Title: Validation of field inhomogeneity calculations through a geometric distortion phantom

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Structured Abstract:

Introduction: MRI is commonly used to detect soft-tissue damage associated with orthopedic implants; however, the difference in magnetic susceptibility between metals and tissue gives rise to substantial magnetic field inhomogeneity, leading to image artifacts. The most promising technique to overcome these artifacts is multispectral imaging, whereby a series of excitation pulses with increasingly offset center frequencies are used to generate a set of images that can be combined to cover the full frequency spectrum present around the implant. However, these techniques have not made it into widespread clinical use largely due to the overall image blurring that occurs as a result of both the overlapping Gaussian pulses and frequency encoding error correction. Recent development in efficiently calculating implant induced field inhomogeneity leads to the hypothesis that multispectral imaging can be improved by making use of computed field maps, particularly as a means to predict the excitation volumes of each individual pulse used to make up the combined image. This study aims to test the spatial accuracy of these field maps by correlating the predicted field inhomogeneity induced by a titanium implant to marker deviation in the scanned phantom.

Methods: A distortion grid phantom with an embedded titanium hip stem implant was 3D-printed with PLA and submerged in a copper sulphate solution. The phantom was scanned at 3T with a GE split head coil with a 3D turbo spin echo sequence (15x15x30 cm FOV, 1 mm isotropic resolution, TE = 35 ms, TR = 3000 ms, BW = 62.5, readout along Z-axis, 8:52 scan time). A field map was calculated based on the implant geometry and susceptibility (titanium χ = 180 ppm). The deviation of the scanned marker centroids along the readout direction (Z), which is directly affected by the field inhomogeneity experienced by the marker, was compared and correlated to the calculated field map at each markers' nominal location using a Pearson correlation coefficient.

Results: The scanned marker deviation along the Z-axis are significantly correlated ($p<0.0001$) with an r value of 0.8337 (95% CI: 0.7563, 0.8881) to the calculated field shift at the marker's nominal location.

Discussion: The correlation between observed marker deviation and calculated field shift indicates that the field inhomogeneity calculations are spatially accurate. A limitation of this study was that the markers near the implant, which experienced the largest field shifts, were mostly obscured by signal dropout. This led to most of the observed markers' predicted field distortion magnitude to be under 4 ppm. However, the strong correlation between observed deviation and these small predicted field distortions lends confidence to the hypothesis that simulations of implant induced field distortion can used to improve multispectral imaging for metal artifact reduction.