ENDOVASCULAR INTERVENTIONS USING LOW-FIELD MRI WITH SPIO NANOPARTICLES – AN ALTERNATIVE TO X-RAY GUIDED TECHNIQUES?

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PURPOSE

Intermittent claudication (CLI) is often treated using a minimally invasive approach with X-ray guidance. Low field magnetic resonance imaging (lf-MRI) using super-paramagnetic iron oxide (SPIO) nanoparticles could be a positive contrast [1], radiation-free alternative for guidance due to its open system configuration. Therefore, the feasibility of this method was investigated in phantoms.

METHODS

Different characteristics for performing endovascular interventions using lf-MRI and fluoroscopic techniques were identified (Table 1). The proposed surgical workflow when using lf-MRI is adapted with respect to fluoroscopic techniques (Figure 1). The following series of experiments was conducted in this research using an ESAOTE G-scan Brio 0.25T MRI system:

A clinically relevant range of SPIO [1] nanoparticles concentrations (0 mM – 4.096 mM) was scanned using T₁-weighted 2D spin echo sequences (Figure 2).

B Experiments were performed on a phantom mimicking iliac and femoral mean blood flow (Figure 3) using 3D balanced and spoiled gradient echo sequences (Figure 4).

3. Subtraction images and maximum intensity projection images were created (Figure 5).

RESULTS

FIGURE 2 Small tubes filled with a range of SPIO concentrations (circles in image), inside chicken breast show the possibility of positive contrast at low magnetic field. The optimal CNR was found at a concentration of 0.4μM iron, which is far below toxicity levels [1] (3).

FIGURE 3 Schematic overview of the phantom. The bottle contains a solution of manganese chloride (0.1 mM MnCl₂) to mimic tissue. The tube was filled with a solution representing blood (0.07 mM MnGlu) with or without contrast agents (0.01μM iron).

FIGURE 4 Coronal images of the flow phantom. The mean signal intensity inside the tube is increased with 22% when SPIO contrast (0.9 μM Fe) was used. Left: results with the tube mimicking blood without SPIO contrast. Right: results with the tube mimicking blood with SPIO contrast.

FIGURE 5 Left: subtraction of the MRI scan with flow without SPIO contrast from the scan with SPIO contrast. No contrast adjustments were made or smoothing filters were used. Right: 3D maximum intensity projection (MIP) of the resulting subtracted image.

FIGURE 1 Workflow diagrams of a typical hybrid operation (intervention) on a patient with CLI using fluoroscopy (left) or low-field MRI (right). Note that the different colors depict the use of different imaging modalities before and during the intervention.

DISCUSSION

Fusion with high quality pre-operative imaging should be used extensively in an lf-MRI intervention, to compensate for the impaired spatial and temporal resolution. Stenosis and structures of at least 1 mm must be distinguishable by the fused techniques to operate successfully and safely. 3D-MRI can even provide the operator with cross-sectional information of the vessel which can ideally be used to guide catheter insertion. Although we used pre-established concentration levels in phantom models, contrast injection techniques and contrast agent clearance rate determine the injection quantities in vivo.

CONCLUSION

The current state of using lf-MRI with positive SPIO contrast is far from clinical application. Fusion possibilities with pre-operative high quality imaging should determine the eventual resolution during intervention and whether lf-MRI with SPIO contrast is sufficient enough for endovascular interventions.

REFERENCES


TABLE 1 Important characteristics of low-field MRI, high-field MRI, and fluoroscopic techniques when deployed for endovascular interventions.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Low field MRI</th>
<th>Fluoroscopic techniques</th>
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<tbody>
<tr>
<td>Imaging type</td>
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<td>Accessibility</td>
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<td>Dimensions</td>
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<tr>
<td>Spatial resolution</td>
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<tr>
<td>Temporal resolution</td>
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