# Clinically usable tool for dynamic scan-plane tracking for real-time MRI-guided needle interventions in a high-field-open MRI system

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**Purpose:**
In clinical routine we use an open MR-system (Figure 1) for needle interventions in freehand-technique with the physician practicing from inside the magnet. To facilitate the adoption of MRI as an interventional modality and to reduce the necessity of a well-trained team to operate the scanner we need an interactive, intuitive and real-time-capable scanner control operable from the patient bed side. Hence, we developed a hand-held, actively tracked needle guidance tool with respective MR system software modifications to allow for simple-to-use, fast and accurate scan plane controlling with inherent registration to the MRI coordinate system. For an initial evaluation of workflow implications and accuracy, volunteer tests and phantom puncture tests were performed.

**Materials and Methods:**
The needle guidance tool is directly connected to the MR system (Panorama 1.0T, Philips Healthcare, Best, NL) as a regular multi-channel receive coil and the tool can be used to control real-time MR imaging for optimal guidance and navigation. The hand-held scan-plane control device (Figure 2 A and B) is equipped with a guide bar to automatically align the needle path with the device and with real-time imaging. Additionally, a thumb switch allows performing fast, immediate 90° scan plane rotations around the needle axis without actual rotation of the device while simultaneously toggling between two viewports available in the real-time interactive scanner user interface. The relative position and orientation of a real-time image displayed in one viewport is indicated using geometry indicator lines in the other viewport. The scan-plane control device is equipped with 4 resonant, active micro-coils tuned to 42.5 MHz that contain spherical glass beads encapsulating Gd-doped water as signal sources. The micro-coils, connected to the MR system via the standard coil front-end connector, feature a B0-compensated design for optimal performance independent of the marker orientation and can be actively tuned/de-tuned for both optimal imaging and tracking quality [1]).
The thumb switch is implemented by moving one of the micro-coils between two calibrated positions detectable by the MR tracking sequence and thus does not require additional cable routing to the MR scanner. Thus, only a single, 3m long, highly flexible 4-channel RF cable (Philips-InVivo, Best, NL) is required and allows optimal handling of the device. The cable is equipped with 4 RF traps to ensure RF-safety by preventing uncontrolled coupling of the body-coil.
The interface box (Figure 2 A) pre-amplifies the MR signals received by the micro-coils and contains the MR coil driver unit and tune/de-tune circuitry for minimal B1 disturbance during transmit. The 3D positions of the µ-coils are measured by a projection-based MR tracking sequence [2] with improved tracking accuracy using a special spoiler technique [1,4] to get rid of large volume magnetization along with B0 inhomogeneity and gradient distortion correction [1]. Based on these positions, the estimated 3D position of the needle guide is calculated by the MR scanner software and allows manual, free angulation and positioning of the real-time imaging slices along the needle path.
Volunteer and phantom puncture tests were performed to verify image quality, speed and accuracy of the needle guide and to determine the optimal clinical workflow using the developed technology. An MR-compatible 20G Inconel Chiba needle was used for puncturing. A spoiled gradient echo sequence (TR/TE=11s/6s, FA=35°, FOV=300x300mm2, Voxel=2.0x2.4x8mm3) with interleaved µ-coil tracking sequence was used for fast continuous imaging [3].
The presented needle guidance system and software received MDD: 93/42/EC approval as a medical device intended for clinical investigation.

**Results**
Freehand geometry control of the scan plane in real time was successfully performed in a clinically realistic setting (Fig. 2, left). Accurate auto alignment of continuous image acquisition with the needle axis could be verified and phantom puncture test were performed successfully with the needle guidance tool (Fig. 3). The tool allowed autonomous, full control of the scanner from the patient bed without frequent interaction with an MR system operator to define appropriate scan geometries for the intervention. Consequently, puncture times were very short and accuracy is comparable with the technique described in [3].

**Conclusion**
The needle guide allows the interventionalist flexible and intuitive control of the real-time imaging geometry with high accuracy, while providing simple means to keep imaging aligned with the axis of a needle being advanced into the tissue. The device may also serve as a general tool for MR-guided interventions that benefit from flexible control of real-time imaging since the device allows definition of the imaging plane similar to when using an ultrasound probe-head.

**References**
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**[2]** J. L. Ackerman, *Proc. Conf.5th SMRM*, 1986
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**[4]** C. Dumoulin et al., Proc. ISMRM, 4165, 2010

**Figure 1: A**: Needle guidance tool setup at the patient bed. A 3m long highly flexible 4-channel RF cable was used for better handling of the scan plane control device.
**B**: Close-up view with flexible coil for interventions.
The needle guidance tool also allows real time imaging comparable to the handling of an ultrasound transducer.

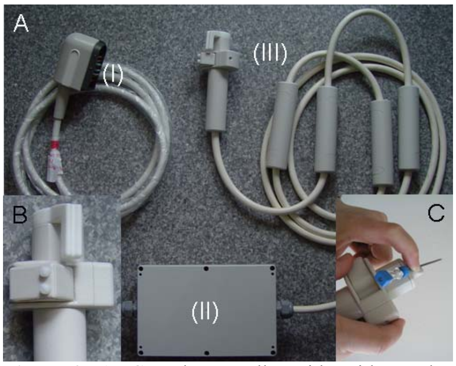

**Figure 2: A:** Complete needle guide with standard coil plug (I), connectable into the MR front-end, interface box (II), hand piece (III) and cabling.
**B:** Needle guide bar and thumb switch at the end of the hand grip **C:** Scan plane control device with thumb switch and needle aligned along the guide.

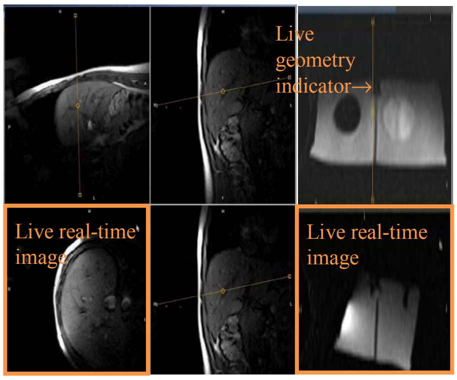

**Figure 3: Left:** Real-time image acquired with interleaved marker tracking sequence demonstrating image quality. The tracked live image is displayed in one viewport (lower left in this example) while the other viewports contain static prior frames with live geometry indicator lines. **Right:** Phantom puncture tests performed with the Needle guidance tool.