Repeatability and reproducibility of brain quantitative susceptibility mapping.

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Title Repeatability and reproducibility of brain quantitative susceptibility mapping.

Target Audience Researchers and clinicians interested in quantitative susceptibility mapping.

PURPOSE Quantitative susceptibility mapping (QSM) is a novel MRI method for quantifying magnetic sources in the human body such as iron, blood products, and calcification [1]. The clinical utility of QSM has been demonstrated in a large number of preliminary clinical studies on various brain diseases, including microbleeds, multiple sclerosis, Alzheimer's etc. [2, 3, 4]. Despite the rapid adoption of the QSM technology by clinicians, there is a limited knowledge on QSM measurement variability when performed on the same scanner within the same imaging session (repeatability) or on different scanners, particularly those made by different manufacturers (reproducibility). Such information is valuable for accurate clinical interpretation of longitudinal QSM changes and important in the design of multi-site studies. The purpose of this study was to assess the repeatability and reproducibility of QSM measurements on ex vivo brain samples and healthy volunteers at 3 Tesla.

METHODS We performed multi-echo spoiled gradient echo imaging on 2 formalin-fixed ex vivo brain specimens and in the brain of 7 healthy volunteers (5 male, 2 female, ages 23 to 44 years) at 3T on two different canners (GE HDxt and Siemens Magnetom). Each imaging subject was scanned twice with QSM on the same scanner in a single imaging session to assess repeatability, followed by another imaging session within 7 days on a different scanner to assess reproducibility. The acquisition parameters were matched as much as possible between the two scanners: TR=54 ms, field of view (FOV) = 24 cm, matrix size = 312x384 (interpolated to 512x512), flip angle = 20^0, TE1 = 4.1 ms, 11 echoes, echo spacing = 4.4 ms, slice thickness = 2 mm, number of slices=64, 1 scan average. QSM images were reconstructed from the field maps using PDF algorithm for background removal and MEDI algorithm for dipole inversion [5, 6]. The magnitude images were used to co-register the QSM maps obtained from different scans using the FSL package [7, 8]. ROI analysis was used to measure the mean QSM values in iron-rich regions of the brain, including red nucleus (RN), substantia nigra (SN), caudate nucleus (CN), putamen (Put) and globus pallidus (GP) (Fig.2). Linear regression and Bland-Altman analyses were used to quantify the intra-site and inter-site variability of QSM measurements.

RESULTS. 1 volunteer scan from site 2 was excluded from QSM comparison analysis because of a large number of artifacts in the phase data. Inter-site ex-vivo specimen images had correlation coefficients of 0.99 and a mean difference of $(0.69 \pm 2.55) \times 10^{-3}$ ppm (Fig. 1). For human volunteers, these values were 0.97 and $(-0.60 \pm 9.98) \times 10^{-3}$ ppm for site 1 scans (n=7), 0.97 and $(-0.47 \pm 1.37) \times 10^{-2}$ ppm for site 2 scans (n=6) and 0.96 and $(0.42 \pm 1.42) \times 10^{-2}$ ppm (n=6). The mean differences are more than 100 times smaller than the average susceptibility measurement. We note that our susceptibility measurements agree with recently published values [9]

DISCUSSION AND CONCLUSION

Our results showed that QSM brain MRI scans have good repeatability and reproducibility, though phase artifacts may have to be watched for on some scanners. We attribute the slightly lower correlation for head scans compared to ex-vivo brain specimens to the greater difficulty in positioning human subjects and in removal of background field contributions from the sinuses and bone tissue. Bland-Altman plots indicate that the two MRI systems we used may be used interchangeably.

