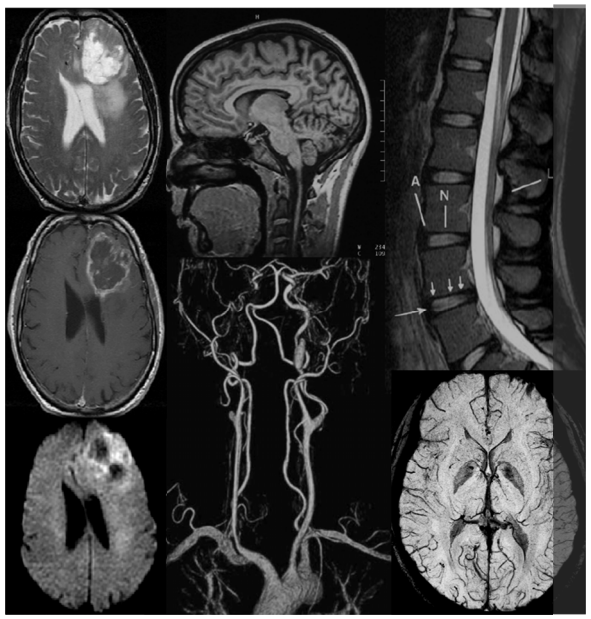

Magnetic Resonance in Medicine
Susceptibility Weighted Imaging (SWI)

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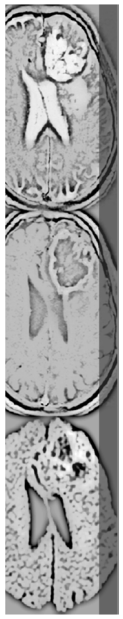
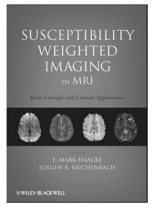
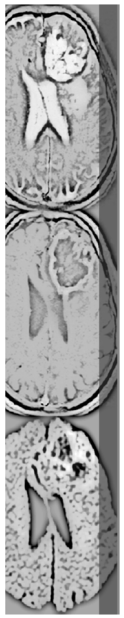


Content http://cflu.lab.nycu.edu.tw/

- Susceptibility weighted imaging (SWI)磁化率權重影像

- Susceptibility Weighted Imaging in MRI: Basic Concepts and Clinical Applications
- Haacke et al., Review of SWI, Part 1, AJNR, 30: 19-30, 2009.
- Mittal et al., Review of SWI, Part 2, AJNR, 30: 232-259, 2009.





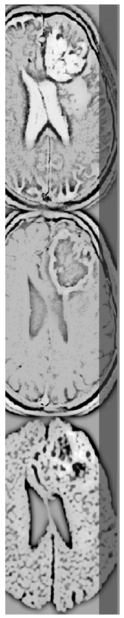
Intended Learning Outcomes

After this class, you should be able to…

- Describe procedure to obtain susceptibility weighted image (SWI)
- Explain the relation between phase changes and susceptibility
- Interpret the image findings on SWI.

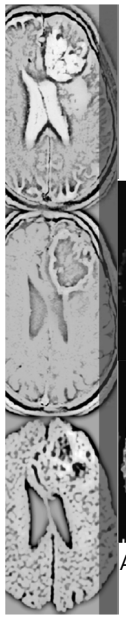
Susceptibility weighted imaging (SWI)

