Musculoskeletal needle placement with MRI image overlay guidance

Gregory S Fischer[1], Anton Deguet[1], Csaba Csoma[1], Russell H Taylor[1], S J Zinreich[2], Gabor Fichtinger[1]

[1] *Johns Hopkins University, CISST ERC, Baltimore, MD, USA*
[2] *Johns Hopkins Hospital, Dept. of Radiology, Baltimore, MD, USA*

gfisch@jhu.edu

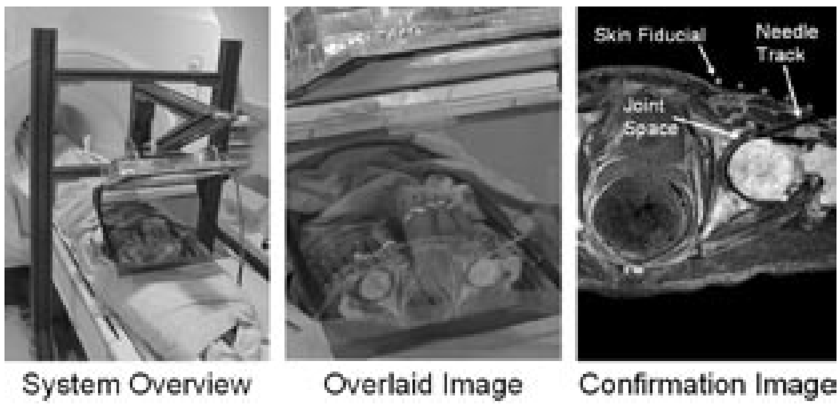
Introduction: Magnetic Resonance Imaging (MRI) is superior to other imaging modalities in detecting diseases and pathologic tissue, and has unmatched potential for guiding, monitoring and controlling interventions [1]. In most needle based procedures (biopsy, injection, drainage, ablation, etc.), the high sensitivity of MRI in detecting lesions allows for good visualization of the pathology, and its superior soft tissue contrast helps to avoid sensitive structures in the puncture route. To assist needle insertion, we propose a 2D augmented reality image overlay device similar to those in [2,3]. The approach makes closed bore high-field magnets available for interventions without involving prohibitively complex and expensive engineering entourage.
We consider two motivating applications. MR arthrography is the imaging gold standard to assess small ligament and fibrocartilage injury in joints. In direct arthrography (DMRA), contrast is directly injected into the joint; the procedure consists of two consecutive sessions: 1) a needle is driven to the joint space under radiological image guidance (typically CT or fluoroscopy) and gadolinium contrast is injected and 2) a diagnostic MRI session to visualize the distribution of contrast in the joint space. Our approach to DMRA eliminates the separate radiologically guided needle insertion and contrast injection procedure by performing the entire procedure in a single setting. Needle insertion in and around the spine are prevalent and could greatly benefit from MRI guidance, but currently no exigent solution exists to make this possible in a safe, simple and inexpensive manner.

We propose MR image overlay to augment MR-guided needle insertion. By seeing the target anatomy while performing the needle insertion, the clinician can clearly visualize the needle path and guide it appropriately. The physician can execute the procedure without turning his/her attention away from the patient, and execute the same series of motions and actions as conventional freehand procedures.

Methods: The image overlay system displays transverse MR images on an LCD display, which are reflected back to the physician from a semi-transparent mirror. Looking though this mirror, the MR image appears to be floating in the appropriate location in the body. Users from all viewpoints share the same scene without any auxiliary tracking. The intersection of the mirror and display surface planes is marked with a transverse laser plane that is used for constraining the needle to the image plane. A virtual needle guide is displayed on the overlay and used for constraining the in plane rotation.
In the workflow, a set of parallel cylindrical fiducials are placed on the skin in the region of interest and aligned in the sagittal direction (Invivo TargoGrid). Transverse MRI slices are acquired, and a single slice is selected as the insertion plane. The image is transferred to the planning and control software on a stand-alone PC where the target and entry points are selected. A visual guide along the trajectory is overlaid on the MR image and rendered on the overlay device. The patient is translated out of the bore such that the image plane lies in the overlay's transverse laser; the physician holds the needle at the entry point behind the mirror and adjusts the angle to the virtual needle guide while holding the needle in the laser plane. Coincidence between the corresponding fiducial marks on both the patient and in the overlaid image indicates correct alignment. Any misalignment is quickly corrected by software and the needle is inserted to the predetermined depth.

Results: Joint arthrography needle insertions have been performed on porcine and human cadavers in a 1.5T GE Signa scanner. Twelve separate insertions using 18G, 10cm MR-compatible needles (E-Z-EM) were performed in the joint space of the shoulder on fresh porcine cadavers; needle insertion depths ranged from 26-43mm.Ten separate insertions have been performed on human cadavers; the insertions were into the hip joint and the depths ranged from 30-54mm. Planning and confirmation images were examined by two board certified radiologists to determine whether the tip of the needle landed in the joint space. The needle was successfully inserted into the joint on the first attempt in all cases.
Spinal needle insertions have been performed in with the MR image overlay on interventional phantom (CIRS Inc.). Successful access of all anatomical targets was verified in MRI visually; paramagnetic needle artifact and the lack of distinct target points did not allow for precise error measurement. Functionally equivalent earlier trials with a CT image overlay have proven the technique

reliable for guiding percutaneous spinal access on human and porcine cadavers [2].



MR image overlay used to guide joint arthrography needle insertion

Discussion: Initial cadaver and phantom experiments support the hypothesis that the MR image overlay can provide accurate needle placement while significantly simplify the arthrography procedure by eliminating separate radiographically guided contrast injection. The system appears to be useful in spinal needle placement, however, independent measurement of accuracy will have to support this claim in later trials. In our studies, by visualizing target anatomy and providing a visual guide, the MR image overlay allowed for accurate needle placement on the first attempt consistently. Presently, IRB approval is being sought to commence clinical trials in joint arthrography. Concurrently, a dynamic overlay system is underway, which will be smaller in size and moved dynamically over the body, thereby allowing for needle insertion in arbitrary planes guided by reformatted images. Funding provided by Siemens Corporate Research and NSF EEC-9731478.

References

[1] Jolesz FA. : Interventional and intraoperative MRI: A general overview of the field, J Magn Reson Imaging 8(1) (1998), 3–7.

[2] Fichtinger G, Deguet A, Masamune K, Fischer G, Balogh E, Mathieu H, Taylor RH, SJ Zinreich and Fayad LM : Image Overlay Guidance for Needle Insertions in CT Scanner, IEEE Transactions on Biomedical Engineering 52 (2005), 1415–1424.

[3] Stetten GD, Chib VS.: Overlaying ultrasonographic images on direct vision, J Ultrasound Med. 20 (2001), 235–240.