Clinical 7 Tesla Contrast-Enhanced Breast MRI

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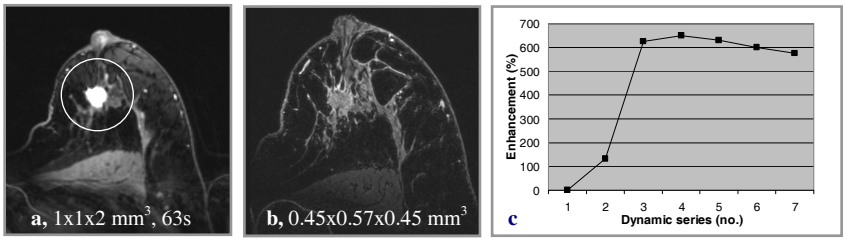
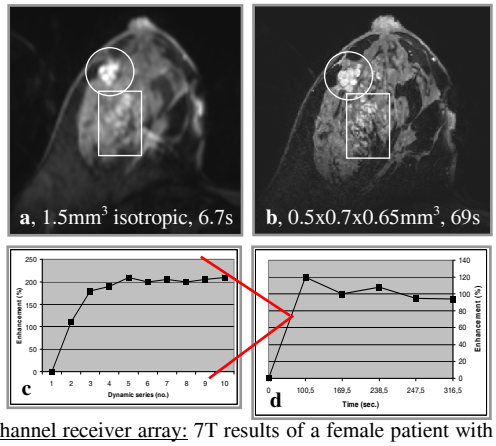
Introduction Breast imaging at 7.0 Tesla (7T) offers new diagnostic possibilities that have the potential to improve staging and follow-up of breast cancer patients. However, preliminary results at 7T so far have demonstrated clinical unacceptable image quality, mainly due to RF coil limitations. With recent advances in RF coil designs using focused fields for transmission, up to 30-channel reception and the ability for bilateral coverage, we show that clinical 7T contrast-enhanced (CE) breast imaging is now feasible.

Materials & Methods First, the feasibility of 7T CE breast MRI in patients with a suspicious breast mass was assessed, using an efficient unilateral dual-channel RF breast coil with focused transmit fields. The scan protocol included a dynamic-series consisting of 7 consecutive gradient echo (GE) scans [FOV 160x160x160mm^3, acquired resolution 1x1x2 mm^3, binomial FA 20°, TR 5.3, temporal resolution 63s], with which twenty patients were imaged. The exams were evaluated for image quality, lesion identification and classification according to the BI-RADS-MRI lexicon. The breast coil setup was then improved by incorporation of a 30-element receiver array to exploit the SNR available at 7T. The new dynamic series made for this set-up enabled ultrahigh temporal resolution imaging combined with ultrahigh spatial resolution imaging, using a T1w 3D GE sequence. After the pre-contrast baseline scan, first 10 consecutive ultrahigh temporal resolution scans were performed [FOV 160x160x165 mm^3, acquired resolution 1.5 mm^3 isotropic, binomial flip angle 6°, TR 3.1 ms, temporal resolution 6.7s], after which 5 consecutive ultrahigh spatial resolution scans were performed [FOV 160x160x160 mm^3, acquired resolution 0.50x0.70x0.65 mm^3, binomial flip angle 9°, TR 9.9 ms, temporal resolution 69s]. Moving forward, a third setup was realized using a bilateral dual-channel transmit and receive breast coil. The dynamic sequence consisted of 7 consecutive GE scans matched to the conventional 3T protocol [FOV 350x160x160 mm^3, acquired resolution 1x1x2 mm^3, flip angle binomial 8°, TR 5.3 ms, temporal resolution 67s]. Here we present the first breast cancer patient imaged with the bilateral set-up at 7T, with direct 3T comparison. IRB approval and written informed consent was obtained in all patients.

