Accuracy Evaluation of Phase-Only Cross Correlation (POCC) Guidance Sequence for Real-Time 3T MR-Interventions

P. Zamecnik[1], A. J. Krafft[2], F. Maier[2], J. Groebner[2], H-P. Schlemmer[1], and M. Bock[2]
[1]Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany, [2]Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany

Introduction

MR-guided interventions require a high image quality, short acquisition times and a high precision. In clinical routine such procedures are increasingly performed in closed-bore high field MR systems. Unfortunately, such systems only offer a limited patient access. Recently, an automatic tracking technique has been presented, which uses a passive MR marker for real time needle guidance during prostate biopsies [1, 3] or to guide a laser fiber in an experimental thermoablation (LITT) of the liver [2]. The real time passive marker tracking employs a phase-only cross correlation algorithm (POCC) to automatically localize the passive marker. In this study the geometric accuracy of this POCC needle guidance approach was evaluated in a phantom experiment at 3 T.

Material and Methods

A non-transparent agarose phantom (Figs. 1+2) containing 15 fiducial targets (cranberries) was used to study the precision of the POCC-based tracking technique. The phantom was composed of 4 agarose layers with an average thickness of 1.2 cm (cf. Figs. 3+4). In each of the 3 lower layers, 5 fiducial targets were randomly distributed. The diameters of these fiducial targets varied from 7.6 to 8.2 mm (mean diameter: 7.8±0.2 mm, cf. Figs. 3-5). An in-house developed flexible instrument holder was used (Fig. 1 +2) which could be directly connected to the MR table. Its distal end features a plastic connector with a ball joint for instrument attachment.

A plastic cylinder (Invivo GmbH, Schwerin, Germany) filled with contrast agent solution (Gd-DTPA/H_2O 1:100) was used as a passive. A phase-only cross correlation algorithm determines the marker position from two tracking FLASH (TR/TE = 3.75/1.61 ms, FOV: 350×350 mm^2, matrix: 256×256, partial Fourier: 4/8) images in real-time. Based on the marker position, a trueFISP (TR/TE = 3.75/1.61 ms, FOV: 350×350 mm^2, matrix: 256×256, partial Fourier: 4/8) imaging slice is automatically aligned in parallel with the marker, and thus, with the instrument (e.g. puncture needle) which can be inserted through the central opening of the marker. The total duration of one tracking cycle (2 FLASH images + 1 trueFISP image) amounted to about 1 s The POCC sequence was implemented on a 3 T clinical, whole body MR system (TimTrio, Siemens Medical Solutions, Erlangen, Germany).

At the beginning of the experiment, the passive marker was attached to the ball joint of the holder and moved manually under real-time guidance (Fig. 3). After alignment with one of the fiducial targets, the MR-compatible puncture needle was advanced to the target under real-time guidance (Fig. 4). To measure the distance *D* of the needle to the target, T1w FLASH 3D high-resolution images were acquired at the end of the procedure with the needle in place (Fig. 5). The distance was calculated for each target from the geometric center of the fiducial target and two characteristic points along the needle trajectory (Fig. A). These 3 points were defined manually using standard Syngo (Siemens Medical Solutions, Erlangen, Germany) workstation provided by the manufacturer.

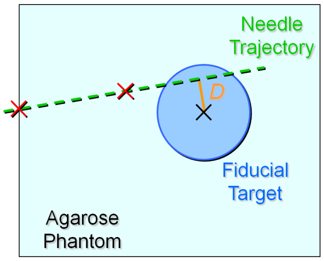

Fig. A Schematic of precision analysis.

Results

A mean distance between the geometric center of the fiducial target and the trajectory of the needle of *D* = 1.46±0.86 mm was found. All 15 targets were successfully penetrated, with a mean total duration of the procedure of about 4-5 min for each target. Alignment of the passive marker and insertion of the puncture needle could be performed very fast as the corresponding slice orientation was automatically adjusted online at an update rate of about 1 s. Figure 5 shows the final position of the puncture needle successfully perforating one of the targets.

