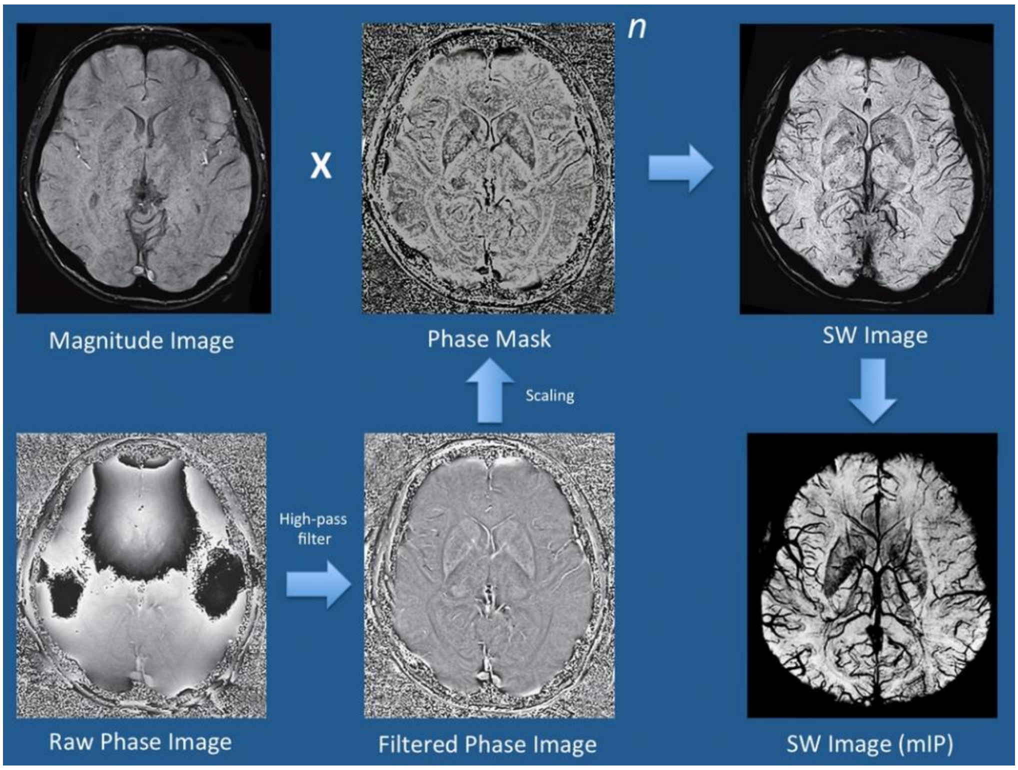
SWI exploits the magnetic susceptibility differences of various compounds, such as blood, iron, and diamagnetic calcium, which have inherent properties which allow them to serve as sources of MR contrast.
-Diamagnetic materials have all their electrons paired, and are repelled by a magnetic field. Diamagnetic materials include calcium and oxyhaemoglobin.
-Paramagnetic materials have at least one unpaired electron in the system; paramagnetic and ferromagnetic materials are attracted by a magnetic field.
The paramagnetic deoxyhaemoglobin serves as an intrinsic contrast agent on SWI sequences, and is low in signal. This causes magnetic field inhomogeneity due to two effects: a reduction of T2* and a phase difference between the vessel and its surrounding tissue. (This property also forms the basic principle for blood oxygen level dependent functional and venographic imaging).

Paramagnetic substances display positive phase shift in left-handed MR systems such as Siemens magnets. Hence, the phase images are particularly useful for differentiating between paramagnetic susceptibility effects of blood products such as deoxygenated haemoglobin, intracellular methaemoglobin, hemosiderin and ferritin (positive shift) and diamagnetic effects of calcium (negative or no shift).

SWI is a gradient echo sequence which uses local magnetic susceptibility to create contrast between tissues.