磁化率權重影像

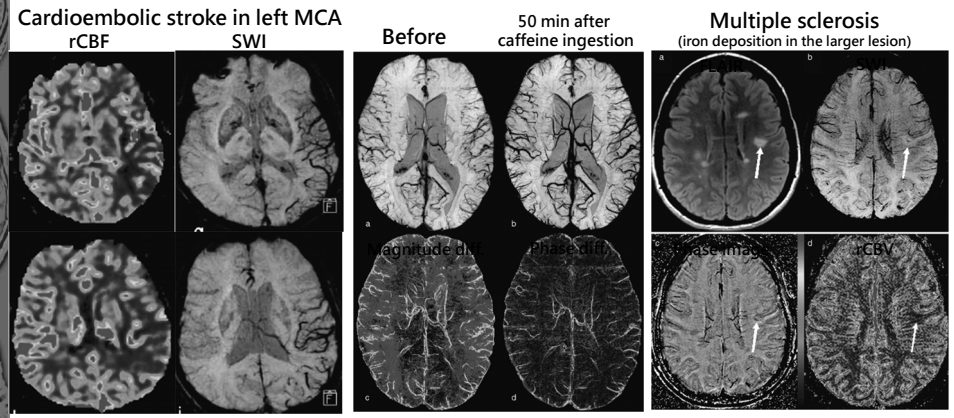


Susceptibility weighted imaging, SWI

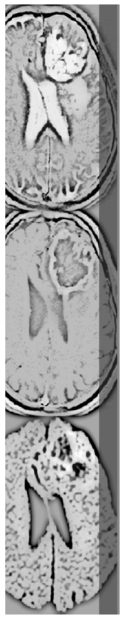
- SWI is an MR technique that utilizes the magnetic susceptibility differences
  - Visualize small veins in the brain
  - Microbleed
  - Sensitive to iron & calcification
- Susceptibility differences can be used as a new type of contrast, similar to T1W, T2W, T2*W, and PD.



SWI Examples

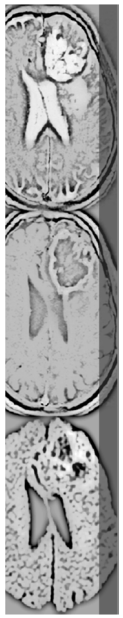


Acute ischemia/vasoconstriction→ increase OEF to maintain $CMRO_2$



Clinical Applications of SWI

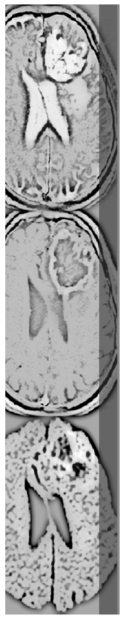
- SWI offers information about tissues with different susceptibilities from surrounding tissues.
  - deoxygenated blood (去氧血紅素), iron storage (hemosiderin or ferritin), calcium (鈣化)
- Numerous Clinical applications
  - Hemorrhages
  - Cerebrovascular and ischemic brain diseases
  - Traumatic brain injuries
  - Arteriovenous malformations
  - Neurodegenerative diseases
  - Breast microcalcifications



History of SWI

BOLD: Blood Oxygenation Level Dependent

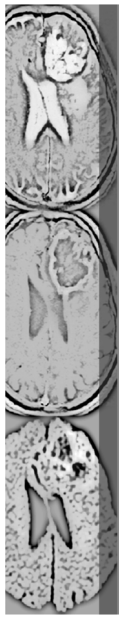
- Originally proposed by Reichenbach et al. as "MR venography" or "BOLD venographic imaging"
  - Small vessels in the human brain: MR venography with deoxyhemoglobin as an intrinsic contrast agent. *Radiology, 1997.*
- Haacke et al. 2004
  - Susceptibility weighted imaging (SWI)



Magnetic Susceptibility

- When an object is placed in an external magnetic field H, magnetization is induced in the object.
- Magnetic susceptibility is the magnetic response of a material when it is placed in a magnetic field.
  M = χH
  - χ = susceptibility (ppm)
  - M = induced magnetization
  - H = applied field
- If diamagnetic, $\chi < 0$
- If paramagnetic, like deoxygenated blood, $\chi > 0$

Haacke et al., AJNR 2009.

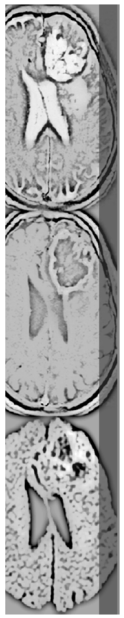


Susceptibility and Phase Relations

- MRI equations
  $\omega=\gamma B_0$
  - Phase, $\psi=\omega t$
  - Phase changes, $\Delta\psi=\Delta\omega*TE$
- Relating to susceptibility,
  - Since $\Delta\omega=\gamma\Delta B$ and $\Delta B=g*\Delta\chi*B_0$ g is a geometric constant.
  - $\Delta\psi=-\gamma\Delta B*TE$
    $=-\gamma g\Delta\chi B_0*TE$

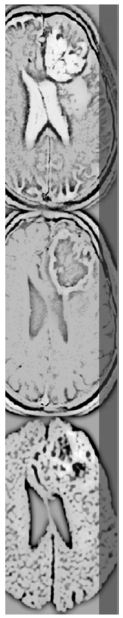
Change of susceptibility can result in the phase shift.

Haacke et al., AJNR 2009.



Imaging Acquisition

- High-resolution 3D gradient echo imaging with 3-direction flow compensation
  - Long TR
  - Long TE (~40 ms at 1.5T, ~25 ms at 3.0T) to get T2* weighting
- Utilize both magnitude and phase images



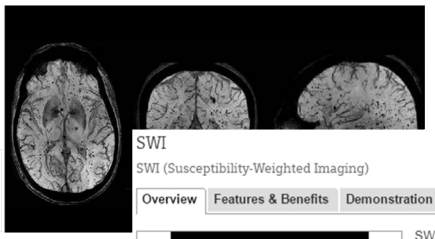
Commercial Name

- GE: SWAN, Siemens: SWI

SWAN

Designed for excellent visualization of vasculature and blood products.

