Tri-Directional Velocity-Encoding Phase Contrast MRI in patients Undergoing Aortic Valve-Sparing Root Replacement

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Introduction: Aortic root replacement with a mechanical valved conduit is the conventional surgical technique for treating aneurysms of the aortic root in younger patients. Newer valve-sparing techniques, such as the David procedure [1], have evolved recently as a potentially more desirable method for repairing aneurysms as it preserves the native valve and may restore normal flow dynamics and characteristics across the aortic root. Restoration of normal laminar flow through the aortic root and ascending aorta is one objective of valve-sparing root replacement. Conventional phase-contrast MRI can measure velocity and flow across the valve however, since velocity is usually encoded in one direction only, it produces only a uni-dimensional map of flow. It is now feasible to encode velocity in three directions during the same phase contrast acquisition [2]. When this data set is subjected to a color-coded three-dimensional post-processing tool, it is possible to generate a 3D rendering of flow across the aortic valve. This technique may be particularly useful in patients undergoing valve-sparing root replacement where demonstrating a normal laminar flow pattern post surgery may predict a positive clinical outcome.

Purpose: The purpose of this study was to evaluate patients pre and post valve sparing surgery using a tri-directional phase contrast MRI technique.

Methods: 12 patients underwent tri-directional phase contrast MRI on a 1.5T Avanto scanner (Siemens Medical Systems) before and after valve-sparing root replacement using a modified re-implantation technique. The modified approach used is unique to this center and involves annuloplasty and graft tailoring to create new sinuses of Valsalva and restore root geometry. Contiguous axial cine phase-contrast images were obtained orthogonal to the aortic valve and sinuses (Fig.1). The parameters for the phase contrast technique were as follows: TR/TE: 8.0/4.0 msec; flip angle 15^0; FOV 250 x 340 mm; matrix 86 x 192; 6 mm thick slice; acquisition time: 24 secs per slice; 3 lines per segment; velocity encoding (VENC) 150, 90, 90 cm/sec x, y, z directions respectively. The acquired phase contrast images were used to calculate and visualize the time-resolved 3-dimensional velocity fields as color-encoded vectors projected onto the corresponding rephased (anatomical) images (4D Flow software). These post-processed images were reviewed by 2 independent observers. Laminar flow (Fig. 2) was scored on scale of 1-4 (1=poor, 2=fair, 3=good, 4=excellent). Laminar flow was defined as parallel or near parallel vector lines. Turbulent flow (Fig.3), indicated by circular or semi-circular vector lines, was scored on a scale of 1-3 (1=mild, 2=moderate, 3=severe). Cardiac parameters (ejection fraction, end-systolic volume, end-diastolic volume), measured from short axis cine steady state free precession images were recorded pre and post surgery for each patient. Clinical outcome was measured by reviewing the medical record at 1 month and 6 months post-surgery. The presence of angina, dyspnea (NYHA grades 1-4) and orthopnea were noted. The results of the phase contrast analysis were correlated with cardiac parameters and clinical outcome.

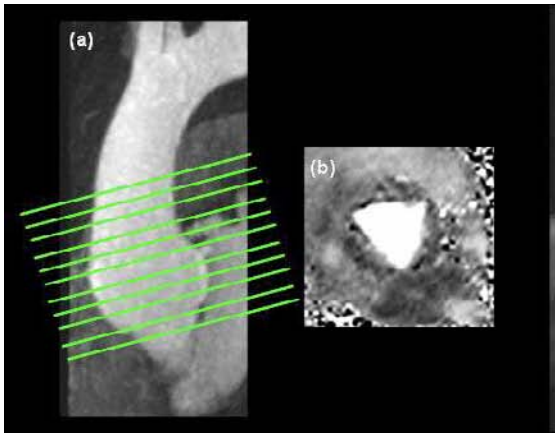

Fig. 1a. Stack of phase contrast images acquired orthogonal to vessel wall. Fig. 1b. Axial phase contrast image through aortic valve

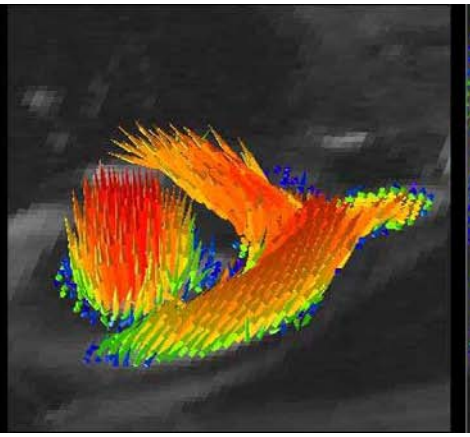

Fig 2 Axial View through aortic valve at peak systole showing through-plane flow.

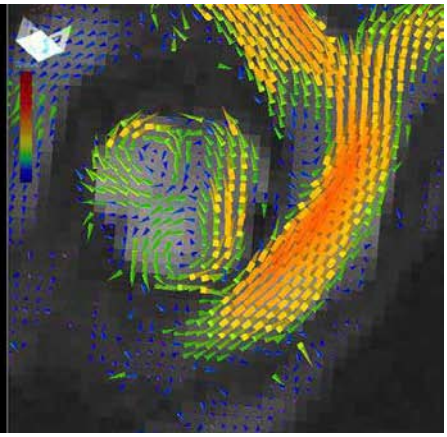

Fig. 3. Axial view through aortic value showing in-plane flow. Circular color-coded lines represent turbulent flow.

A total of 30 axial phase contrast image data sets were generated from the 12 patients imaged. The average score pre-surgery was 1.9 for laminar flow and 2.1 for turbulence. The average score post-surgery was 3.1 for laminar flow and 0.9 for turbulent flow. There was positive correlation with ejection fraction and clinical outcome. All patients had a positive clinical outcome at 6 months follow-up.

Discussion: Initial results indicate that tri-directional phase contrast MRI is feasible and may help predict clinical outcome in patients undergoing valve-sparing surgery for aneurysmal disease of the ascending aorta. Future work includes three-dimensional spatial encoding, higher acceleration parallel imaging and incorporation of respiratory compensation.

References

1. Gleason T. J Thorac Cardiovasc Surg.2005; 130: 601-603 2. Kvitting et al. J Thorac Cardiovasc Surg,127: 1602-1607, 2004.