Correction of B_0 field inhomogeneities improves susceptibility-weighted breast echo planar spectroscopic images

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Introduction

High spectral and spatial resolution (HiSS) signals of water and fat can be obtained to enhance anatomic and functional information in MR images [1]. HiSS data are acquired rapidly using echo planar spectroscopic imaging (EPSI) [2,3]. With EPSI, high resolution water and fat proton spectra can be obtained from individual pixels at the spatial resolution of conventional anatomic images or better [2]. From the proton spectra of the water and fat resonances acquired at high spectral and spatial resolution, a variety of novel images can be produced by mapping certain spectral characteristics [2]. For example, capillaries can be visualized by mapping a component of the water signal that appears at a certain frequency, thus indicating the possibility of angiogenesis near a breast lesion.

Spectra obtained from individual pixels often reveal complicated line-shapes including multiple resonance peaks and inhomogeneous spectral broadening**.** In breast tissue, this often reflects the influence of subvoxelar blood vessels or microcalcifications on local magnetic susceptibility – causing the frequency of components of the water peak to shift. The detailed structure of the water line can provide important information regarding subvoxelar anatomy and physiology and help to identify pathologies such as invasive carcinomas. However, this can be obscured or lost due to static magnetic (B_0) field inhomogeneities introduced by macroscopic gradients. This study proposes a method for post-acquisition mapping and correction of global B_0 field inhomogeneities to enhance sensitivity to local magnetic susceptibility variation, thus producing diagnostically useful information.

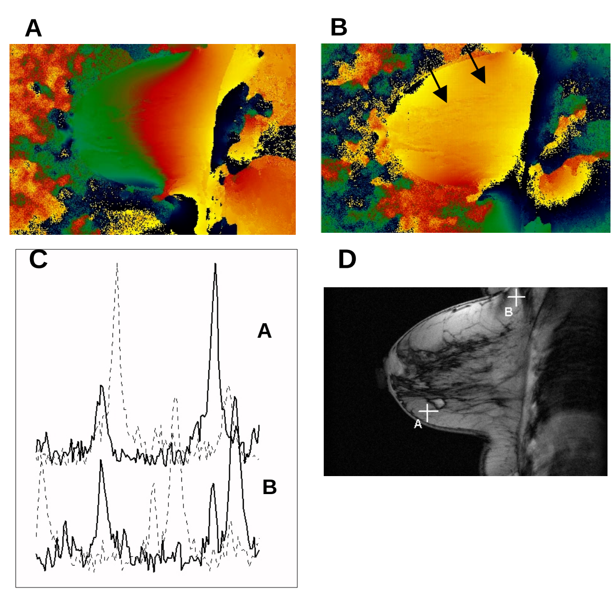
Methods

All data were acquired on a 1.5 T Signa clinical system (GE Medical Systems, Wilwaukee, WI) equipped with Echo Speed Plus gradients with a maximum slew rate of 120 mT/m/sec and a maximum amplitude of 23 mT/m. Signal was detected using a dedicated, phased array breast coil. Shimming was performed prior to acquisition using the standard GE protocol supplied with the magnet. HiSS images were acquired using an EPSI sequence [4] composed of a slice selection gradient (4 mm slice thickness) followed by a phase encoding gradient step (256 phase encoding steps), and the acquisition and simultaneous application of trapezoidal gradient echo pulses with alternating polarity, which produces the gradient echo chain (128 gradient echoes). A crusher gradient was applied after the echo train and each gradient echo was sampled at 384 points. The data were digitized with a bandwidth of 62 kHz and the time between the centers of neighboring echoes was approximately 3.0 ms. The proton free induction decay (FID) was sampled for a total of 384 ms and the repetition time (TR) was 500 ms. The resulting data had in-plane spatial resolution of less than 1 mm (for a field-of-view of 24 cm or less) and a spectral resolution of approximately 2.6 Hz. Data was processed using custom-built software in IDL (Interactive Data Language, Research Systems Inc., Boulder, CO). The details of the field mapping and post-processing B_0 field correction will be discussed in the presentation.

Results

The effect of post-processing evaluation and correction of macroscopic B_0 field gradients across the breast in a representative patient is shown in Figure 1. The figures compare images generated by spatially mapping the frequency of the fat resonance at each pixel before (A) and after (B) field correction. As illustrated, post-processing correction markedly improves field uniformity as is apparent by the decreased color variation in (B). A T1-weighted image is shown for anatomic reference (D). The effect of the frequency corrections on the spectra is illustrated in (C) which shows improved alignment of two spectra from the pixels indicated by the cross-hairs in (D) following field correction (solid lines). The B_0 field map obtained following frequency correction (B) shows subtle features that cannot be seen in (A). For example shifts in magnetic field between ducts and surrounding fat are evident in (B) – and as a result the ducts are clearly delineated. Other structures that may correspond to blood vessels (arrows) can be seen in (B) but not in (A).

Figure 1.



Discussion

Prior to field correction, spectra show very poor alignment of spectral resonance peaks, which makes difficult the identification of subtle frequency shifts associated with local physiology or anatomy. Following the correction of macroscopic gradients however, spectra can be aligned, and inter-voxel spectral shifts clearly delineated. In addition, interesting variations in the water-fat separation between neighboring pixels in small regions (on the order of 1 mm^3) are seen – suggesting subvoxelar variations in magnetic susceptibility. With effects of macroscopic B_0 field gradients removed, B_0 field maps can be evaluated and the potential for correlation with pathologies such as DCIS or other lesions investigated. Thus, this approach may have clinical potential as a non-invasive diagnostic application.

References

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