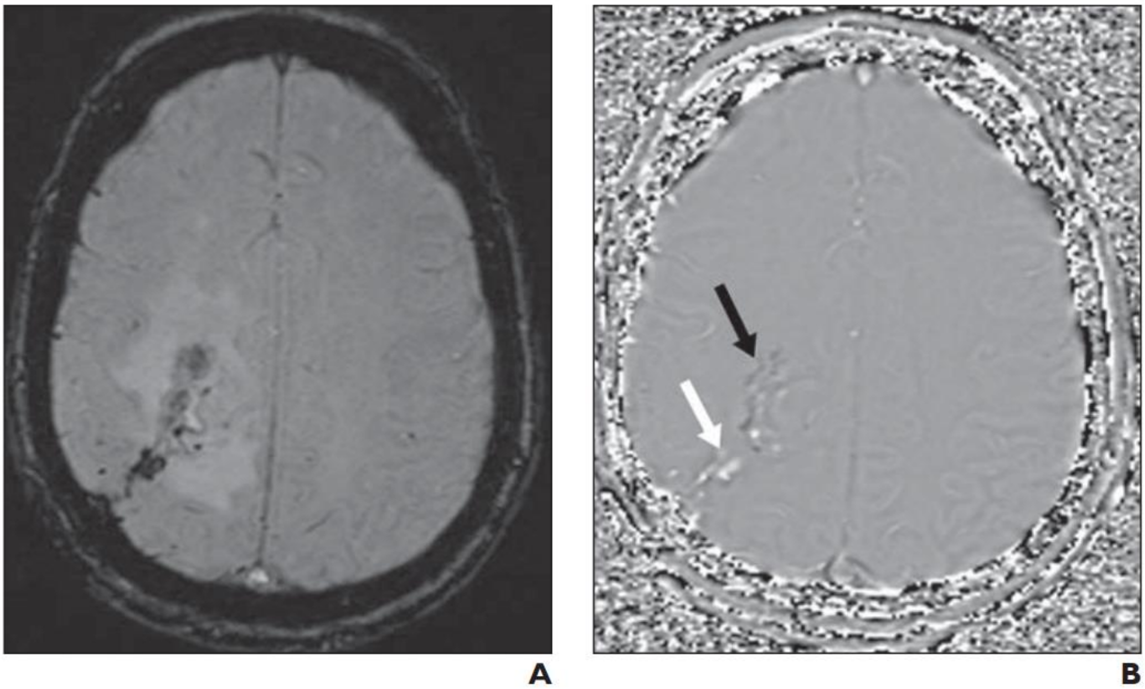
SWI:

GE **magnitude image** is acquired, displaying background tissue with spin-density-like contrast.
A ***raw phase image*** is characterized by large "macro"-susceptibility gradients due to generalized field inhomogeneities as well as distortions due to air and bone at the skull base.
Digital high-pass filtering takes place to remove these low-frequency fluctuations, and additional local phase correction algorithms are used to reduce artefacts at the skull base. The end result is a ***filtered phase image*** that is saved and used to create a ***phase mask*** which scales data from the filtered phase images over a 0-1 range to accentuate tissues with different susceptibilities. The magnitude image is digitally multiplied by this phase mask, typically four times.
This results in a ***susceptibility-weighted (SW) image***, which simultaneously contains both magnitude and phase information.



Phase information can be used to distinguish paramagnetic substances (like iron and blood) from diamagnetic substances (like calcification). The ***filtered phase images*** displays paramagnetic blood products having signal intensities opposite to diamagnetic calcifications (but both will appear dark on SWI images).

Currently, this relationship is scanner dependent: on SWI phase, microhaemorrhage (and blood in the sagittal sinus, or internal cerebral veins) are bright on a Siemens image ("left-handed" scanner), but dark on the GE image.



From: Berberat J, Grobholz R, Boxheimer L, Rogers S, Remonda L, Roelcke U. Differentiation between calcification and hemorrhage in brain tumors using susceptibility-weighted imaging: A pilot study. Am J Roentgenol 2014; ***202****: 847–50.*

The effects produced by a lesion not only depend on its magnetic susceptibility but also on its own shape and the shape of the tissue in which it is embedded. In the phase image the lesion may appear as a dipole, which produces a bright rim at the equator and dark areas below and above the lesion (see arrows), which indicates that the lesion contains paramagnetic hemosiderin.
The opposite is seen in a diamagnetic lesions: the phase in these axial images displays the opposite effect and the equatorial rim is dark and the two poles below (a) and above (c) the lesion are both bright.