Quantitative susceptibility mapping of bone using ultra-short TE sequence

Alexey V. Dimov[1,2], Zhe Liu[1,2], Pascal Spincemaille[2], Jiang Du[3], and Yi Wang[1,2]
[1]*Department of Biomedical Engineering, Cornell University, Ithaca, New York, United States,* [2]*Radiology Department, Weill Cornell Medical College, New York, New York, United States,* [3]*University of California (San Diego), California, United States*

Target audience: Researchers interested in quantitative susceptibility mapping for muscular-skeletal imaging.

Purpose:

Quantitative susceptibility mapping has been previously applied to neuroimaging [1], breast and abdominal imaging [2, 3]. It is useful for the detection and quantification of calcium, iron deposits and contrast agents [4]. Because of the lack of ionizing radiation, its application to musculoskeletal imaging has high potential merit but is hampered by the rapidly decaying bone signal ($T_2^*{\sim}300\,\mu s$). With a conventional GRE sequence ($TE \geq 2\,ms$), no meaningful susceptibility values may be assigned to bone voxels during QSM reconstruction.

In the current work we address this issue by using an ultrashort echo time (UTE-GRE) pulse sequence for MR signal acquisition; preliminary results demonstrate successful reconstruction of bone susceptibility using the proposed technique both *ex-* and *in-vivo.*

Methods:

Implementation: 3D UTE pulse sequence [5] was implemented at 3T (GE Healthcare, Waukesha, WI). The sequence used a nonselective hard pulse (pulse width $100\,\mu s$) to achieve volumetric excitation, followed by 3D radial ramp sampling.

Phantom imaging: A porcine hoof embedded in agarose was scanned both on CT ($0.6 \times 0.6 \times 0.6\,mm^3$, $120\,kVp$, $200\,mA$) and MRI ($FA = 10$, $FOV = 16\,cm$, $0.6 \times 0.6 \times 0.6\,mm^3$, 75000 projections, $TR = 9.6\,ms$, $TE = 0.05$, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 1, 2, 3 ms).

In-vivo imaging: The wrist and knee in 2 healthy subjects were scanned on MRI using the same scan parameters as for the phantom. Field was estimated using a graph cut based field processing method (SPURS) [6], followed by adaptive fat/water separation [3], background field removal and nonlinear dipole inversion [7].

Results:

Comparison of ex vivo CT and QSM images are shown in Fig. 1 along with results of ROI analysis of both images (Fig. 2). It can be noted that the good correspondence between diamagnetic regions in QSM and regions of high Hounsfield units values in CT was reflected by a strong linear correlation; the resulting bone susceptibility values (~-2.5 ppm) were close to literature values [8]. Fig. 3 demonstrates results for the volunteer wrist and knee scans.

Discussion:

Magnetic susceptibility mapping in the bone is feasible, yet certain precautions should be taken. First, optimized phase unwrapping and water/fat separation is required for field estimation. Second, the field map has relatively low SNR in the bone due to lower phase accumulation. Third, in its current implementation the scan time is longer than that of the conventional GRE (~1 hour in total), and additional optimization of the acquisition strategy (such as parallel imaging) will be required.

Conclusion:

The preliminary *ex vivo* and *in vivo* data in upper and lower extremities demonstrate the feasibility of using UTE-GRE for susceptibility mapping in the bone.

References:

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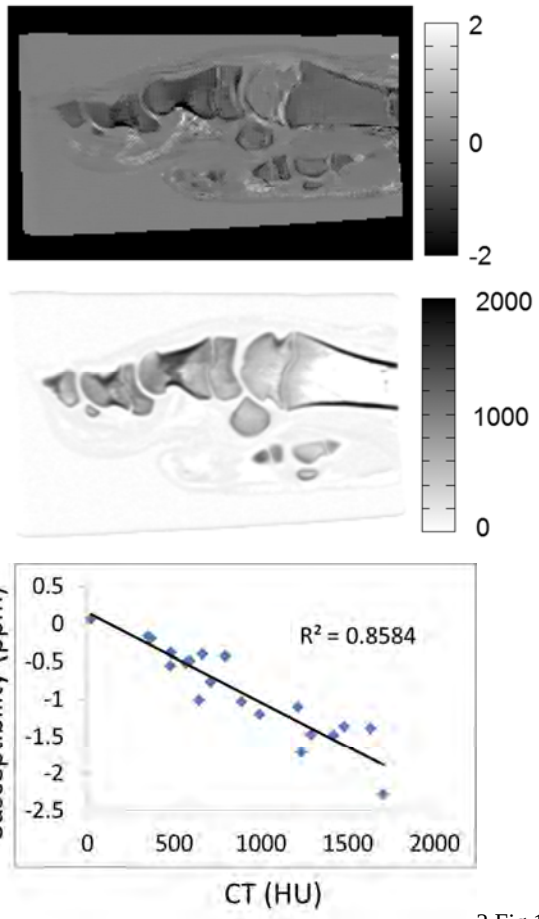

2 Fig 1
a) Comparison of pig hoof QSM and CT. b) Linear regression of CT (Hu) and QSM (ppm) measured in ROIs drawn in the bone.

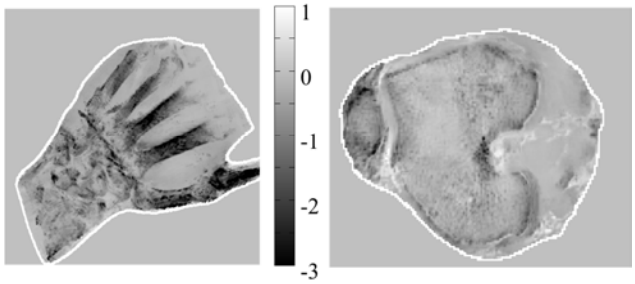

Fig 2 In-vivo QSM in the extremities in a healthy subject. left: thick mIP QSM of the wrist; right: axial QSM thin mIP of the knee susceptibility map