Fast Parametric Imaging of the Spine with Radial IDEAL-GRASE

M. I. Altbach[1], Z. Li[1], A. Bilgin[1,2], and K. L. Weiss[3]

[1]Radiology, University of Arizona, Tucson, Arizona, United States, [2]Electrical and Computer Engineering, University of Arizona, Tucson, Arizona, United States, [3]Radiology, University of Cincinnati, Cincinnati, Ohio, United States

Introduction: Each year millions of Americans are affected by spine pathologies. These include ubiquitous disco-vertebral degeneration; fractures, often osteoporosis related; and bone metastases, resulting primarily from breast and prostate cancer.

MRI is used in the evaluation of the spine. MRI can quantify vertebral morphology, act as a surrogate marker for fracture risk in cross sectional studies and differentiate between osteoporosis and other underlying pathology [1,2]. Nonetheless, routine T1 and T2 MRI methods are sometimes limited in the detection of vertebral metastases. T1 methods typically provide good soft tissue contrast between normal bone marrow and metastases due to the presence of fat (short T1) in the former but not in the latter. Unfortunately, normal bone marrow may have heterogeneous or diminished lipid content, confounding interpretation. The presence of lipid can also limit the sensitivity of conventional T2 methods for the detection of metastases as both neoplasm and lipid demonstrate similar hyperintensity on T2-weighted images. The acquisition of fat-suppressed images can help overcoming this problem. However, fat suppression using conventional chemical-shift imaging often fails when applied to large FOV sagittal spine imaging, due to field inhomogeneity. Chemical-shift suppression based on inversion recovery (STIR) is insensitive to field inhomogeneity but suffers from reduced SNR and mixed contrast that is dependent on T1.

Recently, a new radial MRI method for lipid/water separation was developed [3]. The method is based on the acquisition of gradient echoes within spin echo periods (GRASE) and uses an iterative algorithm (IDEAL) [4] for the robust separation of lipid and water signals with correction for field inhomogeneity. An advantage of the radial IDEAL-GRASE technique is that data can be processed to calculate T2 and $T2^{\dagger}$ maps. The purpose of this work is to illustrate the potential of the radial IDEAL-GRASE technique for spine imaging.

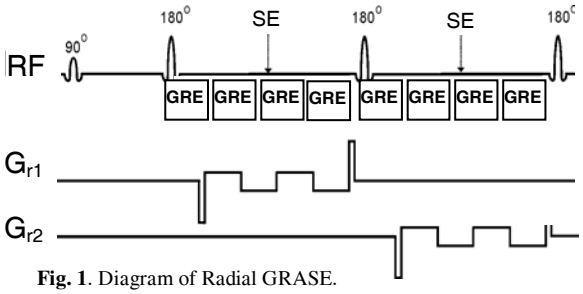

Fig. 1. Diagram of Radial GRASE.

Methods: A diagram of the radial GRASE pulse sequence in shown in Fig. 1. Within each SE period several gradient echoes (GRE) are collected at different echo shifts from the SE point. The images generated from the echo-shifted data are used in the iterative algorithm described in [4] to obtain a lipid and a water image without the effects of field inhomogeneities. Since data are collected with a radial k-space trajectory, the oversampling in the center of k-space allows us to calculate T2 maps using the GRE that are closest to the SE point and the processing algorithm described in [5]. Once T2 is calculated, $T2^{\dagger}$ can be obtained from the change in signal intensity of the echo-shifted GRE images.

Radial IDEAL-GRASE data were acquired with echo shifts = ($-3\pi/2$, $-\pi/2$, $\pi/2$, $3\pi/2$), BW = ±62.5 kHz, ETL = 8, matrix size= 256×512, TR=2s, NEX=1, FOV=34 cm, slice thickness=4 mm. The total acquisition time was 2 min 12 s.

