Inline directionally independent magnitude of velocity maps for visualization and quantification of jet flow

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INTRODUCTION

Pediatric patients with congenital heart diseases often have irregular blood flow patterns (jet flow) with variant orientation and distributions. Phase contrast magnetic resonance imaging (PC-MRI) with velocity encoding provides flow visualization and quantification of peak velocity within the core of jet flow. 2D slice oriented orthogonal to jet flow with through-plane velocity-encoding is commonly used in clinical studies [1,2]. However, post-stenotic jets frequently exhibit a degree of eccentricity and can change direction throughout the cardiac cycle. Irregular and narrow jets can be more difficult to be measured.

Purpose: we propose inline computation of velocity magnitude independent of direction, eliminating reliance on optimal slice orientation and facilitating clinical evaluation of irregular flow patterns as found in stenotic jets.

METHOD

Imaging

Studies were performed on 11 patients (4 male, 7 female, 4-22yr) with congenital heart disease on Siemens 1.5T scanner (Avanto, Siemens Healthcare, Erlangen,Germany). Data were acquired under free breathing using a PC sequence with 3 flow encoding directions (i.e through-plane, anterior-posterior (AP) and right-left (RL)) and one flow compensated reference, using the following parameters: TR/TE =26/3.4 ms, resolution = 1.2x1.2x5.0mm,VENC=100-400cm/s, 3 averages, 30 reconstructed cardiac phases).

Processing

(1) Magnitude of velocity map. Phase differences between each flow encoded and the flow compensated images were quantified in terms of velocity for each direction ($V_{Through}$, V_{AP} and V_{RL}). Next, the root sum square of 3 directional velocities yielded pixel-wise magnitude of velocity independent of direction. All processing was programmed in the Siemens Image Calculation Environment (ICE) enabling immediate visualization and evaluation of results.

(2) 3D velocity vector. ROIs of the jet flow were drawn manually on the magnitude of velocity map. Within each ROI, a 3D velocity vector defined by [$V_{Through}$, V_{AP}, V_{RL}] were generated in each pixel. The flow pattern was visually assessed by inspecting the 3D velocity vectors overlaid on color-coded magnitude of velocity map. Vector visualization was performed using Matlab software.

RESULTS

Over all patients, the peak velocities calculated from magnitude of velocity map for forward flow in systole and regurgitant jets present in diastole demonstrated an 8±10% (mean ± std, n = 18) increase over single direction measurements. In cases where the slice orientation was appropriately orientated, little benefit was seen with the magnitude of velocity calculation. However, in cases of turbulent flow, eccentric jets or poor slice placement, more significant differences were observed up to 32%.

CONCLUSION

Conventional PC-MRI with 1D encoding typically underestimates peak velocity due in part to reliance on a through-plane velocity-encoded 2D slice orientated perpendicular to the jet. Magnitude of velocity calculation provides peak velocity measurement that is independent of slice orientation, flow direction and temporally variable jet direction. Inline computation of magnitude of velocity provides immediate visualization and integration with conventional post-processing tools. Overlaid 3D velocity vector maps provide direct visualization of the orientation and flow pattern of the jet flow.

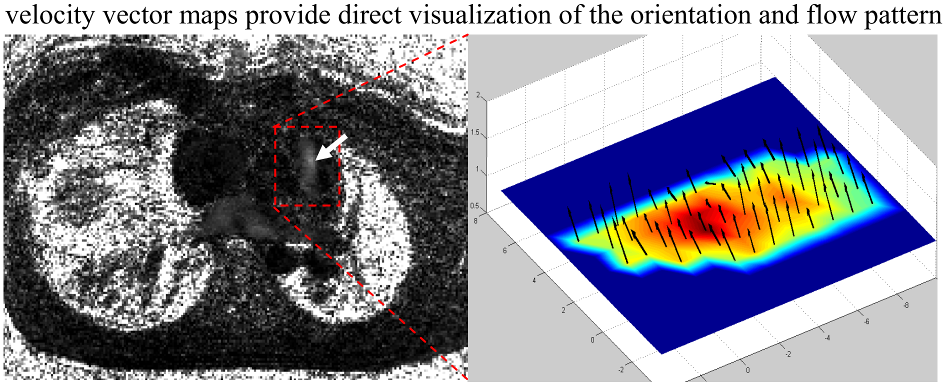

Figure 1.(a) Magnitude of velocity map (inline function) and (b) overlaid 3D velocity vector map (matlab) within a jet flow ROI in a representative patient with pulmonary regurgitant jet flow (white arrow).

References: [1] Lotz *et al.*: *RadioGraphics*. 2002, 22:651-671. [2] Zhao *et al.*: *MRM*. 2000. 18:697-706.