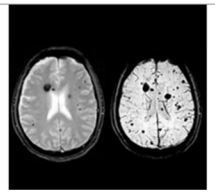
(Susceptibility-Weighted ANgiography)



SWI

SWI (Susceptibility-Weighted Imaging)

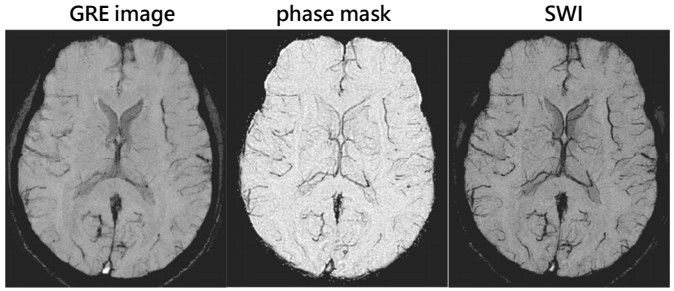
Overview | Features & Benefits | Demonstration of Use



SWI is a new type of contrast in MRI which exploits the susceptibility differences between tissues. As a result SWI detects substances with different susceptibilities than their neighboring tissues such as deoxygenated blood, products of blood decomposition and microscopic iron deposits much better than conventional MR techniques. Among other things, the method allows for highly sensitive proof of cerebral hemorrhage and high resolution display of venous cerebral vessels.

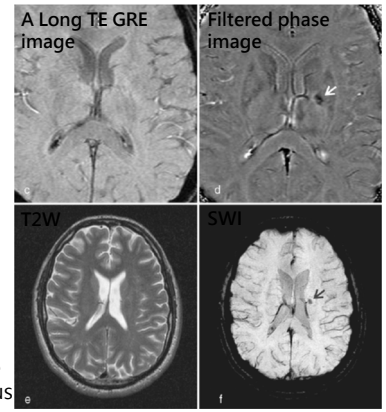
SWI vs. conventional GRE

- The use of the filtered phase to enhance contrast.



SWI vs. conventional GRE

- Tissues that have very low and uniform iron distribution will show a phase effect, but not a T2* effect.
  - Without phase dispersion → no T2* effect.



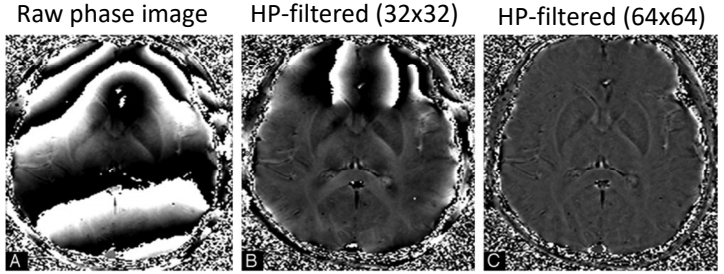
Microbleed at the left globus pallidus

HPF: high-pass filter

Outline of SWI processing

1. Acquire high-resolution 3D GRE with flow compensation.
2. Apply HPF to phase image to obtain SWI filtered phase data.
3. Create phase mask depending on sign.
4. Multiply phase mask by original magnitude image to obtain "merged SWI magnitude data. "
5. Perform a minimum intensity projection (mIP) over neighboring slices

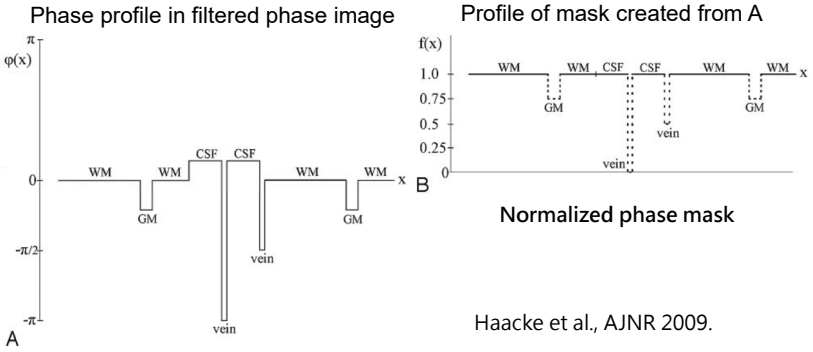
Filtered phased images



1. Truncate original image ρ(r) to central n x n complex image $\rho_n(r)$.
2. Zero-fill elements outside central n x n elements
3. Complex divide ρ(r) by $\rho_n(r)$ to obtain a new image, $\rho'(r) = \rho(r)/\rho_n(r)$

Haacke et al., AJNR 2009.

