Detection of breast micro-calculcations at high-field MRI.
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Introduction: Ductal carcinoma in situ (DCIS) is considered a potential precursor to invasive ductal carcinoma [1]. It is therefore treated as such, with surgery, often followed by radiotherapy. Approximately 62-98% of DCIS presents with micro-calculcations on mammography [2-4]. MRI has been shown to be able to aid in the diagnosis of DCIS [5]. Unfortunately, up to today clinical MR imaging protocols are not able to detect micro-calculcations. However, the concurrent MRI detection of micro-calculcations with enhancing breast masses and non-mass lesions may aid in discriminating likely higher-grade from likely lower-grade DCIS lesions and may improve the detection rate of small high-grade invasive lesions associated with micro-calculcations. Herein the feasibility of the detection of micro-calculcations with high-field MRI by exploiting the effect of the difference in susceptibility of calculcations and glandular tissue on the signal phase is investigated. First, the potential of the method is tested in a phantom setup containing various particles of calcium hydroxyapatite [4]. Second, the method is demonstrated in ex-vivo breast tissue containing micro-calculcations confirmed on mammography.

Materials and Methods: The phantom experiment was performed on a phantom consisting of an agarose gel (2%) doped with 20 mg/L MnCl2 of calcium. As for the phantom experiments, we attempted to fixate the specimen. As for the phantom experiments, we attempted to fixate the specimen. For the ex-vivo experiment, the breast specimen was obtained after skin-sparing mastectomy surgery. It was imaged on a 3T whole-body MR system included a multi-echo (15 echoes) fast field echo sequence (FOV 200x160x80 mm3, 3ms isotropic resolution, flip angle 10°, TR 72ms, first echo 3ms and echo spacing 2ms, read-out bandwidth 1kHz/pixel) with a scan duration of 32:47min. An ex-vivo breast specimen was obtained after skin-sparing mastectomy surgery. We were traced by calculating the phase derivative at TE=27,6ms at two slices of the mastectomy specimen. The calcifications in the MR images of both the phantom and breast tissue specimen were traced by calculating the phase derivative [7]. To remove the influence of B0 inhomogeneities, the derivative of the 1st echo was subtracted from the phase derivative images at the odd echoes. Results were compared to CT (thickness 0.67mm, increment 0.33mm, voltage 140kV and current 250mA, scan duration of 4.13s) in the phantom setup and to mammography for the mastectomy specimen.

Results: The magnitude image in Figure 1a depicts several diamagnetic disturbances, but is clearly distorted by B0-inhomogeneity. The comparison with CT (Hounsfield units of calcium) shows these disturbances are indeed calcifications. The phase derivative image (Figure 1b) is not hampered by B0-inhomogeneity and shows a high sensitivity for the calculcations. All calcifications, with particles down to a size of 3x1 voxels or smaller on CT, were detected. The calcifications exhibit the characteristic blooming pattern for a diamagnetic disturbance, which extends beyond the object-size [8]. The applicability of this technique ex-vivo is shown in Figure 2. The phase derivative image (Figure 2a, b) again shows characteristic blooming pattern calcifications (circles), the insert in Fig. 2a illustrates the six lobed pattern of a paramagnetic disturbance formed by the air balloon that is used to fixate the specimen. As for the phantom experiments, the mammogram of the breast (Figure 2c) clearly confirms the MR-detected calcifications (circles), with the smallest calcification measured to be of submillimeter size.

Discussion: Both the phantom and the ex-vivo experiment show the feasibility of detecting micro-calculcations on high-field MR. The magnitude images can be used to detect field disturbances, but cannot discriminate between calcium and, for example, a hemosiderin-rich blood clot. The magnitude images are furthermore severely hampered by B0-inhomogeneities. The insensitivity to B0-inhomogeneities of the phase derivative makes these images, together with the inherent high sensitivity for field disturbances, the method of choice especially at high magnetic field strengths. The phase derivative allowed characterization of the calcifications in the phantom and ex-vivo specimen. These successful attempts are a first step towards future in-vivo application. However, in-vivo measurements will be challenging because of field disturbances due to breathing and air in the lungs [9]. Before in-vivo application, such problems need to be addressed, for example by using the method of van Gelderen et al. and methods based here upon [10,11]. Both the phantom and ex-vivo experiment illustrate the very high sensitivity to small field disturbances, such as calcifications, at high field MRI. The increased SNR of 7T allows for ultra-high morphological imaging, which combined with contrast-enhancement and concurrent detection of micro-calculcations may improve the detection and evaluation of DCIS [6]. In conclusion, we have demonstrated the feasibility of detecting micro-calculcations with high-field MR, in a phantom and in an ex-vivo breast specimen.