Discussion and Conclusion

The accuracy of the procedure proved to be very high. Safe and precise instrument guidance was demonstrated with the automatic tracking sequence during insertion of puncture needle into the fiducial targets in a 3 T MR system. The experimental flexible holder allowed for precise and mechanically stable placement of the instruments (marker and needle). During the entire intervention, no manual and time consuming slice repositioning was needed (total procedure time including targeting about 4-5 min). The image quality during the procedure was good with only small artifacts caused by the biopsy devices and some typical trueFISP banding artifacts at the rim of the phantom.

The POCC technique is advantageous over active tracking methods as it requires no active RF coils which pose potentially severe safety hazards for both patient and interventionalist due to RF-induced heating. The ability of this technique to hit small targets within short intervention times and with a high precision could be successfully demonstarted. This technique enables accurate instrument monitoring and good anatomical imaging during the whole procedure making it suitable for real-time biopsies of millimeter-level sized lesions (e.g. in prostate cancer). In a next step, further clinical evaluation will be initiated and a complete intervention with automatic real-time tracking guidance at 3 T will be performed.

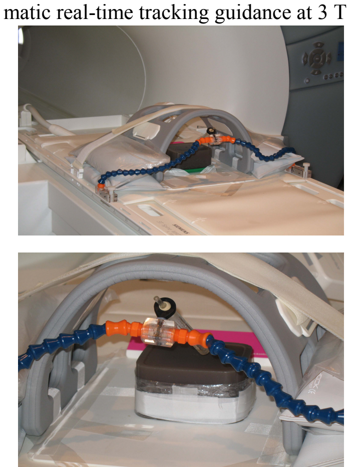

Fig. 1+2 Experimental setup with phantom, flexible instrument holder and passive marker.

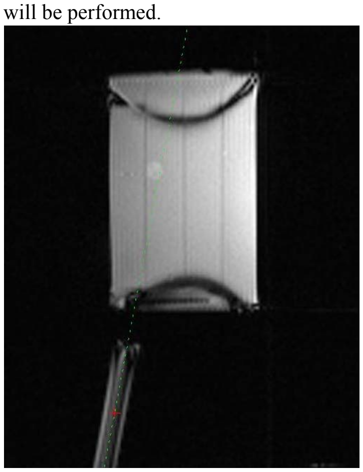

Fig. 3 POCC online image during the targeting process, sagittal view. The theoretical needle trajectory is overlaid in green.

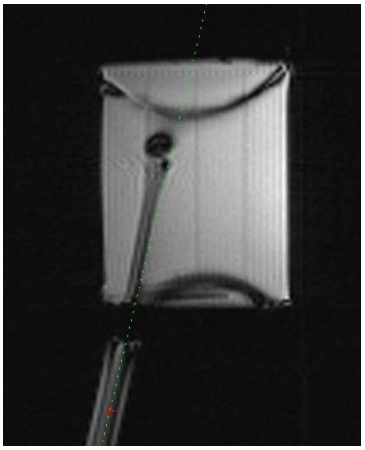

Fig. 4 POCC image after needle penetrating the target, sagittal view.

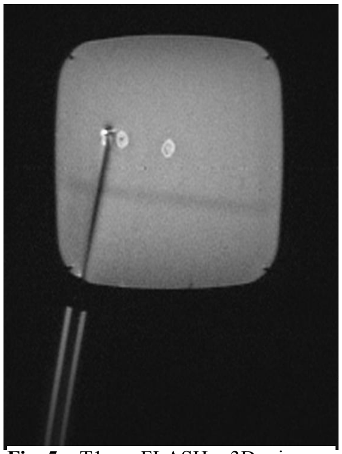

Fig. 5 T1w FLASH 3D image, imaging plane parallel to the needle, acquired after target penetration.

References
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