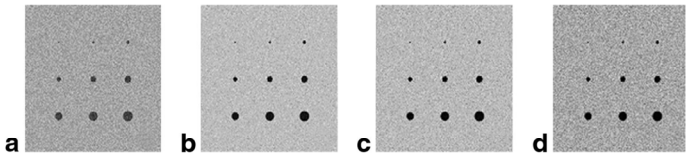
Phase Masking Process



Haacke et al., AJNR 2009.

Phase Mask Multiplication

$$\rho(x)_{new} = f^m(x)\rho(x)$$

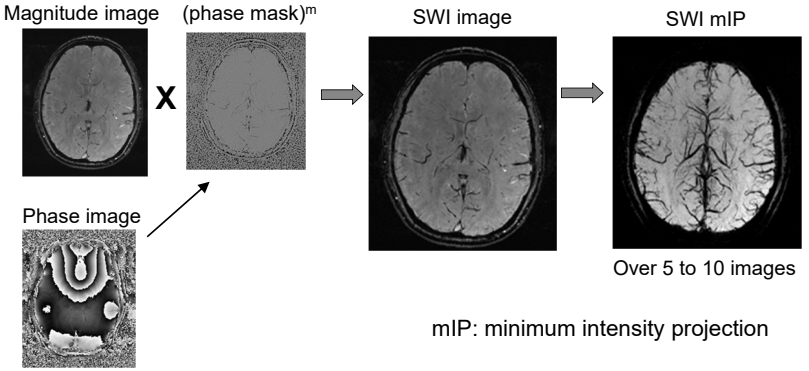


m=1 m=4 m=8 m=16

Best CNR

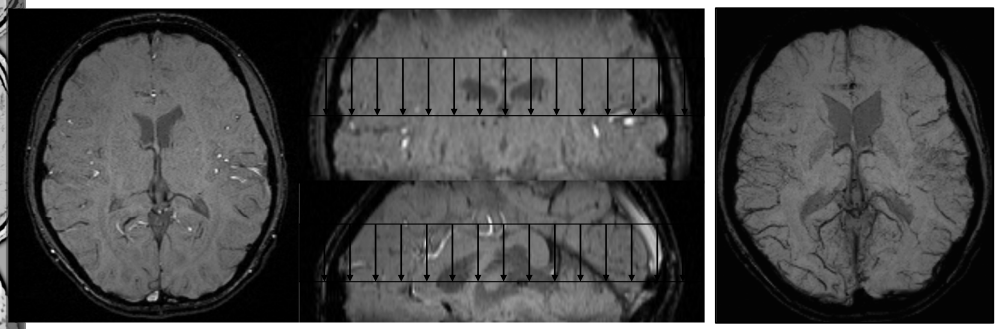
Haacke et al., MRM, 2004.

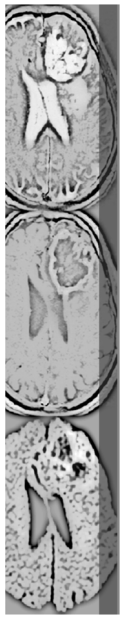
Outline of SWI processing



mIP: minimum intensity projection

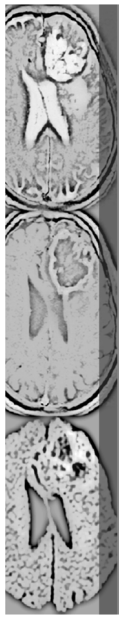
mIP: Minimum Intensity Projection



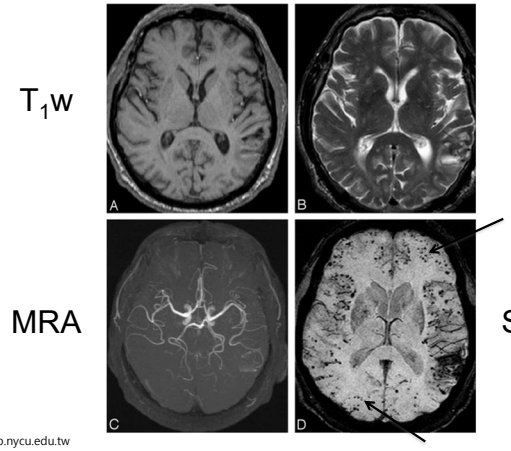


Clinical Applications

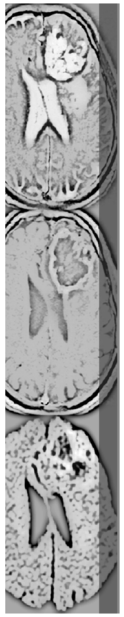
- Hemorrhages
- Cerebrovascular and ischemic brain diseases
- Traumatic brain injuries
- Arteriovenous malformations
- Neurodegenerative diseases
- Breast microcalcifications