Results and Discussion: Figure 2A shows the spine of a patient with a metastatic lesion in L2 (*white arrow*), a hemangioma in L4 (*arrowhead*), and Modic II endplate changes (a condition related to fatty marrow conversion due to degenerative disc disease) at L4-5 (*black arrow*). This image was acquired with a conventional T2-weighted method where fat and water are observed together. While the definition of the hemangioma (which is a benign lesion) is good, the definition of the metastatic lesion is poor. This is because the metastasis and the bone marrow have nearly similar signal intensities. As shown in Fig. 2B, water and lipid are well separated with IDEAL-GRASE throughout the entire FOV. The metastatic lesion is well defined in the water, lipid, and lipid-to-water ratio (L/W) images. As can be seen from the lipid image and L/W map, the region occupied by the metastasis does not contain lipid, whereas the non-affected vertebral bodies and the hemangioma do. The L/W map also helps identifying and characterizing the endplate pathology as subacute Modic II changes (increased L/W related to lipid infiltration/) from the alternative acute Modic I changes which is characterized by diminished L/W due to marrow edema.

The characterization of pathologies can be further improved if the lipid/water information is combined with the $T2/T2^{\dagger}$ information obtained from the data (Fig. 2C). For example, hemangiomas have typically high L/W values (as shown in Fig. 2) whereas metastatic lesions have low L/W values. The T2s are also different. In this example $T2_{metastasis}$=75±17 ms and the $T2_{hemangioma}$=126±19 ms. Some hemangiomas, however, do not contain lipid and are difficult to differentiate from metastatic lesions. Hemangiomas, however, grow within the cortical bone (an area of high susceptibility) whereas metastatic lesions destroy the bone (which reduces the susceptibility as shown in the $1/T2^{\dagger}$ map). Thus $T2^{\dagger}$ may play an important role in differentiating these lesions. $T2^{\dagger}$ and L/W maps can also be used to assess bone quality [6] and can potentially be used to predict if a patient with bone metastasis or osteoporosis is at risk for bone fracture.

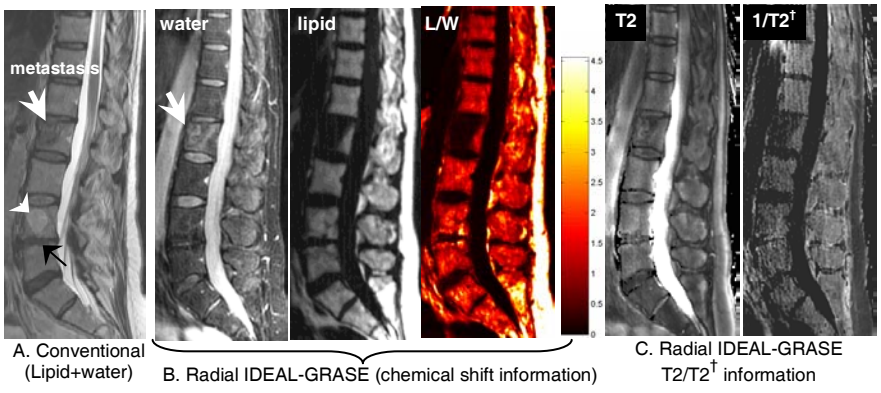

Fig. 2. Patient with L2 spinal metastasis, L4 hemangioma, and L4-5 Modic II endplate changes.

Conclusions: In this work we introduced a radial IDEAL-GRASE method for fast imaging of the spine. The method yields lipid and water images with a field inhomogeneity correction as well as quantitative parameter maps of lipid-to-water ratio, T2 and $T2^{\dagger}$. This information can be used to identify and characterize benign from malignant lesion as well as other pathologies resulting from degenerative processes.

Acknowledgements. Work supported by NIH (grant CA099074) and the AHA (grant 0355490Z).

References: (1) Meyers SP et al Arch Intern Med 1991; 151, 683. (2) Cyteval C et al Osteoporos Int 2002; 13, 468. (3) Li et al ISMRM 2006, 739. (4) Reeder S et al MRM 2005; 54, 636. (5) Altbach MI, MRM, 2005: 54, 549. (6) Wehrli FH et al Radiology 2000; 217, 527.