3T MR of the Prostate: Reducing Susceptibility Gradients by Inflating the Endo-rectal Coil with a Barium Suspension

Y. Rosen[1], B. N. Bloch[1], R. E. Lenkinski[1], R. L. Greenman[1], R. P. Marquis[1], N. M. Rofsky[1]

[1]Radiology, Beth Israel Deaconess Medical Center, Boston, MA, United States

Introduction

There is increasing interest in using localized magnetic resonance spectroscopy (MRS) of the prostate as a complement to MRI in evaluating patients with prostate disease. Most prostate MRI/MRS examinations are performed with an endo-rectal coil in order to improve the signal-to-noise ratio (SNR) of the study. At our institution, the commercially available endo-rectal coil (MRinnervu, Medrad, Pittsburgh, PA) is inflated with air (80 cc) in order to seat the coil against the prostate gland. This creates an air-tissue interface that can lead to the presence of magnetic susceptibility gradients within the gland. Because of proximity, the magnitude of these gradients is larger in the peripheral zone, where approximately 70% of the tumors occur. In principle, these gradients may be corrected by shimming. However, the requirements for shimming may be quite stringent since MRS is applied to measure the relative levels of choline and citrate which are separated by 0.55 ppm (30 Hz at 1.5T and 60 Hz at 3T). The idea to use liquid perfluorocarbon (PFC), which has a magnetic susceptibility similar to that of a tissue, to improve the field homogeneity has been previously described (1). More recently, it has been shown that spectral resolution improves when the endo-rectal coil is inflated with PFC, both for phantoms (2) and patients (3), in terms of line-width and metabolite peak separation. The drawbacks of using PFC are its cumbersome disposal and relative high cost. In the present study we investigated the possibility of inflating the endo-rectal coil with a barium sulfate suspension. We assessed the suitability of this agent by determining field maps in normal volunteers when the endo-rectal coil was inflated with air, PFC and barium successively. We also explored the relative improvement in each case when high-order shim (HOS) was applied.

Methods

Volunteers: The study was performed on 5 healthy volunteers, age range 22-60 years.

MRI: MRI scans were performed on a 3T scanner (GE, Waukesha, WI). T_2-weighted images were acquired with an 8-channel pelvic surface coil (USA Instruments, Aurora, OH, USA) combined with a disposable endo-rectal prostate coil (MRinnervu, Medrad, Pittsburgh, PA), with a FSE sequence (TE/TR=160/6820 ms, FOV=14x14 cm^2, matrix=256x192, slice thickness=2.2 mm).

Field maps: The distribution of B_0 was measured by constructing phase maps from images of the central axial slice (perpendicular to the axis of the prostate), acquired with the endo-rectal coil. A FSE sequence that allows changes in the time interval between the RF excitation and refocusing pulses was used. The images were acquired using a FOV=15x15 cm^2, slice thickness=10 mm, matrix=128x128, with TE/TR = 68/600 ms. In the first acquisition, the refocusing pulse was applied at half the time interval between the excitation pulse and the echo formation time (22 ms) so that the lipid and water signals were in phase. In the second acquisition, the refocusing pulse was shifted by 2.2 ms, while the readout gradient didn't change. Both lipid and water signals were at a 2π phase-shift relative to the first image.

For each volunteer, these scans were performed when the endo-rectal coil was inflated with 80 cc air, followed by PFC (Alliance Pharmaceutical, San Diego, CA), and a barium suspension (Liquid Polybar, E-Z-EM Canada Inc., Westbury, NY). For each of the 3 media, the field was mapped after linear shim, and then a repeated measurement was performed after applying high order shim (HOS) on a region-of-interest (ROI) around the prostate.

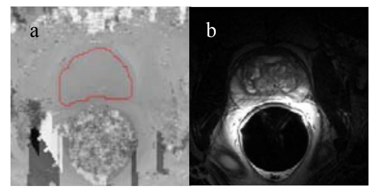

Fig.1. a) A field map of one of the volunteers acquired when the coil was inflated with air. The red line shows the ROI defined for the field distribution analysis. B) A T_2-weighted image of the same slice. The acquisition parameters of both are in the text.

