Quantitative Susceptibility Mapping: A comparison between COSMOS and weighted L1 regularization from single orientation

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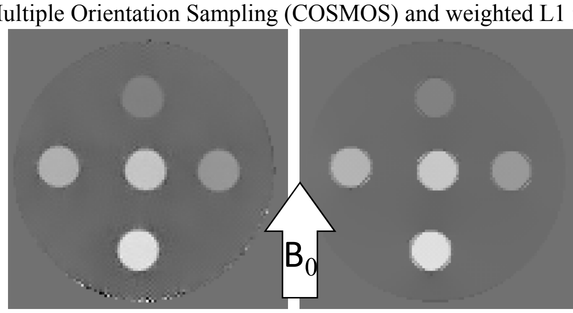
Introduction: Quantitative Susceptibility Mapping (QSM) provides both visualization and quantification of endogenous and exogenous susceptibility contrast. Finding the susceptibility distribution from the measured field map requires a deconvolution of that field map with the unit dipole response, a process which is ill-posed [1]. Several techniques have been proposed to solve the problem by multiple orientation sampling [1], regularization [2,3], or truncated Fourier space division [4]. In this study, we compared two previously validated reconstruction techniques, Calculation of Susceptibility through Multiple Orientation Sampling (COSMOS) and weighted L1 in phantom and brain imaging. .

Materials and Methods:

COSMOS acquires the same anatomy multiple times oriented along different directions and does not make any assumptions about the susceptibility distribution. The data from the different orientations are registered spatially. Next, a conjugate gradient (CG) algorithm is used to fit the unknown susceptibility distribution to the measured field map.



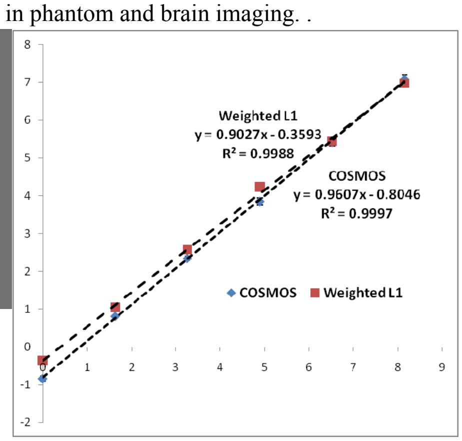
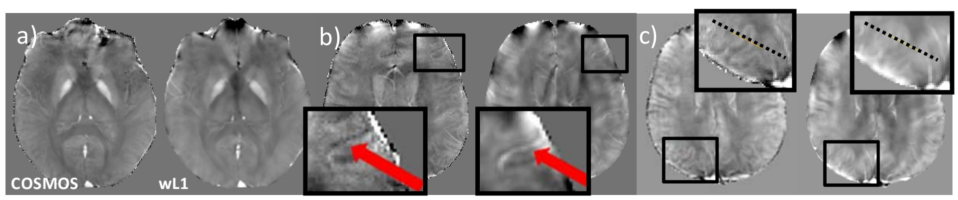


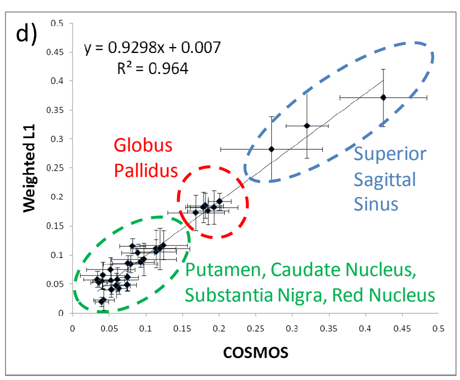
Fig. 1) Left is COSMOS, right is weighted L1 reconstruction. Neither has visually detectable streaking artifacts.

Weighted L1 only requires one orientation, but assumes that an edge on the susceptibility map closely matches a corresponding edge on the T2* weighted image that is acquired together with the phase map. The following equation was solved: $\min_\chi |W_G G\chi|_1, \text{s.t.} |W(D\chi - b)|_2^2 < \varepsilon$, where χ denotes the susceptibility spatial distribution, b is the measured magnetic field, D denotes the matrix representing the convolution kernel of the dipole and G denotes an operator such as the gradient operator. W compensates the phase noise variation and W_G is a mask which is inversely proportional to the T2* magnitude edge image.

Phantom experiment: A water phantom containing five vials with concentrations of Gd ranging from 1% to 5% with 1% increment was imaged using a GE 1.5T scanner (Waukesha, WI, USA). Imaging parameters were: resolution 1mm^3 isotropic, BW=±62.50kHZ, TR=30ms, FA=30˚. Four TEs=1.7, 2.2, 4.2, 14.2ms were used for field map estimation. Data were acquired from the optimal three orientations (-60°,0°,60°) [1]. Both COSMOS and weighted L1 were applied and the results were compared quantitatively in 5 Regions Of Interests (ROIs) with the experimentally known susceptibility value.

Healthy volunteer experiments: Informed consents were obtained from all volunteers (n=3). Small angle COSMOS [5] acquisitions were performed at 3T (GE Waukesha, WI, USA) to accommodate the limit head coil space. A 3D gradient multi-echo sequence was run axially with TE=5,10,15,20,25ms, TR=40ms, FA=20˚, BW=±31.25kHz. Image resolution was 1×1×3mm^3. Reconstructions were obtained from both COSMOS and weighted L1. ROIs (globus pallidus, putamen, caudate nucleus, substantia nigra and red nucleus on both hemispheres) were manually segmented by a radiologist. Mean susceptibility values reconstructed by these two methods were compared in these ROIs.





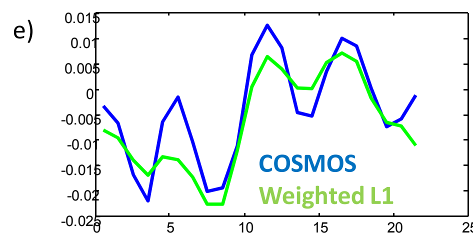


Fig. 2) pair wise comparison between COSMOS and weighted L1 a) slice showing basal ganglia b) vessel depiction c) gray/white matter contrast d) quantitative susceptibility comparison e) intensity profile along the dotted line in c.

Results: In the phantom study, both techniques reconstructed a susceptibility map without streaking artifact. The mean susceptibilities in the ROIs agreed well with expected values (the slope of the fit between the calculated and the known susceptibility values was over 0.90 with R^2~1). In the brain study, we have the following findings: 1) Both COSMOS and weighted L1 reconstructed a brain QSM without streaking artifacts (Fig. 2a). 2) The weighted L1 slightly underestimated susceptibility compared to COSMOS (slope of the fit between the two sets of calculated susceptibilities was ~0.93). 4) Small vessels are better visualized on weighted L1 maps (Fig. 2b). 3) White and gray matter are better depicted on the COSMOS maps (Fig.2c).

Discussion and conclusion: The preliminary comparison showed good agreement between COSMOS and weighted L1 reconstruction. COSMOS keeps full fidelity to acquired data, which may explained the reason for better contrast in white/gray matter. Weighted L1 does not require rotation and the subsequent image registration, which greatly improves its practicality and avoids downgraded resolution by residual misregistration..

Ref: [1] Liu et al. MRM:61:196-204; [2] de Rochefort et al. MRM: *in press*; [3] Kressler et al. IEEE TMI: 2009; [4] Shmueli et al. MRM: 2009;[5] Liu et al. ISMRM 09:465