Imaging-Guided Percutaneous Punctures Using a Combined MR Imaging / C-Arm CT Approach: A Pilot Study Assessing the Feasibility

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Introduction

The first MR image-guided biopsies were performed in the mid eighties in close bore systems. Major challenges were the lack of continuous guidance of the needle in such scanners, the relatively time consuming workflow, and the need for special MRI-visible needles. Open MR scanners allowed for an easier workflow but availability of such scanners is limited. In contrast, conventional closed bore MR scanners, that provide excellent image quality, are available in almost every hospital. Yet, the closed bore magnet design is still not conducive to the performance of MR imaging-guided procedures and most magnet rooms are not ready to be used for interventional procedures.

In the angiography suite, however, equipment and staff is trained for interventional procedures. Although most of the angiography rooms are used for vascular procedures, many modern C-arm systems are capable of providing 3D information based on cone beam CT imaging. Although these images might not be sufficient to provide information on actual lesions, they offer enough information for coregistration with previously acquired MR images. The goal of this study was to use a combined MR C-arm CT approach and to test the use of C-arm CT (CACT) images augmented with MR images image guided needle punctures in phantoms.

Method

The experiments were performed on a 1.5 Tesla closed bore magnet system (Magnetom Espree, Siemens Medical Solutions, Erlangen, Germany) and an angiography system equipped with a flat detector C-arm (Axiom-Artis dTA, Siemens Medical Solutions, Forchheim, Germany) using the 5sDR preset (DynaCT®, Siemens Medical Solutions, Forchheim, Germany) with an acquisition time of 5 s. The biopsy phantoms consisted of plastic buckets filled with gelatin gel. To mimic lesions within the phantom, 10 plastic rings with 6 mm radius and 1 mm height were embedded in the gel. The rings were placed with their longitudinal axis parallel to that of the bucket at different spatial locations and levels. The needle used for the simulated biopsy was a 20cm long 18-gauge needle. The second phantom consisted of an anthropomorphic phantom mimicking the upper abdomen with multiple liver lesions.

To prepare the image guided biopsy procedure, MR images of the phantoms were acquired using an axial gradient echo sequence (FLASH3D, TR,TE: 9, 5 ms; 25dg flip angle; 1mm slice thickness). Subsequently, the phantom was transferred to the angiography table and CACT images were acquired using the flat detector C-arm. Both image data sets were transferred to a Leonardo workstation and both were combined using fusion software with the CACT providing the spatial information and the MR providing the soft tissue contrast to detect the lesion. Then the CACT dataset augmented with the MR dataset was sent to a custom made puncture guidance tool. For the biopsy experiments, stereoscopic fluoroscopic images were used to detect the needle that was then interactively guided towards the targets. The needle path was graphically enhanced with a thin virtual cylinder; in addition, the entry point and the target were marked as dots within the fused images. 10 biopsy experiments using rings targets and 2 artificial liver lesions measuring 15 and 20 mm were completed. Prior to every experiment, the needle path was planned based on multiplanar images of the 3D datasets. This needle path was also visualized on the different fluoroscopic images. Upon completion of the ring punctures, gadolinium doped gel droplets were inserted through the needle and left in place inside the gel phantom at the needle tip. MR control scans were then acquired in order to assess the distance of the marker to the target. The position of the markers was measured in relation to the center of the ring. The anthropomorphic phantom was brought back into the MR scanner immediately after the puncture with the biopsy needle still in position and the needle position was confirmed using MR images.

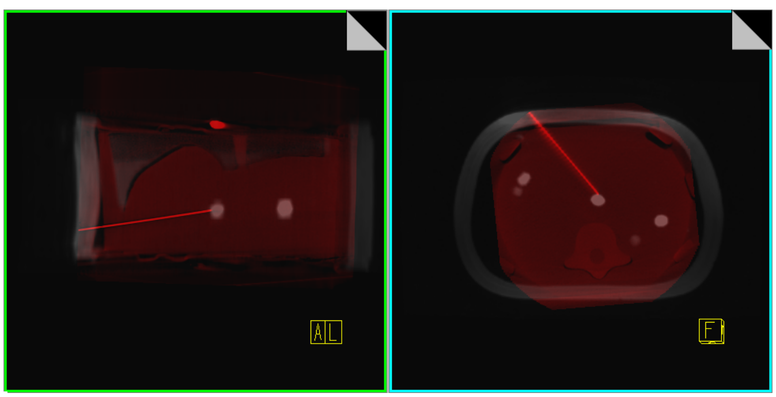

Fig. 1: Screenshot of the fused MR image before the puncture and the CACT dataset (red overlay) after the puncture (coronal and axial view). The real needle (bright red overlay) is located in the center of the cyst.

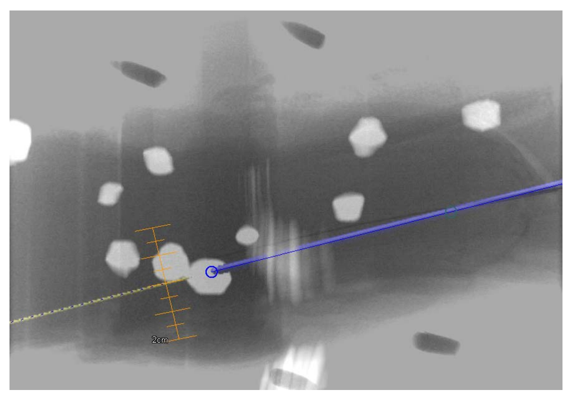

Fig.2: Screenshot acquired during needle guidance. MR image showing the cyst augmented onto the fluoroscopic image. Blue line represents the needle trajectory, blue circle shows the target.

Results

In the ring phantom experiments the needle guidance based on fluoroscopic images facilitated the puncture for all 10 targets. Targeting was performed solely based on the information contained in the MR images. The needle tip was correctly placed inside the rings in 8 cases with a maximum deviation of 5mm. Two rings were missed with a deviation of 8 and 12 mm respectively.

In the anthropomorphic phantom, the needle was successfully placed based on MR images using stereoscopic fluoroscopic guidance in both lesions. The deviation from the desired target point was 10 mm and 8 mm respectively.

Discussion

The puncture technique presented, that combines spatial information provided by C-arm CT with soft tissue contrast provided by MR imaging has proven to effectively facilitate image guided needle punctures in phantoms. MR images acquired shortly before the procedures in a closed magnet are mapped into the CACT. This method provides an elegant means to perform percutaneous interventions with information from a closed bore MR scanner in an intervention friendly environment such as an angiography suite. Although the experiments performed in this study were performed in a combined MR-Angio suite (XMR suite), the workflow we used does not necessarily require such a setting. In principal, coregistration of CACT and MR images can also be performed with images acquired in different locations.

It is important to note, however, that ultrasound and CT alone are certainly capable to cover the vast majority of image-guided biopsies in a clinical setting. MR image guidance, if at all available, is mainly used in cases that clearly benefit from its use. This might be different in the scenario we show in our experiments. Here US, CT and MR imaging can be utilized for imaging purposes. In the angiography suite, in which invasive procedures are business-as-usual, punctures can be performed using fluoroscopic guidance. The ability to provide 3D information based on a 3D CACT dataset allows an integration of MR information thus allowing for easy and reliable targeting for lesions otherwise not visible.