Post Processing: Phase images were reconstructed from the raw data, and 2π phase jumps were unwrapped according to the 2D region growing approach previously described (4), using a locally-developed IDL program. Subtraction of the 2 phase maps yielded the final phase map representing B_0 inhomogeneity-induced phase. This map was readily translated to a field map (in Hz) using the equation: *Field (frequency) = phase / 2π*Δt* (*Δt* equals twice the echo-shift, 4.4 ms).

For each volunteer, a ROI of the prostate was defined, and this ROI was used to analyze all the field maps created for this volunteer. The B_0 inhomogeneity was calculated as the standard deviation (SD) of the field distribution within the ROI of the prostate. Statistical comparisons were performed using paired Student's t-test.

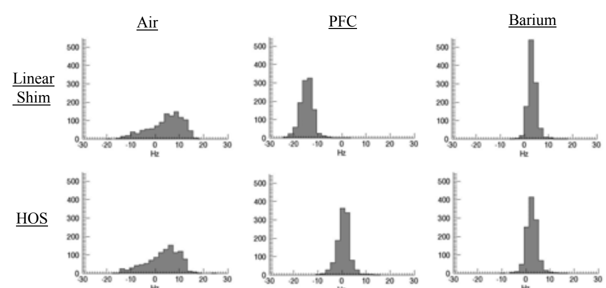

Fig. 2. Histogram plots describing the field distribution in the prostate of one volunteer. Note that HOS did not seem to provide a substantial improvement for any of the media, and that in this case the best homogeneity was achieved with the barium suspension.

Results

Fig.1 shows an example of a field map created for one of the volunteers, with the ROI we defined for B_0 measurements. The distribution of the field in this ROI, described by a histogram, is presented for each of the inflating media, after linear and high-order shim respectively, in Fig.2. Note that the asymmetry in the field distribution when the coil was inflated with air disappeared when the air was replaced by either PFC or barium. The width of the distribution did not change appreciably after applying HOS in any of the three examples shown. In this case it is evident, just by observing the histograms, that inflating the coil with the barium suspension provided the best B_0 homogeneity. The average SD's of the field for all the volunteers are presented in the box plot in Fig.3. The improvement in field homogeneity in comparison to air was statistically significant for both PFC and barium ($P<0.03$). In these preliminary results, the barium suspension seemed to produce slightly better homogeneities than PFC, but the difference between them was not statistically significant.

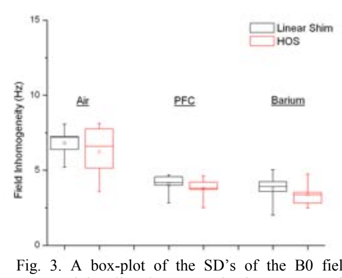

Fig. 3. A box-plot of the SD's of the B0 field measured in all volunteers. The improvement in field homogeneity in comparison to air was statistically significant for both PFC and barium.

Discussion

Our results, obtained at 3T, show that inflating the endo-rectal coil with a barium suspension provides an alternative to PFC for removing magnetic susceptibility gradients in the prostate. The application of HOS after the balloon was inflated with either the barium suspension or the PFC showed little or no improvement, suggesting that only linear shims will suffice. These barium suspensions are readily available for clinical use, are easily disposed, and are relatively cheap. Moreover, since they are routinely used as contrast media in radiological studies of the GI tract, toxicity is of no concern. Further studies are underway to compare the benefits of inflating the endo-rectal coil with barium suspensions or with PFC on *in vivo* MRS 3D-CSI spectra of the prostate at 3T.

References: 1. Eilenberg SS et al. Artif Cells Blood Substit Immobil Biotechnol. 1994;22(4):1477-83. **2.** Choi H et al. Annual RSNA Meeting 2003. **3.** Choi H et al. Annual RSNA Meeting 2004. **4.** Hedley et al. Magn Reson Med. 1992 Mar;24(1):177-81.