CORRECTION OF MACROSCOPIC FIELD INHOMOGENEITIES IN 3D QUANTITATIVE GRE IMAGING BASED ON NONLINEAR PHASE MODEL AND SNR MAPPING

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Introduction: In 3D gradient echo (GRE) imaging, strong macroscopic B0 field gradients (Gr) are observed at air/tissue interfaces and in the presence of metallic objects. In particular, at low spatial resolution, the respective field gradients lead to an apparent increase in the intra-voxel dephasing [1, 2] and subsequently to signal loss or inaccurate R2* estimates [3]. If the macroscopic gradient through a voxel (Gr) can be estimated [5], its influence can be removed through post-processing [1]. The proposed correction strategies usually assume a linear phase evolution with time [1]. However, near the edge of the brain, the paranasal sinus and temporal lobes, this assumption is often broken [2, 3, 4]. In this work, we explore a model that considers a non-linear dependence of the phase evolution with echo time. The correction model is then weighted by the SNR map computed from the magnitude image in order to remove singularities caused by inaccurate field map estimation. We tested the performance of the proposed model for correcting of artifacts in a physical phantom with different $MnCl_2$ concentrations and in vivo clinical studies.

Material and methods: The measured signal decay $S_n(TE)$ is a product of the true decay S(t) and the signal loss due to B0macro F(TE) [1]. Standard approaches assume that phase evolution is linear and that a 3D-linear-Sinc-correction (LSC) [1, 5] adequately describes F(t). However, in the presence of large B0macro, the linear term no longer dominates the phase evolution [2, 3, 4]. Consider that the phase evolution can be described as combination of a linear and a random component [5, 6], we can describe the phase dispersion's signal loss F(TE) with the expected phase evolution as shown in Eq. (1) where $\Delta\varphi$ is the phase shift, TE_N is the N[th] echo time and β is a parameter determined by the random walk theory [6]. To further enhance the algorithm proposed in [3, 4], the proposed Non-Linear-Sinc correction NLSC is weighted by a factor computed from SNR maps and then the correction is performed according to Eq. (2) where ω is a parameter determined iteratively beforehand to ensure better and accurate correction. The correction procedure was tested on a phantom containing 5 spheres of $MnCl_2$ and clinical scans(40 invivo data) acquired on a Skyra-3T scanner (Siemens Healthcare, Germany) using a 1.6×1.6×1.6 mm³ 3D-GRE TR/ES/47/1.23ms Phantom/In-vivo/17/32 echoes. A weighted field map was computed from the phase images and the correction was performed offline using customized Matlab scripts (Mathworks, USA).

$$\Delta\varphi_n(TE_N) = (N\cdot\beta)^{\frac{1}{2}}\delta\varphi(\Delta TE) \quad (1)$$

$$S_n(TE) = 1/V_n\rho_n(TE_N)\prod_r L_r sinc\left(\frac{\gamma}{2}\cdot\left(\omega-\frac{1}{SNR}\right)\cdot(N\cdot\beta)^{\frac{1}{2}}\Delta TE\cdot Gr(r)\right) \quad (2)$$

Results and discussion: Fig.1 (upper row) shows the impact of the correction on phantom data. At low $MnCl_2$ concentrations, all corrections remove the expected R2* bias; however, near the right edge and in the spheres with huge artifacts, LSC results in overcorrection (Fig. 1B). NLSC (Fig. 1C) and NLSC_SNR_weighted (Fig. 1D) provide an accurate correction without any overestimation. Near the phantom edges and air bubbles, the NLSC_SNR_weighted shows an enhancement in removing singularities due to poor field gradient estimation. For the clinical data (Fig. 1, Lower row), the corrections remove the small R2* bias in regions with high SNR. However, the LSC fails near the brain edges, paranasal sinus and around the cingulate region. Internally the NLSC and NLSC_SNR_weighted better remove the singularities in the R2* image and better preserve white-matter structures. Similar to the phantom study, the NLSC_SNR_weighted enhances the removal of high R2* artifacts near the brain edges and in the paranasal sinus regions. Due to the SNR weighting, the enhanced algorithm performs an additional correction dependent on image SNR, thus enabling to better remove the singularities.

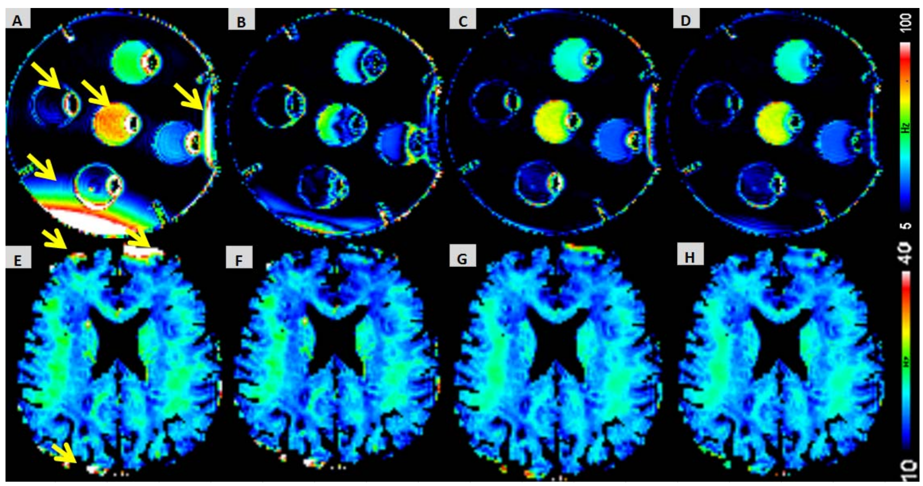

Figure 1: **Upper row: Phantom study and lower row: clinical study, (A, E) without correction, (B, F) LSC, (C, G) NLSC, (D, H) NLSC_SNR_w**

Conclusion: The proposed enhanced correction is based on 1D random-walk theory and SNR weighting attempts to account for non-linear phase evolutions that result from the presence of large B0macro and noise in region with low SNR. The correction is equivalent to the LSC and NLSC in regions with high SNR but appears more robust in regions of large or abrupt changes in B0macro. This enhanced correction technique shows promise to improve R2* measurements in regions of large susceptibilities and needs to be further evaluated.

References: **[1]** D.Yablonskiy et al, MRM 2012,000 :000-000. **[2]** Zeng et al, MRM 2002,48 :137-146. **[3]** C.Fatnassi et al, ESMRMB 2013, 26:234:235. **[4]** C.Fatnassi et al, ISMRM 2014. **[5]** M.A. Fernandez et al, MRM 2000.44 :358-366. **[6]** Solid state physics, Kittel, 8th edition 2005.

This work is supported by HIRSLANDEN Lausanne, Clinique Bois-Cerf, Switzerland