High resolution MR imaging and spectroscopy of the human breast at 7T using a focused field RF coil setup

D. W. Klomp[1], A. Raaijmakers[2], M. Korteweg[1], B. van de Bank[1], C. Possanzini[3], V. Boer[1], F. Visser[3], N. van de Berg[2], and P. Luijten[1]
[1]Radiology, University Medical Center Utrecht, Utrecht, Netherlands, [2]Radiotherapy, University Medical Center Utrecht, Utrecht, Netherlands, [3]Philips Health Care

Introduction

Contrast enhanced breast MRI has clinical relevance in cancer diagnoses and treatment monitoring, however at a limited specificity. Functional MRI techniques, like diffusion MRI and MR spectroscopy will contribute to improved specificity but compromised in sensitivity due to low spatial resolution. At 1.5T or 3T the improve of spatial is hindered by low signal to noise ratios even when multi element receiver arrays are used. Higher field strength like 7T can improve SNR, but it may be limited by non uniform excitation and restricted RF power deposition (SAR). However, SAR can be reduced substantially when using focused field RF coils in transmit and receive,. We designed an RF coil for 7T with focused RF in the human breast and we assessed RF power deposition using numerical calculations. With this setup we obtained an extremely high sensitivity and able to reach a spatial isotropic resolution of 450µm in a 3D T1 weighted lipid suppressed MRI. This is to our knowledge the highest sensitivity ever reported.

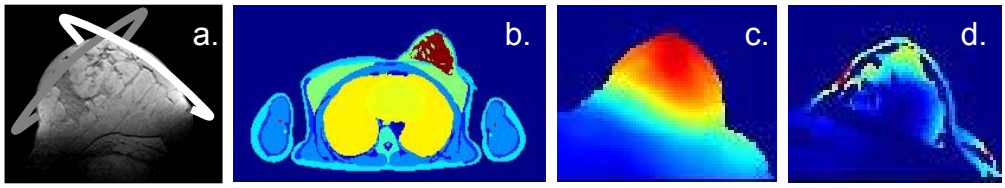

Fig1. Measurements and simulations of the focused field uniformity and RF power deposition of the RF coil. a) the circles indicate the location of the dual channel transmit and receive RF coil. b) anatomical model merged with segmented data from 7T MRI images. c) B1 profile and d) SAR of the human breast

Methods

A two-channel unilateral RF coil was designed and built consisting of two circular loops oriented closely to the breast at + and - 45 degrees with respect to the prone position of the subjects (fig 1). Each element was tuned to 298MHz, combined with quadrature hybrid and interfaced via home-built transmit-receive switch and preamplifier to a whole body 7T MR system (Philips, Cleveland). 3D MR images with and withoud lipid suppression were obtained from five volunteers at a spatial resolution of 1 mm isotropical at low RF power deposition (flip angle of 10 degrees (binominal 1-2-1 for lipid suppression), TR=8.8ms, TE=2.3ms), 1.5 minutes scantime). These images were used to locate the areas of glandular tissue, fat tissue, skin and muscle with respect to the position of the coil elements, which were indicated using MRI sensitive markers. Finite difference time domain calculations have been applied to calculate SAR and guarantee safe use of the coil. To illustrate the high senstitivity that can be obtained with this setup within safety guidelines, ultra high resolution MR images were obtained from patients with infiltrative ductal carcinoma (Inversion recovery multishot TFE (factor 30), 12 degree flip angle, TR=7ms, TE=3ms, adiabatic IR lipid suppression, acquired resolution = 0.45mm isotropic). In addition, as choline levels are low in healthy subjects, MRS has been obtained in healthy volunteers (semi LASER, with MEGA water and lipid suppression, TE=118ms, TR=4s, voxelsize = (1.5cm)3).

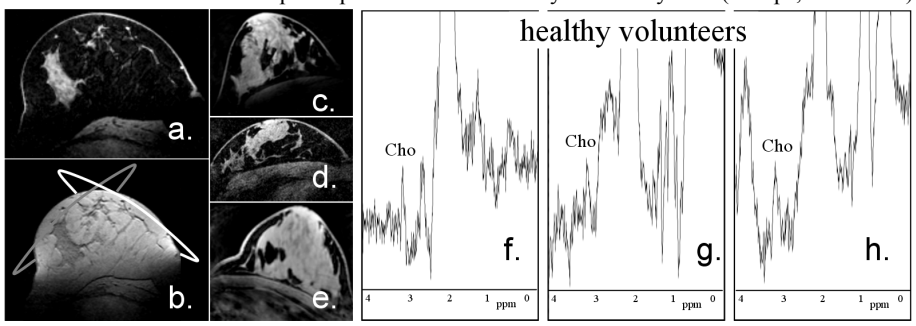

Fig2. MR images and spectra obtained with the focused field RF coil at 7T from breasts of healthy volunteers. Excellent lipid suppression (a versus b, and c-e) could be obtained and levels of choline could be easily observed in the MRS of healthy glandular breast tissue (f-g).

Results and discussion

The 3D MR images obtained at low RF power (Fig 2a-e) were used to calculate RF power deposition in the body, which is 0.6W/kg/$(\mu T)^2$ (Fig 1a-c). With this focused field setup, good image uniformity can be obtained within the breast and it drops off at the chest wall. In addition B0 shimming, even at 7T ,remains excellent as can be judged from the lipid suppressed 3D datasets (Fig 2a-e, 3a-c). Finally, sensitivity is sufficient to detect choline levels (quatified as 0.1mM/kg_water) even in healthy subjects (Fig 2f-h) and the setup allows 3D MRI of the entire breast at an isotropic resolution of 0.45mm.

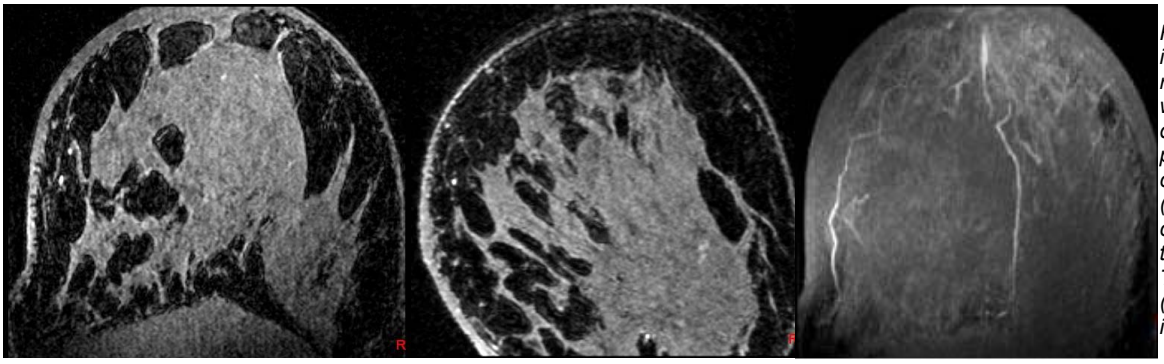

Fig3. high resolution (0.45mm isotropic) MR images reconstructed from the 3D T1 weighted lipid suppressed dataset obtained from the patient with breast cancer. The coronal (left) and transversal (middle) image illustrate the coverage of the RF coil, while the MIP (right) illustrates the T1 weighting of the method (recognized by the hyper-intense vasculature).

Conclusion

Ultra high resolution MR images of the female breast can be obtained at 7T using a focused RF field coil setup, which allows maintaining a relatively low RF power deposition, while maximizing sensitivity. In this way we could even detect choline levels of 0.1 mM/kg_water in healthy subjects.