The Characterization of MRI Artifacts Surrounding Brachytherapy Seeds for use in Localization

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Introduction

An accurate post-implant evaluation of the dose administered by prostate brachytherapy is useful in radiotherapy. In order to obtain this dosimetric information, the precise geometric location of the implanted seeds, as well as an accurate anatomical delineation of the prostate gland and surrounding structures must be obtained. At present, CT is used to pin-point the seed locations, but its anatomical images reveal poor gland delineation. MRI offers a much better anatomical outline, but localization of the seeds in this modality is hindered by the complex magnetic distortions surrounding them. This abstract investigates the nature of the image artifacts caused by these magnetic field distortions at different field strengths. Characterizations of these artifacts were obtained by both image acquisition and numerical simulations. The idea of using these artifact characterizations for an automatic search algorithm is also introduced.

Methods

Simulation

A 3 dimensional susceptibility map of a brachytherapy seed (IMC6711, OncoSeedTM) surrounded by water was created (Figure 1). Using this susceptibility map, a magnetic distortion map (F_Z) was calculated using a three dimensional extrapolation of an algorithm outlined by Bhagwandien et al [1]. (see Figure 2)

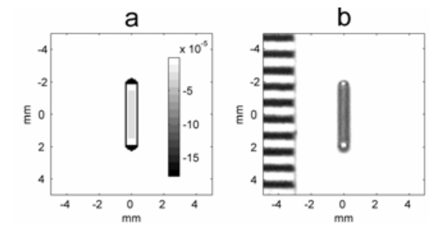

Figure 1. a Susceptibility map. b. Photograph of seed shown on same scale.

A signal mask with the same dimensions as the distortion map was created in which all voxels corresponding to water were assigned a 1, and the region inside the seed (incapable of producing signal) was assigned 0. Another mask, M_{SS}, was created to represent slice selection as would be modified by the magnetic distortions, defined by:

$M_{SS} = 1$ where $| Fz + G_{SS} - B_0 | \leq (sl \times g_{SS})$, and

$M_{SS} = 0$ where $| Fz + G_{SS} - B_0 | > (sl \times g_{SS})$,

where G_{SS} is the slice select gradient, sl is the slice thickness and g_{SS} is the nominal slice-selective gradient strength.. The misrepresentation of the pixel locations was then modelled using a pixel carry-over technique. These pixel shifts will only occur in the frequency-encode direction, as it is only the read gradient that is present during the data-acquisition process. The magnitude of these pixel shifts were modelled according to the relation $(Fz(i,j,k)-B_0)/g_R$, where g_R is the nominal gradient strength.

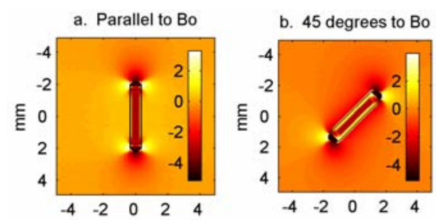

Figure 2. Examples of magnetic distortion simulations for two seed orientations with respect to B_0. Image units are [sign(PPM) × ln(|PPM| + 1)] for improved visualization.

Imaging

Images of a single prostate brachytherapy seed suspended in a porcine gel (3% wt.) were obtained using a turbo spin echo sequence (RARE [2]) on both 1.5 T and 3 T Philips Intera whole-body scanners. The seed was positioned in two different orientations: one with its long axis parallel to the B_0 field, and the other rotated 45 degrees in the horizontal plane. All images were acquired coronally with the following parameters: slice thickness = 1mm, FOV = 107 mm, a square matrix of 608 interpolated to 1024, 16 averages, a TE of 40 ms, with a turbo factor of 9, and a centre-out phase-encoding scheme. The frequency encode direction was applied both parallel and perpendicular to the B_0 field.

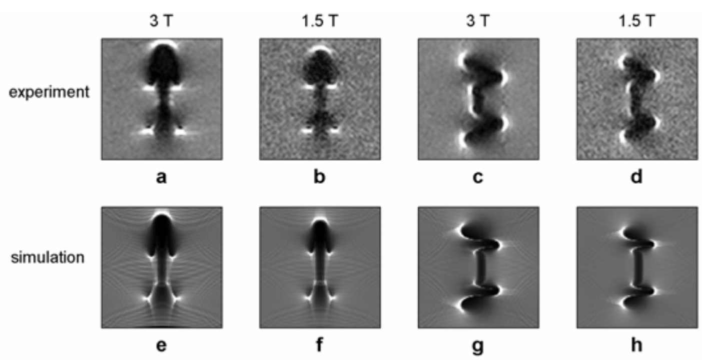

Figure 3. Appearance of both experimentally acquired and simulated images of prostate brachytherapy seeds. Note the changes when the read encode direction is changed from parallel to Bo (first two columns) to perpendicular (second two columns).

Results

Simulations were demonstrated to accurately describe the image artifacts (see Figure 3). As expected, the 3T artifacts are larger due to the heightened magnetic distortions. As can be seen in this figure, the image appearance is largely dependent on the orientation of the seed with respect to the frequency encode direction.

Due to the a priori knowledge of the seed location in the simulations (Figure 4), it is possible to position the seed within the acquired image. As can be seen here, the seed's orientation with respect to B_0 plays a large role in the resulting image.

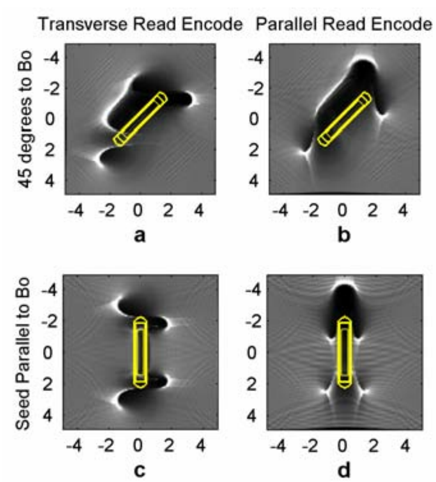

Figure 4. Position of seeds within the simulated images at 3.0 T.

Conclusions

The appearance of image artifacts from prostate brachytherapy seeds was successfully modeled. This information will be useful in attempts to localize seed positions in MRI. It is the hope of the authors that this information can be applied in the development of an automatic search algorithm, through the use of the simulated artifact structure as a kernel.

References

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