Positive Contrast Imaging of Microhemorrhages in Patients with Traumatic Brain Injury

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Introduction

Traumatic brain injury (TBI) involves a heterogeneous and complex spectrum of pathologies that can include hemorrhage, axonal shear injury (DAI), and ischemic/hypoxic injury. It has been suggested that the presence of hemorrhage in DAI is predictive of poor outcome (1). SWI is highly sensitive to blood products in hemorrhages and deoxyhemoglobin in venous blood and therefore has been actively used to evaluate TBI patients. Previously, we have developed a multiecho SWI technique for evaluation of microhemorrhages in a military population (2). Positive contrast imaging based on phase contrast mapping (PGM) (3) and susceptibility gradient mapping (SGM) (4, 5) are relatively new techniques that produce high contrast-to noise ratio (CNR) for areas of local magnetic susceptibility variation. Applying positive contrast technique to assess localized abnormalities associated with hemosiderin deposition could provide additional information for detection and diagnosis of microhemmorage (6). Furthermore, positive contrast techniques have been applied for quantification of iron concentration in vivo (7) and are potentially applicable for monitoring hemosiderin deposition in longitudinal studies. The purpose of this study was to explore the potential clinical utility of PGM and SGM to provide better characterization of microhemorrhages in TBI patients.

Methods

Image acquisition:60 TBI patients were imaged on a 3T GE750 scanner (GE Healthcare, Milwaukee, WI) with a 32-channel phased array head coil. 3D flow-compensated multiecho gradient-echo images were acquired with the following parameters: TR = 45 ms, Flip angle = 20°, 5 echoes, first TE = 13ms, echo-spacing = 6 ms, scan matrix = 512 × 256, : Field of view = 24 × 24 cm^2 , 1.5 mm slice thickness, 88 - 96 slices and asset_factor = 2.

Image analysis: Only the middle echo image with TE = 25 ms was used for SWI, PGM and SGM analysis. SWI images were processed using the SPIN software package (HUH-MR Research Radiology, Wayne State Univ., Detroit, MI). PGM and SGM images were generated with an in-house designed software using IDL. An object with a magnetic susceptibility that deviates from its surrounding creates an inhomogeneous magnetic field leading to a shift of the affected echo in k-space. PGM and SGM detect this echo shift using slightly different approaches. Specifically, PGM calculates the phase gradient in the image space using a fast Fourier transform without the need for phase unwrapping (3). SGM determines the echo-shift in k-space using a series of truncated and zero filled k-space lines to locate the sudden drop in signal intensity(5). To be comparable with SWI, the phase gradient and susceptibility gradient were computed only in the x and y directions. Minimum (SWI) and maximum (PGM, SGM) projection was performed on calculated images over 7 slices (final thickness = 10.5 mm).

Results

The PGM and SGM techniques generated significantly higher CNR for the twelve ROIs manually drawn on the eight patients with identifiable microhemorrhages (Figure 1, **p<0.01). PGM and SGM generated similar CNR for all the hemorrhages detected. However, the CNR improvement of PGM and SGM was not consistent across different ROIs. For example, Figure 2 a-c demonstrates that the microhemorrhage is clearly visible on the SWI image while it is barely visible on the corresponding PGM and SGM images. Figure 2d-f illustrates a typical case of improved CNR for microhemorrhage detection with the PGM and SGM techniques. Compared to SWI, PGM and SGM depict some fine structures within the hemorrhage which might provide additional information about the age and evolution of the blood products (Figure 2, g-i).

Discussion

Two positive contrast techniques PGM and SGM were investigated as complementary approaches of SWI for microhemorrhage detection. In general, PGM and SGM improved the CNR for the local regional of interest and depicted more detailed information on the microhemorrhages which might provide additional information for diagnosis. However, the CNR improvement was not consistent across subjects. Furthermore, both PGM and SGM lost the background brain anatomical information suggesting that positive contrast techniques could only be employed as a complementary technique to the standard SWI processing.
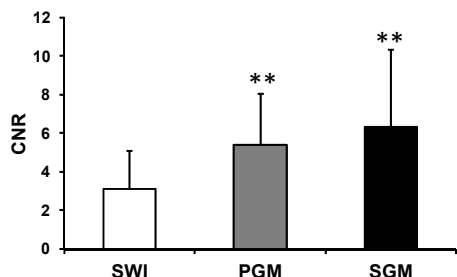
Figure 1. PGM and SGM demonstrated significant higher CNR compared to SWI technique. ** p<0.01.
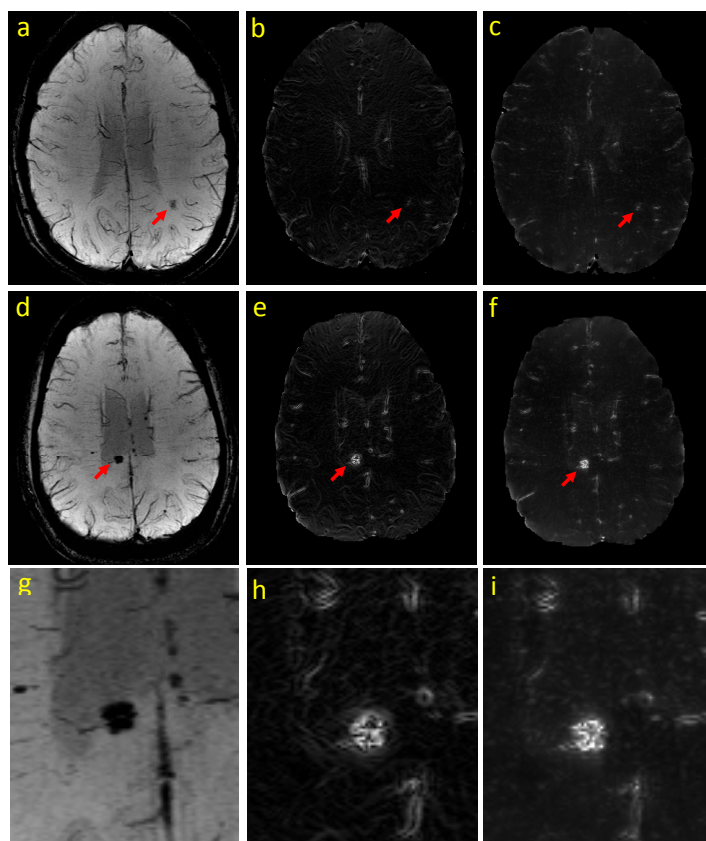
Figure 2. SWI (a,d), PGM (b,e) and SGM (c,f) images from two patients. Red arrows indicate hemorrhages. Images g, h and i are the zoomed views of the hemorrhage illustrated in d, e and f.

References

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