Introduction

The suitability of a subject's arm for arteriovenous fistulae creation is often examined by ultrasonic imaging. However, while this method is sufficient for a diagnostic method, the absence of 3-dimensional geometry does not facilitate further investigation by means of Computational Fluid Dynamics (CFD), which illuminates more information, such as wall shear stress, velocity profiles and flow structures. Magnetic Resonance Imaging (MRI) provides such 3D information, but is more spatially restrictive than Ultrasound. Given the spatial restriction of the MRI bore, few positions are available for scanning the arm. As no ideal position is determined, the effect on vascular geometric structure is examined in a single case and commented on.

Methods

A healthy subject was scanned in a Siemens MAGNETOM Trio MRI scanner in two positions. Firstly, lying prone with the arm outstretched above the head and secondly lying supine with the arm down by the side. This is illustrated as “the superman” (b) and “the supine” (a) position in figure 1. The scanning area was of the upper arm focusing on the brachial artery, basilic and cephalic vein. Two MRI scanning sequences were used. These were the 2D time-of-flight (2D TOF) and the true-FISP with parameters indicated in table 1.

Scan data were imported into 3D Slicer 4.3.1. Vessel geometry was segmented manually in each slice based on image contrast and slice continuity. The humerus bone was also reconstructed and used as a reference to align both scan positions using an Iterative Closest Point (ICP) algorithm in MeshLab 1.3.3. Cross-sections of the brachial artery and cephalic vein were taken at approximately 5 mm intervals along vessel path, with origin slices at physiological landmarks such as vessel junctions.

Vessel comparisons were performed for statistical significance using a paired t-test between both reference to align both scan positions using an Iterative Closest Point (ICP) algorithm in MeshLab. Diameter was estimated from area by assuming a 3D geometry does not facilitate further investigation by means of Computational Fluid Dynamics (CFD), which illuminates more information, such as wall shear stress, velocity profiles and flow structures. Magnetic Resonance Imaging (MRI) provides such 3D information, but is more spatially restrictive than Ultrasound. Given the spatial restriction of the MRI bore, few positions are available for scanning the arm. As no ideal position is determined, the effect on vascular geometric structure is examined in a single case and commented on.

Vessel shape and diameter has been shown to change with arm position. MRI scanning was performed using two sequences, the 2D TOF and True FISP as shown in figure 2. The True FISP was chosen as a more reliable sequence as the 2D TOF showed partial corona shadowing on vessel and was more prone to noise in smaller vessels. The volunteer was scanned in the two positions as shown in figure 1. Examining the vessels in figure 3(a), the supine is more stretched than the superman, but centreline profiles appear similar. The distal section of the superman (left-top) is somewhat compressed, which might be caused by head or pillow pressure. In (b) the basilic vein is irregular and absent in sections for the supine position which contrasts with the full form of the superman position. As the coil is wrapped around the arm, combined with the minimal space for the body and arm within the MRI bore suggests pressure was applied on the vein collapsing it. The superman position appears full as pressure was not applied to it and the vein may have filled greater due to restriction of return flow at the shoulder due to the position. The artery (c) showed little change in diameter but displayed a helical form in the superman. Figure 4 examines the change in diameter over the vessel length. The artery (i) shows little change and was not considered significant. This acts as a control, ensuring that changes are not some inherent MRI parameter. Only the cephalic vein was plotted as the basilic was incomplete for the supine position. Some changes were noted in (ii) and was modestly significant while (iii) was deemed a significant difference between the two positions. Differences appeared most notable distal of the vein confluence. With clinical measures and base line wall shear CFD calculations based off of MRI reconstructions, awareness must be given when examining collapsible structures in pre and post arteriovenous junction creation.