



Joint Arthrography with MRI Image Overlay: Porcine Trials



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BACKGROUND

- MR arthrography (MRAr) is the imaging gold standard to assess small ligament and fibrocartilage injury in joints.
- MRAr typically consists of two consecutive sessions:
 1. An interventional session where a needle is driven to the joint space and MR contrast is injected under fluoroscopy or CT guidance
 2. A diagnostic MRI imaging session to visualize the distribution of contrast inside the joint space and evaluate the condition of the joint.

SIGNIFICANCE

Our approach to MRAr is to eliminate the separate radiologically guided needle insertion and contrast injection procedure by performing those tasks on conventional high-field closed MRI scanners.

HYPOTHESIS

MR arthrography procedures can be shortened and simplified by combining the interventional and diagnostic steps with the help of MR image overlay guidance.

SYSTEM CONCEPT

The basic concept of the augmented reality 2D image overlay is shown in Fig. 1. Transverse MR images are displayed on an LCD display, which are reflected back to the user from a semi-transparent mirror. Looking through the mirror, the anatomical image appears to be floating in the appropriate location in the body. Users from all viewpoints can share the same scene without any auxiliary tracking.

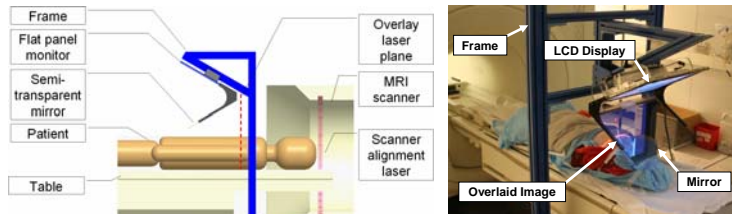


Fig.1 – System configuration for MR image overlay (left) and system in use during porcine trials (right).

After the entry point is selected, three degrees-of-freedom (DOF) motion of the needle needs to be controlled:

1. The overlay image with superimposed needle guide controls insertion angle in image plane (first DOF)
2. The overlay device's laser plane controls out-of-plane orientation (second DOF)
3. A virtual depth gauge on the overlay image controls insertion depth (third DOF)

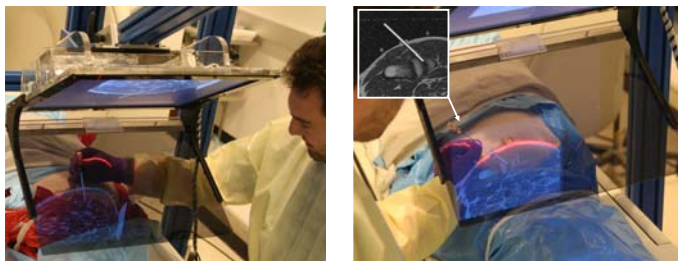


Fig.2 – Needle insertion procedure in porcine shoulder using MR image overlay guidance. Inlay shows the targeting MR image with superimposed visual needle guide.

ACKNOWLEDGEMENTS

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CLINICAL WORKFLOW

The typical workflow for a needle insertion using the MR image overlay is as follows:

1. Place the patient on the table and place imaging coil over the target site.
2. Prepare the site of intervention and place skin fiducial.
3. Translate the patient into the scanner and acquire a thin slab of MRI images.
4. Transfer image to the planning software; select the target and entry point (Fig. 3(left)).
5. Superimpose visual needle guide on targeting image and render on the overlay device.
6. Translate out the patient to align the entry point with the overlay's laser plane.
7. Adjust calibration to make the skin fiducials and corresponding image points coincide
8. Insert needle along visual guide while aligned with the laser plane (Fig. 3(center)).
9. Insert the needle to the predefined depth while maintaining alignment.
10. Translate the patient into the scanner and acquire a confirmation image (Fig. 3(right)).

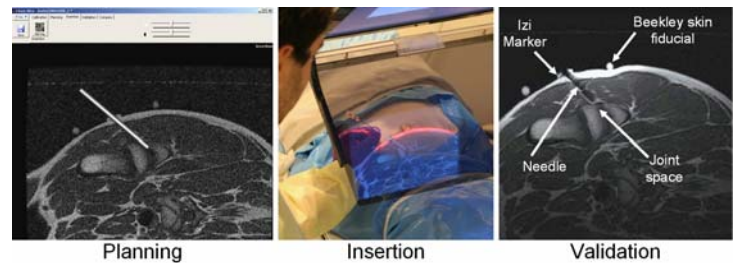


Fig.3 – Clinical workflow starting with imaging and planning (left), rendering the image and inserting the needle under image overlay guidance (center), and verifying the insertion accuracy (right).

RESULTS

MR overlay guided needle insertion trials targeting the joint space of the shoulder have been performed in three trials with 55-85lb post-euthanasia pigs. 12 of out of 12 insertions were successful on first attempt with an average time of ~20 min (calibration, planning, insertion, confirmation). Results are shown in Fig. 4.

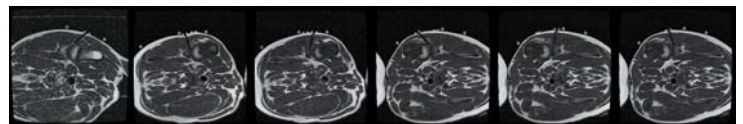


Fig.4 – Typical results from needle insertion into the joint space of porcine shoulders.

Since submitting this work, we have moved on to human cadaver trials. In one cadaver, 10 needle insertions targeted the joint space of the hip using MR image overlay guidance. All 10 were successful on the first attempt. Results from this trial are shown in Fig. 5.

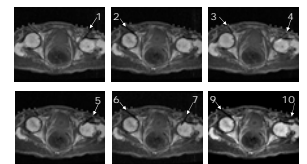


Fig.5 – Preliminary hip arthrography trials in human cadavers

DISCUSSION

The image overlay system has been implemented for use on MR scanners. Using overlay guidance, MR Arthrography can be shortened (~20 min) and simplified by allowing contrast injection in the MRI scanner. This technique provides for more accurate insertion with fewer attempts and is generally applicable for needle placement procedures.

Quantitative accuracy analysis of needle insertions under image overlay guidance is underway; the analysis includes a comparison between overlay and other techniques (bi-plane laser guide, handheld protractor guide and traditional freehand) as in Fig. 6.

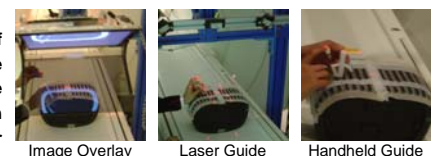


Fig.6 – Accuracy analysis is being performed for image overlay technique with a quantitative comparison between overlay guidance and other techniques