Specialty area: Emerging Clinical Techniques/SWI

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Highlights: 1. SWI utilizes both magnitude and phase; 2. SWI can be acquired in a few minutes; 3. SWI visualizes veins, hemorrhages, iron deposition and calcification; 3. some limitations of SWI can be overcome with quantitative susceptibility mapping.

Susceptibility-Weighted Imaging (SWI)

Target audience: clinicians interested in learning the principles and applications of SWI.

Objectives: to understand the underlying concepts of SWI; to recognize the benefits and pitfalls of SWI in clinical practice and to integrate SWI into clinical protocols.

PURPOSE: SWI (1) utilizes both magnitude and phase data acquired by gradient-echo sequences to generate a unique tissue contrast. SWI has been increasingly applied in clinical imaging especially in neuroimaging (2). Two prominent examples are the generation of venogram and the visualization of cerebral microbleeds. This lecture will review the basic principles of SWI, its clinical applications, challenges and potential solutions.

METHODS: In gradient-echo images, variations of tissue magnetic susceptibility result in signal cancellation in the magnitude and frequency shift in the phase. While magnitude images are routinely used in MRI, phase images are traditionally discarded as they are typically severely corrupted by phase wraps and overwhelmed by non-tissue-specific background phases. By filtering out the background phases and combining the filtered phase with the corresponding magnitude via a multiplicative relationship, SWI is able to dramatically enhance the contrast between tissues of differing magnetic susceptibility.

RESULTS: SWI are applicable on all common clinical MRI scanners (e.g. 1.5 T and 3.0T). However, signal-to-noise ratio (SNR), resolution and efficiency are best achieved at higher field strengths. Imaging parameters (flip angle, TR, TR and bandwidth) should be optimized based on the field strengths. Higher field strengths allow shorter TE and TR, thus improve acquisition efficiency. The higher SNR at higher fields may also be traded for higher spatial resolution.

Clinical applications of SWI are broad and growing. In general, SWI provides excellent contrast for diseases involving vascular malformation, intracranial hemorrhage, iron deposition and calcification. Common diseases where SWI has made significant impacts include, for example, traumatic brain injuries (TBI), stroke, venous anomalies, multiple sclerosis (MS) and brain tumors.

DISCUSSION: SWI has been proven to be a useful tool for a wide range of neurological diseases. SWI of the brain can be achieved in 3-7 minutes at 3T depending on the resolution requirement. This high efficiency allows SWI to be flexibly included in routine neuroimaging protocols. Correctly interpreting clinical SWI images requires good understandings of the contrasts involved in generating the images, which include magnitude, phase and the processed phase maps. Many “dark spots” may appear in SWI images. It is important to be aware of the potential overlapping appearances of small veins and microbleeds. Some limitations and challenges of SWI including, e.g. orientation dependence and differentiation between iron and calcium may be overcome with the technique of quantitative susceptibility mapping (QSM) (3, 4).

CONCLUSION: SWI has found broad clinical applications in neuroimaging. While SWI provides an excellent contrast for microbleeds and iron deposition, other applications are also emerging.

REFERENCES: 1. Haacke E.M. et al, MRM 2004; 52:612-618. 2. Haacke E.M. et al, AJNR 2009; 30:19-30. 3. de Rochefort L. et al, MRM 2010; 63:194-206; 4. Li W. et al, NeuroImage 2011; 55:1645-1656.