Hematoma Volume Measurement in Gradient Echo MRI Using Quantitative Susceptibility Mapping

Shuo Wang, Min Lou, MD, PhD; Tian Liu, PhD; Deqi Cui, PhD; Xiaomei Chen, PhD; Yi Wang, PhD

Background and Purpose—A novel quantitative susceptibility mapping (QSM) processing technology has been developed to map tissue susceptibility property without blooming artifacts. We hypothesize that hematoma volume measurement on QSM is independent of imaging parameters, eliminating its echo time dependence on gradient echo MRI.

Methods—Gradient echo MRI of 16 patients with intracerebral hemorrhage was processed with susceptibility-weighted imaging, \( R^2* (=1/T2^*) \) mapping, and QSM at various echo times. Hematoma volumes were measured from these images.

Results—Linear regression of hematoma volume versus echo time showed substantial slopes for gradient echo magnitude (0.45±0.31 L/s), susceptibility-weighted imaging (0.52±0.46), and \( R^2* \) (0.39±0.30) but nearly zero slope for QSM (0.01±0.05). At echo time=20 ms, hematoma volume on QSM was 0.80x that on gradient echo magnitude image (\( R^2=0.99 \)).

Conclusions—QSM can provide reliable measurement of hematoma volume, which can be performed rapidly and accurately using a semiautomated segmentation tool. (Stroke. 2013;44:2315-2317.)

Key Words: gradient echo ■ hematoma volume ■ intracerebral hemorrhage ■ magnetic resonance imaging ■ quantitative susceptibility mapping
volume=1.43; \( R^2=0.90; \) \( P<10^{-3} \), and \( R^2* \) (\( R^2* \) volume/QSM volume=1.15; \( R^2=0.92; \) \( P<10^{-3} \)), shown in Figure 2.

Hemorrhage volume measured on QSM ranged from 7.0 to 63.4 mL, with a median of 17.65 mL and interquartile from 11.7 to 24.2 mL.

**Discussion**

Our results demonstrate that QSM reduced the TE dependence of GRE MRI HV measurements from magnitude, SWI, and \( R^2* \) images, providing a HV measurement independent of imaging parameters in GRE MRI.

This result is consistent with the report that QSM can provide a reliable measurement of the burden of cerebral microbleeds and is understood from physics underlying the GRE MRI data acquisition. Micro- and macrohemorrhages contain paramagnetic components (hemosiderins, methohemoglobins, etc.) that generate magnetic fields. Fields extending beyond their source locations cause blooming artifacts in GRE magnitude images. Blooming artifacts depend on phase accumulation, which is proportional to TE and local fields. Consequently, the SWI and \( R^2* \) images are dependent on TE, resulting in TE-dependent overestimation in HV measurements from GRE MRI.

Quantitatively, the magnetic field at a point in space, measurable from GRE phase images, is determined by convolving paramagnetic sources with the dipole kernel. To eliminate blooming artifacts dependent on GRE imaging parameters, the dipole kernel deconvolution must be performed to reveal tissue magnetic properties, which is QSM technology.

This technical study is limited by the number of patients and lack of CT correlation and may be followed by a future study on a large cohort of patients with CT correlation. Many stroke centers obtain a CT then a follow-up MRI because of MRI’s unparalleled rich tissue contrast in imaging brain tissue. Therefore, estimating a precise HV by MRI in comparison with CT could be important in assessing hematoma expansion using different modalities. HV from CT=0.8* HV from the GRE magnitude image at TE=15 to 20 ms (approximately reference TE here) was reported.\(^{11}\) We observed QSM volume/magnitude volume=1/1.24=0.8 (inverse of the slope in Figure 2). The suggestion that the HV measured by QSM may be approximately the HV measured by CT needs to be confirmed in future study.

Efforts exist to develop efficacious treatment of intracerebral hemorrhage, which has caused increasing hospital admissions with persistently high mortality rates.\(^{12}\) Although HV serves as a measure for the effects of potential interventions in clinical trials, like INTERACT,\(^{13}\) in vivo MRI characterization of brain tissue and vasculature may allow better understanding and management of hematoma expansion\(^{14,15}\) and would be important in developing and applying intracerebral hemorrhage therapy. QSM of tissue magnetic property may become an essential part of a hemorrhage MRI protocol.

**Sources of Funding**

This work was supported in part by grants from US NIH (R01EB013443, R43NS076092, and R01NS07237), China National NSF (81171095), and Zhejiang Provincial NSF (LR12H09001).
Disclosures

Drs Liu and Wang are listed as inventors on patent applications related to the QSM technique. The other authors have no conflicts to report.

References

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Stroke. 2013;44:2315-2317; originally published online May 23, 2013;
doi: 10.1161/STROKEAHA.113.001638
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://stroke.ahajournals.org/content/44/8/2315

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