Seeing Microbleeds with SWI

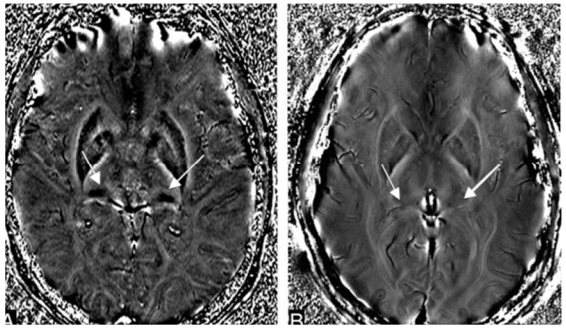


Mittal et al., AJNR 2009.



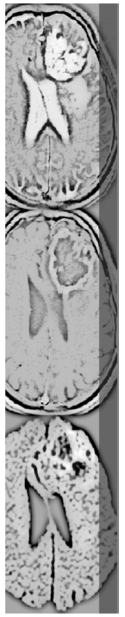
SWI in Multiple Sclerosis

MS Patient Normal Volunteer



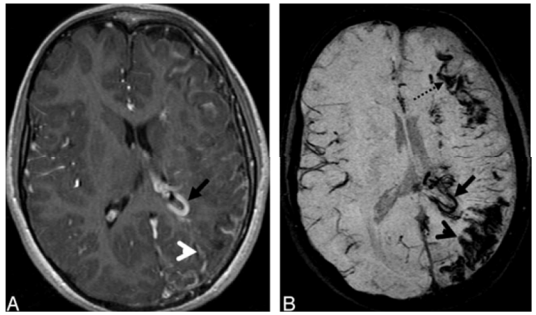
Mittal et al., AJNR 2009.

Iron build up in the pulvinar in MS indicated with SWI



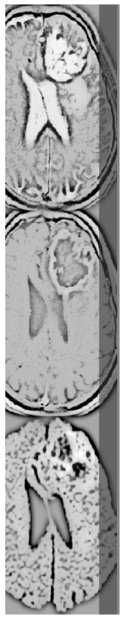
Sturge Weber Syndrome

Often found in children leads to vascular malformation.



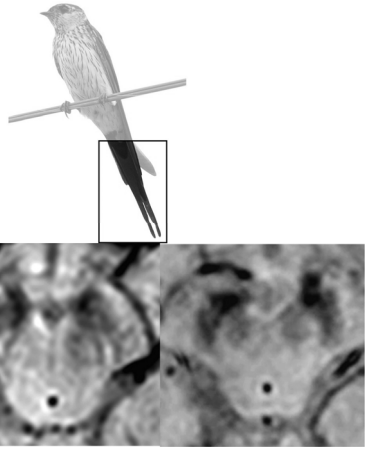
Post-contrast T1w
Leptomeninges (arrowhead)
Periventricular veins (arrow)

SWI – calcification of gyri (dotted/arrowhead)
Periventricular veins (arrow)

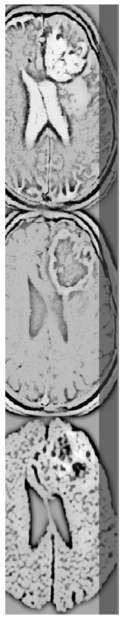


Swallow tail sign

- The swallow tail sign describes the normal axial imaging appearance of nigrosome-1 (黑質體1) within the substantia nigra (黑質) on high resolution SWI.
- Absence of the sign (absent swallow tail sign) is reported to have a diagnostic accuracy of greater than 90% for Parkinson disease.



http://radiopaedia.org/articles/swallow-tail-sign



Recap

- Deoxygenated blood (去氧血紅素), iron storage (hemosiderin or ferritin), and calcium (鈣化) have different susceptibilities from surrounding tissues.
- Change of susceptibility can result in the phase shift.
- The filtered phase image is used as mask to multiply with magnitude image.
- SWI is particularly useful for the diagnosis of microbleed, calcifications, and neurodegenerative disease.

THE END

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