REFERENCES

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Reproducibility for ex-vivo specimens

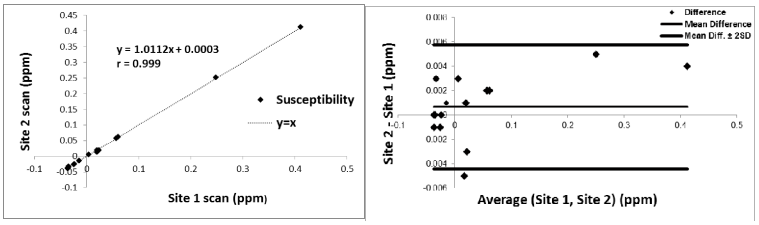

Fig.1. Scatter and Bland-Altman plots comparing QSM measurements acquired at sites 1 and 2. Data points are mean voxel values of ROIs drawn in the cortex, white matter and basal ganglia. The last two points are from gadolinium references with known susceptibility values.

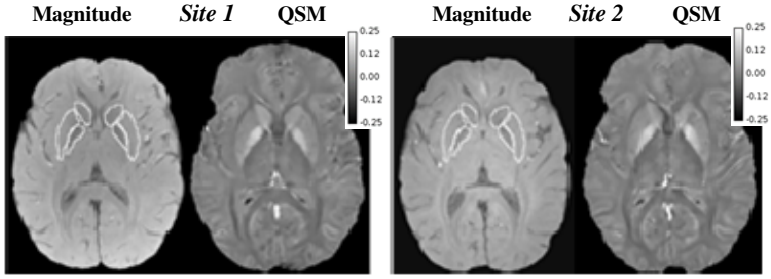

Fig.2. An example of manually traced ROIs of the caudate nucleus, putamen and globus pallidus on co-registered magnitude and QSM images from site 1 (left) and site 2 (right).

Repeatability of human brain QSM at site 1

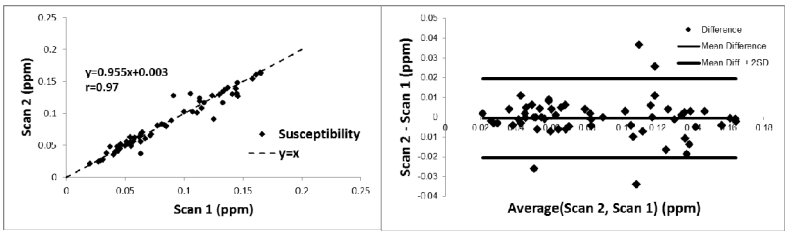

Fig.3.Scatter and Bland-Altman plots for repeated QSM measurements of all volunteers acquired at site 1.

Repeatability of human brain QSM at site 2

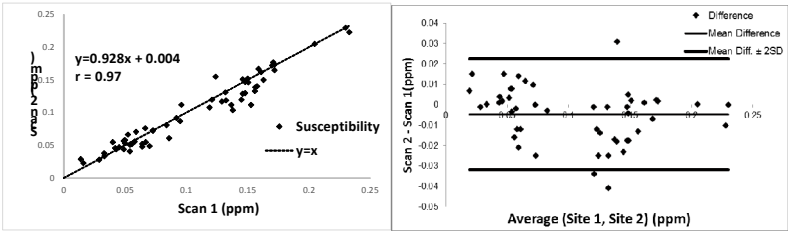

Fig.4. Scatter and Bland-Altman plots for repeated QSM measurements of all volunteers acquired at site 2.

Reproducibility of human brain QSM

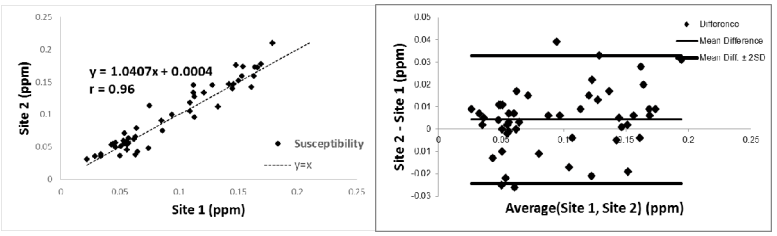

Fig.5. Scatter and Bland-Altman plots for QSM measurements of all volunteers acquired at sites 1 and 2.