MRI guided robotic assisted pain therapy

A. Melzer[1]

[1]IMSaT, University Dundee, Dundee, Scotland, United Kingdom

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Objective. A fully MR-compatible assistance system INNOMOTION (Innomedic, Herxheim & FZK Karlsruhe Germany) [1] was developed to provide precise and reproducible instrument positioning inside the magnet. The Objective was to determine targeting precision during MRI guided percutaneous interventions in a clinical trail for bilateral facet joint injection of steroids at spine segment L5 S1.

Materials and Method.s The pneumatic robotic assistance system is fully MR-compatible and consists of a robot arm which can be manipulated in 6 degrees of freedom [1]. The robot arm is attached to a 180° arch that is mounted to the patient table of the scanner and can be passively prepositioned on the orbit at vertical (0°, ± 35°, ± 67°) at each sides of the orbital according to the region of interest (e.g. spine, liver, kidney, breast). Active positioning measurements are achieved via fiber optically coupled limit switches, rotational and linear incremental sensors (Fig. 1 a, b). Pneumatic cylinders with slow motion control have been developed to drive five degrees of freedom (DOF). Cross platform MRI compatibility has been achieved for 1.5 T MR scanner, Magnetom Symphony, Siemens, Erlangen, Germany (2) and 1.0 T Gyroscan , 1.5 T Intera Philips, Eindhoven NL and GE 1.5 Tesla is currently under preparation.

The application module for clinical use provides manual translation and rotation of 22 – 12 G coaxial probes (e.g. cannulae for biopsies, RF or Laser applicators, endoscopes, etc). A pneumatic drive for the cannula insertion has been developed for experimental use. The arch is movable and can be firmly attached to the patient table of the MR system with exchangeable fittings suitable for all MRI plat forms. A graphical user interface provides planning of insertion on the MRI images.

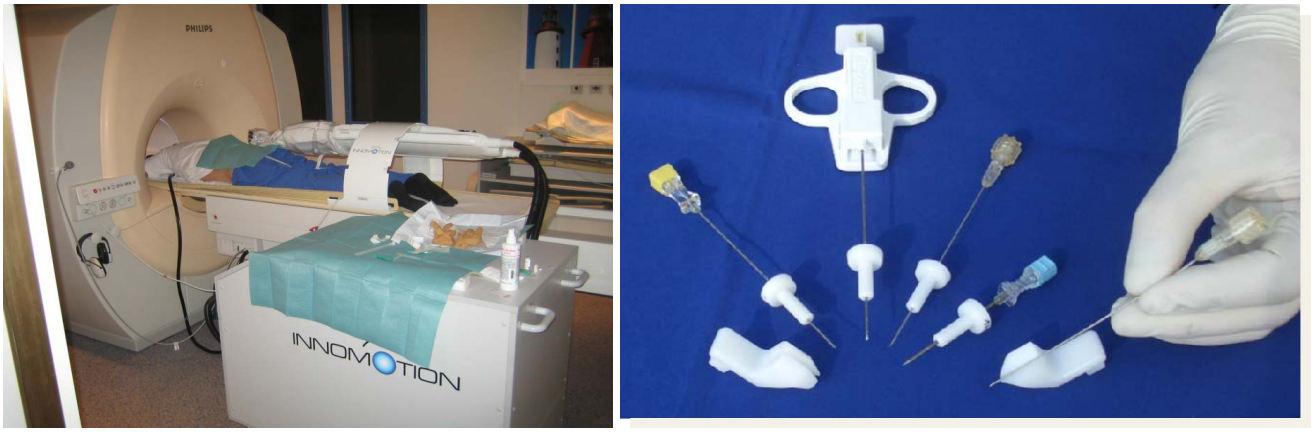
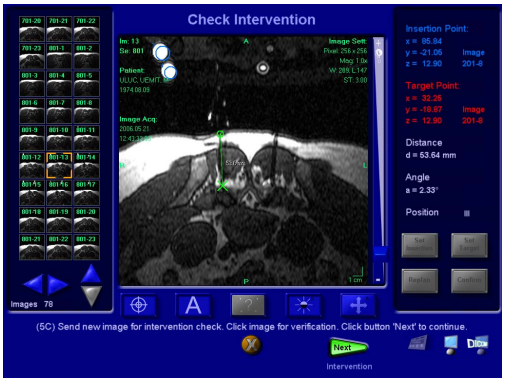


Fig. 1 (a) INNOMOTION 6 DOF assist system (b) cannula set for MRI guided procedures (in vivo, ex Daum GmbH)



The system is prepositioned and firmly attached to the table with clamps. Pre-interventional images sent via network in DICOM format to the computer of the assist system. Insertion site and a target point are selected on the graphical user interface monitor and the coordinates sent to the control unit and the application module is moving to the insertion site on the skin. The cannula can then be inserted through a guiding sleeve.

The MRI procedures were performed a 1.5 T Intera Philips, Eindhoven, NL, The evaluation of target precision and safety has been conducted during MRI guided percutaneous interventio ns on 16 patients 4 female and 12 male with informed consent. All patients had previous MRI scan of the spine and have been treated via CT guidance at the same segment. 20 and 22 G MR-compatible Titanium grade 4 cannulae (MRI Devices-Daum, Schwerin, Germany) were then manually inserted in depth of 4,8 to 6,7 cm. Gradient Echoes sequences (TR = 4.4 ms; TE = 2.2 ms; FA 70°; TA = 0.7 s) were used for cannula guidance and drug instillation of 5 mm Mepivacain and 40 mg triamcinolone. Precision of insertion point and insertion angle has been determined by using image overlays (Fig. 2).

Fig. 2: Target precision of 20 Gauge cannula, robotic guided left and manual right .

Results All interventions were successfully completed. Position and orientation of all cannula insertions were appropriately visualized on axial MRI images. Precision of insertion site in axial plane was +/- 1mm (min of 0.5 mm and max of 3 mm). Angular deviation in the transverse plane of the cannulae shows +/- 1° with min of 0.5 and max of 3°. MR on table time was 45 to 11 min and the last 5 procedures could be performed in less than 15 min. Despite minor side effects of increased sweating in two patients and prolonged menstruation in one patient no major adverse events have been noted.

Conclusion: Cross platform MRI compatibility can be achieved by using polymer, ceramics, pneumatic drives and optoelectronic sensors. Control of the insertion under real time MRI is not required for precise position the tip of the cannula in the volume of interest. To ease the procedure tip tracking techniques might be helpful.

References

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