

# Validation System of MR Image Overlay and Other Needle Insertion Techniques

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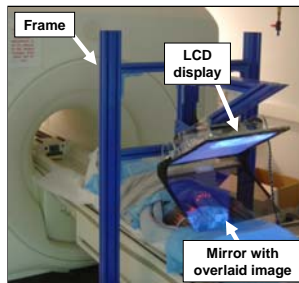
## Background/Problem

MRI has an unmatched potential for guiding, monitoring and controlling minimally invasive interventions. In needle based procedures, the high sensitivity of MRI in detecting lesions allows excellent visualization of the pathology, and the high tissue contrast helps to avoid critical structures in the puncture route [1]. Our comprehensive program at Johns Hopkins investigating CT/MRI guided assistance techniques for needle placement procedures necessitates a comparative validation environment. Clinical equipment is prohibitively expensive and often inadequate for precise validation. Particularly, measuring needle placement accuracy directly in MRI (at typical \$500/hour room charge) is greatly limited by paramagnetic artifact and lack of small targets. To answer these needs, we have developed a laboratory validation system for measuring operator performance in using different assistance techniques. The validation system can be applied to varying methods of assistance ranging from augmented reality guidance methods to tracked navigation systems and autonomous robots.

In this paper, we describe the validation system and its use for comparative analysis of virtual image overlay, bi-plane laser guidance, and unassisted freehand techniques. The overlay displays CT/MR images and a virtual needle guide over the patient [2] and is calibrated such that the overlay image appears to be floating inside the patient in the correct size and position (Fig. 1.). The bi-plane laser guide uses intersecting transverse and adjustable parasagittal laser planes to mark the trajectory of insertion [3], as in Fig.2.b.

## Tools and Methods

The procedural workflow is tested in clinical setting (Figs. 2.a-b) and then quantitative measurements are performed in a functionally equivalent laboratory configuration (Figs. 2.c-d). We constructed an interventional phantom from a human cadaver lumbar spine embedded in multiple layers of tissue mimicking gel. We placed stereotactic fiducials on the box, allowing for automatic registration between anatomical images, phantom and needle incorporating an electromagnetic tracking

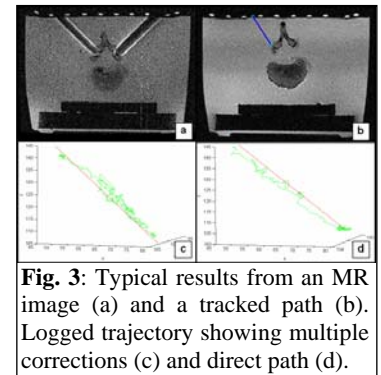


**Fig. 1:** MR image overlay during joint arthrography needle insertion in human cadaver hip joint.

coil (Aurora, www.ndigital.com) as in [4]. Target and entry points are selected on MR images, and passed on to the navigation system tested. During insertion of the tracked needle, the trajectory is recorded and the performance of the operator (such as accuracy, time, adjustments, reinsertions, etc.) is analyzed.

## Results

To demonstrate workflow, four needle insertions were performed with each technique in clinical MRI environment. As expected, accuracy could not be assessed due to large artifacts (Fig. 3a.). In the validation testbed, the measured needle trajectories were graphically overlaid on the plan and targeting MR image as shown in Fig. 3b. Twenty insertions were performed with each technique. Position and orientation errors were measured. Initial analysis showed that the results correlate with direct validation performed using fluoroscopy described in [3]. The image overlay's mean error in the image plane was 1.4mm and 2.5° with standard deviations of 0.5mm and 1.9° respectively. The laser guide's average error was 1.8mm and 2.0° (1.2mm and 1.8° standard deviation), and freehand produced average errors of 2.0mm and 5.2° (1.4mm and 2.3° standard deviation).



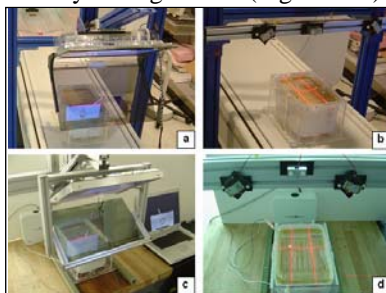
**Fig. 3:** Typical results from an MR image (a) and a tracked path (b). Logged trajectory showing multiple corrections (c) and direct path (d).

## Conclusions/Discussion

Initial assessments of the image overlay, laser guide, and freehand needle insertions were performed with the system. Experiments with experienced radiologists are currently underway. These experiments will provide large scale accuracy assessment of needle insertion procedures using commercial surgical navigation systems, image overlay, laser guide, and traditional techniques. The goal is to quantitatively compare placement accuracy, consistency, and other important characteristics such as gestures [5].

## References

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**Fig. 2:** Image overlay (a,c) and bi-plane laser guide (b,d) with spine phantom. MR scanner trials (a,b) and laboratory configuration with tracked needle (c,d).