x 2 mm in an attempt to match the PWI data to other high resolution maps.

Materials and Methods:

All MR imaging were carried out on a 1.5 T scanner (Siemens, Sonata). PWI was performed with SE-EPI sequence (TR 2200 ms; TE 98 ms; FA 60 degrees; matrix 256 x 256 with interpolation, sense factor 4; FOV 256 mm). With these parameters, in-plane resolution of 0.5 x 0.5 mm was achieved. SWI of 3D-FLASH, pre and post contrast MRA, and pre and post T1WI for the calculation of CBV were obtained with the resolutions of 0.5 x 0.5 x 1 mm.

Analysis of PWI with deconvolution, phase processing of SWI, and creation of T1-CBV maps were done on our original software (Perfusion Mismatch Analyzer, PMA). Overlay images of these maps were created to see the matching and correlation between these maps.

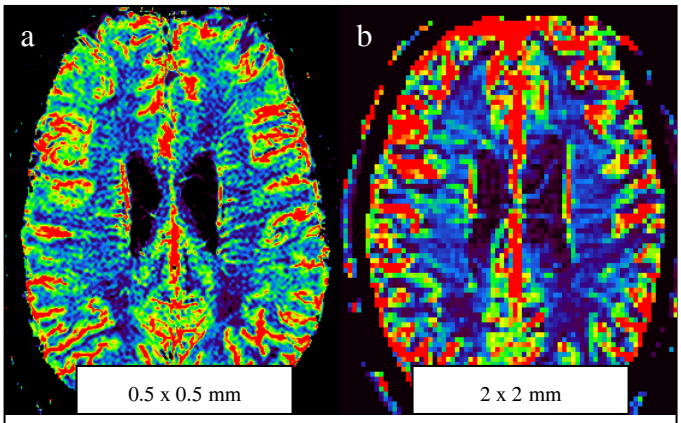

Fig 1. PWI-CBF of high resolution (a) and normal resolution (b)
High resolution CBF shows small vessels without blurring. Gray matter can also be seen clearly compared to normal resolution PWI.

Results and Discussions:

High resolution PWI was successfully obtained with parallel imaging. Compared to normal resolution PWI, the following advantages were observed on CBF and CBV maps; the blurring of blood vessels was minimal, fine details of blood vessels were observed, gray matter was clearly separated from blood vessels, and small vessels like medullary veins could be seen (Fig 1). Small cortical vessels, that were never seen on full-width half maximum (FWHM) and time-to-peak (TTP) map of normal resolution PWI, were also visualized on high resolution PWI maps (Fig 2). As these vessels corresponded well to SWI, they assumed to be veins.

Blood vessels seen on PWI are thought to be both arteries and veins, however, venous structures on SWI were well matched to PWI-CBV, compared to arteries on MRA (Fig 3). In addition, the overlay of the SWI phase onto the PWI-CBV map separated the veins from the arteries and reveals that most of the information shown in the PWI-CBV maps appeared to come from the micro-vasculature and the veins.

T1-CBV has several advanteges to PWI-CBV, i.e. there is little geometric distortion; it does not exaggerate signal losses outside the main vasculature; the entire brain can be imaged without susceptibility artifacts; high resolution images are possible; it is easy to separate the main vessels from the background tissue and finally it the overlay onto the T1W data itself is straight forward since it comes from T1W images. However, our high resolution PWI has the same resolutions of 0.5 x 0. 5 mm and was superior in visualization of gray matter.

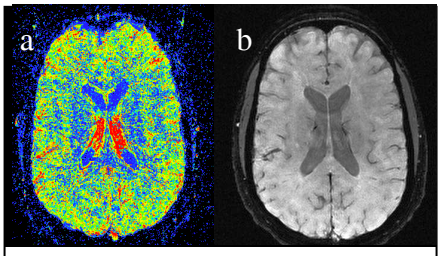

Fig 2. FWHM map (a) and SWI (b)
Small cortical veins, which are never seen on FWHM map of normal resolution PWI, can be clearly seen. Correlation to SWI is also good.

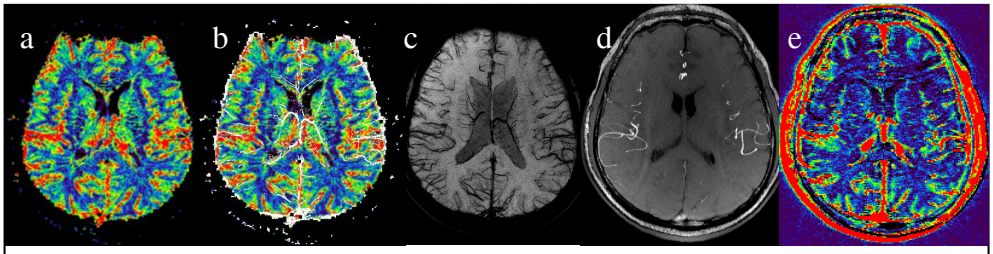

Fig 3. Comparison of PWI, SWI, MRA, and T1-CBV Images
CBV map of high resolution PWI shows blood vessels and gray matter clearly, without blurring (a). Phase information of SWI is matched well to venous structures in overlay image of the SWI onto PWI-CBV (b). As compared to SWI (c) and MRA (d), most of the vascular structures seen on PWI-CBV seem to be veins.

Conclusions:

Our preliminary results suggest that visualization of small fine vessels of the brain can be achieved by increasing the resolution of DSC-PWI. Combination of high resolution maps of PWI, SWI, MRA and T1-CBV can provide additional information about macro and micro circulations and vasculature of the brain.

References:

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