Evaluation of a real time MR-guided interactive navigation device: phantom and animal experiments

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Introduction

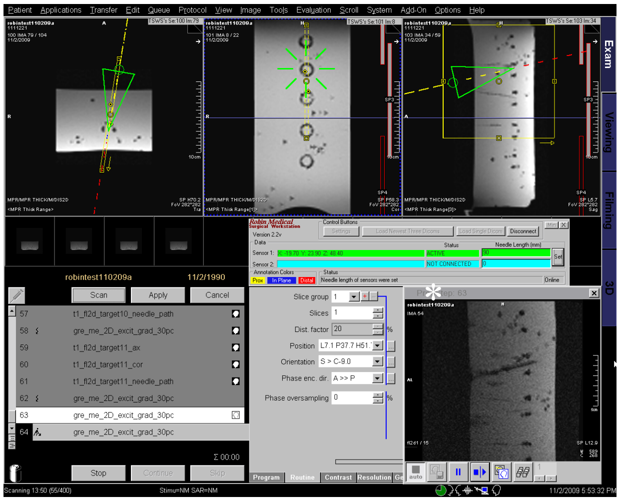
Image guidance for percutaneous biopsy, drainage and therapy not only decreases procedural risk by allowing physicians to access locations that cannot be accessed without real-time feedback, they also improve diagnostic yield by precisely targeting focal lesions. Currently, percutaneous image guided punctures rely mainly on ultrasound and computed tomography guidance. Based on the unparalleled soft tissue contrast and exquisite anatomic detail of magnetic resonances imaging, MR guided punctures have been shown to provide very accurate targeting. The enthusiasm of radiologists to take advantage of the superb imaging features of MRI, however, are significantly hampered by difficult access to the patient, lack of interventional user interfaces and lack of interactive tools for improved workflow. Although the access problems have been overcome with vertically open magnets, these systems offer inferior image quality due to low field strengths and are becoming less available. In large bore magnets, which are available at 1.5 and 3T, access to the patient is feasible but workflow remains problematic. The purpose of this study was to test the feasibility and accuracy of a tool that allows for interactive adjustments of the needle plane during a MR-guided puncture

Method

The experiments were performed in a 1.5 Tesla closed bore magnet system (Magnetom Espree, Siemens Healthcare, Erlangen, Germany). The biopsy phantoms consisted of plastic buckets filled with gel candle wax. To mimic lesions within the phantom, 15 plastic rings with a 14 mm inner diameter and 2 mm height were embedded in the gel. The rings were placed at different spatial locations and levels. 15 real time MR-guided punctures aimed at the center of the rings were attempted using a 20cm long 12.5-G MR-compatible carbon fiber needle (custom prototype) and an interactive navigation system. A*n in-vivo* animal experiment was conducted in an anesthesized pig using an approved institutional animal care and use committee protocol. Targets in the animal included the shoulder joint and cervical neuroforamina, which were targeted using a 20cm long 20-G MR-compatible needle (Fig.1, MReye Chiba Biopsy Needle, Cook Incorporated, Bloomington, IN).

The navigation system (EndoScout®, Robin Medical, Inc. Baltimore, MD) uses a sensor that determines location and orientation of a probe within the magnet using the MR gradient field. The sensor coils are embedded in a hand held device, which is attached to a needle. During imaging, the system acquires gradient signals in three dimensions, calculates a puncture trajectory, and overlays this trajectory on the MR scanner monitor. For the actual puncture, three steps are required. First, diagnostic MR images are acquired, either using a 3D sequence or 2D images in axial, coronal and sagittal orientations. Based on these multiplanar images target and needle path are selected. One image for each orientation containing the target structure is selected, displayed on the MR screen and transferred to an external computer using a LAN Ethernet connection for image registration purposes. Second, an overlay on the MR monitor (Fig. 2) is activated for puncture guidance, which shows the needle path as a thin line on top of the MR images as well as a real time image along the planned needle path. Third, the interventional radiologist inserts the needle that is attached to the hand held device containing the sensor coils (Fig. 1). Based on the position and orientation of the sensor within the magnet, the orientation of the needle trajectory is displayed on the in-room monitor outside the magnet. Upon completion of the punctures, MR control scans were performed in coronal, sagittal and axial orientation to determine the final needle position in order to measure the distance of the needle tip/marker to the ring center/target for calculation of the Euclidian distance (overall error). In addition, the actual needle position was compared to the trajectory determined by the navigation system, to calculate the system error.

Fig.1: *Setup during biopsy in a pig. Navigation probe (arrow) attached to the needle, surface coil (open arrowhead)*



Version 2.2v

Data

		Status	Needle Length (mm)
Sensor 1:	X: -19.70 Y: 23.90 Z: 48.40	ACTIVE	90
Sensor 2:		NOT CONNECTED	0

Status: Needle length of sensors were set — Online

robintest110209a 11/2/1990

57		t1_fl2d_target10_needle_path
58	⚡	gre_me_2D_excit_grad_30pc
59		t1_fl2d_target11_ax
60		t1_fl2d_target11_cor
61		t1_fl2d_target11_needle_path
62	⚡	gre_me_2D_excit_grad_30pc
63		gre_me_2D_excit_grad_30pc
64		gre_me_2D_excit_grad_30pc

Σ 00:00

Slice group: 1
Slices: 1
Dist. factor: 20 %
Position: L7.1 P37.7 H51.
Orientation: S > C-9.0
Phase enc. dir.: A >> P
Phase oversampling: 0 %

Scanning 13:50 (55/400)
Stimu=NM SAR=NM
11/2/2009 5:53:32 PM

Fig. 2*: Screenshot of the MR in-room monitor during a phantom experiment. The top 3 windows show the overlay of the navigation system (green/yellow overlay) with pre-acquired MR images in axial, coronal and sagittal orientation. On the lower right side (star) the real time MR images are displayed.*

Results

In the ring phantom experiments, the radiologists successfully placed the tip of the needle inside the targets in all fifteen 14-mm-diameter rings. The mean 3D total error (distance from the centre of the plastic ring (target) to the position of the needle) was 4.9 ±2.8mm. The placement error in x, y and z directions (relative to the target) were -1.6, 0.2 and 1.7 mm. The system error (deviation of the real needle from the overlay calculated by the navigation system) was 1.95±1.2 mm.

In the animal procedure, overlay of the needle trajectory on the baseline MR images (Fig. 2, upper row) provided abundant information to find the target and to determine the entry plane, leading to a straightforward puncture whether requiring single or double angulations of the puncture path. The real-time MR imaging feedback in a separate window provided important information to confirm the position as well as depth information as the needle was advanced towards the target. The needle was successfully advanced into all three targets in vivo.

Discussion

The real-time gradient based navigation system for MR guided punctures combines real-time overlays on high quality MR images acquired before the procedure with real time MR imaging feedback provided during the puncture. The system makes locating the entry point intuitive and provides an elegant means to perform percutaneous interventions in a wide bore MR imager. Our phantom results show high technical accuracies and the animal procedures indicate that real-time feedback along the puncture trajectory makes needle guidance very intuitive. The overall accuracy of the navigation system suggests it is safe for use in the clinical realm. We expect it to be beneficial in cases that require MR imaging techniques to visualize targets that are otherwise not visible. It could also be helpful for more complex procedures that require oblique puncture trajectories or positioning of multiple needles/applicators or punctures of multiple lesions.