Overview of the clinical utility of 4D Magnetic Resonance Angiography (MRA) in the management pathway of a patient with an extremity Arteriovenous Malformation (AVM)

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1. Background
The diagnostic utility of conventional digital subtraction angiography (DSA) as the gold standard in identifying the vascular anatomy and flow characteristics of AVMs could now be superseded. Advances in 4 dimensional (4D) contrast enhanced magnetic resonance imaging (CE-MRA) is now establishing itself as an alternative to DSA. This emerging technology has potential benefits in providing both diagnostic and post treatment information for clinicians by employing a non-invasive vascular imaging technique.

AVM Classification [3]
- The classification system for vascular abnormalities was defined by the 1996 International Society for the Study of Vascular Anomalies (ISSVA). Two distinct biological categories separated the presence of endothelial cell turnover to yield either vascular neoplasms or vascular malformations.
- AVMs are classified as vascular malformations.
- They are subdivided into fast or slow flow. High flow AVMs are typically congenital and are characterised by a combination or arterial and venous vessels.
- Conventional T2 and T1 weighted sequences demonstrate serpiginous signal voids with an absence of any discernible focal mass. The role of post gadolinium T1 weighted with fat saturation imaging can visualise any intrasosseous involvement of the AVM [34].
- Histologically, Ballen et al (2011) defined the vessels of the nidus (central part) of the AVM to have dense walls are thrombotic and are associated with calcifications. The endothelial lining is dysplastic with an irregular growth pattern and diminished apoptosis [11].

2. Aim
The aim of this poster is to provide an overview of the role of 4D MRA in the management pathway of a patient with a shoulder AVM. It will
- Outline the physical principles that underpin Time Resolved Magnetic Resonance Angiography (TR-MRA).
- Provide an example of an imaging protocol for 4D CE-MRA for an AVM of the shoulder - see section 5.
- Demonstrate case study images to include conventional MRI, plain X-ray, Angiographic Embolisation and follow up 4D TRAK MRA – see section 6.
- Discuss the advantages and pitfalls of the technique.
- Conclude with implications for best clinical practice.

3. Sequence Requirements

The development of high static field strength equals higher Signal to Noise Ratio (SNR)
MR Data yields both anatomical and functional information
Parallel imaging e.g. Sensitivity Encoding (SENSE) for fast sequence acquisition
High specification coil technology. Direct digitization of the MR signal within the receiver coil which increases SNR

4. TR-MRA
- To achieve functional data it is necessary to kerp the segments of k space that are actually scanned.
- The ‘keyhole’ technique in TR-MRA involves repeated scanning of central k space (image contrast) with peripheral k space (spatial resolution) scanned only once.
- The information that is absent from the single scan of outer k space is then added to each of the incomplete dynamic sets. This will result in a complete filling of k space for each step in time.
- Development of CENTRA ‘keyhole’ alongside parallel imaging (SENSE) to increase acquisition speed and half Fourier acquisition is the basis of Philips’ ‘Temporal Resolution MR Angiography with CENTRA Keyhole (4D TRAK)’[12].

5. Imaging Protocol for 4D TRAK CE-MRA utilising a Philips 1.5 Tesla Ingenia Scanner

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>4.1millisecond (msec)</td>
</tr>
<tr>
<td>TE</td>
<td>1.5msec</td>
</tr>
<tr>
<td>Flip Angle</td>
<td>35°</td>
</tr>
<tr>
<td>Field of View (FOV)</td>
<td>300millimetre (nm)</td>
</tr>
<tr>
<td>Voxel Size</td>
<td>0.8 x 0.8 x 0.8mm³</td>
</tr>
<tr>
<td>NSA</td>
<td>1</td>
</tr>
<tr>
<td>Parallel Imaging</td>
<td>SENSE R/L -2; A/P -3</td>
</tr>
<tr>
<td>Coil</td>
<td>dStream Torso Coil</td>
</tr>
<tr>
<td>Total Scan Time</td>
<td>4 minutes 53 seconds (secs)</td>
</tr>
<tr>
<td>Technique</td>
<td>3D TI FFE with 4D TRAK</td>
</tr>
<tr>
<td>K-Space Filling</td>
<td>Keyhole (40%) with centric k-space filling</td>
</tr>
<tr>
<td>Dynamic Keyhole Scan Duration</td>
<td>13secs</td>
</tr>
<tr>
<td>Contrast</td>
<td>Double dose using 0.2millimoles/kilogram (mmol/kg) of Dotarem, pump injected at 1.5millilitres/second (m/sec) followed by 20mls of saline at 0.5mls/sec</td>
</tr>
</tbody>
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6. Case Study Images of a 24 Year Old Female with a Congenital Right Shoulder AVM

7. Advantages
- Non invasive delineation of the arterial and venous blood supply with excellent spatial resolution for pre planning or follow up embolisation procedures.
- Ability to differentiate between fast and slow blood flow.
- The identification of a fast flow AVM is important as caution is required when injecting a sclerosing agent (Polidocanol) into the venous vessels. Excessive force can cause the agent to enter the arterial system and flow distally from the AVM. This risks distal tissue ischaemia.

7. Pitfalls
- Patient immobilisation is required for the duration of the scan.
- To reduce blurring of the images it is advised to complete the entire k space reference scan after the dynamic scan.

8. Conclusion
The aim of this poster was to provide an overview of the clinical utility of 4D TRAK MRA. Incorporated was the case study of a patient who was administration a sclerosing agent to treat an AVM of the right shoulder. The technique of 4D MRA provides non invasive identification of a slow or fast flowing AVM which can be either used for pre planning embolisation or post procedure follow up. Excellent spatial and temporal resolution was obtained with the use of SENSE and high specification coil technology. The evolution of 4D TRAK should be considered as a valuable alternative to conventional DSA in the imaging management of these patients.

References
2. BALLAN D; CAJAL A; FOUNTAÏL L; VIN A; TREAT G; LOW D; EPCLÉMAN M. (2011) Vascular anomalies; what they are, how to diagnose them and how to treat them. Current Problems in Diagnostic Radiology: Vol 42 pp 253 – 247