MR Flow Imaging Reveals Unique Flow Patterns Linked to Different Leaflet Fusions with Bicuspid Aortic Valve

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Purpose: Bicuspid aortic valve (BAV) is the most common congenital cardiac abnormality. It is associated with significant morbidity due to increased risk of aortic aneurysm formation and dissection[1]. Prior studies have shown that abnormal valve morphology leads to altered flow patterns and hemodynamic burden in the ascending aorta. This is correlated with increased risk of thoracic aortic enlargement[2]. Recent studies show that right-left (RL) and right-noncoronary (RN) leaflet fusion patterns are correlated with distinct patterns of aortic enlargement[3]. These studies suggest that unique hemodynamic alterations occur with different valve fusion patterns and may be associated with aortic enlargement in patients undergoing CMR surveillance. We hypothesized that unique flow patterns in the ascending aorta, associated with RN and RL leaflet fusion, could be accurately identified and quantified using phase-contrast cardiac MRI techniques (PC-CMR).

Methods: A retrospective chart review spanning a 10 year period (2003-2013) identified 60 patients with BAV who underwent CMR studies that included axial phase-contrast sequences in the tubular ascending aorta. Fusion patterns of RL (n=48), RN (n=10), and LN (n=2) were determined using a combination of echocardiography and CMR. LN fusion pattern was excluded from analysis due to small sample size. Proprietary flow quantification software (Medis Medical Imaging Systems, Netherlands) was used for vessel segmentation and to calculate peak systolic flow displacement, a previously described parameter[4], which represents the normalized, weighted average of measured flow velocities as it differs from the vessel midline. Patients with significant systolic flow displacement values (>0.1), as previously determined, were grouped into quadrants: right-anterior (RA), right-posterior (RP), left-anterior (LA) and left-posterior (LP),[4] Rightward (RA and RP) and leftward quadrants (LA and LP) were then combined for further analysis. Patients without significant flow displacement were designated as "midline" and not assigned to quadrants. Valve fusion pattern was compared with flow displacement quadrants, right vs leftward direction and demographic parameters using AVNOA, Fisher's exact test and Pearson's correlations.

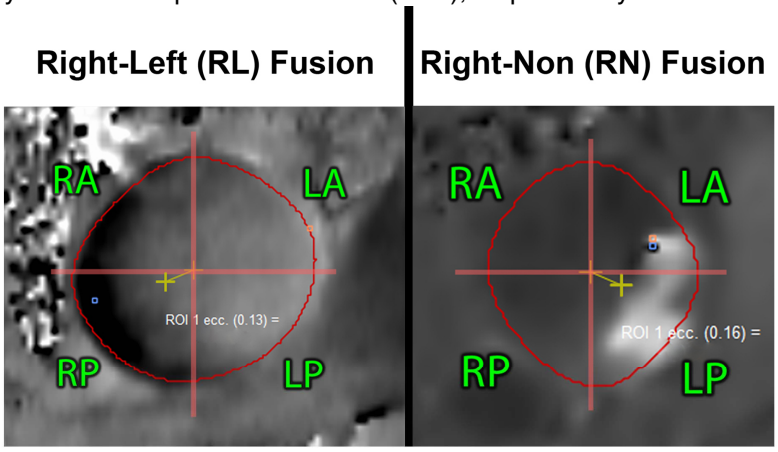

Figure: Example of RL fusion pattern producing a right-posterior (RP) quadrant flow displacement, compared with RN fusion pattern producing a left-posterior (LP) quadrant flow displacement.

Results: The average patient age was 29.1 ± 13.6 y (RL: 30.5 ± 13.5 y; RN: 22.7 ± 12.5 y), and the majority of patients were male (overall 37/58; RL 29/48; RN 8/10). Average displacement was 0.15 ± 0.7, and did not significantly differ between fusion patterns. No correlations were found between age or sex and fusion pattern. In patients with RN fusion, the majority of flow was either leftward or midline (2/10 LA, 3/10 LP, 1/10 RA, 4/10 midline), while flow in patients with RL fusion was predominantly rightward (31/48 RP, 12/48 RA, 1/48 LA, 4/10 midline). When only considering patients with significant flow displacement, RL fusion was associated with rightward systolic flow in almost all cases (43/44 patients), while RN fusion was associated with leftwards systolic flow (5/6 patients). These differences were highly significant by Fisher's exact test ($p<0.0001$). Additionally, patients with RN fusion were statistically more likely to have "midline" flow (displacement <0.1) than RL patients (40% vs 8% respectively, $p=0.008$). The presence of rightward flow displacement (RA or RP) on phase contrast sequences predicted RL fusion pattern (Sensitivity 83%, Specificity 98%).

Discussion: The results show significant differences in systolic flow jet displacement associated with different bicuspid aortic valve morphology. The more common RL fusion pattern was associated with flow displacement in a rightward direction, whereas the less common RN fusion was associated with leftward and midline systolic flow. These findings support the importance of unique aortic hemodynamics related to different patterns of valve fusion.

Conclusion: There are significant differences in systolic flow patterns between patients with RL and RN leaflet fusion patterns with rightward flow displacement being highly associated with RL fusion patterns. Our findings support a flow-mediated etiology for aortic dilation in patients with BAV and should be taken into consideration when performing longitudinal analysis on mixed groups of BAV patients with RL and RN fusions.

References:
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