Results

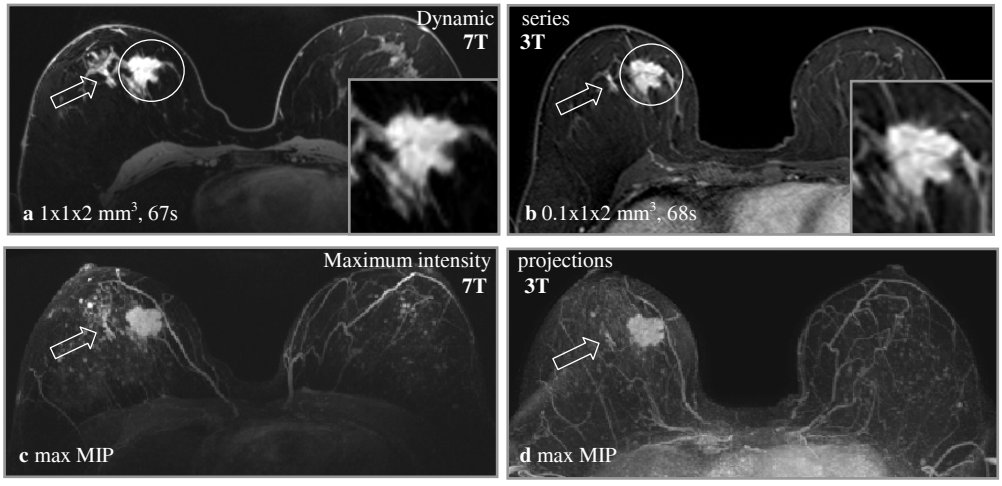


Unilateral dual-channel RF breast coil: Twenty female patients with mass lesions on conventional imaging were successfully imaged at 7T. Of the 23 known suspicious lesions, 20 were prospectively identified by two observers: 19/19 malignant lesions and 1/4 benign lesions. All exams were compatible to BI-RADS-MRI conform assessment. The **figure** shows a case of a female patient with a BI-RADS 5 lesion on conventional imaging. **a**) transversal 7T image that were an irregular mass lesion with irregular margins was visualized (circle). After contrast injection the lesion showed strong homogeneous enhancement. **b**) transversal 7T image of the high resolution imaging showed great morphological detail. **c**) kinetic curve analysis showed rapid initial enhancement, followed by a wash-out pattern in the delayed phase, for the most malignant part of the tumor. The lesion was categorized BI-RADS-MRI 5. Final pathology showed an invasive ductulolobular carcinoma.



30-channel receiver array: 7T results of a female patient with a papilloma. **a**) ultrahigh temporal resolution image, **b**) ultrahigh spatial resolution image, **c**) kinetic curve of the ultrahigh temporal resolution (6.7s) scans, **d**) 'conventional' high spatial resolution kinetic curve. This setup allowed for obtaining ultrahigh resolution information on both morphologic and kinetic characteristics in 8 minutes, were the lobular mass is visualized on both images (circle). Furthermore, an area of background enhancement due to dense breast tissue was visualised (square).

Bilateral dual-channel breast coil: 7T and 3T results shown side by side of a 54-year-old female patient with an invasive ductal carcinoma and ductal carcinoma in situ grade 2. **a** and **b)** transverse images of 2nd post-contrast injection series showed an irregular mass lesion with irregular margins on both field strengths (circle and zoomed-in image in right lower corner). **c and d**) maximum intensity projections showed symmetric background enhancement. Kinetic curve assessment showed a rapid rise and wash-out pattern in the delayed phase for the most malignant part of the tumor on both field strengths. An additional area of linear enhancement was detected (arrow), however additional biopsy did not show any malignant cells.



Conclusion We have shown that clinical 7T breast MRI is feasible and compatible to BI-RADS-MRI conform analysis. Due to efficient field focusing of the transmit local coils, strong contrast enhancement can be obtained (up to 6-fold), while the high density receiver array provides unprecedented up to 8-fold increased spatial resolution within the temporal resolution of detecting the contrast enhancement kinetics. The extension to bilateral imaging has concluded the steps towards clinical usage.