MRI as a tool for pre and post-operative assessment of arterio-venous fistulas

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The arteriovenous fistula (AVF)

- HD requires high blood flow for good clearance (600ml/min)
- CVC not suitable for long-term use due to stenosis/infection
- AVF - Surgical connection between artery and vein
- Vein dilates & flow increases
Problems

• High failure rates: meta-reviews find 60% patency rates between 1-2 years [Rooijens 2004, Weale 2008]
• Multiple factors identified as predictors of lower failure rates
• NIH main factor behind flow limiting stenosis
**Pre-operative imaging**

- Patients commonly undergo pre-op US
- Vessel sizes, and health assessed
- Central vessel problems can be missed
- "Pre-access vessel mapping alone is clearly not enough to plan a dialysis vascular access." - Pre-Access Creation Evaluation—Is Vein Mapping Enough?, Vachharajani 2015

Credit: Rose Ross (ReDVA)
Post-operative surveillance

- Monitoring/surveillance physical & US exams
- If monitoring or surveillance indicate a problem -> DSA
- Diagnostic imaging of dysfunctioning AVFs
- DSA can identify stenosis, and treatment performed in same session

Credit: Marco Salsano
MR imaging of Vascular Access

- MRI research has showed good stenosis detection in VA patients
- NSF association with GBCAs may have lead to negative trend in research
• Evaluation of MEDIC sequence for upper-limb extremity angiography
• MRI imaging of healthy and patient volunteers
• Comparison with US results
• Post-operative imaging of patient volunteers
This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement no 324487

Materials and methods - participants

- 16 Volunteers – 10 healthy (NHV1-10), 6 ESRD (AVP1-6 awaiting AVF)
- 2 imaging locations – upper or lower arm
- AVP1,3,6 brachio-cephalic AVF
- AVP2,5,7 radio-cephalic AVF

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Number (N=16)</th>
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<tbody>
<tr>
<td>Age</td>
<td>44±16</td>
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<tr>
<td>White race</td>
<td>16</td>
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<tr>
<td>Diabetes</td>
<td>4</td>
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<tr>
<td>Arterial fibrillation</td>
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<td>Upper arm imaging</td>
<td>5</td>
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<tr>
<td>Lower arm imaging</td>
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Materials and Methods – Imaging times

- 10 healthy volunteers – 1 US and 1 MRI scan
- 6 Patient volunteers:
  - Pre & post-op US
  - 4 patients pre & post-op MRI
  - 2 patients pre-op MRI

### AVP Times

- **AVP1**: 4 days → 24 days
- **AVP2**: 10 days → 17 days
- **AVP3**: 8 days → 26 days
- **AVP5**: 8 days
- **AVP6**: 9 days
- **AVP7**: 38 days → 20 days

Pre-op imaging → AVF Creation → post-op imaging
Methods - Ultrasound imaging

- Siemens s2000
- Volunteers imaged in seated position
- Arterial, venous diameters and peak-systolic velocity measured
- PSV from US used to guide subsequent MRI

Doppler-US image of arterial segment of AV fistula on patient-vol
Methods - MRI imaging

- 3T Siemens Trio-PrismaFIT
- Imaging in lying position with arm relaxed
- 10cm region covering upper or lower arm

**MEDIC – morphology**
- TR/TE: 29/16ms
- Flip angle: 30
- Thickness: 6mm

**PC-MRI – flow**
- TR/TE: 61.7/5.88ms
- Flip angle: 8
- FOV 150*200mm
- VENC: 70-250cm/s
<table>
<thead>
<tr>
<th>Morphology Assessment</th>
<th>Velocity Assessment</th>
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<tbody>
<tr>
<td>Osirix light</td>
<td>Segment</td>
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<tr>
<td>Vessels assumed to be oval</td>
<td>ROI drawn round vessel of interest</td>
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<td>2 diameter measurements on minor and major axis</td>
<td>Semi-auto propagation of ROI</td>
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<tr>
<td>Area plotted as a distance of anastomosis</td>
<td>Automatically exports flow info to excel</td>
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<tr>
<td>Biological landmarks used to manually register image locations</td>
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</table>
Results – Imaging outcome of volunteers

- All 16 volunteers scanned as planned
- Initial observation revealed PC-MRI unsuccessful in AVP5 and HV2
- MEDIC poor quality in HV4
- US data not recorded for HV6
• AVP1 original fistula site abandoned due to calcification – secondary site successful
• AVF7 developed infection – affected MRI image quality
• Stenosis developed in 4 patients (AVF1,2,3,6) between 6-12 weeks after surgery
• Whole group results compared between MRI and US
• Differences between groups compared for each modality
• No differences between MRI and US for whole group
• Differences seen in measurements on MRI between healthy and patient groups

<table>
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<tr>
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<th>US</th>
<th>MRI</th>
<th>p-value</th>
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<tr>
<td>Whole-Group</td>
<td>Cephalic vein diameter</td>
<td>Cephalic vein diameter</td>
<td>0.78</td>
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<tr>
<td>(n=16)</td>
<td>Radial artery diameter</td>
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<td>Radial artery PSV</td>
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<td>HV-AVP</td>
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<td>radial artery PSV</td>
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</table>
• Radial artery PSV in ESRD group $P<0.05$
• Mean
• Low patient sample size for radial PSV measures
Results – Radial artery diameter on MRI

- Lower radial artery diameter in patients
- Difference seen on MRI (P<0.05)
- Also seen on US (P=0.02)
• Lower diameter in patient volunteers (red)
• P=0.012
• Mean healthy
• Mean patients
Results - Pre and Post-Surgery - morphology

- Large increases in vessel size seen on both modalities
- MRI shows non-uniformity in these changes
- Significant spots of lower dilation in AVP3 – pictured (red)
• Large increases in arterial PSV shown on both modalities
• Large increase in venous velocity
• Changes in waveform seen on both modalities
Conclusions & Discussion

- MRI able to provide detailed 3D spatial information – area areas of low dilation important?
- MRI may be more sensitive to velocity and geometric differences between groups
Limitations

- Small numbers – exacerbated by different scanning locations
- MRI wasn’t used in AVF planning
- MRI known to underestimate vessel sizes
- Potential mismatch between measurement areas
Future work

- Subsequent analysis of MRI and US data – six month post-operative
- CFD simulations of blood flow using patient specific models
- Comparison of MEDIC with ToF sequences
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