

Joint Arthrography with MRI Image Overlay: Porcine Trials

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Introduction:

In contemporary practice, MR Arthrography (MRA) consists of two consecutive sessions: 1) a fluoroscopically or CT-guided needle placement session to inject gadolinium contrast into the joint space and 2) a diagnostic MRI imaging session to evaluate the condition of the joint. Our approach to MRA is to eliminate the separate radiologically guided needle insertion and contrast injection procedure by performing those tasks on conventional high-field closed MRI scanners. We propose a 2D augmented reality image overlay device to guide needle insertion, thereby making diagnostic high-field magnets available for interventions without a complex engineering entourage. The device consists of an LCD screen that projects images onto a semi-transparent mirror. Looking at the patient through the mirror, the MRI image appears to be floating inside the patient with correct size and position, thereby providing the physician with two-dimensional tomographic vision to guide needle placement procedures from any view point.

Materials/Methods:

The MRI image overlay system is conceptually similar to an earlier CT-compatible embodiment [1]. It consists of an MR-compatible LCD screen (off-the-shelf 19" LCD display retrofitted to be MRI-safe and RF shielded) that is housed in an acrylic shell and rigidly attached to a semi-transparent mirror and a laser line generator. Maintaining the same angles between the LCD and mirror and that of the mirror and laser plane are critical; the optimal angle was found to be 60°. This overlay unit is attached to a modular extruded fiberglass frame as in Fig. 1. The freestanding frame arches over the scanner bed and allows for transverse images to be displayed on a patient in the correct position. The encoded couch is translated out of the bore by a known amount, so that the plane of insertion coincides with the plane of the overlay image marked by the laser. The image alignment process is performed directly on the patient by determining the in-plane transformation between the overlaid MR image and the view of the patient situated behind the mirror. The transformation consists of the following: *scale* based on the known FOV and monitor pixel spacing, *flip* based on the known patient orientation and *in-plane transformation* made up by a rotation and translation that are determined by aligning the MRI image with fiducial markers on the skin.

The workflow is as follows: (1) The patient is positioned and three fiducial tubes are placed on the skin (MR-Spots - Beekley, Bristol, CT) over the plane of interest. (2) A small stack of transverse MRI slices with a slice thickness appropriate for the targeted joint are acquired. (3) A single MR slice is selected as the insertion plane, the patient is translated so that the appropriate slice lies in the scanner's alignment laser, and the appropriate entry point is marked on the skin with hollow IZI multi-modality markers (IZI Corp., Baltimore, MD). (4) A new transverse MRI image of this slice is reacquired with the entry point fiducial in place. (5) The image is transferred directly in DICOM format to the planning and control software implemented on a stand-alone laptop computer. (6) The computer is used to mark the target and entry points, draw a visual guide along the trajectory of insertion and mark the depth of insertion (Fig. 2-a). (7) The image is rendered on the image overlay device and the patient is translated out so that the entry point fiducial lies in the overlay's laser plane. (8) The overlay image is aligned as described earlier: the tube and entry fiducials are visible on both the patient and in the overlaid image; coincidence between the corresponding marks indicates correct calibration and entry point alignment, respectively. (9) The needle is inserted as 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 plane of the laser (Fig. 2-b).

Experiments and Results:

Experiments have been performed in a 1.5T GE Signa Excite MRI scanner using spin echo imaging. The needles were inserted under image overlay guidance into the joint space of the shoulder on fresh porcine cadavers sacrificed in unrelated studies. Twelve separate insertions using 18G by 10cm MR-compatible diamond-tip needles (EZ-EM, Inc., Lake Success, NY) were performed into a total of five joints in a total of three pigs (55-85lb, female pigs) with insertion depths ranging from 26-43mm. Contrast was not injected because that would not have been realistic in the stiff joints of the cadavers. The endpoint of the trial was to determine whether the needle tip landed in the joint space. A typical confirmation image after insertion is shown in Fig. 2-c. Planning and confirmation images were examined by two board certified radiologists to determine whether the tip of the needle landed in the joint on the first attempt in all twelve cases. The average time for an insertion was approximately 20min. In further qualitative studies, insertion attempts in stationary soft-tissue targets with depths up to 100mm were successful on the first attempt, without failure.

Discussion:

The porcine cadaver experiments support the hypothesis that the MRI image overlay can aid in needle placement while significantly simplify the MRA procedure by eliminating the need for a separate, traditional radiographically guided, contrast injection. Human cadaver trials are currently underway to analyze the safety and robustness of the system on human anatomy. We have also conceptualized a smaller version of the image overlay device that can be flexibly positioned inside a short-bore magnet where the patient will not be shuttled in and out, so that we can employ near real-time imaging update. A further design is in the works for a mobile overlay device that will allow for needle insertions in arbitrary oblique planes by dynamically reslicing the 3D volume.

References:

[1] Fichtinger G, Deguet A, Fischer G, et al.: Image Overlay Guidance for Needle Insertions in CT Scanner, *IEEE Trans. Biomed. Eng.* 52 (2005), 1415-1424.

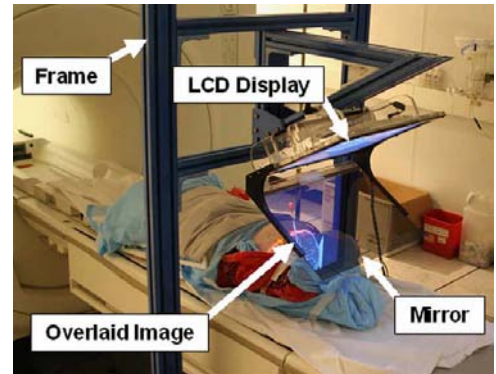


Figure 1: Layout of MRI image overlay system during 1.5T porcine MRA trials.

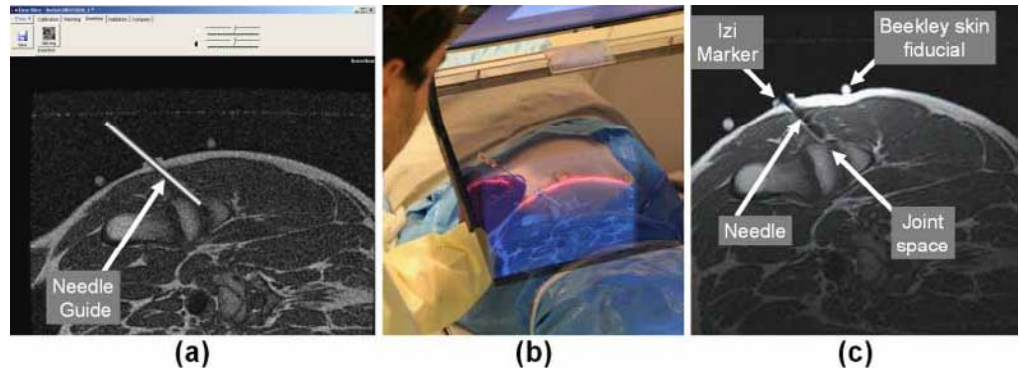


Figure 2: Typical workflow using image overlay: Take image with fiducials in place, determine plan and display needle guide (a). Insert needle using Overlay guidance (b). Take confirmation image and verify results by comparing plan and actual needle track (c).