Correlation analysis of stenotic aortic valve flow patterns using phase contrast MRI

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Introduction

MRI methods for assessing valvular disease, particularly phase-encoded velocity mapping, have achieved a level of accuracy comparable to the clinically used methods, transthoracic echocardiography and cardiac catheterization. If MRI is to become widely accepted in a clinical cardiology setting, the relatively longer times required for acquisition and processing of MRI data must be addressed. One method for improving patient throughput is to automate scans as much as possible. This has the added benefit of reducing the human error inherent in manual selection of scan acquisition planes. In this study, we initiate a systematic investigation of the possibilities for designing an automated approach to the evaluation of cardiac valvular disease (specifically aortic stenosis) using the "velocity-time integral" method.

Purpose

As a preliminary step for automating any imaging protocol, potential sources of error in data analysis must be assessed. In the case of quantitative valve flow imaging, we postulated that the major sources might be: 1) misalignment between the imaging plane and the flow jet, and 2) variation in the longitudinal placement of the imaging plane relative to the aortic valve plane. Effects of image plane misalignment appear to be minimal for technologist-assisted plan-scanning, as reported earlier by our group[1]. In this study we evaluate the effect of longitudinal variability on stenotic flow jets, with the use of cross-correlation methods to describe the *similarity* of flow patterns at selected distances from the valve plane. Cross-correlation results measure the "sameness" of flow data between aortic levels, and hence indicate the extent of error that could be encountered from variations in the longitudinal position of the imaging plane relative to the jet flow profiles.

Methods

Patients with aortic stenosis documented via echocardiography were imaged using a 1.5T MRI scanner (NT Intera CV, Philips Medical Systems). Quantitative images were obtained about the aortic valve plane using a free-breathing, retrospectively gated velocity encoding technique sensitized for flow in the through-plane direction (TR/TE/alpha=6.0ms/2.9ms/30°, 30 frames/heartbeat, 2 NSA, typical voxel size=1.0x1.3x9.0mm^3, typical encoding velocity 4 m/s). For quantitative flow measurements, one plane was positioned just to the aortic side of the valve at its greatest excursion toward the apex. Two more planes were positioned distally parallel to this plane, offset 10mm(+) and 15mm(++) from its center.

Using IDLv.5.5 (Research Systems Incorporated) and Philips' PRIDE image processing tools, translational cross-correlations were performed between the + and ++ level scans for each patient, calculated from a rectangular region of interest circumscribing the aortic lumen.

Results

The patient population (n=22) comprised 6 mild, 4 mild-moderate, 4 medium, 2 medium-severe, and 6 severe cases of aortic stenosis. Cross-correlation functions computed between aortic lumens on the + and ++ imaging planes exhibited an average maximum value of 0.88±0.11 (0.59-0.99), indicative of excellent similarity of flow patterns at 1 and 1.5 cm from the valve plane. A sample analysis is shown in Figure 1. The maximum correlation value occurred at the center point of the data sets (or "0,0" offset) for 20 of 25 patients, and at a nonzero offset of up to 4mm in the remaining 6 . In the group with a zero offset, the average maximum correlation was 0.92±0.07 (0.66-0.99) and echocardiography revealed a range of stenoses from mild (3) to moderate (4) to severe (5). For the group with nonzero offset, the average maximum correlation was 0.75±0.11 (0.59-0.87); and echocardiography revealed 3 mild, 1 mild-moderate, and 1 severe stenosis.

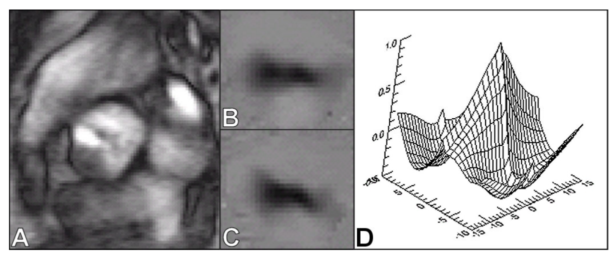

Figure 1: A) Zoomed segment of magnitude image of the aortic valve; B,C) Velocity-mapped images 1cm and 1.5cm above valve plane, respectively; D) Cross-correlation function between 1cm and 1.5cm images. Values range from 0 to 1. Note correlation peak (value 0.99) at (0,0).

Discussion

Previously, Caruthers *et al.* outlined a simple and rapid protocol for conducting phase-encoded velocity mapping MRI studies to quantify the severity of aortic stenosis in a clinical setting dependent on the ability of trained MR technologists to establish imaging planes rapidly and accurately.[1] They found strong agreement between MRI and echocardiographic data, and determined that the MRI data accrued only small (~3%) errors due to misalignment of the imaging plane with the flow jet. The present study assessed the dependence of the observed flow profile on *longitudinal* positioning of the acquisition plane distal to the aortic valve. We observed that cross-correlation functions computed between the imaging planes manifested an average maximum correlation value of 0.88. For the group with nonzero offset, the maximum correlation value was slightly higher (0.92), suggesting strong similarity between flow profiles 1.0 and 1.5 cm above the valve plane. Exact longitudinal positioning of the image acquisition plane within this range may not substantially affect measurement results, potentially lending well to automated data acquisition.

Conclusions

A useful automated imaging system must be effective for all presentations of the disease. That the majority of cross-correlation functions maximized at (0,0) offset have high maximum correlation values indicates that there is no change in the shape of velocity profiles between 1 and 1.5cm distal to the valve plane which would influence outcomes of valve quantification. Because those data sets with slight dissimilarities did not constitute a homogenous subgroup, we conclude that an automated slice selection algorithm would be robust against distance above the valve plane at least within a range of 1.0-1.5cm.

References

[1]Caruthers SD *et al*. Circulation. 2003 Nov 4; 108(18): 2236-43.