A Robotic Manipulator System for Breast Biopsies Inside a High-Field Whole-Body Scanner

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Synopsis
14 patients with suspected cancer based on the findings of contrast-enhanced breast MRI underwent 14-G large core breast biopsies (LCBB) by using an MR-compatible robotic manipulator operating inside a 1.5 T whole-body magnet. 7 patients underwent surgery and the histological findings of LCBB and excisional biopsy were compared. In 5 patients biopsies were histopathologically confirmed. One tubular carcinoma was missed; one invasive cancer was underestimated as atypical ductal hyperplasia. 7 patients with benign findings are still in the follow-up period. The study demonstrates the possibility to perform MR-guided LCBB inside a scanner by using a robotic manipulator system.

Introduction
Recently, a new remote-controlled MR-compatible prototype manipulator system (ROBITOM) has been introduced (1,2). This system allows to take breast biopsies inside a high field scanner of 1.5 T using a large core breast biopsy (LCBB) device due to an automatic, computer-controlled positioning unit. The aim of this study was to provide a proof-of-principle of this new approach by investigating the feasibility to perform biopsies and to evaluate first clinical results of LCBB using this system.

Material and Methods
The current version of the robotic system operates in combination with a Gyroscan ACS II 1.5 T MR-scanner (Philips Medical Systems, NL) and the built-in body coil. 14 female patients (mean age: 47.9 ± 13.1 years) were included with suspicious contrast enhancement during dynamic breast MRI, such as rapid enhancement with signal intensity increases over 80% during the first 120 s after CM followed by plateau or wash-out behavior. Lesion size was not used as an inclusion criterion. Breasts were compressed by a sliding plate at the caudal end and an open sliding frame at the cranial end of the fixation unit after disinfecting the skin and the compression device. Patients with a compressed breast thickness thinner than 25 mm were excluded.

All diagnostic MRI was performed with the manipulator located at the rear-end inside the bore. Dynamic contrast-enhanced scans were performed using a multi-slice, T1w, 2D GRE sequence in transverse orientation (TR/TE/α 96/5/80, TH 4 mm, gap 0.4 mm, FoV 350 x 350 mm², matrix 256 x 256, 24 slices) acquired at 1 minute intervals before and after i.v. administration of a Gd-DTPA bolus (0.1 mmol/kg) for 8 minutes. The first scan of the dynamic series was subtracted from the post-contrast scans. After lesion localization coordinates (x, y, and z) were determined with respect to two oilmarkers, which are affixed to the patient’s support device and are easily seen on the images. After entering the x and y positions into the remote-control unit the extension arm of the manipulator moved to the predetermined position at the cranial side of the breast fixation device. Following local anaesthesia a small incision of the skin was made to ease the insertion of a titanium alloy 13 G trocar (Bard, Covington, USA) into the breast tissue. The trocar was inserted manually into the tissue from the rear opening of the scanner bore and its position was controlled by imaging. A spring-loaded, high velocity modified biopsy device (Bard, Covington, USA) equipped with a 14 G LCBB needle was inserted into the 13 G trocar. Between 3 and 6 specimen were harvested with the same biopsy device. The total procedure time was between 50–70 minutes. Specimen were histopathologically evaluated. If histology revealed malignancy the patient underwent open surgery. In two patients the referring surgeon preferred additional diagnostic extirpation despite the benign histological finding. All patients with histologically benign findings of the LCBB are followed up.

Results
All 14 lesions were clearly identified on the subtracted dynamic MR images. No artefacts were observed on the images affecting image quality or the ability to localize the lesion precisely. No electromagnetic interference was observed between the manipulator system positioned inside the bore or the remote control located outside the magnet within the fringe field and the MR system. The needle tip was located correctly at the expected position in front of the selected lesion in all cases. 6 patients were diagnosed with breast cancer after histopathological evaluation of the excisional biopsy specimen. Four of these 6 cancers had equal findings in the histopathological analysis of the specimen taken during LCBB. One false negative result was obtained in a patient with tubular carcinoma who was diagnosed with fibrosis based on the histology of the LCBB specimen. Atypical ductal hyperplasia (ADH) was diagnosed in one patient following histopathological examination of the LCBB specimen. Histology of the specimen harvested by open surgery, however, revealed an invasive ductal carcinoma (IDC). In one patient diagnosed with adenosis due to LCBB, the finding was confirmed by excisional biopsy. All remaining seven patients had benign histopathological findings of the LCBB specimen. All MR-guided interventions assisted by the manipulator system were successfully completed. None of the procedures had to be interrupted or stopped. No severe side effects were observed. None of the patients reported pain severe enough to require any analgesic medication after the intervention. No adverse event occurred which required surgical intervention after manipulator assisted LCBB.

Discussion
These first clinical results demonstrate that LCBB of breast lesions is feasible with the manipulator. Localization of a suspicious lesion and subsequent MR-guided LCBB is possible without having to move the patient out of the magnet bore and back inside. This should help to improve the precision and accuracy of such procedures. The trocar tip was navigated in all cases to the correct location where it had been expected on the images of the MR-control scans. An in-vivo proof-of-principle of a novel MR-compatible robotic manipulator system has been provided with promising potentials to reduce pain, scarring, radiation exposure, and time associated with surgical biopsies.

References