Improved Stent Visualisation with High Flip Angle Magentic Resonance Angiogram during XMR Procedures

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Introduction: X-ray and MR interventional suites (XMR) are facilities that incorporate both MR and x-ray imaging and using a registration technique it is possible to integrate the superior structural information of MR images with conventional x-ray images allowing for safer cardiac catheter intervention. As part of an on-going study we have used this technique to perform stent implantation in three patients with coarctation. However, post procedure stent lumen imaging in such cases is usually performed under x-ray angiography as the metallic susceptibility artefacts from the stent affect MR angiogram sequences. This is a major hindrance to performing interventional stent implantation exclusively under MRI.

Hypothesis: In order to improve MR imaging of stent in-vivo we used a high flip angle MR angiogram sequence post-stent implantation.

Method: This is a prospective study looking at stent implantation and visualisation in a series of patients with coarctation using XMR guidance. In all patients a three-dimensional magnetic resonance angiography (MRA) images (T1 fast filed echo, TR 9.1,TE2.1, flip angle 40^o NSA1, slice thickness 1.6mm^3) of the aorta was obtained to produce a volume rendering of the aorta. Following MR acquisition the patients were moved to the x-ray end of the suite where optical tracking was used to determine the transformation matrices relating MR and x-ray image coordinates thus allowing real-time fusion. Registration errors were previously shown to be clinically acceptable. Stent (Cheatham Platinum (CP), NuMed Inc, USA) implantation was performed using the XMR technique at the x-ray end of the suite under general anaesthesia (figure 2). MR angiogram was then repeated with a flip angle of 90^o chosen based on in-vitro studies of the CP stent, which is made of a special alloy of platinum and iridium. Multi slice 'black blood' turbo spin echo (TR 833 ms, TE 80 ms, slice thickness 6 mm) images, through plane phase contrast (TR 6.9 ms, TE 3.8 ms, flip angle 15, slice thickness 7mm) and invasive pressure measurements were performed pre and post stent implantation providing valuable anatomical and physiological information. Stent position was confirmed on x-ray. We then carried out signal intensity measurements within the stented aorta and compared them with non-stented aorta. We also compared the signal intensity measurements in a similar cohort of patients where the conventional MRA sequence (low flip angle) was used.

Figure1: Top-low flip angle MRA & volume rendering of stented aorta, Bottom: high flip angle MRA and volume rendering of stented aorta

Figure2: XMR overlay showing volume rendering of narrowed aorta superimposed on conventional x-ray image

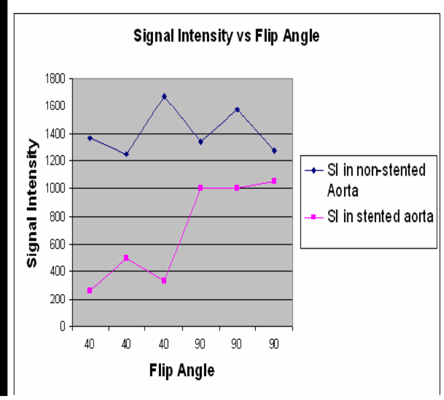

Table1: Signal intensity vs flip angle in stented and non-stented aorta

Results & Discussion: We were able to clearly visualise the lumen of the stented aorta in all patients and also volume render the stented region after deployment from the MR angiographic images. The measurements of the stented aortic lumen on angiographic (high flip angle) and 'black blood' images were comparable. Signal intensity within the stented aorta was significantly lower at a flip angle of 40^o as compared to a flip angle of 90^o (table 1). Signal intensity within non-stented aorta was only slightly lower at 90^o as compared to 40^o allowing adequate overall visualisation of the aorta. The ratio of signal intensity of the stented and non-stented aorta with conventional MRA was lower than that with high flip angle MRA (0.25 vs 0.74). Flip angle optimisation allows for reliable visualisation of stent lumen on MR angiograms. Higher flip angles have been previously shown in in-vitro studies to overcome the RF caging artefacts of stents made of nitinol and certain other alloys [1,2]. In our in-vitro work we found 90^o to be optimal for imaging CP stents and as shown in figure 1(bottom images) the improved signal within the aorta at higher flip angle even allows volume rendering of the stented aorta. The orientation of aortic stents in our cases was near parallel to B_0 and therefore the MR artefacts were less severe.

Conclusion: High flip angle MRA allowed us to visualise the lumen of the CP stents implanted in all patients. This is important as it allows us to rapidly detect in-stent stenosis thereby guiding the interventional cardiologist without having to perform an x-ray angiogram. Further work is being carried out to optimise imaging sequences to allow for better intraluminal stent imaging.

References: 1. van Holten J et al. Magn Reson Med. 2003 Oct;50(4):879-83; 2. Bartels LW et al. J Vasc Interv Radiol. 2001 Mar;12(3):365-71.