# Visualization of diamagnetic materials inside paramagnetic lesions in the human brain

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**Introduction**:

Hemorrhage and calcification may present simultaneously in the same lesion and are almost indistinguishable from each other on conventional MRI. Recently gradient echo phase images and quantitative susceptibility mapping (QSM) have been reported for identifying isolated small calcifications [1, 2]. Here, we assess phase imaging and QSM for differentiating calcification from hemorrhage in the same lesion, using CT as the reference standard.

**Materials and Methods**:

20 vascular malformation patients who have undergone both CT and a 3T MRI exam were retrospectively analyzed. Patients without calcified lesions on CT were excluded. The MR protocol included a multi-echo gradient echo sequence, with the following imaging parameters: 8 echoes with a uniform TE spacing = 5.5ms; TR = 50ms; voxel size = 0.469×0.469×2 $mm^3$; matrix size = 512×512×58; BW = ±62.5kHz, FA = 25° and NEX = 1. A homodyne reconstructed high-pass filtered phase image was calculated from the 5$^{th}$ echo (TE=27.5ms), and a QSM was reconstructed using the morphology enabled dipole inversion method (3). Hyperintense lesions (intensity >100 Hounsfield Unites) on CT were identified as calcifications. The signal intensities of these lesions on MRI phase and QSM images were evaluated.

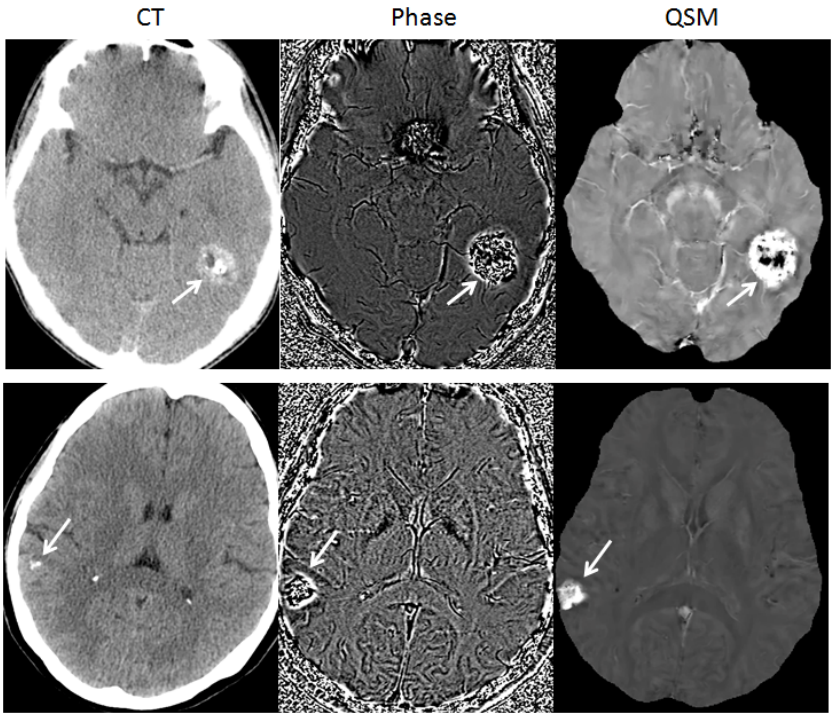


Fig. 1. Representative cases of CT, phase and QSM. In the first patient (top row), CT showed a calcified lesion with a dim bright rim, the same lesion on the phase image had a noisy appearance, while on QSM it showed as hyperintense lesion with a hypointense core. In the second patient, CT showed a small calcified lesion, the same lesion on the phase image again had a noisy appearance, while QSM showed a non-uniform hyperintense lesion with the periphery brighter than the center.

**Results**:

6 of the 20 patients had calcified lesions on CT, one lesion per patient. Five of these lesions also showed dim bright rims (voxel intensity between 40~70H.U.). All lesions were found on both phase images and QSM. The lesion on phase images appeared to be corrupted by noise. Lesions demonstrated two distinct patterns on QSM: a) a hyperintense lesion with a hypointense core in 4 patients (top row in Fig.1), and b) a nonuniform hyperintense lesion whose periphery was brighter than the center in the other 2 patients (bottom row in Fig.1).

**Discussion:**

The noisy appearance of calcifications on phase images may be due to the relatively long echo time (TE=27.5ms), which could have led to substantial dephasing that was further emphasized by the high-pass filter. In comparison, these lesions on QSM have more structured appearances, depicting various susceptibilities of components of that lesion. It has been confirmed that calcification is diamagnetic (negative value in QSM) while iron in hemosiderin is paramagnetic (positive value in QSM) [4]. When both calcification and iron are in a same voxel, the estimated volume susceptibility of that voxel will depend on the relative proportion of calcification and iron, causing the observed non-uniform pattern on QSM (Fig.1 bottom row).

**Conclusion**:

When calcifications are accompanied by hemorrhages, the lesion phase signal is corrupted by noise. QSM demonstrates spatial variation of susceptibility, suggesting the ability to identify calcifications in or near hemorrhages.

**References**:

[1] Zhen et al. JMRI 29(1):177-82; [2] Schweser et al. MedPhys 37(10):5165-78; [3] Liu et al. MRM 66(3):777-83; [4] Liu et al. MRM 61(1):196-204.